Global Protocol for Community Scale Greenhouse Gas Emissions: a trial application in the West Highlands of Scotland

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Title

Global Protocol for Community Scale Greenhouse Gas Emissions: a trial application in the West Highlands of Scotland

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Abstract

The measurement of greenhouse gas emissions and removals is essential to effective action on climate change. Assessments of greenhouse gas emissions are now carried out at a number of different levels, including both the national and corporate level. Greater public participation may also help to reach climate change mitigation targets and one way to support this is to develop emissions accounts for local areas that are identifiable to those who live there. A new standard, the Global Protocol for Community Scale Greenhouse Gas Emissions (GPC) was issued in 2012 and provides rules to facilitate an account for a whole community. This standard has been trialled through an application of the proposed accounting rules to an area of the West Highlands of Scotland. The accounting rules were clear to follow and the main practical difficulties were not with the standard itself but with the availability of sufficiently disaggregated data. The main weakness identified with the GPC is that it is predominantly focused on providing a production-based inventory, whereas we suggest that community level inventories will be most relevant to community level action if the scope of the inventory focuses on the emission sources that can be influenced by the community.

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1. Introduction

In 2012 the Global Protocol for Community Scale Accounting (GPC) was issued by the World Resources Institute, in collaboration with C40 Cities Climate Leadership Group, ICLEI Local Governments for Sustainability, the United Nations Environment Programme, and the World Bank (Arikan et al, 2012a). This article describes an application of the GPC for the community of Lochaber in the Scottish west Highlands, and offers a discussion on how the application of the protocol can be made easier, and how the scope and utility of the protocol can be enhanced.

While the priority for community wide accounting has been on cities where the majority of the world's GHG emissions are generated (Ibrahim, 2012), the GPC is also intended to be "useful for sub-national entities such as towns, districts, counties, prefectures, provinces, and states pursuant to appropriate modifications" (Arikan et al, 2012b, p2). Applying the protocol to the rural community of Lochaber is intended to generate lessons for the "appropriate modification" of the GPC for rural applications, as well as lessons for the development of the protocol more generally.

The threat of negative impacts from climate change is well established (IPCC, 1990, 1995, 2001, 2007, 2013), and the need for mitigation action is broadly recognised by policymakers, as evidenced by international, national, and regional policies and programmes (UNFCCC, 2013, EU 2013, Scottish Government 2009). Action at international and governmental level has been backed up by engagement from local government and voluntary initiatives from businesses and householders.

Accurate measurement of emissions is an essential part of effective work on climate change. At the national level, the UNFCCC encourages all countries to provide national inventories of anthropogenic emissions (UNFCCC, 1992, article 4a), with guidance for doing so developed by the IPCC (Eggleston et al 2006, Penman et al 2003, Houghton et al 1996). At the organisational or corporate level a number of accounting and reporting standards have emerged including the GHG Protocol's Corporate Standard (WBCSD/WRI, 2004) and ISO 14064-1 (ISO, 2006).

Action at the sub national level has been focussed on cities whose share of energy emissions is due to reach 73% by 2030 (Bader and Bleischwitz, 2009). The C40 cities for Climate Leadership, launched in 2005 by Ken Livingstone and the EU Covenant of Mayors launched in 2009 have spurred action in some cases exceeding the goals and actions of many governments

(Kennedy et al, 2010). A number of greenhouse gas inventories have been compiled for cities (Hillman, 2010, Kennedy, 2010, Kennedy, 2012, Ramaswami, 2011) seeking to develop a clear, replicable system that can support effective action on mitigation with a reasonable commitment of resources. The GPC is the latest attempt to bring clarity to this area. It has been supplemented in the US with the production of the *US Community Protocol* (ICLEI-US, 2012), intended to provide detailed guidance for local governments and in the UK with the publication of *PAS 2070: Specification for the assessment of greenhouse gas emissions of a city* from the British Standards Institution (BSI, 2013).

A number of inventories have also been undertaken for non-city local communities, such as Chandler's (2012) assessment for King County in the State of Washington. A detailed account was attempted for the town of Biggar in the Scottish Borders (Barthelmie 2008) based on local activity data though the authors reported high levels of uncertainty due to lack of data. Several UK based community groups have attempted to measure emissions using the Resources and Energy Analysis programme (REAP) developed by the Stockholm Environment Institute, a software package for the calculation of consumption based emissions from environmentally extended input output (EE-IO) data (Dawkins 2010).

1.1 Production and consumption-based accounting

It is not intended that this article should provide a comprehensive taxonomy of the different forms of carbon accounting that have been developed, but the distinction between production-based and consumption-based inventories helps to locate the main characteristics of the GPC. Production-based inventories aim to quantify the greenhouse gas emissions produced within a jurisdiction or boundary, while consumption-based inventories quantify all the greenhouse gas emissions associated with the goods and services consumed within a jurisdiction or boundary (Larsen and Hertwich 2009). The national inventories submitted to the UNFCCC are production-based accounts, while examples of consumption-based inventories include *Scotland's Greenhouse Gas Footprint* (Scottish Government, 2012) and *Greenhouse Gas Emissions in King County* (Chandler et al, 2012) both compiled from financial data using EE-IO.

