Co-financed by the European Regional Development Fund

Inspire Policy Making with Territorial Evidence

REPORT //

QGasSP – Interim report

Quantitative Greenhouse Gas Impact Assessment Method for Spatial Planning Policy

Adjusted Interim Report // June 2021

This report is conducted within the framework of the ESPON 2020 Cooperation Programme, partly financed by the European Regional Development Fund.

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Disclaimer

This document is an interim report.

The information contained herein is subject to change and does not commit the ESPON EGTC and the countries participating in the ESPON 2020 Cooperation Programme.

The final version of the report will be published as soon as approved.

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Abbreviations

CDP	County Development Plan
BER	Building Energy Rating
CCS	Carbon capture and storage
CIBSE	Chartered Institution of Building Services Engineers
CLC	CORINE Land cover
CLMS	Copernicus Land Monitoring Service
CO2e	Carbon Dioxide equivalent
COICOP	Classification of Individual Consumption According to Purpose
CORINE	Coordination of Information on the Environment Land Cover
CRF	Common Reporting Format tables
EFDB	Emission factor database
EGTC	European Grouping of Territorial Cooperation
EIO	Economic input-output
EPC	Energy performance certificate
ESDAC	European Soil Data Centre).
EU	European Union
FI	Finland
GHG	Greenhouse Gasses
GPC	Global Protocol for community-scale greenhouse gas emissions inventories
GWP100	Global Warming Potential after 100 years
HBS	Household budget surveys
IE	Ireland
IO	Input-Output approach
IPCC	Intergovernmental Panel on Climate Change
IWA	Oivan Oy
LCA	Life Cycle Assessment
LPIS	Land Parcel Information System
LULUCF	Land-use, Land-use Change and Forestry
NAP	Northern Area Plan
NFI	National Forest Inventory
NIR	National inventory report
NPF3	Scotland's Third National Planning Framework
PAS	Publicly Available Specification
QGasSP	Quantitative Greenhouse Gas Impact Assessment Method for Spatial Planning Policy
SEA	Strategic Environmental Assessment
SEI	Stockholm Environment Institute Tallinn centre
TalTech	Tallinn University of Technology
UI/UX	User Interface / User Experience Design
UK	United Kingdom
UNFCCC	United Nations Framework Convention on Climate Change

1 Introduction

1.1 Objectives of the project

The objective of the QGasSP project is to produce a methodology that will allow competent planning authorities at national, regional and local administrative levels to quantify the influence of spatial planning policies on greenhouse gas (GHG) emissions in a consistent manner. More specifically, the objective is to address the knowledge demands and technical requirements of the four stakeholders included within this Targeted Analysis Project:

- the Eastern and Midlands Regional Authority (IE)
- Scottish Government – Planning & Architecture Division (UK)
- Department of Infrastructure, Northern Ireland (UK) and
- Regional Council of Kymenlaakso (FI).

The key research questions are as follows:

- How can consistent and comparable GHG baseline emissions data be collected at national, regional and local levels to assess the urban and land-use share of GHG emissions relevant for spatial planning policy and practice?
- How can the efficacy of spatial plans and possible alternatives be systematically modelled, via standardised quantitative methodologies and accounting protocols, to determine their overall impact on GHG emissions, and aid cross-country, inter-regional and inter-municipality comparisons?
- How can a better scientific understanding be developed of how national, regional and local planning authorities can prioritise relevant GHG mitigation strategies, including through enhancing the effectiveness of the SEA process, to rapidly build political will for climate action?

GHG quantification in spatial planning is currently not harmonised by European or international standards: cities and countries have developed their own methods, which are being applied to monitor their own GHG emissions. There is a significant variation in the availability and structure of datasets across Europe, furthermore, the planning systems in each European country differ from one another. To overcome the lack of international harmonisation in GHG quantification in spatial planning, the service providers have chosen to focus on a limited set of direct emission sources that have a major impact on total CO_2 emissions and are directly dependent on spatial planning decisions. The set of emission sources are listed in Annex 2. These sectors are:

- Building energy use
- Transportation & Infrastructure
- Land use change.

The QGasSP project is carried out by the researchers and experts from:

- Stockholm Environment Institute, Tallinn Unit, SEI Tallinn
- Codema - Dublin's Energy Agency
- Helsinki-based IT consultancy Oivan Oy (IWA Oy)
- Tallinn University of Technology, Academy of Architecture and Urban Studies (service provider)
- University of Iceland (as a sub-consult for the service provider).

1.2 The content of the interim report

This interim report will provide preliminary responses to the research questions of the project and also gives an update on the progress of the QGasSP project covers Task1–Task 3 including:

- Model development and the quantification methodologies for the tool
- The development of the baseline analysis and the pilot case studies
- Status of the tool development.

2 Project implementation

Six interlinked tasks were established for the implementation of the assignment. The task schedule is presented in Annex 1. The status of the task implementation is as follows:

Task 1: Methodological framework; lead: SEI Tallinn, completed in January 2021.

Task 2: Baseline analysis; lead: SEI Tallinn, to be completed by the end of May 2021.

Task 3: Model development; lead: Oivan, to be completed by the end of August 2021.

Task 4: Case study pilots; lead: Codema, to be completed by the end of the project.

Task 5: User manual and guidance; lead: TalTech, to be commenced in August 2021.

Task 6: Coordination, communications and reporting; lead: TalTech (continuous throughout the project).

Figure 1 shows the progress with the tasks by mid-April 2021.

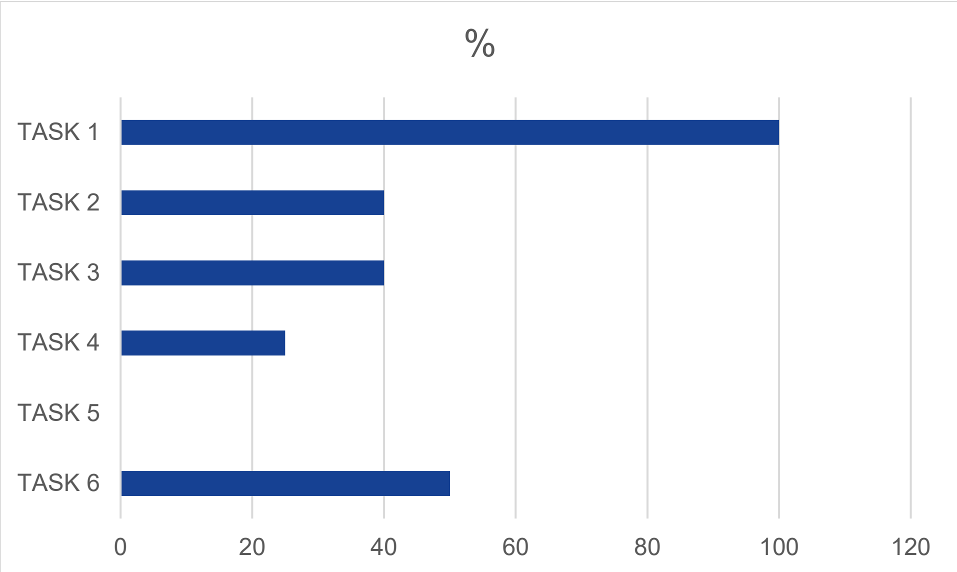

Figure 1: Progress with the project tasks in the mid-April.

In accordance with the project plan, the research team has been preparing a tool which can quantify GHG emissions of any European region in two modes. 1) applying territorial approach (in the former documents this was referred to as production-based approach) and 2) applying consumption-based approach. The two approaches are described in greater detail in chapter 3.

Task 1 was completed at the end of January 2021, currently, work on the baseline analyses and the application of the calculation methods continues under task 3. As a result of Task 1 and a peer review of the project's methodology, the service providers have made the decision to apply the Tiered hybrid Life Cycle Assessment (LCA) method in the consumption-based approach. This provides a solution to the crucial challenges encountered with pan-European methodologies, which includes one of the three key research questions: how to collect consistent and comparable GHG baseline emissions data at national, regional and local levels? Following this decision, professor Jukka Heinonen from University of Iceland has joined the team as advisor and expert of the Tiered hybrid LCA method.

In Task 3, the service providers made the decision to create a tool with a modular structure, in which localised sectoral quantification models can, at a later date, replace the first versions created in this project. The tool will be published as an open-source code. These solutions will, firstly, encourage territories and cities to adopt the tool, as they can incorporate their existing datasets in the tool. Secondly, this helps to future-proof the tool, as it will be able to support future developments of GHG quantification.

Overall, the project is proceeding on schedule, although the local data collection process has turned out to be time-consuming, which is mainly due to the diversity of formats and structures of local datasets.

3 Methodology and model development

3.1 Introduction

This chapter is based on Task 1 and Task 3, and provides preliminary responses to two of the research questions:

- How can consistent and comparable GHG baseline emissions data be collected at national, regional and local levels to assess the urban and land-use share of GHG emissions relevant for spatial planning policy and practice?
- How can the efficacy of spatial plans and possible alternatives be systematically modelled, via standardised quantitative methodologies and accounting protocols, to determine their overall impact on GHG emissions, and aid cross-country, inter-regional and inter-municipality comparisons?

The lack of harmonization becomes visible when collecting local datasets. In all emissions sectors, European countries and territories (and cities) have created their own databases with detailed information which is locally relevant. But the structure, the terminology and the taxonomy applied in these databases are not harmonized. Applying datasets with different kinds of structures makes the comparison of the baseline analyses and the quantification results more difficult. Moreover, these local datasets typically focus on locally originating territorial emissions, but leave out the global production and supply chains, and therefore, can lead to biased policy-guidelines.

Comparable European data for GHG quantification can be created through standardization. The harmonization of European datasets is not within reach in this project, therefore the QGasSP project needs to find a way to operate with incoherent datasets.

One difficulty to overcome origins from the fact that spatial planning is done in various scales. The target areas for the GHG quantification can vary in size; they can be anything between a large territory and a tiny part of a town or a rural muncipality. Thus, the number of potential target areas in Europe is enormous, and this kind of all-inclusive area-specific data of all scales cannot be collected and inserted in the tool beforehands as one single effort. Moreover, any attempt to specify the possible target areas during the tool design would limit the use of the tool. Therefore, the new tool needs to apply a flexible system which allows the user define any target area for the quantification, and then provides an opportunity to upload datasets which are relevant to this specific target area – disregarding the size and type of the area. Including predefined datasets in the tool is possible in national quantification tools, such as SPACE, when the number of potential target areas is known.

Another challenge for a future-proof tool is that the data for GHG quantification does not consist of constants but is changing all the time. Typically European, national and local datasets are updated annually. For this reason, the tool will need maintenance: the datasets need be updated so that the tool always uses the most relevant data available and the quantification results are reliable, supporting just decision-making.

In the QGasSP model, the GHG baseline emissions data collection is based on the combination of top-down and bottom-up approaches.

In this context, “top-down” means applying European datasets, which provide comparable data, typically at a national level. This data origins from databases such as Eurostat. As it is not possible to read automatically the updates in various European databases, the European default datasets of the tool need to be up-dated by the owner of the software. In this way the accuracy of the results remains high also in the future.

Here “bottom-up” refers to the collection of local data. “Local” refers here to any target area, which is selected for quantification, spanning in size from territories down to local detailed plans.

The tool will be able to quantify GHG emissions also without the bottom-up local data (using the default datasets uploaded by the owner of the tool) - but in this case the accuracy of the results is not high. For example in the quantification of the GHG emissions from traffic, national modal share (default data, top-down) may differ significantly from the modal share of the target area (local data, bottom-up). The latter should be prioritized whenever possible. This is further demonstrated in chapter 6.2 Importance of local data.

To start the GHG quantification with the local data, **an expert user** is expected to create a local set-up. Expert user is a person who is familiar with the GHG quantification principles and has access to local datasets, for example environmental specialist of planning department or consult. The local set-up includes collecting and inserting local datasets, and this process is instructed in one of the user manuals. The local set-up needs to be done once, and preferably up-dated whenever the local datasets are updated. This could be once in 1–3 years.

The local set-ups are saved and open for any user. For example, once the set-up for Dublin is created, all users of the tool can carry out GHG calculations concerning Dublin without expert-level knowledge on GHG quantification. An accumulative number of datasets in the tool will make it attractive for new users.

Once the local set-up and the baseline analysis are done by an expert user, the GHG quantification of different kinds of policies and spatial plans within this region can be done without expert-level knowledge. The user can be, for example, a planner who wants to evaluate the impacts of alternative solutions. In the tool, the impact of the spatial plan/policy can be compared with the baseline and evaluated against the climate neutrality target.

In principle, the target area for the quantification can be of any size. In practise, the parameters of the tool are more suited to quantify the GHG emissions of larger areas, such as territories and cities. Very small target areas, such as urban quarters, would require specific parameters and more detailed (building level) data as well as functionalities which would be difficult to combine with the ones relevant for territories.

To address the objective of comparability of results, the QGasSP tool will provide two frameworks for GHG quantification. These are 1) territorial GHG quantification (in the inception report referred as “production-based approach”) and 2) consumption-based GHG quantification. Similarly to the former EcoCity Evaluator tool, both modes are included in the same tool.

The first mode, the territorial approach, is similar to the methods that the cities and regions typically apply today. Territorial approach can be used to monitor the development within the target area, but the results cannot be compared. The first version of the tool includes three modules to quantify the CO_2 emissions in three main sectors, which are most relevant to spatial planning policies. However, the modularity of the tool enables the creation of new modules to cover new emission sectors to make the quantification more complete.