The different results from production and consumption-based accounts have shown that in the UK consumption based emissions are much higher than those from production based accounts (Barrett, 2013) while similar studies in China show that China's production-based emission far exceed its consumption-based emissions (Vause et al, 2013), and this difference in results raises questions about which approach is more relevant for managing emissions.

Some accounting approaches offer a hybrid of production and consumption-based inventories, for instance the ICLEI US Community Protocol proposes the use of two main categories of emissions: those from sources located within the boundary of the community and those arising as a result of activity in the community wherever the emissions physically occur (ICLEI-USA, 2012, p12). The in-boundary emissions correspond to a production-based inventory, and the "activity" based inventory includes both production and consumption-based elements. The BSI PAS 2070 takes this further and proposes both an enhanced version of the GPC categories referred to as Direct Supply Chain Plus which adds emissions from key goods and services, and a separate consumption based account derived from EE-IO data generated for the local area (BSI, 2013)

The GPC is primarily focused on providing a production-based inventory, but some emissions sources outside of the geographic boundary of the community are also required. However, the developers intend to expand the guidance provided in future versions of the standard in order to fully cover both production and consumption-based emissions (Arikan et al, 2012b, p8).

2. GPC scope and calculation methods

For this case study the detailed guidance from the 0.9 version of the *Global Protocol for Community Scale Greenhouse Gas Emissions* (GPC) (Arikan, 2012a) has been used to create an inventory for the Lochaber area, a sub division of the Highland Council local government area in the northwest Scottish Highlands.

The protocol separates emissions into four main categories. These are: 1. the use of energy in stationary units; 2. the use of energy in mobile units; 3. waste; and 4. industrial process and product use. In the final pilot version (1.0) (Arikan, 2012b) a fifth category is designated as agriculture, forestry, and other land uses (AFOLU) and a sixth category as other scope 3 emissions but no guidance is available yet for these two categories. The emission categories used in the protocol correspond to those in the IPCC guidelines for national greenhouse gas inventories, but the geographic scope of the emissions sources included in the GPC differ from those used for national inventories; for example, the emissions from waste include those associated with community waste that is disposed of outside the geographic boundary of the community.

In order to transparently report the emissions that are inside and outside the community's geographic boundary the GPC requires the classification of emissions into three scopes.. Scope 1 covers direct emissions from sources within the geographic boundary. Scope 2 covers energy related indirect emissions from the consumption of grid supplied electricity, heating or cooling (where generation occurs outside the community boundary). Scope 3 covers other indirect emissions occurring outside the geographic boundary of the community. Details are shown in Table 1.

Insert Table 1 here

The GPC specifies the detailed calculation methods for each emissions source, with the calculation algorithms largely following those provided by the IPCC guidelines for national inventories.

Direct (scope 1) emissions from stationary units include all use of fuel in homes, offices, industrial units, and stationary machinery.

Direct emissions from fossil-based power generation should be included where this occurs in the study area; however, this was not applicable in the case of Lochaber.

Indirect (scope 2) emissions from stationary units are those associated with the use of grid supplied electricity, heating or cooling, that is generated outside the geographic boundary of the community. Emissions from mobile units include those from on and off road vehicles, as well as rail, air, and water transport systems, and also mobile machinery. Direct (scope 1) emissions are those from fuel combustion within the study area, and scope 2 emissions are those from the use of electric vehicles inside the study area (when the electricity is generated outside the area). The protocol also provides the option for a more complex approach for accounting emissions from mobile sources which involves identifying the origin and destination of each journey. For journeys that either start or end outside the community area 50% of the emissions are allocated to the reporting community, and are reported as scope 3. This split was not feasible for road transport but has been recorded for rail and water borne vehicle emissions.

Municipal waste emissions are calculated for material that is landfilled, incinerated or biologically treated. For landfilled waste methane emissions are calculated based on degradable organic carbon and methane generation potential assuming a 75% capture rate at the landfill. The equation is specified in the GPC (Arikan et al 2012a, p57), The CO_2 emissions from landfilled waste are excluded on the assumption than any waste decaying to CO_2 will be from a biogenic source. Incinerated waste is analysed to determine the carbon content and the fraction of carbon that is of fossil fuel origin. Emissions from biologically treated waste are subject to a calculation based on IPCC conversion factors.

Emissions from wastewater treatment and handling are calculated through a series of equations, dependent on the amount of material subjected to different processes to calculate the methane and nitrous oxide released.

Emissions from industrial processes are those produced during specified manufacturing processes. Product use emissions describe gases emitted during the use of petroleum based products such as paint, bitumen and aerosols.

Detailed guidance for emissions from agriculture, forestry and other land use has not been included in the GPC though their importance is acknowledged. At the national level in Scotland, agriculture and related land use contributed approximately 20% of greenhouse gas emissions (Scottish Government, 2013). In view of the rural nature of the study area a partial calculation for agricultural emissions was made for livestock following the procedure set out in the UK Annual Report on the UK Greenhouse Gas Inventory for 2012 to the UNFCCC (Brown et al, 2012).

The GPC version 1.0 (Arikan, 2012b, p 8) requires the reporting of the six gases included in the Kyoto Protocol at the date that the GPC was published (CO_2, CH_4, N_2O, HFCs, PFCs and SF_6) and the total in CO_2 equivalent tonnes. Emissions factors in all cases for stationary and mobile units were taken from Defra's GHG Conversion Factors for Company Reporting (Defra 2012). Waste emissions were derived by calculation; industrial process emissions were taken from reports to the Scottish Environment Protection Agency; and enteric methane and nitrous oxide emissions from livestock were calculated following guidance from the UK Greenhouse Gas Inventory annexes (Brown, 2012).

3. Application of the GPC to Lochaber

3.1 The study area

The Lochaber district is made up of two wards of the Highland Council administrative area. It covers 5,180 square kilometres (Lochaber Biodiversity Group 2004) with a population of 19,319 in 2010 (Highland Council 2012) making it one of the most sparsely populated parts of the UK with large areas of peat and heather covered upland including Ben Nevis, the highest mountain in the UK. The largest single employer in the area is the local authority with 30% of employees working in the public sector and the largest sector is hotels and restaurants with 34% of employees (Highlands and Islands Enterprise, 2011). Industry includes an aluminium smelter, an aggregate quarry, a sawmill, a distillery and a fish farming enterprise. Land based enterprises include extensive forestry, hydro electricity generation and livestock production. There is a long indented coastline with marine passenger transport, marine haulage, a fishing industry and pleasure craft. The Caledonian Canal runs through the area with movements dominated by leisure craft.

This study was carried out in the summer of 2012 between May and August. The inventory year is 2011, though because of data availability, some data was sourced from earlier years. Department of Energy and Climate Change (DECC) energy statistics are from 2010 for electricity and gas consumption, and from 2009 for other fuels. Scottish Pollutant Release Inventory (SPRI) reports are for 2010.

3.2 Energy use in stationary units

Direct emissions from energy consumption in stationary units proved a complex source to account for accurately. Data was gathered from interviews with public sector bodies and several of the largest industrial firms. An attempt to survey householders only achieved a very small response with ten survey returns which were therefore not used. Local authority level data on sub-national use of other fuels (DECC, 2012a) was used to develop an estimate of domestic oil and coal use at household level but data for gas use was only available for piped gas and not the bottled gas used in the area.

Some difficulty was met in distinguishing clearly between the use of fuel in machinery, which should be recorded as stationary fuel use, and the use of fuel for off road vehicles. The Forestry Commission, for instance, keeps a record of fuel use for its felling operations but does not distinguish between hand held chainsaws and vehicles used in felling operations, though staff assisted in reaching an estimated split.

An estimate of energy use was developed for accommodation businesses based on a per capita rate derived from the DECC data on sub-national use of other fuels. To complete this picture a sample survey of businesses would be needed.

Indirect emissions from the use of grid supplied energy were easier to identify. DECC publishes statistics on electricity consumption at Middle Layer Super Output Area (MLSOA) level as part of the Digest of UK Energy Statistics and this enables the exact ward areas to be identified (DECC 2012b). The DECC data gave 2010 results for domestic and non-domestic electricity consumption. However, figures for half hourly meter users are not disaggregated to MLSOA level due to commercial confidentiality, and this data is only reported at local authority level. This data gap was addressed by approaching the largest businesses in the area and asking if they would contribute this data. The total of 689,086 MWh was heavily dominated by Rio Tinto Alcan whose electricity consumption in 2011 was 659,906 MWh, all from the company's own hydro generation plant, and a zero emission factor was applied to this electricity consumption. Following the GHG Protocol corporate standard, emissions from all other electricity consumption in Lochaber have been calculated using Defra grid rolling average factors for electricity generation (WBSCD/WRI 2004, p87). However, the hydro electricity used by Rio Tinto Alcan may be included in the Defra factor, in which case the low-carbon electricity would be double-counted. If the smelter electricity consumption emissions were calculated using the grid rolling average factor, thereby avoiding double-counting, the result would be 318,299 tCO_2e (almost doubling the total). In the absence of more detailed guidance on the use of site specific emission factors, the main results presented include the smelter emissions using a zero emissions factor.