The latter, i.e. the consumption-based approach, enables the cross-country, inter-regional and inter-municipal comparisons. Today, the cities and territories are less familiar with this approach, but it is endorsed by many researchers (for example (Heinonen, et al., 2020); (Afionis, et al., 2017) and the C40 cities (Ramboll; C40 Cities Climate Leadership Group, 2020).

In the consumption-based mode, the QGasSP tool applies the tiered hybrid LCA method, which is described in detail in chapter 3.5. The tiered hybrid LCA method shows not only the local direct emissions, but also the global life cycle consequences of local activities. In the consumption-based mode, the quantification covers an extensive number of emission sectors, and applies local data on the three key emission sectors to make the results more accurate. The tiered hybrid LCA method is applied in research, but there are no known tools which would be based on this method. As a methodology it provides a solid response to the two research questions presented in the beginning of this chapter.

Along with the Green Deal climate commitments, the new tool is increasingly likely to be used to compare and analyse the alternative pathways towards carbon neutrality, which the European Union aims to reach by 2050. Thus, the baseline analysis needs to span at least until 2050. Moreover, it would be beneficial, if the carbon offset solutions could be specified and quantified with the same tool.

3.2 International standards and guidelines on GHG quantification

The model utilizes the following standards and guidelines:

- IPCC Guidelines for National Greenhouse Gas Inventories: (Eggleston H.S., 2006) (Hiraishi, 2014) (Calvo Buendia, 2019)
- the Global Protocol for community-scale greenhouse gas emissions inventories (GPC), published in 2014 (World Resources Institute; C40 Cities Climate Leadership Group; ICLEI - Local Governments for Sustainability, 2014).
- PAS 2070: Specification for the assessment of greenhouse gas emissions of a city (PAS, 2013).

3.3 European data for top-down quantification

The model applies the following European datasets as default values:

Energy use in buildings

- EU Buildings Database will be used to give information on the total floor area and energy demand by fuel type per m^2 for both residential and commercial buildings
- CO_2 emission factors: Covenant of Mayors Emission Factors for Member States of the European Union
- CO_2e emission factors for various types of fuels and renewable energy sources: IPCC EFDB (IPCC, 2021).

Traffic and infrastructure

- Modal shares: Eurostat
- CO_2e emission factors for the various modes of transportation
- Prognosis on technology development
- Grid electricity CO_2e emission factors (Covenant of Mayors)
- CO_2e emission factors for various types of fuels and renewable energy sources.

Land use change

- CO_2 emission factors for the quantification of land-use change: IPCC Land Use, land-use Change and Forestry (LULUCF) sector methodology along with national (NUTS0) implied emission factors submitted in the NIR and CRF tables is applied to relevant case study pilots.

Consumption approach

- The multiregional input-output matrix, environmental extensions describing emissions intensity, and a large part of the vector of final demand are taken from Exiobase
- Additional user/consumer behaviour (showing monetary purchase of goods and services) is determined from household budget surveys. These are prepared by local statistics authorities and compiled together by Eurostat.

Local datasets collected for the baseline analysis are introduced in the chapter 4 and Annex 2.

3.4 Territorial approach

Territorial GHG quantification is a straight-forward way of estimating the direct GHG emissions within the selected target area. However, the comparisons between territories are not possible. The territorial GHG quantification can be used to steer and monitor the GHG emission development within a single territory, city or area. These are the so-called Scope 1 emissions (Greenhouse Gas Protocol)

If the logic of the territorial approach is strictly followed, some difficulties in GHG accounting occur. For example, if the power plants which provide energy for the buildings and transportation are outside the target area, they should be excluded from the analysis; in some cases this would result in zero CO_2e emissions for energy use in buildings. Energy production outside the target area constitutes the so-called Scope 2 (Greenhouse Gas Protocol), which is a typical extension to the territorial approach.

For this very practical reason, the GHG quantification frameworks applied by the territories and cities today tend to apply mixed approaches. Although these methods in general are based on territorial approach, the GHG emissions of energy production for example are typically allocated to buildings (where the energy is used), no matter where the energy is produced. The GHG emissions of traffic activity are often quantified with the data of local mobility surveys, which actually belong to the consumption-based approach, although typically omit any indirect emissions (other than fuel combustion). However, quantifying the climate impact of land-use changes within the target area is clearly a territorial component in a GHG quantification framework.

3.4.1 IPCC LULUCF method - strengths and limitations

The QGasSP service providers will implement the Land Use, Land-use Change and Forestry (LULUCF)[1] sector methodology according to the IPCC guidelines (Eggleston H.S., 2006) (Hiraishi, 2014) (Calvo Buendia, 2019) for quantifying territorial carbon emissions under land use. LULUCF is an inventory sector defined by the IPCC that covers anthropogenic emissions and removals of GHGs resulting from changes in terrestrial carbon stocks. It covers the carbon pools of living biomass (above- and below ground), dead organic matter (dead wood and litter) and organic soil carbon for six broad land categories: forest land, cropland, grassland, wetlands, settlements (urban areas) and other land. Both emissions and removals of GHGs can be estimated according to the LULUCF methodology.

In addition, wood products such as timber used in construction or furniture, referred to as harvested wood products (HWP), can be reported as an additional pool within the LULUCF sector. However, they will not be included in the tool due to the complexity of HWP reporting and limited timeframe of the QGasSP project, and due to the availability of numerous wood product models, including in the project stakeholders countries. Depending on the balance between carbon inflows and outflows, the HWP pool can be either a carbon sink or source, as carbon is added to the HWP pool when new products are produced and released when older products reach the end of their useful life and are burned or sent to solid-waste disposal sites, where they decompose at varying rates. Thus, changes in carbon stocks associated with the production and end use of HWPs fall within a broader system that includes forest ecosystem carbon balance, attendant changes in manufacturing emissions from displaced products (e.g., concrete), emissions from biofuels, and decay in disposal sites. The potential of HWPs as a carbon sink is only realized if future market activity is sufficient to, at the very least, offset the decay from previously consumed products. Eventually, socioeconomic factors like population, income and trade, will determine the amount of wood products produced and consumed in the future, and thus, the carbon sequestration potential of the HWP pool on regional scales. Population and income levels are expected to rise, however, the future developments of socioeconomic factors are uncertain, making the contribution of HWP production to carbon stored within HWPs in end uses difficult to predict (Johnston & Radeloff, 2019). The 2013 Revised IPCC Good Practice Guidance (Hiraishi, 2014) suggests using the production approach, which only allows to account for HWPs made from domestic harvests that may underestimate the contribution of the HWP carbon stored in end uses because it ignores traded timber (Johnston & Radeloff, 2019). According to the IPCC methodology there are three HWP categories - sawnwood, wood-based panels, and paper and paperboard, while HWP used for energy purposes and HWP in solid waste disposal sites are excluded as well as HWP resulting from deforestation[2]. To calculate the annual emissions and removals of carbon from the HWP pool the IPCC outlines guidance related to three tiers of input availability. Tier 1 “Instantaneous oxidation” method assumes that the annual amount of carbon leaving the HWP pool is the same as the annual carbon inflow to the pool. In consequence, this method corresponds to an estimate of no change in HWP carbon stocks. It equals the assumption that all carbon in the biomass harvested is oxidised in the removal year (i.e. year of harvest) and is equivalent to reporting no net-emissions from HWP, as the annual change in carbon stock in HWP is zero. Tier 2 method assumes that emissions from the HWP pool follow a first-order exponential decay function, where the CO_2 stock of the HWP category at the beginning of each year expands as new products enter the pool and contracts as existing products decay based on each product’s half-life. Under a Tier 3 method, more accurate country-specific information is applied. This includes activity data and/or emission factors (i.e. service life information of HWP), which is intended to improve the accuracy of the estimates. For purposes of simulating carbon stock in wood products, models with a simple structure may be sufficient, but to compare climate change mitigation options,

[1] LULUCF is also referred to collectively as agriculture, forestry and other land use (AFOLU). In the QGasSP project the land use sector is limited to the scope of LULUCF methodology.

[2] Decision 2/CMP.7 (Land use, land-use change and forestry) contained in document FCCC/KP/CMP/2011/10/Add.1 states that harvested wood products resulting from deforestation shall be accounted for on the basis of instantaneous oxidation

complex models are needed (Brunet-Navarro, et al., 2016). A Tier 2 method based HWP module could be built in the QGasSP tool in the future, however the main difficulty wood product models face, which is a lack of data, remains. Reliable data regarding time- and location-specific wood removals, industrial processes, and the use phase, which is important to estimate product lifespan and removal rate, is generally lacking. Hence, wood product models heavily rely on assumptions (Johnston & Radeloff, 2019). In addition, several EU countries have adopted their own HWP models. The carbon gains and losses in the HWP pool are estimated in the UK using the CARBINE model, in Ireland using the separate HWP model in conjunction with the Canadian Forest Service Carbon Budget Model framework (CFS-CBM) model, and in Finland using a flux-data method.

Carbon dioxide (CO_2) is the main greenhouse gas responsible for climate change (IPCC, 2013). The main GHG occurring in the LULUCF sector is also CO_2, while non-CO_2 emissions are predominantly non-key categories[3] in the EU LULUCF sector (Kuikman, et al., 2011), therefore non-CO_2 emissions like nitrous oxide and methane will not be incorporated into the web-based tool in the first approximation. The LULUCF sector non-CO_2 emissions are derived from a variety of sources, including emissions from soils, for example from nitrogen inputs when fertilising forest land, cultivation of organic soils and soil organic matter mineralization (e.g. due to land use conversion and drainage of forest soils), and from anaerobic decomposition of organic material in wetlands. Non-CO_2 emissions also emerge from combustion of biomass, dead wood and litter (forest fires). Non-CO_2 GHG emissions from agricultural land, e.g. CH_4 and N_2O emissions from livestock and manure management emissions do not depend on land characteristic, and are covered by the inventory sector 'agriculture' and are therefore not part of the LULUCF sector (Kuikman et al., 2011). Emissions of CH_4 and N_2O equaled in 2019 about 12% of total annual net carbon removals in the EU LULUCF sector (European Environment Agency, 2021). Thus, excluding non-CO_2 emissions in the tool does underestimate total LULUCF sector emissions to a certain extent. The quantification frame of LULUCF non-CO_2 emissions could be added in the tool in a post-project maintenance and development stage, however, the aim the QGasSP project and rationality of this functionality must be taken into account, for spatial planning does not cover specific activities, e.g. the area of prescribed burning or usage of fertilisers on a land, that cause non-CO_2 emissions.

The LULUCF sector has numerous inherent characteristics that complicate reporting and mitigation activities. Managed land is strongly influenced, but not entirely controlled by human intervention. A complex set of processes in terrestrial vegetation and soil cause both carbon emissions and removals, which can result in either net emissions or removals on balance over an area of land. Furthermore, the capacity for terrestrial vegetation and soil to remove carbon from the atmosphere saturates because ultimately, a steady state will occur in the balance of emissions and removals for a given area of land. As a consequence of saturation, the potential to mitigate greenhouse gas emissions through vegetation management is finite. Emission reductions or increased removals achieved through mitigation activities in the LULUCF sector are also potentially reversible due to a phenomenon known as impermanence. In addition, agriculture and forestry measures can indirectly contribute to GHG mitigation through growing and harvest of biomass to substitute for GHG intensive materials and fossil fuel (Kuikman, et al., 2011).

Justification for applying the IPCC LULUCF methodology for land use sector in the QGasSP project is the following:

- The IPCC methodology is applied worldwide, including among the EU countries, and serves as the basis for reporting GHG emissions under the UNFCCC and the Paris Agreement. All the QGasSP case study pilot countries already implement the IPCC methodology for reporting annual GHG emissions, however this is usually done at a national scale.

[3] Key categories are GHG inventory categories which individually, or as a group of categories (for which a common method, emission factor and activity data are applied) are prioritised within the national inventory system because their estimates have a significant influence on a country's total inventory of greenhouse gases in terms of the absolute level, the trend, or the level of uncertainty in emissions or removals. Whenever the term key category is used, it includes both source and sink categories. (2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories)

- The IPCC methodology and related national inventory reports (NIR) follow the TACCC principles - transparency, accuracy, completeness, comparability and consistency; meaning the methodology is harmonized across countries and allows adequate comparison of GHG emissions from land use between countries and regions which was one of the aims of the QGasSP project.
- All land use categories, carbon pools, as well as the carbon sinks and sources are accounted for, thus the full potential of CO_2 reduction can be estimated when comparing the climate impact of different spatial planning documents and strategies.
- Six broad IPCC land-use categories form the basis of estimating GHG emissions and removals from land use and land-use conversions. The land uses may be considered as top-level categories for representing all land-use areas, with sub-categories describing special circumstances significant to emissions estimation, and where data are available. The categories are broad enough to classify all land areas in most countries and to accommodate differences in national land-use classification systems.
- National inventory reports with accompanying common reporting format tables (with implied emission factors) are updated annually and reviewed by UNFCCC. Thus, NIR and CRF tables provide up-to-date land use data that can be integrated into the spatial planning GHG quantification tool database.
- Although the IPCC LULUCF methodology has been developed to estimate GHG emissions and removals at a national level, the structure, data requirement and GHG quantification is also applicable at smaller scales.

Two essential data needs are identified in the IPCC guidance:
1. Area or area change data for the land use categories
2. Information on associated carbon stocks and relevant GHG emissions factors.