The GPC encourages communities to develop "local-specific energy emissions coefficients" (Arikan et al, 2012a, p.34), and a similar approach is suggested in the U.S. Community Protocol for Accounting and Reporting of Greenhouse Gas Emissions (ICLEI 2012, p.29). However, there are problems with this approach, such as the impossibility of tracking the physical electrons from specific generation facilities. The GHG Protocol is currently developing guidance on accounting for electricity emissions, and resolving these issues is beyond the scope of the current article. We therefore highlight this as an area for future development.

3.3.1 Mobile units – road transport

For emissions from road transport an attempt was made at a calculation based on fuel sales and all local retailers were approached but only one was able to take part. On road emissions were therefore calculated using the Department for Transport data on Annual Average Daily Flows. In Lochaber 26 points covered 170 miles of the 253 miles of A roads in the area. This leaves 83 miles of A roads, 169 miles of B and C roads and approximately 300 miles of U roads. A full emissions account would need to capture traffic on these roads though it is likely to be much less than that for the major roads.

3.3.2 Mobile units - rail

Fuel consumption data for passenger rail transport was provided by First Scotrail, and journey times and lengths were available from the timetable (Network Rail, Table 227). It was straightforward to apportion emissions to journeys within and outside the area though there could be dispute about the final end point for journeys of individuals. Rail freight emissions were harder to quantify, and estimates were made on the basis of advice from the train operator and from interview data. Estimated emissions from rail freight were drawn from data reported in research for the Department for Transport (Clarke, 2011). A steam train operates in the summer months and coal consumption was obtained from Friends of the West Highland Line.

3.3.3 Mobile units – water borne transport

Water borne transport emissions are complex and varied as described above.. Mallaig and Corpach are the major ports with several other small harbours and moorings throughout the area. Data was drawn from interviews and from earlier studies. A study commissioned by Highlands and Islands Enterprise provided the basis for estimates of water borne ferry mileages (Hill, 2008).

Fuel data in some cases enabled very precise calculations such as that of 11,013 tCO_2e for fishing boats operating from Mallaig and 10,442 tCO_2e for fish feeding and transport boats from Mallaig, both for 2011.

A significant proportion of the emissions from water-borne transport are from trans-boundary freight in bulk carriers. This is based on an estimate for transport from the aggregate quarry at Glensanda on Loch Linnhe. The quarry operates entirely using sea transport. Scottish Transport Statistics recorded 5,591,000t aggregate exported in 2009, 1,439,000t domestic traffic and 4,152,000t foreign traffic (Transport Scotland, 2011, table 9.6(a)). Following details on the company website the UK journey has been estimated on sea miles to the Thames and overseas journeys on sea miles to Rotterdam to give tonne kilometres and Defra conversion factors for bulk carriers have been applied. Glensanda is one of the largest aggregate quarries in Europe and the fourth largest export port in Scotland.

3.3.4 Mobile units – other

No account was attempted for air transport. There is no airport in Lochaber but people from the area use air transport from other locations. Helicopter flights take place on behalf of the police, the health service and the rescue services and these emissions need to be captured in a full account.

Off road transport includes emissions from vehicles used on farms, on construction sites, at warehouses and mobile plant in industrial premises. A partial estimate was calculated based on fuel data from interviews and data on emissions from the Scottish Pollutant Release Inventory (SPRI) for the Glensanda aggregate quarry. The quarry reports a total release of 11,415t CO_2 in 2010 (SEPA 2012). As it was not possible to analyse this data in detail it has been divided with half allocated to stationary units and half to off road vehicle emissions.

3.4 Waste

Lochaber has a privately operated landfill site that takes all the municipal waste from the area that is landfilled. Highland Council's Annual Waste Data

Report and the Council's participation in research on waste composition enabled a clear estimate to be made for this part of the account. Waste analysis was derived from a 2009 study on the composition of municipal waste in Scotland carried out for Zero Waste Scotland (WastesWork and AEA, 2010).

It was not possible to verify the methane recovery rate at the site within the time scale of the study and a default of 0.75 was used. The Council has records of exported waste and its final treatment which allowed waste landfilled outside the area to be included in the study. Biological treatment is confined to simple aerobic composting of green waste and Council records are precise. While there is no requirement from the GPC to do so, a full account could usefully include private sector waste. The landfill operator also provides a skip service to the local area and further afield in the west Highlands, though much of this is for construction waste with a high proportion of inert material, and therefore minimal emissions. Some businesses have recycling and disposal collections to elsewhere in Scotland.

Although staff from Scottish Water and Veolia provided details of waste water management, wastewater emissions proved difficult to establish. Calculations are proposed based on a series of different treatments and efforts were made to establish the quantities of material subjected to different processes. In the study area, a pumped system in the main town of Fort William is supplemented by a network of twelve treatment stations and septic tanks throughout the district. All material from the area is taken to a centralised treatment works at Caol and sludge is then processed further at an anaerobic digestion plant at Inverness. Material is often subject to a series of treatments and therefore it proved difficult to model this with precision. The estimate given is based on population with a calculation of 4,558 people using treatment in septic tanks and 14,761 using treatment in anaerobic and facultative treatment lagoons. The latter produced the bulk of estimated emissions, 5,158 tonnes CO_2e of a total of 6,195 tCO_2e. Further work is needed to give a satisfactory result for this sector though it is unlikely to be a significant part of the account.