Obtaining the above mentioned data, however, might be difficult to acquire. Reporting of land use emissions is a technically complex matter, which is subject to ongoing improvement, refinement and gap-filling both for determining spatial land use changes and accompanying emissions. There are several limitations and difficulties when applying the LULUCF methodology in the QGasSP project tool, some of which are addressed as following:

- Land representation and defining land use categories: Geographically explicit data is needed for calculating land use emissions and removals. Countries use various methods to obtain land area data, including annual census, periodic surveys and remote sensing. Each of these methods of data collection will yield different types of information. For example UK uses a mix of National Forest Inventory (NFI) data, Land Cover Map 2015, UK Directory of Mines and Quarries and Google Earth imagery, digital map of RB209 soil types; Ireland uses a combination of CORINE land cover data set, NFI, maps and aerial photography, EU Land Parcel Information System (LPIS), Indicative Soils Map of Ireland; Finland uses NFI, LPIS, aerial images, Finnish georeferenced soil database etc. The service provider acknowledges that the approaches and applied databases are appropriate for each country, however, the aim of the QGasSP project is to develop a robust, simple and standardised tool for quantifying GHG impacts of spatial planning policies, with pan-European applicability. Hence, the use of open source pan-European datasets is recommended. The QGasSP service providers propose to use the Copernicus Land Monitoring Service (CLMS) for determining spatially explicit land use classes and relevant areas for the case study pilots for the baseline analysis.

  CLMS provides Corine Land Cover (CLS) vector datasets that are based on the classification of satellite images produced by the national teams of the participating countries - the EEA members and cooperating countries (EEA39). National CLC inventories are further integrated into a seamless land cover map of Europe. The resulting European database relies on standard methodology and nomenclature with the following base parameters: 44 classes in the hierarchical 3-level CLC nomenclature. There are different CLS datasets, like base status layers (minimum mapping unit (MMU) 25 hectares) and CLC-Change layers (MMU=5ha). Status layers synthetized with CLC-Change layers are called Corine Land Cover "CLC accounting layers" and are 100m raster datasets that comprise CORINE Land Cover status layers, modified for the purpose of consistent statistical analysis in the land cover change accounting system at EEA (Copernicus Land Monitoring Service, 2021; European Environment Agency). The accounting layers will be applied for determining current land use types and CO_2 emissions and removals in the case study pilots for baseline analysis.

  There are also several limitations to the CORINE maps. Theprovided land classes are broad and do not cover all the LULUCF land use specialties, for example CORINE does not distinguish active peat extraction areas. Furthermore, the IPCC LULUCF methodology allows countries to have flexibility in defining the six land use classes, which makes it difficult to align the 44 CORINE land classes according to the 6 IPCC land use classes. Also the mapping unit of >5 ha might limit the accuracy of determining land classes on small scale planning.

- LULUCF methodology requires to determine general soil type (organic or mineral soil) for each land use class, while only a few EU countries have spatially explicit soil maps. The service providers are currently testing the applicability of the ESDAC European Soil Database (European Soil Data Centre, 2013).

- Availability and accuracy of emission factors: The IPCC guidelines define three “tiers” to indicate different levels of accuracy, whereby the tier three method is the most accurate and the tier one method the least accurate. National GHG inventories comprise data with different levels of accuracy. By default, country-specific implied emission factors will be applied for case study pilots. The service providers acknowledge that this top-down approach has the drawback that applied emission factors reflect the national average for a certain emission source but not necessarily the actual local emissions. To overcome this drawback, the user of the GHG quantification tool can replace the top-down emission factors by local (bottom-up) data.

- Data uncertainty: Land use sector comprises highly complex and dynamic ecological systems which translates in uncertainties of the estimates and of their attribution. Uncertainties associated with land use are significantly higher than those in the energy and industrial sector. For example, the combined uncertainty of emission factor and activity data of CO2 emissions exceeded 100% for forest land, cropland, grassland and wetlands in Ireland's 2020 national GHG inventory submission. At sector level, LULUCF emissions estimates have the highest uncertainty also in the UK's and Finland’s 2020 national inventory reports.

- Temporal variability of emission factors: In the current tool development stage, land use baseline scenario and subsequent emissions and removals due to land use are calculated based on a simple linear function: Emissions = (activity data) x (emission factor). The most up-to-date implied carbon-stock-change factors converted to CO_2 emission factors from national GHG inventory reports are applied by default. The emission factors reflect current environmental state and are subject to change due to technical corrections as well as constant dynamic changes in the environment (carbon density). While changes in soil C stocks are relatively slow and occur over decades, changes in the biomass carbon stocks are rapid, e.g. due to the sigmoid growth of a stand of trees. Thus, it is highly recommended to update the emission factors in the course of future use of the tool. Furthermore, the time period of the transition from old to new land-use category is assumed by default 20 years. The IPCC Tier 1 method assumes that biomass, dead wood and litter pool carbon losses occur entirely in the year of the transition (e.g. deforestation), while relevant carbon stocks increase over a period of 20 years after land use change (e.g. afforestation). After 20 years, the area converted enters the category “Land Remaining” where different assumptions and emission factors are applied. Thus, in order to quantify the total impact of land use change, at least a 20-year time period should be taken into account. However, countries that use higher tiers and complex models (e.g. UK’s CARBINE model) might apply shorter or longer time periods than the default IPCC 20 year period, thus calculating total land use impact over the default transition period of 20 years might introduce a bias.

  In order to quantify the impact of land-use change by 2050 and further, the default IPCC assumptions will be integrated into the GHG quantification tool, meaning land-use change emission factors will be applied for the first 20 years after which emission factors for land remaining in the same land use category are applied. Thereby, the post-20-year emissions must be handled very critically, especially if the country-specific default emissions factors are used, for the latter represent the environmental situation and emissions today, however, land use emissions are highly sensitive to temporal changes.

The baseline quantification process

Land use baseline scenario is constructed by determining current land use classes in the case study pilots using CLC accounting layer dataset and the European Soil Database as far as applicable. In the city of Edinburgh Copernicus Urban Atlas 2018 and Street Tree Layer 2018 datasets will be applied. Additional data will be requested from stakeholders or other organizations when necessary, for example the semi-state peat production company that owns the commercial bogs in County Meath Bord na Móna will be contacted to obtain more detailed data for peat extraction sites. Carbon emissions and removals are subsequently quantified using the LULUCF sector implied emission factors of the relevant case study pilot's national inventory reports submitted in 2021 to the UNFCCC.

3.4.2 Energy use in buildings

Open-source data has been prioritised and pan-European datasets will be used where applicable to allow replicability across EU regions. These pan-European data-sets may be more useful for regional analyses, and more specific local data-sets required for more realistic local development plan assessment. When different levels of data are available, the higher level of quality should be selected.

The buildings considered at a European level will be commercial and residential, the EU Buildings Database will be used to give information on the total floor area for both residential and commercial buildings, whilst it also gives information on average energy demand per m^2 for the different building types. This data is also broken down by fuel type and will help to quantify the energy demand from both commercial and residential buildings. National emission factors for heating fuels and the CO_2 of electricity will be used to convert the energy demand into emissions

At a local/ regional level, local level data will be used to analyse the energy use and emissions from the following buildings:

- Commercial
- Residential.

Residential

The methodology to quantify emissions from the residential sector includes firstly, identifying the total number of housing units in an area, through national housing census information, which are grouped by period built and housing type i.e. apartments, detached, semi-detached and terraced houses. The dwellings are grouped by period built dependent on building regulation periods, which is country specific.

Regional energy performance certificates (EPCs) or in Ireland Building Energy Ratings (BERs) give energy related information on residential buildings. In Ireland the BER database contains data from all the registered BER to date such as the energy required for normal use of space heating, hot water, ventilation and lighting per metre squared area of a residential unit. The final energy rating given to a household is in kWh/m^2/year and an energy efficiency scale from A to G is also applied. It also provides insight into other data such as the type of household, year of construction, location, floor area, and fuel use.

Once all the dwellings have been grouped by type and construction period, the energy data in each subset is averaged in order to establish the energy consumption. To find the total energy by fuel use in the residential sector, these energy consumption figures are then applied to the total residential units for each construction period. Resulting in a total energy demand for a specified area broken down by fuel, dwelling type and construction period. These figures are then multiplied by national emission factors to produce CO_2 emissions from the residential sector.

Commercial

The methodology used for the calculation of the commercial baseline includes two main data sources - commercial buildings broken down into building use and floor areas, and energy consumption benchmarks for commercial buildings. For the Irish and UK countries, benchmarks from the Chartered Institution of Building Services Engineers (CIBSE) will be used, and a similar dataset for Finland will be made use of.

These benchmarks provide typical energy usage per square metre of floor area for different business categories, amalgamated from numerous surveys. Commercial energy benchmarks are presented as fossil fuels and electricity, where fossil fuels primarily refer to energy used for heat generation.

To calculate the energy use for each property, each 'property use' must be matched to a benchmark. The energy use for the different property uses must then be multiplied by the corresponding floor area, which gives a total energy demand for the different commercial building uses. This total energy demand broken down by fuel type (fossil fuel or electricity) is then multiplied by national emission factors to provide total emissions from the commercial sector in a specified area.

3.4.3 Traffic and infrastructure

In the territorial approach, the quantification of transport emissions should cover all transport activity within the target area. Ideally, the data source would be based on traffic counts and would provide data in distance travelled per vehicle type. In practice, territorial studies tend to utilise the mobility surveys of the region's population, which is more suited for consumption-based studies as this includes all travel, even travel outside the target region. Thus, to improve accuracy, long-distance trips should be excluded.

The QGasSP model will apply European emission factors for fuels and a European dataset for the grid electricity emission factors.

In accordance with EN15643-5 (CEN/TC 350, 2017), transport is considered as a use of infrastructure. With respect to the construction of new developments, the tool will provide a placeholder for the construction of infrastructure, these figures can be quantified using GHG emission factors which detail the material emissions per meter (streets, railroads, roads, tramlines, subway lines etc.) or square meter (squares etc.).

In the territorial approach, the construction activity should include only the direct emissions caused within the target area. Thus, there is a difference to the methods applied in carbon footprinting of construction works (in accordance with EN 15804 (CEN/TC 350, 2019) and EN15643-5 (CEN/TC 350, 2017)). Typically, the carbon footprint analyses apply a consumption-based approach, including all global emissions, meaning, even accounting for emissions generated elsewhere.

3.5 Consumption-based approach - the Tiered hybrid LCA method

The consumption-based quantification applies the tiered hybrid LCA methodology, which combines two different types of life cycle assessment. More specifically, it uses an environmentally extended economic input-output approach (EIO) with 'enhanced' data from selected sectors derived from process-based LCA. The sectors (industries) to be covered with process data in this project are the land use sector, traffic and infrastructure and buildings.

Considering a consumption approach is important because it assigns emissions to an end-user (consumer), rather than simply to where they are produced. Visitors to a region, therefore, have their emissions counted under the totals of their region of origin. This allows different drivers of high-emission (e.g. unsustainable consumption) to be addressed and so provides greater leverage for reduction than simply using a territorial approach alone. The limiting case of this can be seen, for example, in contrasting 'out-of-boundary' travel to a new commercial development with 'in region' shopping. Although a pure territorial approach might show a reduction in emissions for the 'out-of-boundary' case, it is clear that this is not an accurate reflection and could lead to unfavourable conclusions. In contrast, by tracking the emissions through expenditure, the consumption approach is sensitive to these changes, and thus can lead to better policy guidelines.

Territorial- and consumption-based approaches are in reality complementary. Certain emissions may be covered using one methodology, whilst others are considered in both. This can be seen by returning to the example of a new commercial development. If this is located inside the boundary of the region of interest, then the consumption approach will not take into account emissions generated by visitors from neighbouring regions, since it only considers emissions due to residents of the target area. However, such emissions will be covered using the territorial approach. In contrast, the emissions from residents within the target area will be counted in the consumption approach, irrespective of whether the development is located inside or outside the region, as discussed above. Figure 2 illustrates these boundary differences and complementarity between the two approaches. This was also discussed in detail in the inception report in the context of different emission scopes.

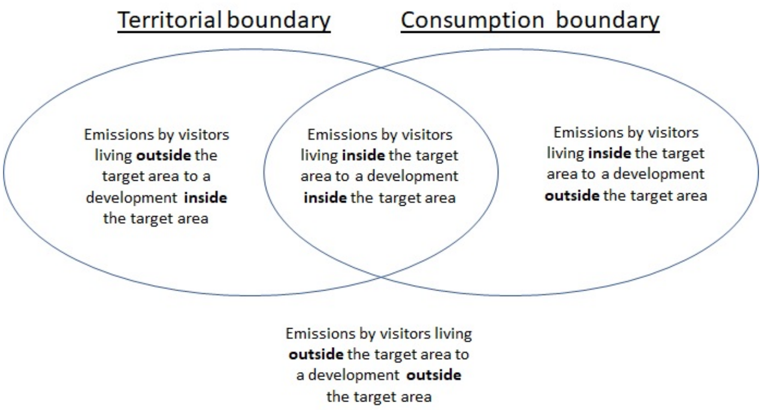

Figure 2: Conceptual emissions boundaries for a new commercial development from the perspectives of both a territorial- and consumption- based approach

Finally, tracking emissions through economic consumption must also be justified. Here, the available academic literature is clear in providing a correlation between income, expenditure and final emissions (https://iopscience.iop.org/article/10.1088/1748-9326/6/1/014018, also this: https://iopscience.iop.org/article/10.1088/1748-9326/aac72a/pdf). Simply put, all consumption will lead to emissions and at any given time higher consumption will typically lead to higher emissions. Any results have to be drawn in light of this fact and the multiple emission feedback loops existing through global supply chains. This is especially true given that changes will be 'locked-in' through the long lifetime of spatial planning decisions. Although this is clearly a sensitive area, a tool that simply provides straightforward conclusions without addressing the role of spatial planning in promoting sustainable consumption would not be suitable to the pressing need of reducing GHG emissions.