3.5 Industrial process and product use

The relevant process for Lochaber is the smelting of aluminium where significant amounts of carbon dioxide and perfluorocarbons are emitted during the electrolysis process. This is reported to SEPA through the SPRI and constitutes a rare example of a part of the account that is complete and accurate.

It was not possible to identify emissions for product use during the time scale of the project. There are no large industrial uses that would lead these to be particularly significant in the study area but it could be included in further survey work in order to improve this section of the inventory.

3.6 Agriculture, forestry and other land uses

Because of the rural nature of the area an estimate is given for emissions from livestock. Census figures were obtained from the Scottish Government Agricultural Census conducted in June 2011. The census is based on parishes, nine of which contain data relevant to Lochaber. Two of these, Glenelg and Lismore & Appin, contain data from areas lying outwith the Lochaber administrative district but pending further disaggregation, this data was used as the best available. The area is characterised by beef and sheep production and emission calculations were completed using the methodology described for the UK Greenhouse Gas Inventory (Brown et al, 2012) for enteric methane fermentation and greenhouse gas emissions arising from manure. A full account would require an assessment of emissions from managed soils.

It was not possible within the timeframe to complete an account of the emissions and carbon sequestration from forestry. Their importance was underlined by a Highland Council report in April (Highland Council, 2013) which draws on DECC local authority emissions statistics to show that in Highland removals in 2010 totalled 1,714,700 tCO_2. Forestry is significant in Lochaber and the inclusion of this sector would be likely to have a substantial impact on the total picture.

4. Results

While the results reflect the data gathered during the study, they are far from giving a complete picture. Some emission sources are fully covered by high quality data; these include industrial process emissions and domestic electricity emissions. Other sectors contain good quality data based on actual fuel use contributed by interviewees but are incomplete, and these include direct emissions for commercial and industrial facilities and water borne transport. Some emissions sources/sinks, such as forestry, have not been included at all, and should be assessed for future iterations of the inventory. A summary of results is shown in Table 2 using an amended version of the reporting template proposed for the GPC.

Insert Table 2 here

From the data available the largest emissions sources are electricity consumption in homes and business, and on road transportation, both accounting for 22% of total emissions. The next in importance were industrial processes and water borne transport both at 19% of total emissions. The smallest emission source included in the inventory was waste disposal, which contributed just over 1% of total emissions.

The breakdown of indirect energy emissions (Figure 1) shows domestic consumption as the largest sector (though it should be noted that Rio Tinto Alcan's electricity emissions were calculated using an emission factor of zero due to the use of hydro power).

Insert Figure 1 here

The largest emissions source within the on-road transport sector is from cars, taxis, and motorcycles, Figure 2. This may be explained by the distances between settlements and limited public transport provision in rural areas.

Insert Figure 2 here

Over half of the emissions from water borne transport are associated with the Glensanda aggregate quarry, which accounts for 53% of total emissions from this sector, as shown in Figure 3. The emissions from fishing boats and fish farming operations were also large, with each accounting for 17% of total water borne transport emissions, and therefore also warrant attention for potential abatement opportunities.

Insert Figure 3 here

Per capita emissions come to 18.77t CO_2e significantly higher than the 9.5t CO_2e reported for Highland by DECC (DECC, 2013). This is due to a number of factors: the inclusion of sources not previously measured (fishing contributes 1.2t per capita and agricultural emissions 1.55t per capita), the presence of large industries (estimates for smelting are 3.39t per capita and aggregate quarrying 2.61t per capita) and the incidence of higher emissions for heating and for transport due to geographical circumstances.

5. Discussion

A number of insights into the practicality of implementing the GPC were identified during the process of completing the case study. These practical issues are discussed first, followed by some reflections on the scope and utility of the information presented in the inventory.

5.1 Practical issues

Firstly, on a positive note, it should be highlighted that it was possible to compile this initial inventory for Lochaber with modest personnel or financial resources. An estimate of the total person-hours spent on the inventory is in the region of 400 hours (with a high proportion of the time spent identifying the best available sources of data, which would not be required for future iterations of the inventory). Given this level of resource requirement, developing an inventory should be within the grasp of most communities the size of Lochaber.

The main practical difficulty identified was with the availability of data, particularly at a disaggregated level. While the availability of disaggregated data on fuel consumption has improved since the difficulties encountered by the Biggar study (Barthelmie, 2008), there were still a number of instances where data were only partially available, for example: the DECC data for fuel use did not include bottled gas; disaggregated half hourly metered electricity data were not available below the local authority level; and data for daily traffic flows only covered major roads.