Returning to the tiered hybrid approach, the advantages of this methodology are:

- Extra data required for the calculation can readily be collected from known databases. Such data is already available and harmonised for the whole of Europe.
- The full supply chain is considered by including an EIO - truncation errors are minimised.
- The use of an EIO also means the whole economy can be modelled, and can include placeholders for sectors not considered within the initial tool.
- The greater accuracy and relevance of process-based LCA based on local data sets is maintained.
- All three of the most important greenhouse gases are included in the Exiobase EIO database (CO_2, CH_4, N_2O) in terms of global warming potential over 100 years (GWP100). In total, 19 different types of emissions are included representing both combustion and non-combustion emissions.

One disadvantage of the approach is that resolution is limited to the country level. However, there is some scope to look at smaller scales by changing part of the vector of final demand subject to Eurostat consumption surveys, as discussed below.

It is important to once again highlight the stated aim of developing enough flexibility to afford comparable results across the whole of Europe. As such, any methodology will inevitably face a compromise between this flexibility and enabling local specificity. Indeed, on the consumption-side, this can be translated into a distinction between generally promoting (bottom-up) process-LCA or (top-down) IO-LCA. An entirely bottom-up approach would not be feasible given the potential size of target areas and scope of emissions considered, and would further be susceptible to truncation errors that could limit accuracy. This is circumvented by basing the approach on IO data, whilst the incorporation of some local data mitigates the associated problems. It should further be stated that the more process-LCA data is used, the greater the results will deviate from the national picture and the more the resolution will be improved. Finally, MRIO approaches, supplemented by local or specific data where available, are the clear direction of travel in the academic literature. A choice along these lines is important for ensuring the tool is future proof.

The equation for the emissions within tiered hybrid can be described as:

$$\underline{A\,B}^{-1}\underline{k} \;+\; B\,(I - A)^{-1}k \;=\; LCA_{process} + LCA_{IO} \qquad (1)$$

where:

k = Final demand vector, describing the monetary value of different products required on average by an actor. Such actors can for example be an average household. In reality, separate demand vectors (6 in total) will also be included to describe expenditure by different types of actors, such as by government and capital.

A = Input-output matrix. A matrix describing the normalised flows between each ‘industry’ or ‘product’ considered. For Exiobase, the database used here, there are ~ 200 products in ~ 170 different industries that describe different areas of the economy.

I = Identity matrix. This is a matrix of the same dimensions as A, with the values down the main diagonal equal to exactly 1, and all other values being equal to 0.

B = Vector describing emissions from a unit of output from each industry. This is also known as the environmental extensions. Different environmental extensions exist for different GHGs and different forms of emission (direct combustion, agricultural emissions, cement production, etc) and need to be summed together to give total emissions. There are also other environmental extensions representing other forms of environmental footprint, such as water, land use or non GHG pollutants.

Emissions = a vector or table of emissions. Here, each row would correspond to a different emissions sector, such as emissions from energy use in buildings. These can be summed to get the total emissions.

Note that the ‘hat’ terms refer to the process LCA part of the calculation and can be similarly defined as for the IO-based LCA. However, although described here in Matrix notation, the process-based LCA does not have to be formulated using matrices.

Data collection

Turning first to the input-output side of equation (1), the calculation shall proceed through aligning consumption data from Eurostat HBS with Exiobase, (Stadler, 2018), (EXIOBASE Consortium, 2021), a widely used environmentally extended input-output database. This is a ‘multi-regional’ input-output database (MRIO), which means it is more accurate and covers many regions/countries within a single matrix. In total, Exiobase represents 49 countries/regions, including virtually all of Europe at country-level, and the rest of the world with lower resolution. The most recent database is for 2015 (although this is based on the 2011 version), and additional projected data is provided up to the year 2020. IPR issues will be checked.

The consumption by households that is already found in Exiobase will be replaced by values derived from household budget surveys (HBS) available in the Eurostat database (European Commission, 2021) (for each country for which such data exists (EU 27 + UK, Norway and Turkey). The other types of consumption vectors in Exiobase will be used as found. The reason for performing this replacement is that the Eurostat surveys are more detailed, can be expected to be more accurate than the Exiobase base data, are available for more years, and can be aligned with other surveys within Eurostat. It is also data that has been acquired ‘bottom-up’ through surveys of households, rather than from national GDP. This means it is influenced by true expenditure, and is less sensitive to distortion in GDP, such as that encountered in Ireland through multi-national companies (MNC). Hence, beyond these initial replacements, the household demand vector will further be modified subject to the specific details of the area under consideration. This will be performed by incorporating two further types of HBS:

HBS by income quintile for each country
HBS by urban type (city, town/suburb and rural) for each country.

The data for the specific country of interest will thereby be modified by a series of scaling factors based on the deviations from the average consumption due to these two factors. In this way, the baseline calculations in the tool will be sensitive to smaller scales and different socioeconomic conditions than simply those of the country average. Moreover, data will also be included from Exiobase describing the average number of members per household, which allows the expenditure to be determined on a per capita level.

The process-based LCA calculations are taken to the 0^{th} tier. They then correspond to the ‘use phase’ for each of the sectors we consider, for example the combustion of fuel by domestic households. This means that the territorial-based calculations (which should give an accurate value for the ‘use phase’ of each of these sectors) can be used in place of the process-based LCA. The input-output part then describes the emissions resulting from the supply-chain.

The tool will then proceed with a baseline calculation based on these characteristics, followed by an estimation of how these results will change subject to specific spatial planning policy or development decisions.

Traffic considerations

When traffic-related datasets are based on mobility surveys from the same area then the traffic emission calculation can utilise local datasets on modal share and mileage. However, in many cases it is necessary to produce a top-down projection of the traffic data for calculations: an example of this is when we work on a single municipality but traffic data is available for the whole territory.

In some tools, this projection is made by weighing factors, which are applied across the regional average data. The weighing factors are determined by descriptive multiple-choice questions in the tool, which characterise the type of the target area with regards to mobility patterns. An example of these questions can be for example about the size of the nearest city center, availability of public transportation etc.

Challenges which are faced with the Tiered hybrid LCA method, which applies the economic consumption data on mobility, means that the economic consumption data for single municipalities is not available, and a weighing system with pan-European applicability needs to be proposed.

Whenever localised traffic emissions are needed, a local survey can provide this information.

Land use considerations

It is considered challenging to accurately model the LULUCF sector by the consumption approach from the same perspective as the territorial emissions (Balouktsi, 2020). However, the effects of consumption on land-use can still be indirectly considered as a separate environmental footprint. An understanding of the required land to generate the products and services consumed by residents within a target area shall be modelled. This will be done using distinct environmental extensions assigned to different forms of land exploitation (in Exiobase these are: cropland, Forestry, permanent pasture, industrial land and other land use). This will give values in area units, and the dependency of this number on spatial planning decisions will be included in the tool. In contrast, the LULUCF sector in the territorial approach represents the direct impacts and is reported in CO_2e. Note that GHG environmental extensions do exist in Exiobase for certain aspects of land-use, such as direct emissions from agriculture, and these extensions are included in the consumption calculations.

The baseline quantification process

Exiobase is used for the input-output matrix, A, the environmental extension vector, B, in this case representing the GWP100 in units of CO_2e, and the demand vectors from other actors beyond households.

To describe the consumption of households, part of the vector k within Exiobase is replaced with Eurostat consumption surveys. The most recent year for which these are available is 2015 (although a 2020 version is expected and will be used if the data is available before the end of the project). Moreover, the HBS can further be replaced by one specific for the target area being studied should it be available and in the COICOP format. The Eurostat HBS defines consumption by COICOP categories at level 2 and 3. Hence, these will be assigned to different products within Exiobase by multiplication by a 'characterisation' matrix. Initially, this will be based on a procedure performed by Ivanova and Wood in a recent paper (Ivanova & Wood, 2020), where each category in the HBS is assigned to one or more different products within Exiobase. However, this will be further modified to make it more specific by using the average electricity mix of each country, as the HBS surveys do not distinguish between different types of electricity generation. Moreover, the average members per household will be input, based on default values from Eurostat and this value will finally be multiplied by the population of each country to make them suitable for incorporation into Exiobase. The effect of inflation and differences in purchasing power will also be accounted for.

The specific household consumption for the area being modelled will be further modified based on suitable scaling factors derived from more detailed HBS. To give a very general example, example, if the area under consideration is a city, the amount spent by an average consumer on public transport might be greater than that found in the country-wide HBS, and these modifications allow the tool to be sensitive to this. Moreover, the data shall again be scaled subject to the average number of members per household, which can either be the same as the default values available in Eurostat, modified based on more specific data in Eurostat, or knowledge available to the user. This allows for studying the impact of household size on the carbon footprints (through sharing). The standard procedure is to divide the total emissions by the total members of the household (including those with limited spending power) and this will also be followed here.

An initial calculation is performed based on the input-output data. Through this calculation, total emissions shall be calculated for each product-country/region combination in Exiobase. Moreover, a second characterisation matrix shall be used to assign each of these to different emissions sectors, including those considered in the territorial side of the calculations. This will again be based on an assignment given by Ivanova and Wood, modified to arrive at sectors more specific to the goals of QGasSP. Note that this is simply an assignment of emissions, and so the total emissions does not depend on the choice of this matrix. The relevant proportion of these emissions is then assigned to the area of interest using population statistics.

Next the 'use phase' emissions for the three most relevant sectors will be added using the territorial values calculated within the tool. For the sectors included within this project, these will mostly be emissions not covered within the IO part of the calculations, since IO models are 'cradle-to-gate' models which do not consider final combustion within households. However, where double counting may arise, the process-based data will be prioritised, and the equivalent emissions source subtracted from the IO side. Finally emissions can again be scaled using population statistics to get per capita emissions. This enables comparison between different regions.

Modelling the effects of spatial planning policies/developments

The way in which the tool quantifies spatial planning decisions will be subject to the nature of the policy or development under consideration. In most cases, this will proceed via a modification to aspects of the vector of final demand. For example, a policy that promotes active transport would be considered via a comparative reduction in the amount an average household spends on private transport. A second situation could be modelling retrofits designed to improve building energy efficiency. These could be considered by first calculating the emissions associated with the building works through a demand vector representing the typical expenditure for the works by EXIOBASE product type. The resulting energy savings would then be determined through reduced household expenditure on products relevant to heat energy. New building developments can also be considered in a similar fashion, with household consumption using the relevant Eurostat HBS to represent the expected occupants. For example, a new development targeted at relatively richer inhabitants would use the HBS for the richest income quintile in that country. Finally, unlike the HBS, EXIOBASE has separate products for different forms of electricity generation. Therefore, policies to promote local renewable energy generation would be modelled by a relative reduction in household expenditure on electricity generation through fossil fuels and an increase in expenditure on electricity derived from the relevant renewable

Additional modelling shall proceed via changes to the environmental extensions. For example, a future prognosis of technological development shall be considered via a staged reduction in the relevant environmental extension. This is analogous to how future electricity emission factors are determined in a territorial-based approach.

Initial results from the baseline calculations

As a first stage, tentative baseline emissions have been calculated through EXIOBASE. Here, only the IO part of the calculation has been considered, and so emissions due to the ‘use phase’ have yet to be included. As described above, the parts of the demand vector representing consumption of an average household have been replaced subject to the Eurostat HBS for each of the countries where it was possible to do so. Figure 3 describes the emissions determined from the IO calculation for each of the countries covering the case study areas, as well as Estonia. Here the emissions are on a per capita level, and are therefore comparable to one another. The emissions have further been decomposed into different sectors. Note that these are again exemplar results subject to change. For instance, country-specific electricity mixes have yet to be factored in, and fossil fuels by households also has yet to be included.

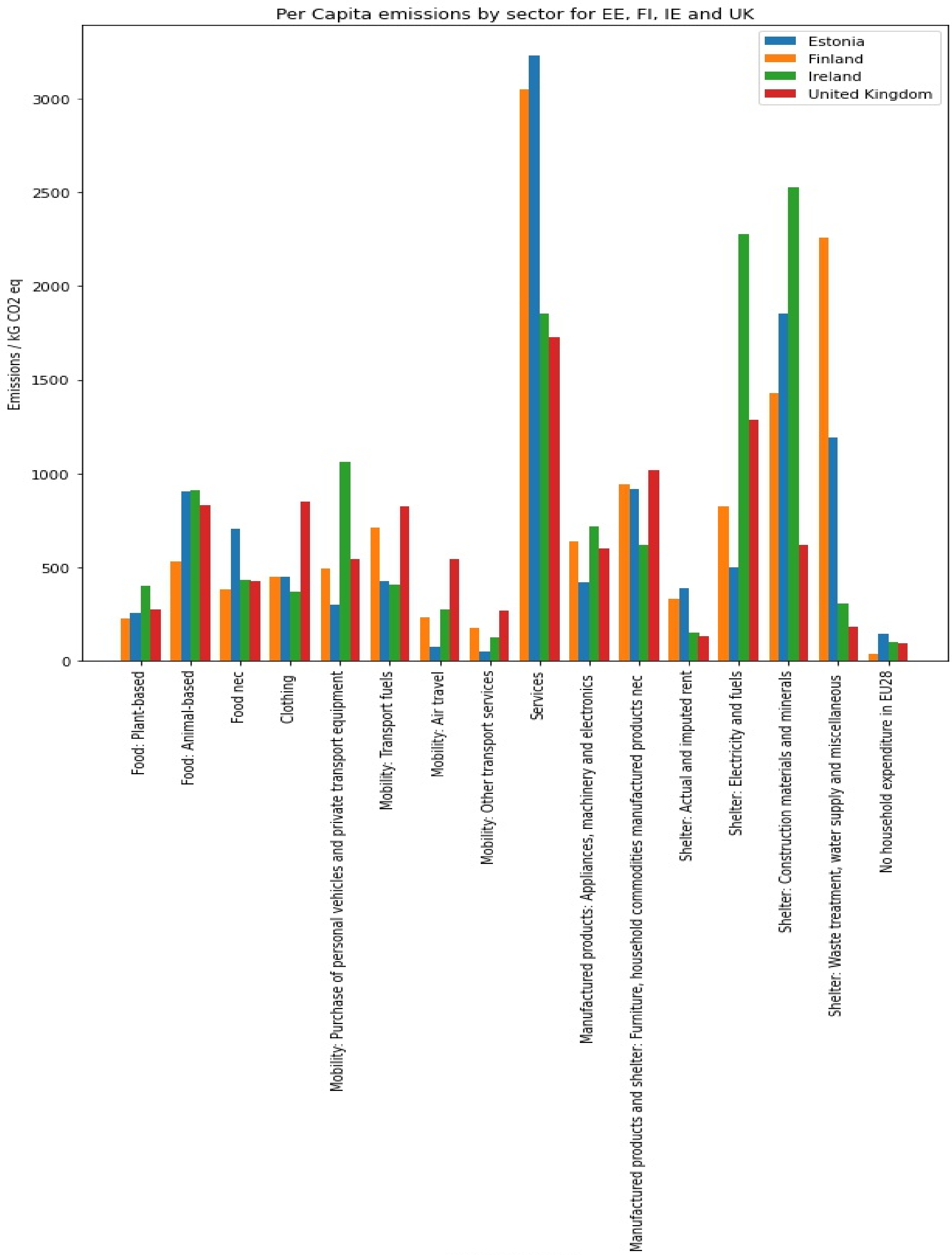

Figure 3: Per capita emissions for different pre-defined sectors for Ireland, UK, Finland and Estonia calculated using Exiobase with household consumption replaced by Eurostat HBS.

4 Case study pilots: baseline analyses

Using local data, where possible, is a priority in the GHG quantification method. Utilising national datasets means less relevant results, which reflect the problems and opportunities on the national level rather than territorial, regional or local level. However, it is important that GHG quantification is possible also when the local data is not available. A list of local datasets which are being made use of in this research are listed in Annex 2.

In order to ensure the tool is robust and applicable to different countries, the selection process of the case study pilots has ensured a diverse variety of situations that might be encountered by spatial planners. Therefore, the stakeholders were asked to provide pilot case studies that cover a range of different urban types, spatial scales, and with both high quality and more limited data availability.

National spatial planning policies for the four case study pilots have been selected, these policy documents range from local, regional and national specific planning policy documents. The scope of selecting varying planning policy documents is to trace down from national to local level specific planning decisions and to assess the tool's applicability over a range of different spatial planning scales.

The use of spatial planning policy documents at different scales have highlighted the importance of developing a tool that is flexible, future-proof and able to quantify policies at different scales. This can be facilitated through the use of placeholders that can be updated by the tool users, which will output results that are specific to the planning scale selected.

The priority of the case study pilots is to ensure that the tool is able to quantify different spatial planning actions. Currently, the service providers are identifying actions from the case study pilots' planning documents to be quantified by the tool, this process is helping to set parameters for the tool which will, in turn, ensure that the tool is meeting the stakeholders' needs and is a robust tool.

It should be noted that three of the case study pilots are using local, county or regional spatial planning policy documents, whilst the Scottish case study pilot, Edinburgh, will be using a national level document. Therefore, since actions from national level policy will be different to local level policy to quantify, the service providers have prioritised the Scottish case study pilot, to help ensure that all different tiered actions from the case studies pilots can be quantified.

4.1 Ireland: County Meath

The Irish case study pilot is County Meath, which lies on the border of Dublin. Meath's close proximity to Dublin, makes it a commuter region and provides a good mix of spatial attributes, having both rural, urban and suburban areas. Over the recent years, Meath has experienced a rapid growth in population which has resulted in an increase in land use change, traffic and has boosted the economy in the area.

It is worth noting that the county has been proactive in the area of climate action and this is showcased in Meath's Climate Action Strategy (which covers the period from 2019 to 2024) (Meath County Council, 2019), which is both is ambitious and pragmatic with the ability to enable others to take action and inspiring them to lead on climate action. Meath is currently in the final process of developing their Meath County Development Plan 2021-2027, and their Climate Action Strategy is very much linked to their County Development Plan. The service providers will be testing out the tool on the Meath County Development Plan 2021-2027.

Baseline for the GHG emissions

The future projection of the baseline GHG emissions includes the impacts of population growth and changes in infrastructure, whilst also taking into consideration the general development of technologies as well as the expected improvements in road networks and public transportation that will have an impact on the citizens of Meath.

Case study:

The Meath County Development Plan 2020-2026 sets out the policies and objectives and the overall strategy for the development of the County over the plan period. This Plan provides a pathway for Meath which will enable the county to continue to make significant contributions to national economic growth recovery by promoting sustainable development and facilitating stable economic growth, and thus, delivering long term benefits for the citizens of the county.

Energy use in buildings

The County Development Plan (CDP) highlights the importance of reducing the county's reliance on imported fossil fuels and encourages the replacement of these fuels with regionally generated renewable energy in an effort to ensure security of energy supply. In so doing, it promotes the use of lower carbon fuels in the home and highlights, where feasible and practicable, the provision of photovoltaic solar panels in new residential developments, commercial developments, and public buildings for electricity generation/storage and/or water heating purposes so as to minimise carbon emissions and reduce dependence on imported fossil fuels and reduce energy costs.

It also seeks to improve the energy efficiency of the County's existing building stock in line with good conservation practice and to promote energy efficiency in all buildings in the County. The CDP also promotes and facilitates the design of new energy efficient buildings and helps to support the use of heat pumps as an alternative to gas boilers, where appropriate, for domestic and commercial development.

Traffic and infrastructure

The emphasis of the CDP is to encourage a modal shift towards walking and cycling, however it is also important to recognise that some essential travel will continue to be made by cars and goods vehicles and the CDP facilitates improvement in road infrastructure to cater for the required improved efficiencies. It is a strategic aim of the CDP to create efficient compact settlements which reduce the need to travel. Maintaining and improving transport networks remains a priority, particularly in relation to the delivery of important infrastructural development and transport measures which support the economic development strategy for the County.

Achieving sustainable patterns of transport in accordance with national and regional policies will enable settlements to function more efficiently and effectively. Increased public transport provision, coupled with enhanced cycling and walking facilities in the urban areas, will provide the means to cater for much of the increased travel demand.

Land use

The Meath CDP only includes urban areas - towns and villages, while no development proposals outside settlements are addressed. Information is also provided for Natura 2000 network sites within and adjacent to settlement boundaries, however Natura sites are protected areas and generally not subject to development. Land Use Strategies are rather generic and most often suggest to regenerate and enhance the natural and physical environment of the settlements.

Meath Climate Action Strategy 2019-2024 sets GHG emission reduction targets and provides County Meath Carbon Baseline for 2012 based on energy consumption in different sectors. Emissions relating to direct land management, e.g. exploitation of soils, peatland or forest management are not included in the baseline methodology. The Climate Action Strategy also sets out eight thematic areas where actions will be taken: economy, mobility, built environment, clean energy, resource management, water, natural resource and planning. Specific actions do not specify recommendations for possible land use changes in the area.

Taking into account the information provided in these policy documents, it is difficult to quantify specific actions relating to land use change. However, the territorial quantification mode of the tool will have built-in options for different land use changes and the tool will be able to quantify relevant emissions and removals. Stakeholders will also have the opportunity of suggesting possible land use changes in the process of the tool development and testing.

4.2 Northern Ireland: Rathlin Island

The case study pilot for Northern Ireland is Rathlin Island. Rathlin is Northern Ireland's only offshore inhabited island, and is mainly rural, with approximately 160 inhabitants, which has been steadily increasing in recent years. It has a number of natural energy resources, including wind, biofuel and geothermal; these renewable energies, however, are not being used to their full potential by the local community.

Rathlin Island falls under the Northern Area Plan 2016 (Department for Regional Development, 2015), (NAP) which was developed by the Department of Environment. The NAP forms the basis of land use planning, decisions on planning applications and sets out to inform the general public, statutory authorities, developers and other interested parties of the policy framework and land use proposals that will be used to guide development decisions within the Plan area.

It is recognised that the challenges that are faced by this island will vary greatly to the challenges faced on the mainland and thus would have to be addressed differently. The spatial planning policy that the tool will test out for Rathlin will be the Northern Area Plan 2016.

Baseline for the GHG emissions

The future projection of the baseline GHG emissions includes the impacts of population growth and changes in infrastructure, whilst also taking into consideration the general development of technologies as well as the expected improvements in road networks and public transportation that will have an impact on the citizens of Rathlin Island.

Case study:

The aim of the Northern Area Plan is to provide a framework for development throughout the area, conforming with the principles and policies of the Regional Development Strategy, facilitating sustainable growth, meeting the needs of communities and protecting environmental attributes.

<u>Energy use in buildings</u>

The Northern Area Plan promotes quality and sustainable building design in Northern Ireland's countryside. The NAP In line with the Department's publication, 'Creating Places' (Department of Infrastructure , 2000), provides guidance on the design, character and layout of new housing developments in Northern Ireland. The guide outlines the contributions which developers will be expected to make to achieve sustainable quality residential developments.

<u>Traffic and infrastructure</u>

The NAP aims to promote the integration of public transport, cycle and footpath networks and new development, in order to ease congestion, reduce dependence on the private car, and encourage the use of more sustainable forms of travel, such as walking and cycling. Whilst the emphasis of the NAP is to facilitate a modal shift, the document also outlines the need to improve connectivity to enhance the movement of people, goods, energy and information between places.

<u>Land use</u>

Rathlin Island Action Plan 2016-2020 aims to conserve the island's exceptional environmental heritage. The local environmental policy priority is to safeguard the island's environmental beauty and heritage, to support the island's agricultural and aquaculture sectors to develop and maintain sustainable practices, and maintain its environmental designations. Large parts of Rathlin Island are designated as the Natura 2000 network sites. Rathlin has been designated as a Special Area of Conservation and a Special Protection Area under the Habitats and Birds Directives. Given the small area and environmental conditions of the island, the demand for major developments is limited. Furthermore, current Rathlin Action Plan's policy actions do not suggest any planned land use changes.

Rathlin Island European Marine Site Management Scheme provides key management guidance that is applicable to the designated marine areas surrounding Rathlin Island plus areas of the Rathlin Island Special Protection Area. Coastal development on the island has been limited in recent years to around the harbour and Church Bay area. No major new developments are presently anticipated for the immediate coastal area of Rathlin. Establishing tidal stream renewable energy devices up to 200 MW in an area off the north east coast of Rathlin Island is being negotiated, however this action is not included as part of the land use (LULUCF) methodology, the latter covers anthropogenic emissions in terrestrial carbon pools. Actions related to renewable energy are addressed under buildings and traffic sectors. Stakeholders will be involved in the process of the tool development and testing in the course of which possible land use changes can be suggested and quantified.

4.3 Finland: Kymenlaakso region

The region Kymenlaakso, in South-East Finland, has a population of 174,000. The largest cities are the harbour city Kotka (55,000 inhabitants), Kouvola (88,000 inhabitants) and the old bastion town Hamina (20,000 inhabitants).

Kymenlaakso makes part of the Finnish *Towards Carbon Neutral Municipalities* (Hinku) (Carbonneutralfinland.fi, 2013) network which brings together municipalities, businesses, citizens and experts to create and carry out solutions to reduce GHG emissions. The 70 municipalities involved are committed to reduce emissions at a more rapid pace than EU targets require. The network aims to create solutions that have economic and social benefits as well as environmental advantages. The GHG emission reduction target is 80% for the period between 2007-2030.

The Kymenlaakso region aims at carbon neutrality by 2040. To this end, the region of Kymenlaakso has compiled a roadmap which includes detailed information on the region's GHG emissions, carbon sinks (LULUCF sector) and the main measures that need to be implemented in different sectors such as industry, forestry and traffic. According to the roadmap, the region of Kymenlaakso has to decrease GHGs mainly from transport, energy production and agriculture sectors. Also LULUCF sector's carbon sinks need to be increased in forests and soils. Measures in the roadmap include for example eco-innovations, cleantech, circular economy approach in all sectors, climate wise forestry, increasing the share of renewable energy, compact urban structure and environmental education and comprehensive cooperation in all sectors.

Baseline for the GHG emissions

The future projection of the baseline GHG emissions includes the changes in infrastructure, whilst also taking into consideration the general development of technologies as well as the expected improvements in road networks and public transportation that will have an impact on the citizens of Kymenlaakso. The population of the Kymenlaakso region is not expected to grow, but it is aging. This may have an impact on mobility and the desired modes of transportation.

The GHG emissions of the Kymenlaakso region have decreased approximately 40 % during 1990-2017. This is mostly due to exceptionally high rates of renewable energy (65 %), the structural change and the technical improvements in industry and vehicles. Biggest sources of greenhouse gases in Kymenlaakso region are energy production, industry and transport (Kymenlaakson liitto, 2020).