Policy-makers and the public agencies that compile statistical information might consider the additional costs involved with providing the data required for community-level greenhouse gas inventories, and compare these costs to the potential benefits of facilitating ownership of climate change mitigation at the community-level. In some cases there would be no additional costs as the data already exists but is not disaggregated due to concerns about commercial confidentiality. The experience from implementing the Lochaber case study was that larger businesses and the public sector were willing to share their data on electricity consumption and other relevant activities, being increasingly familiar with public disclosure of environmental performance and this can set a positive precedent for small and medium enterprises.

Another point on the practicality of the protocol concerns the treatment of trans-boundary emissions from mobile sources, which is a recurring problem for community accounting due to extensive travel for work across boundaries (Kennedy et al, 2010). The GPC currently favours quantifying all direct emissions from transportation within the community area, but also allows the use of a more complex method where journeys that start or end in the area are also included as scope 3 emissions (with 50% of emissions allocated to the community undertaking the inventory). In the Lochaber study, it was not possible to identify the start and end points of journeys, but given the importance of this sector further development of the GPC guidance should be undertaken to identify a practical method which allows analysis of the transport emissions to enable the understanding required to achieve reductions.

5.2 Scope and utility of the inventory

In addition to the practical issues identified above we would also like to offer some reflections on the scope and utility of the inventory results (as presented in Table 1). Firstly, one of our main reflections centres on the idea that the scope of the inventory (i.e. the emission sources that are included) should ensure a clear account is provided of the emissions that can be managed or influenced by the community. This insight is closely tied to the idea that an important purpose of the inventory is to enable the community to understand the emissions it causes, and to manage those emissions over time. Influence should be interpreted in a broad sense, and will occur at different levels. Communities have direct influence though their household and commercial activities, as well as, less directly, through civic and democratic processes such as the planning system for large developments.

The ICLEI-US protocol also emphasizes the importance of "influence" for determining the emission sources and activities included in an inventory (ICLEI, 2012, p 22). Similarly Erickson and Lazarus (2012b) suggest that community-level inventories should be focused on the emissions sources that the community has influence over, and that large industrial emission sources should be reported and managed separately as they are generally outside the community's control. The SEI report on King County (Chandler et al, 2012, p33) stresses the need to combine the criterion of influence with that of measurability and shows how this can be applied in a specific area with core priorities for building energy and local vehicle travel, then for production in the local area and thirdly for emissions from goods and services consumed. They propose a "greenhouse tracking framework" to provide a more continuous account of a community's most relevant emission sources (Chandler et al, 2012, p30). These studies focus on local governments as the main agents for change and it would be useful also to explore the potential of different sectors of the wider community and their various spheres of influence.

The GPC is largely focused on providing a production-based inventory (i.e. an inventory of the emissions occurring within the community area), and this is reflected in the use of IPCC categories and guidance for national production-based accounting. Although the protocol does allow the quantification and reporting of other emissions (i.e. those occurring outside the community area), the guidance for emission sources such as upstream emissions from imported goods and services is currently absent. The emphasis on direct emissions means that communities using the GPC will tend to concentrate on these sources, and less attention will be placed on other sources, even though the community may have more influence in those areas.

In Lochaber, for example, a high proportion of water borne transport emissions (33,350 tCO_2e or 53%) is associated with sea freight of aggregate which is beyond the normal control of the community. This emission source may be contrasted with emissions due to household consumption from imported goods which may, to a higher degree, be within the control of the community. In addition to being an emissions source that can be influenced by the community, a number of studies suggest that this source of emissions is also likely to be large (Erickson 2012a; Scottish Government 2012; Barrett, 2011).

Inventories will be more useful for decision-making and mitigation planning if they include all the emission sources that can be influenced by the community. We welcome the inclusion of the criterion of influence by ICLEI and SEI and would recommend that the criterion for determining which emission sources are included in the inventory should take account of the degree to which the community can control or influence each emissions source, coupled with consideration of the size of the emission source, with priority given to large sources which can be affected by community action. The proposal that the GPC be expanded to include consumption based emissions is already being implemented in the guidance in from ICLEI-US and PAS 2070.

A second reflection on utilising the results from the inventory is that some of the methods used for the GPC differ from other existing carbon accounting exercises already undertaken within the area. For example, the GPC waste method calculates the on-going emissions from waste disposed of during the inventory year, whereas the Scottish Pollutant Release Inventory (SPRI) quantifies emissions occurring within the inventory year (regardless of when the waste itself was disposed). Also the GPC calls for a more comprehensive account than those undertaken to date. For example the Highland Council undertake an organisational-level greenhouse gas inventory, but the scope of the inventory has focussed on the emissions associated with the Council's activities and estate rather than all the emissions from the Highland Council area. When using the GPC inventory to engage with different stakeholders who are already engaged in their own carbon accounting exercises it will be important to clearly communicate the differences in methods and scopes, in order to avoid misunderstandings or confusion.