The GHG emissions baseline created for the carbon neutrality roadmap of Kymenlaakso is presented in Figure 4.

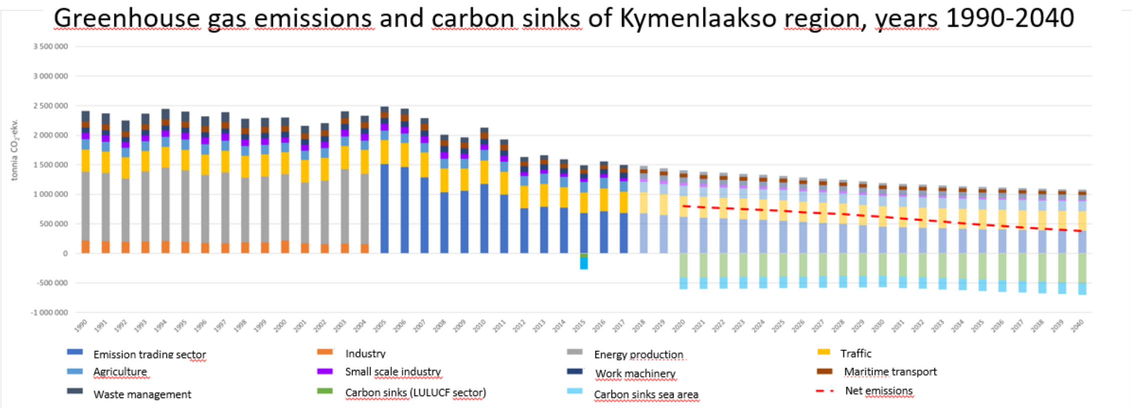

Figure 4: The baseline of the GHG emissions of Kymenlaakso (Kymenlaakson liitto, 2020).

In the QGasSP project, the baseline analysis will be more robust than the one created for the roadmap. The previous study has utilised and cross-examined a large number of national databases on land use, providing accurate results on the impacts of GHGs in land-use. As all the respective datasets would not be available in all European territories, a European GHG quantification model needs to be more simple. However, local data application will be a priority.

Case study:

Traffic and infrastructure

The Finnish case study will focus on the GHG emissions caused by the traffic in the entire Kymenlaakso region. The study is connected to the on-going preparation of the national transport system plan *Liikenne 12* (2021-2032) and a respective regional transport system plan.

-> Action: Estimate the impact of the infrastructural investments on transit traffic and regional mobility.

-> Quantification of the impact in QGasSP:

a) impact on transit traffic mileage within the target region (territorial approach)

b) impacts on the mileage and modal share in the mobility of the residents (consumption-based approach; the process LCA component embedded in the Tiered hybrid LCA model).

In addition, the case study will quantify the impacts of policies which aim at increasing the modal share of bio gas fuelled vehicles, electric vehicles and public transportation. The alternative policies of this study do not include infrastructural investments which would require traffic modelling.

-> Action: Build up a regional network of bio gas stations.

-> Quantification of the impact in QGasSP:

a) gradual increase in the modal share of biogas fuelled cars and buses within the region.

The results will have an impact on the consumption-based study, which reflects the climate impact of the mobility of the residents of the target area.

The regional traffic strategy (Kymenlaakson liikennestrategia 2035, 2015) as well as the regional traffic survey from 2019 provide the necessary basic data for the study.

Energy use in buildings

According to the Carbon Neutral Kymenlaakso 2040 roadmap, the most important GHG emission reduction potentials are in industry, energy use and traffic. As the population in the Kymenlaakso region is aging and declining, planning of new developments is not high.

Land use

Kymenlaakso regional plan 2040 (Kymenlaakson Maakuntakaava 2040) presents general guidelines for planning elements of urban areas (roads, wind farms, waste disposal sites, stores etc). Preservation of natural sites, cultural and historical values and areas are suggested, hiking trails and outdoor activities must be planned and located in such a way that they do not significantly impede the area's agricultural and forestry use. Otherwise, there are no quantifiable recommendations for the development of forest, agricultural or wetland (peat extraction) areas.

The pilot project quantification will include the climate impact of the land use change caused by the major infrastructural investments in the regional traffic plan 2021-2032.

4.4 Scotland: City of Edinburgh

The Scottish case study pilot is the capital city, Edinburgh, which is home to over 901,000 inhabitants, of which a population of over 518,000 live in the City of Edinburgh council area. Choosing Edinburgh as a case study will allow the service providers to test the applicability of this approach based on datasets and typical characteristics for developed urban areas which have a relatively moderate density and contains a good mix of building uses and transport infrastructure.

Scotland has been very ambitious in its climate goals and has set a target to reach net zero emissions by 2045. The pathway to reach these climate goals are set out in the third National Planning Framework (Scottish Government, June, 2014), which sets out a long-term vision for development and investment across Scotland over the next 20 to 30 years. It brings together all the Scottish plans and strategies in economic development, regeneration, energy, environment, climate change, transport and digital infrastructure to provide a coherent vision of how Scotland should evolve over the next 20 to 30 years. Quantifiable actions from the Third National Planning Framework will be tested out in the tool.

Baseline for the GHG emissions

The future projection of the baseline GHG emissions includes the impacts of population growth and changes in infrastructure, whilst also taking into consideration the general development of technologies as well as the expected improvements in road networks and public transportation that will have an impact on the citizens of Edinburgh.

Case study: Quantifying impacts of Scotland's Third National Planning Framework

Scotland's Third National Planning Framework (Not all remarks 3) is a long-term strategy and a national vision of what is expected of the planning system and the actions that it must deliver for the people of Scotland. It is accompanied by an Action Programme, which describes the implementation of NPF3.

Both documents are based on the Scottish Planning Policy, which highlights how, at a national level, important land use planning matters should be addressed across the country.

The general targets listed under the topic "Scotland tomorrow" will be quantified as the impacts of NPF3 within the city of Edinburgh. They include:

- Reduction of total final energy demand by 12 %
- 30% of overall energy demand covered by renewables by 2020 (11% of heat demand, 10% of transport fuels).

In the following, excerpts from NPF3 are converted in the quantifiable actions, and the parameters to be adjusted in the calculation model are identified:

<u>Energy use in buildings</u>

"3.16 Much of our energy infrastructure, and the majority of Scotland's energy consumers, are located in and around the cities network. The cities network will also be a focus for improving the energy efficiency of the built environment. A key challenge, but also a significant opportunity for reducing emissions, lies in retrofitting efficiency measures for the existing building stock." (NPF3 2014, 33)

-> Action: Increasing the retrofitting in the city of Edinburgh; enhancing more ambitious energy efficiency targets for retrofits.

-> Quantification of the impact in QGasSP:

a) increasing the annual volume of retrofitting in the city of Edinburgh (purchased energy for heating in existing buildings)

b) the share of deep renovations (purchased energy for heating in existing buildings)

"3.17 We are seeing an increasing number of district heating networks across the country. We can make much better use of the heat sources we have, including unused and renewable heat, and have prepared a Scotland heat map to help this to happen. We believe that there are significant opportunities for the cities in particular to use renewable and low carbon heat energy. New development should be future-proofed to ensure that connections to existing or planned heat networks are taken forward as soon as they are viable." (NPF3 2014, 33)

-> Action: Developing low-carbon district heating.

-> Quantification of the impact in QGasSP:

a) increasing the share of renewable energy in the district heating network in Edinburgh (emission factor for district heating)

b) applying a low carbon district heating in new settlements (share of households within district heating)

c) alternative low carbon district heating energy solutions (emission factor for district heating).

Hydropower, wind energy and tidal energy form an untapped potential to decarbonize the energy production in Scotland. However, Edinburgh, as the whole Scotland, is part of the UK electricity grid. Therefore, the investments on renewable energy production will have a significant impact on the GHG emissions in the territorial quantification of GHG emissions, as some power plants utilising fossil fuels can be closed down. In the consumption-based analysis, only the changes in the UK grid electricity GHG emission factor will become visible. The climate impact of the local investments has to be estimated at a UK level.

Carbon capture and storage

"3.18 CCS provides a major opportunity to reduce emissions from the energy sector, and to establish Scotland as a world leader in this new technology. This has implications for both land use and marine planning. Where feasible, replacement and new large-scale electricity generation, fuelled by gas or coal but designed to operate with CCS technology, will be located at existing generating sites or in areas of industrial activity close to where the majority of the population live. These sites may also provide opportunities to make residual or unused heat available to a heat network servicing homes and businesses." (NPF3 2014, 33)

"3.19 The conversion of Peterhead gas-fired power station can pioneer CCS technology and make best use of existing infrastructure, including existing pipelines, and help to establish the area as a hub for CO2 transport and storage. A further coal-fired power station with CCS is proposed at Grangemouth. There is consent for a new Combined Cycle Gas Turbine Power Station at Cockenzie, and Longannet will require alterations as requirements for CCS increase. To make best use of existing infrastructure, we have identified proposals for new and replacement facilities at all four sites as a national development. 3.20 In the long-term, we expect that a CCS network may emerge around the Forth, where there is a particular cluster of industrial activities and energy generation and the potential to link to existing pipeline infrastructure. By building expertise, and ultimately connecting this network beyond our national boundaries, there will be scope for the CCS sector to generate significant employment and business opportunities for Scotland." (NPF3 2014, 33)

-> Action: Quantifying of carbon offsets by CCS solutions

-> Quantification of the impact in QGasSP:

a) producing estimates of the carbon offset impact of the CCS investments in Edinburgh.

Land Use

Update to the Climate Change Plan 2018 – 2032 aims to increase the rate of new woodland creation to up to 18,000 hectares in 2024/25, ensuring that forestry and woodlands play an important role in cutting emissions and sequestering carbon. There is also a continuing need to actively address the impacts of past uses of the land, including minerals extraction, through restoration and enhancement. Peatland restoration is planned on a large scale - the rate of peatland restoration will be increased to 22,000 hectares per year.

Scotland’s Third Land Use Strategy 2021-2026 sets out a long term vision for sustainable land use in Scotland. The strategy states that Scotland's landscape will look very different in the future, with significantly more afforestation and peatland restoration. Throughout the lifetime of the strategy, tree planting rates need to increase to 18,000 hectares per year by 2024-2025. Scottish Forestry do not approve (and therefore fund or plant) new woodland creation on deep peat (>50cm), as these deep peats lock up large amounts of carbon as peatland habitats. Peatland restoration will need to increase dramatically to achieve 250,000 hectares by 2030 (restoring 250 kha in 10 years). Emissions from other land uses such as agriculture will also need to fall significantly over the next 5 years. Actions such as overgrazing, however, place pressures on the environment. The aforementioned actions of afforestation and peatland restoration can be quantified, however the actions are not relevant to the specific Edinburgh case study area. Overall, the LULUCF methodology for quantifying carbon emissions and removals within urban areas (settlements remaining settlements) is limited and needs further analysis.

5 Tool development

5.1 Tool functionalities

The project commenced with a thorough review of available tools and best practice in the academic literature, with a particular focus on the case study areas. The specific tools considered included SPACE (UK), Scatter (UK), Ecocity Evaluator (UK), Map Eire (IE), Ecocity Evaluator (FI), and the SYKE tool developed for the city of Tampere. This was alongside broader methodologies such as the Greenhouse Gas Protocol (GPC) for cities and extensive academic literature. It was found that whilst different tools had advantages, none could be seen to encompass the full range of features included in the project brief, including both a comprehensive baseline calculation and detailed analysis of a wide-range of spatial planning policies. Furthermore, none of the tools was based on consumption calculations tracked through economic data using an IO approach, as favoured by most of the academic literature. It was concluded that a new methodological approach was therefore required, based on these findings. Interested readers are referred to chapters 3 and 4 of the inception report where this topic was discussed in greater detail.

The QGasSP project will produce a browser-based open-source tool with a modular structure. It has two modes: territorial quantification mode and consumption-based quantification mode. The project will produce calculation modules for energy use in buildings, traffic and infrastructure as well as land use change. In the modular tool, the quantification modules can be updated and more modules for new CO_2e emission sectors can be included. The aim is to create a GHG quantification framework which is easy to adapt, update and future proof.

The tool is designed for three kinds of users:

- An expert user is capable of creating and updating territorial/local set-ups (inserting target-area specific datasets).
- A non-expert user for example a planner, who can quantify the GHG emissions of alternative spatial plans or policies without the need of an in depth knowledge on GHG quantification.
- A developer user is able to generate and add new or alternative calculation modules in the open-source code of the tool.

The tool version that will be delivered at the end of the QGasSP project will English but will provide users with an option to create new language versions.

An important feature for the tool is its short feedback loop; when any parameter is adjusted, the impact on GHG emissions is displayed immediately. This will help planners identify the most important aspects to work on.

Traffic light indicators and the diversity of datasets

As the pan-European comparability is one of the targets of the project, another important feature is to include three indicators which characterise the results of the quantification. These are:

- comparability: high/medium/low
- accuracy: high/medium/low
- up-to-date: high/medium/low.

In the territorial calculation mode, the comparability is always low: the results of different territories cannot be compared. In the consumption-based mode the results can be compared.

The tool utilizes European default datasets, which enable GHG quantification even without specific data on the target area. These European datasets will need to be updated annually by the tool owner. When the tool is used without local datasets the accuracy of results is low.

The local "bottom-up" data is inserted when a local set-up is created. A local set-up can be done for a region of any size. The QGasSP project will produce four local set-ups: Meath, Rathlin island, Edinburgh and Kymenlaakso. The other local set-ups will be constructed by expert users as new projects start using the tool. The tool collects local set-ups and they can be used by any user of the tool. However, it is important to notice that the reliability of the datasets cannot be controlled. Every new set-up increases the possibilities for cross-regional comparisons and benchmarking across European territories.