As noted above, clarification is needed on the use of site specific electricity emission factors, and also on the reporting of emissions associated with transmissions and distribution losses. Clear guidance in this area already exists in the GHG Protocol corporate standard, which could be adopted in the GPC.

A fourth point is that while the GPC provides a clear identification of major emission sources, a more detailed understanding of the reasons for the emission-generating activities is needed when planning mitigation actions. For example, the GPC inventory results for domestic electricity consumption show the total emissions that could be targeted by mitigation actions, but do not show whether the electricity consumption is for space heating, tumble drying, other appliance use etc. This more detailed information is highly important when designing specific abatement interventions. The Biggar study sought to fill this gap through survey work scaled up through household categorisation derived from the census (Barthelmie, 2008).

A final point is that, based on the Lochaber case study, we fully endorse the intention to update the GPC with guidance on emissions from agriculture, forestry and other land uses (AFOLU). To provide one example of the potential value of AFOLU results, in Lochaber a recent development involved the removal of 180,000 m^3 of peat, and the availability of information on the emissions impact through a community-level inventory would have been highly relevant during the local planning decision process.

6. Conclusion

The Lochaber case study shows that the protocol is clear and applicable, and that the main obstacles to implementation are the availability of data. Data availability could be addressed to a large degree if government statistics agencies are mandated to provide the data required for community inventories, thereby facilitating community action on climate change.

The principle weakness in the GPC itself is that it is primarily focused on providing a production-based inventory, whereas the purpose of managing emissions would be best serviced if priority were given to emission sources that can be managed by the community (regardless of whether these are production or consumption-related emissions). We welcome proposals by ICLEI-US and BSI to ensure that consumption based emissions are included in the account and recommend that the criterion for determining which emissions sources are included in the inventory should be the degree to which the emission sources can be influenced by community action.

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Table 1 Categorisation of results by scopes

Sector		Scope 1	Scope 2	Scope 3
Stationary Combustion (Direct)		Direct emissions		
Stationary Combustion (Indirect)			Use of electricity	
Mobile Combustion	On road	Trips wholly in area		½ cross boundary trips
	Rail	Trips wholly in area		½ cross boundary trips
	Water	Trips wholly in area		No specification for cross boundary
	Air	Trips wholly in area		No specification for cross boundary
	Off road	Direct emissions		
Waste	Landfilled waste			Emissions in area and emissions

				from material landfilled out of area
	Biological treatment and incineration	Treatment in area		Treatment outside area
Waste Water		Treatment in area		Treatment outside area

GPC version 0.9 Arikan et al 2012a

Table 2 Greenhouse Gas emissions for Lochaber

GPC No	IPCC class	Scope	GHG Emission Sources			
				CO_2 equivalent tonnes	% (excluding AFOLU)	%age including agriculture
			Stationary Units			

I.1			**Residential Buildings**			
I.1.1	1A4b	1	Direct emissions (scope 1)	20,024	6%	6%
I.1.2		2	Energy indirect emissions (scope 2)	39,640	12%	11%
I.2	1A2, 1A4a, 1A4c,1A5,		**Commercial and Industrial facilities**			
I.2.1		1	Direct emissions (scope 1)	11,885	4%	3%
I.2.2		2	Energy indirect emissions (scope 2)	33,227	10%	9%
II			**Mobile Units**			
II.1	1A3b		**On-Road transportation**			
II.1.1		1	Direct emissions (scope 1)	74,131	22%	20%
II.1.2		2	Energy indirect emissions (scope 2)			
II.1.3		3	Indirect transboundary emissions (scope 3)			
II.2			**Railways**			
II.2.1	!A3c	1	Direct emissions (scope 1)	2,469	1%	1%
II.2.2		2	Energy indirect emissions (scope 2)			
II.2.3		3	Indirect transboundary emissions (scope 3)	4,028	1%	1%
II.3			**Water borne transport**			
II.3.1	1A3dii	1	Direct emissions (scope 1)	25,420	8%	7%
II.3.2		2	Energy indirect emissions (scope 2)			
II.3.3		3	Indirect transboundary emissions (scope 3)	37,815	11%	10%
II.4	1A3aii		**Aviation**			
II.5			**Off road**			

II.5.1	1A3eii	1	Direct emissions (scope 1)	7,563	2%	2%
III			**Waste**			
III.1			**Solid waste disposal**			
III.1.1	4A	3	Emissions from landfills in boundary (scope 3)	4,391	1%	1%
III.1.2		3	Emissions from landfills outside boundary (scope 3)	12	0.004%	0.003%
III.2			**Biological treatment of waste**			
III.2.1	4B	1	Direct emissions (scope 1)	156	0.05%	0.04%
III.2.2		3	Emissions from treatment outside boundary (scope 3)			
III.3	4C		**Incineration**			
III.4	4D		**Waste water treatment and discharge**			
III.4.1		1	Direct emissions (scope 1)	6,146	2%	2%
III.4.2		3	Emissions from treatment outside boundary (scope 3)	31	0.01%	0.01%
IV			**Industrial Processes and product Use**			
IV.1	2A - 2E	1	Direct emissions from industrial processes	64,405	19%	18%
		1	Direct emissions CF4	837	0.3%	0.2%
		1	Direct emissions C2F6	296	0.1%	0.1%
IV.2	2D - 2H	1	Direct emissions from product use			
Sub total				332,476	100%	

V			**Agriculture Forestry and other Land Use**			
V.1		1	Direct emissions from livestock (scope 1)	30,113		8%
Total				362,589		100%

Figure 1 Indirect emissions from grid supplied electricity

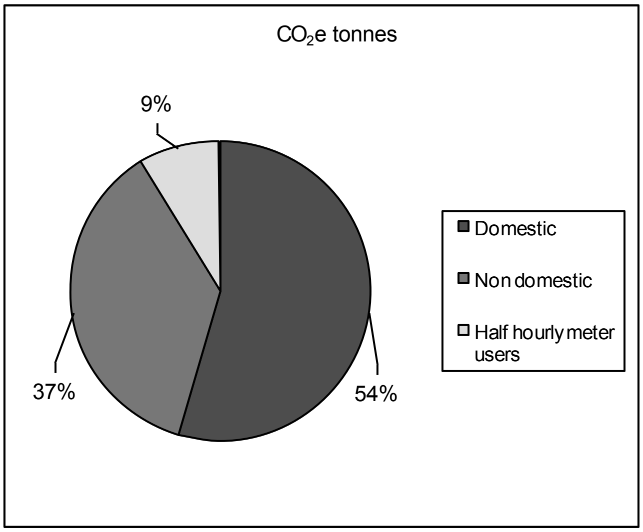


Figure 2 Road transport emissions

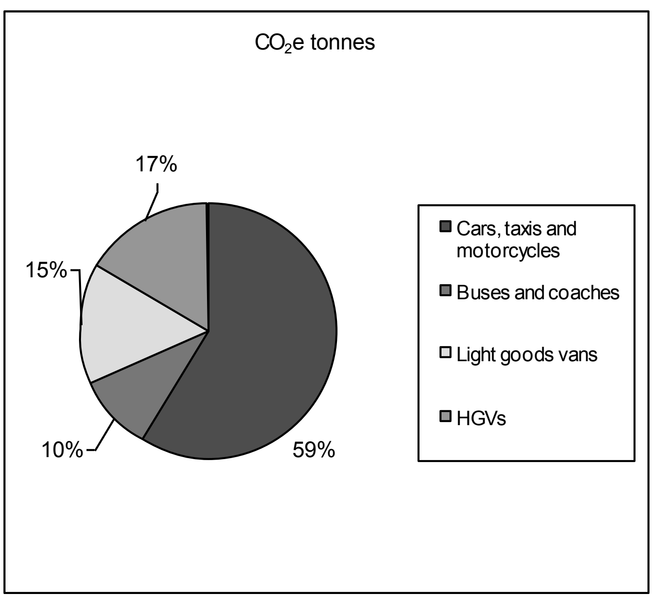
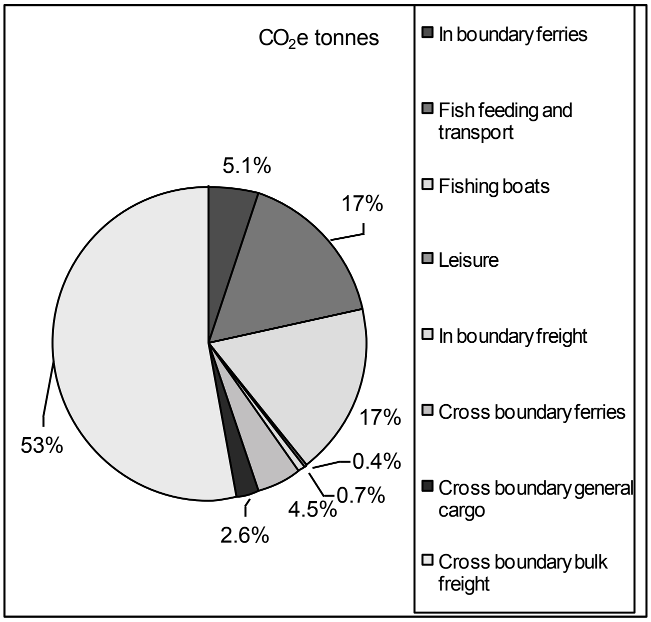


Figure 3 Water borne transport emissions



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