In the calculations, the local datasets override the default data, and make both the baseline analysis and the quantification results reflect the local situation. When the local datasets are available for all sectors and the structure of these datasets is similar to the default datasets, both the comparability and the accuracy of the results in the consumption-based mode are high.

The "up-to-date" indicator warns if any of the datasets applied is more than 5 years old, or if the datasets date back to different years.

5.1.1 Progress to date

The development team from Oivan has received sufficient data and calculation specifications for the implementation of the land-use module, and the work is underway on this sector. Oivan's UI/UX Designer has created user interface plans for the land-use change CO_2 emission calculations module, and these plans, together with the relevant backend and database functionalities, are currently in progress. This first implemented calculation module will also serve as an example for developing all of the calculation modules, as even for just one module, the whole application frame is needed, and also the blueprints for the extendable modules and other supporting global functions.

5.1.2 Next steps

The plan is to fully complete the land-use change calculations module, and then continue with the module that first has the specifications and data available for the most efficient development. Oivan will aim to test the modular nature of the tool itself when developing the remaining modules. The target is to make the tool work just as well with just one module, as it will with four modules. After that, adding the remaining modules already tests the promised modularity and gives a chance to address any potential issues detected on the way.

5.2 User manual & Guidance

Creation of user manual and guidance are Task 5, which is scheduled to commence in August 2021. The user manual consists of five guidance videos (duration 3-4 minutes per each) on the following topics:

1) ESPON GHG tool introduction
2) Guidance for a non-expert user: how to quantify the GHG emissions of a plan or a policy with the ESPON GHG tool.
3) Guidance for an expert user: how to create a local setup in the ESPON GHG tool.
4) Guidance for an expert user: how to integrate a new calculation module in the ESPON GHG tool.
5) Guidance for an expert user: how to create a new language version in the ESPON GHG tool.

The videoclips will be uploaded on YouTube and the tool itself will also include direct links to the videoclips.

The manuscripts for the video guides will be created in August and the guidance videos will be recorded and edited in the TalTech video laboratory in September 2021.

To ensure that the tool is adopted and developed further, a set of continuation projects would be needed. These projects could produce more local set-ups and language versions to help promote the tool, as well as create more advanced calculation modules for the tool, similar, for example, with the Global Protocol for community-scale greenhouse gas emissions inventories (GPC).

6 Conclusions

This chapter aims to provide preliminary responses to the research question:

- How can a better scientific understanding be developed of how national, regional and local planning authorities can prioritise relevant GHG mitigation strategies, including through enhancing the effectiveness of the SEA process, to rapidly build political will for climate action?

6.1 Need for harmonisation

As proposed by the C40 cities and many scholars, applying a consumption-based method would enable comparison across European territories and cities. A better scientific understanding could be gained by developing a harmonised system for the collection and reporting of local datasets. This would enable comparison of data, baseline analyses and result quantifications.

In land-use change, the six IPCC categories seem to form a common ground for the GHG quantification, but they are not very useful in the scale of cities and municipalities. A more refined system of land use categories with GHG emission data, including for example the impacts of peatland, would enable the quantification of GHG emissions from the land use change across Europe.

Although almost all European countries and most of the cities are committed to carbon neutrality, the true meaning of the concept remains difficult to understand: what is the actual ambition level of the climate commitment, if the GHG emissions quantification method is not uniform, and there is no limit for carbon offsetting? A standardized European method and monitoring system for the GHG quantification in spatial planning would logically continue the idea of the shared climate commitment.

The SEA process is integrated in different kinds of spatial planning systems in Europe. It can develop into a powerful mechanism for enhancing territorial and local climate strategies, which may apply GHG mitigation policies that are not applicable or not recognized at a national scale. This is demonstrated by cities, which have taken a forerunner role in climate action.

An examination of GHG emissions through both territorial and consumption-based approach would be a good practise, as it opens two perspectives on the climate impacts, thus providing a better understanding to base the climate action on.

6.2 Importance of local data

For any assessment, the reliability of the results are highly dependent on the quality and accuracy of the data. As described in the chapter 3.1, the European datasets that will be used for the tool development will create comparable results. The comparativeness is however limited to a certain level, as the European data collection methodology might not always be harmonised at the EU level. On the other hand, by using the generic European level datasets, the representativeness of the actual situation of the study area will be compromised, it is therefore crucial to recognize these effects and also communicate it clearly to the future user of this tool.

The use of local data is important in all three of the categories that can be assessed with the tool (buildings, infrastructure, land use change). The following figures demonstrate these effects in the example of traffic modal share. The generic data is derived from Eurostat statistics, which enable assessments in any European country with the tool but this is only based on national level data. This will affect the accuracy of the results at a regional level and using generic data will only allow the identification of a limited number of data classes. In the case of transport modal share, the Eurostat data is split into three categories, meanwhile, the local data retrieved from the project pilot areas include many more categories.

One of the key challenges when aiming for pan-European tool that enables comparisons, but also provides reliable results, is how to harmonize regionally gathered data. At the moment the comparisons with local datasets might not be always possible, as the data is largely dependent on their collection methods and classifications. This creates the possibility to interpret the data in different ways, and thus resulting in different conclusions.

Figure 5 is the pilot area Edinburgh modal share for passenger transport. The data is not specific to the case study area but is based on Scotland as a whole. Data should be as local as possible, but not necessarily for the very specific area being studied, so this scenario is similar to the wider regional data used. The data indicates that the modal share of passenger cars is 52.9% and in the Eurostat data the respective number for the UK is 86%. When eliminating the categories from the Scottish data so that only vehicle transport is assessed, then the passenger car share (including the use of taxi) would be also 86%.

Figure 6 is the pilot area Kymenlaakso modal share for passenger transport, which indicates that 61% of the trips are made by passenger cars. The data from the Eurostat database shows that the use of passenger cars in Finland is up to 84%. The Kymenlaakso data also includes walking, cycling, and other transportation options, whereas the Eurostat data is solely for vehicle transport. If the Kymenlaakso data were to include solely vehicle transport then the share of car transport would be 94%.

These two examples illustrate that generic European datasets can be used to get indicative results, but they are likely to differ from the local situation, as shown in the case of Kymenlaakso.

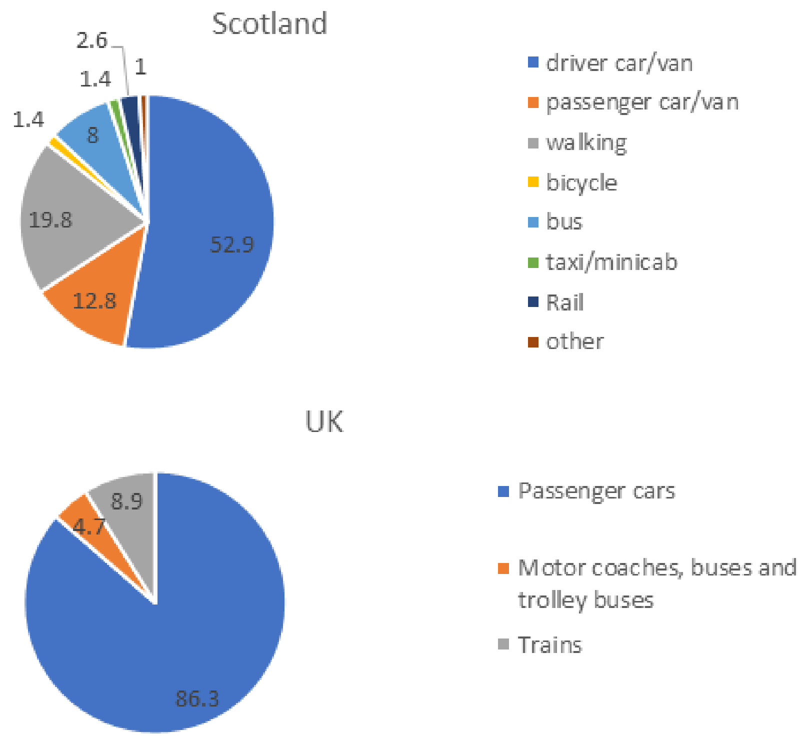

Figure 5: The modal shares in the UK in 2018 according to Eurostat database and according to Journeys made by main mode 2008-2018, Transport and Travel in Scotland Results from the Scottish Household Survey

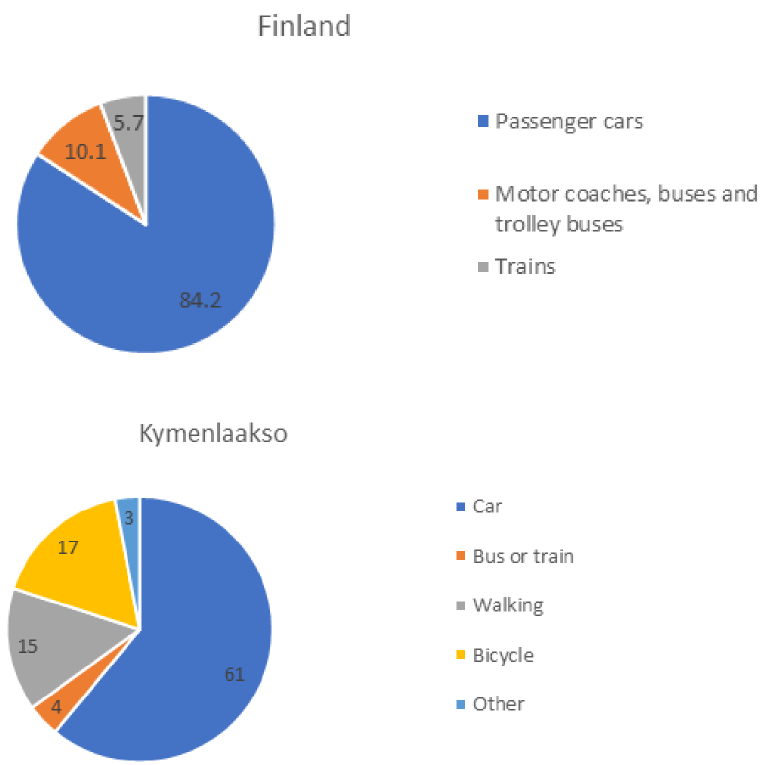

Figure 6: The modal shares in Finland in 2018 according to Eurostat database and according to Kymenlaakson kevennetty liikkumistutkimus 2019, Ramboll.

6.3 The role of the SEA process

According to the SEA Directive (2001/42/EC) (European Commission, 2001), the main role of SEA is to avoid and reduce environmental impacts arising from the implementation of a spatial or sectoral plan or programme. SEA provides alternative scenarios for public debate and the best environmental options for decision makers of the strategic documents. SEA report is usually a supplementary document to the strategic document, justifying the choice of the best environmental option. While the SEA reports of pilot area cases do not provide quantifiable data for the emissions calculations, they still provide important background information about the future plans of the pilot area cases in terms of the changes in emissions arising from buildings, transport and land use change. The SEA reports will be attached to the model as additional source of information..

6.4 Future perspective

The development of urban digital twins provides new opportunities for GHG quantification:

"[A] Digital Twin can be best characterised as a container for models, data, and simulation. Digital Twins enable comprehensive data exchange and can contain models, simulations and algorithms describing their physical counterpart and its features and behaviour in the real world. Until now, Digital Twins have been mainly used in the field of engineering and their implementation for towns and built environment have only recently been discussed.

The implementation of different analytical methods, as well as data and simulations for traffic and emissions, among others, is a great improvement for using the Digital Twin as an analytic and predictive tool. In general, digital technologies and their applications are of great importance for processes bridging formal and rational knowledge with informal and implicit knowledge.

Enriched with quantitative and qualitative empirical data, Digital Twins serve as one promising approach for tackling not only the complexity of cities, but also to involve citizens in the planning process. Combined with VR technologies, they have a great potential to support option testing and scenario development for different planning fields and at all scales." (Dembski, et al., 2019)

The digital twin of the built environment can carry data for the GHG quantification: for example on energy consumption, traffic and mobility, land-use categories etc. The modelling of green environments in digital twins is developing rapidly, and will soon be able to display the climate impact of single plants through algorithmic plant life modelling and soil type information.

The development of computing capacity enables modelling of large areas. The first country-wide digital twin, the digital twin of Estonia, was published in March 2021. This means that the collection of local data, covering both built environment and green environment, can be carried out entirely bottom-up in digital twins. The carbon sink of the natural environment can be directly included in the analysis, if this data is included in the digital twin.

The leading standard for the urban digital twins is CityGML. If this standard could be extended to require a uniform structure for local datasets, one difficulty related to the idea of a pan-European GHG quantification method could be resolved.

When zooming down from the country scale down to cities and territories and further to single buildings in a digital twin, it becomes obvious that a coherent GHG quantification method would be very welcome. A digital twin can provide an access to all relevant data for both territorial and consumption-based approaches in GHG quantification.

Annex

Annex A1 Time table

	2020				2021									
	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV
Task 1				☆										
Task 2								☆						
Task 3											☆			
Task 4				☆						☆	☆		☆	
Task 5													☆	
Task 6													☆	
Delivery 1		☆												
Delivery 2							☆							
Delivery 3													☆	
Kick-off meeting	☆													
Steering Commit-tee Meet-ings[RC1]				1st				2nd						3rd
Manda-tory out-reach events							☆			☆			☆	

☆ =Milestone

Annex A2 Received data from pilot area cases

Data Required		Case Study Pilots			
		Finland - Ky-menlaakso	Ireland - Meath	N. Ireland - Rathlin Island	Scotland - Edin-burgh
ENERGY USE IN BUILDINGS	Residential data which is usually gathered through the census or tabula residential typologies for UK - this should be broken down by type of dwellings (apartments, terraced, detached, semi-detached), period built and if possible, occupancy per dwelling	x	x	x	x
	Database for Energy Performance Certificates or similar, should show the energy performance of different households and ideally includes fuel type, energy use for space and water heating, ventilation and lighting		x	x	x
	Database of all commercial properties, which includes: floor area and property type				
	National emission factors for heating fuels and electricity	x	x	x	x
TRAFFIC AND INFRASTRUCTURE	Statistics on economic consumption per resident				x
	Traffic activity statistics	x			x
	Mobility statistics	x			x
	Modal share	x			x
	National GHG emission factors per mode of transportation	x		x	x
	Future prognoses related to mobility, technical development of vehicles and modal share				
	Grid electricity emission factor and future prognosis	x		x	x
LAND-USE AND LAND-USE CHANGE	Area of different land-use classes under spatial planning (ha):	Stakeholders of case study pilots have forwarded some general information about land use, however not as detailed and not in the format necessary for conducting baseline analysis. Land data should only cover the administrative borders of the case study area, and land use categories should correspond to the IPCC land use categories shown in this table. Service provider acknowledges that obtaining data in the format needed requires additional effort and GIS analysis. Thus, the service provider is currently undertaking initial land use analysis, however additional data from the stakeholders might be needed.			
	1. Forest land				
	2. Cropland				
	3. Grassland				
	4. Wetlands				
	5. Settlements				
	6. Other land				
	Carbon pools considered in all land use classes:				

	1. Biomass: growing stock present before land-use change. Country-specific data can be derived from national greenhouse gas inventory reports, national forest inventory or other data sources specified by the stakeholder. Root-shoot ratio (available in the IPCC guidelines if not specified by stakeholder) will be applied to estimate the share of above- and belowground biomass. 2. Dead organic matter: litter and dead wood. Country-specific data can be derived from national greenhouse gas inventory reports, national forest inventory or other data sources specified by the stakeholder.	Stakeholders have not forwarded region-specific data on biomass or dead organic matter carbon stocks. Some stakeholders sent numerous national databases, however it is not in the scope of the QGasSP project or in the capacity of the service provider to conduct comprehensive analysis on all possible national databases. Service provider acknowledges that obtaining relevant data might be difficult and requires addition effort. However, the goal of the project is to use readily available and accessible data, thus relevant data for baseline analysis will be taken from national GHG inventories and CRF tables.
	3. Soils: area of mineral and organic soils (all soil types should be classified under two main groups-mineral and organic soil). Soil carbon emission factors can be derived from national greenhouse gas inventory reports or other data sources specified by the stakeholder or default EF-s from the IPCC guidelines can be applied.	Soils can be major GHG sources, thus it is crucial to determine broad soil types (mineral and organic) and relevant areas for the case study pilots. Unfortunately stakeholders have not provided the data asked. The service provider is currently undertaking initial analysis on soil distribution using ESDAC open source data. Additional input from stakeholders might be needed.

Annex A3 Method description

The QGasSP project develops a European tool for greenhouse gas (GHG) quantification in spatial planning. The new ESPON tool can be used for both consumption-based and production-based GHG emissions quantifications in all scales of spatial planning. The consumption-based quantification enables cross-European comparisons of GHG emissions. The production-based approach can be applied to monitor the GHG emissions within the target area. The tool applies national data from European databases and local datasets uploaded by the users.

TERRITORIAL GHG QUANTIFICATION

The territorial mode quantifies the direct GHG emissions caused within the boundaries of the target area, and the most important indirect GHG emissions are included in accordance with the definition of scope 1–3 emissions in Greenhouse Gas Protocoll. The model includes three interlinked calculation modules.

The GHG emissions of land use change are quantified through the six IPCC land use categories and a 6x6 matrix, which presents the potential GHG emissions and uptake arising from land use changes between these categories. The matrix applies the national land use emissions factors determined for the LULUCF sector in national GHG inventories.

All traffic within the target area is quantified with the local traffic count statistics and multiplied with the CO_2 emission factor by vehicle type. Scenarios are applied in order to project future development: the CO_2 emission factor for the grid electricity (national), efficiency of combustion engines (European) and the share of electric vehicles (national/European).

The data on the energy use in buildings is based on the statistics (quantity, type, floor area, year of construction, energy use) on the local building stock. Local CO_2 emission factors are applied for district heating and cooling. A national scenario is applied to project a future prognosis on the GHG emissions.

CONSUMPTION-BASED GHG QUANTIFICATION

The consumption-based mode quantifies the GHG emissions caused by the consumption of the residents of the target area. It follows the value chain disregarding where the emissions occur. The consumption-based GHG quantification applies the tiered hybrid LCA methodology, which combines the economic input-output (EIO) LCA with ‘enhanced’ data from the most important sectors (industries) covered with the process LCA data. These sectors are traffic and infrastructure and buildings. The GHG emissions from fuel combustion are added in the EIO matrix results, which include other mobility-related GHG emissions from cradle to gate. The tiered hybrid LCA calculation includes an extensive number of GHG emission categories.

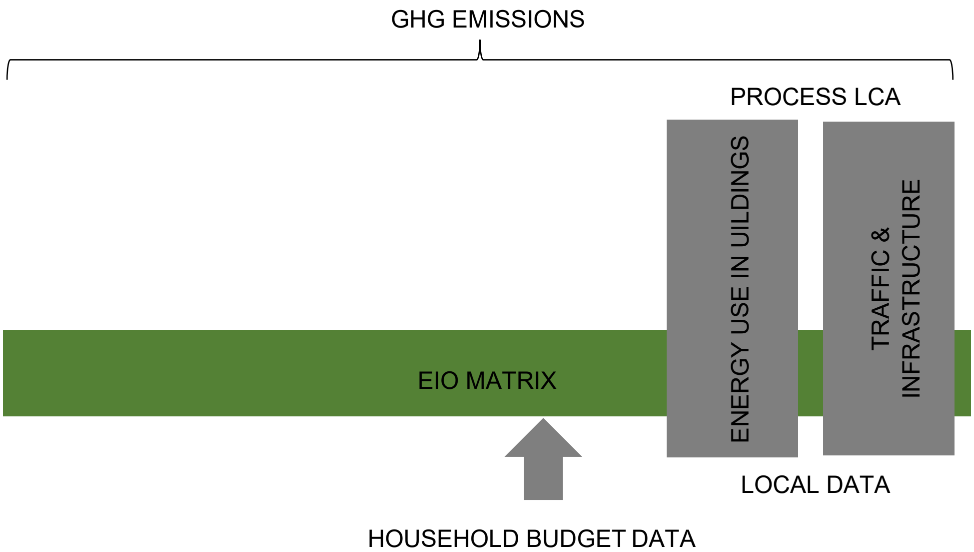

Figure 1. The tiered hybrid LCA method as applied in the tool.

APPLICATION OF THE TIERED HYBRID LCA METHOD

The consumption-based quantification applies the tiered hybrid LCA methodology, which combines the economic input-output approach (EIO) LCA with 'enhanced' data from three sectors derived from process-based LCA. In this way, the full supply-chain (i.e. the higher order tiers) can be described in full by the input-output calculation, whilst maintaining the greater accuracy and relevance of the process-based LCA. The sectors (industries) to be covered are the LULUCF sector, traffic and infrastructure and buildings. It is suggested to only describe the traffic and infrastructure and buildings sectors using tiered hybrid, as accounting for the land use sector is widely seen as extremely challenging.

One important advantage of using tiered hybrid is that most of the extra data needed is already readily available and should be easy to collect. A downside is that the resolution is limited to the country level. These may be some scope to look at smaller scales by changing the vector of final demand subject to Eurostat consumption surveys. As with all approaches based on input-output matrices, however, tiered hybrid will be most appropriate at larger scales.

The equation for the emissions within tiered hybrid can be described as:

$$Emissions = \tilde{B}\widetilde{A^{-1}}\tilde{k} + B(I-A)^{-1}k = LCA_{process} + LCA_{IO} \quad (1)$$

where

k = Final demand vector. This can be at the household level, and because the input-output approach is in economic units, it describes how much the average household spends on each of the industries/categories in the input-output matrix.

A = Input-output matrix (a matrix describing the normalised flows between each 'industry' considered. For Exiobase, there are ~ 170 Industries that describe different areas of the economy). ($(I-A)^{-1}$ is also known as the Leontief inverse, L)

I = Identity matrix

B = Vector describing emissions from a unit of output from each industry

Emissions = a vector or table with one column. Here, each row would correspond to a different emissions sector, such as emissions from energy use in buildings.

Note that $\tilde{B}$, $\widetilde{A^{-1}}, \tilde{k}$ can be similarly defined for the process-based LCA. However, although described here in Matrix notation, the process-based LCA does not have to be formulated using matrices.

The quantification process

1. The process-based LCA calculations are taken to the 0^{th} tier. They then correspond to the 'use phase' for each of the sectors we consider. This means that the production-based calculations (which should give an accurate value for the 'use phase' of each of these sectors) can be used in place of the process-based LCA. The input-output part then describes the emissions resulting from the supply-chain.
2. Exiobase is used for the input-output matrix, A. This is a 'multi-regional' input output database (MRIO), which means it is more accurate. It also covers 44 countries, including virtually all of Europe. The most recent database is for 2015 (although this is based on the 2011 version). IPR issues will be checked.
3. To describe the consumption of households, the data (that is, the vector k) within Exiobase is replaced with Eurostat consumption surveys. Again, these are available for every country within Europe. The reason for performing this replacement is that the Eurostat surveys are available for more years and can be aligned with other surveys within Eurostat. For example, there are also surveys for household expenditure per urbanisation level for each country (as well as per average age, number of household members, etc). This would be one way to determine changes resulting from spatial planning policy. It is also the only way that it might be possible to increase the resolution beyond the country level.
4. A second way to estimate changes in consumption emissions resulting from spatial planning policy would be to change the vector of final demand. For example, if the modal share for traffic changed, this could be reflected in changing the amount the average household spends on transport fuel.
5. Alternatively, for some policies the vector describing the environmental impacts could be changed. For example, the emissions associated with a certain industry could be reduced if that could be associated with a particular policy change.
6. The reason not to change the input-output table is that it is quite complicated, and approximations/modifications can be needed to get accurate results. For example, there may occasionally be

negative values, and these must be dealt with appropriately. Moreover, Leontief inverse matrix could then be precalculated, which would make the calculations quicker.

7. The double counting (i.e. the same emissions are found in the process-based LCA and input-output LCA) is avoided by subtracting the use phase emissions that are derived from the input-output table from the total emissions by following the methodology outlined in PYMRIO (open-source input output calculator written in Python).

Steps to be taken

1. **Align the industries in Exiobase with the categories in Eurostat**. These are not strictly equivalent, and so will have to be mapped onto one another. Depending on the category/industry, possible options are:
    a. One to one – there are equivalent categories in EXIOBASE and EUROSTAT.
    b. One to many – one category/industry in one database relates to multiple categories/industries in the other.
    c. many to many – Multiple categories/industries in one database relates to multiple categories/industries in the other.

    However, this seems to be quite a standard procedure in input-output analysis and is also something to be carried out once, during the tool development stage. The effect of inflation and differences in purchasing power may also have to be accounted for.

    Align consumption categories/industries to corresponding emission sectors. For example, Exiobase has categories for different forms of electricity generation, and these will all contribute to the energy use by buildings sector. The categories that contribute to other important emissions sectors not otherwise included in the initial tool development can also be determined. The input-output calculation will generate emission profiles for all these sectors.
2. **Baseline emissions are calculated**. The dataset is relatively large and involves matrix multiplication (and matrix inversion if the Leontief inverse is not precalculated) using an appropriate software tool (e.g. Python). The output from here will be a table with one column and many rows. Each row will correspond to the emissions from each industry in the IO table.
3. **Sum the emissions results to get the total emissions for each sector.** This is based on stage 2, where the emissions for each industry in the input-output table are aligned to the sectors in our tool. These can then be added to the 'process-based LCA' calculations for the relevant sectors.
4. **Perform the same calculations subject to the relevant policy/development** by changing the vector of final demand.

Annex A4 Responsibilities of the owner of the software

As requested in the tendering document, the service provider will include all the information needed for hosting and developing the tool in the final project report. The tool will be designed to be operational without the need to include private datasets and any dependency on the service provider.

It should be noted that the tool would need some upkeep, thus someone needs to be responsible for the hosting and maintaining of the live software. It is important that the software is kept up to date for both user experience and security reasons. This would mean that possible problems are promptly investigated and resolved, any cyber/data privacy threats are addressed immediately, and that when the open-source community develops the software further, someone takes care of curating, accepting and deploying these changes.

In order to future-proof both the methodology and tool, the research team proposes an open source tool with a modular structure, where the calculation modules can be updated and developed. Furthermore, the tool will have placeholders for new calculation modules, which will extend the scope of GHG quantification.

Open source means that the software's source code is available for users to download, examine and modify. Most open source projects have a public code repository on a website, that contains the full history of the project (code changes), documentation, possibility to download the full project and often, also a link to the actual live and running version of the project's code (working application).

An open source approach enables the use of best practises even as the methodology of GHG quantification would still be developing. The modular structure allows for updates on sectoral calculation models, for example when a methodology is standardised or widely adopted by professionals, then this can be updated in the tool as its modular structure would allow for any updates. In principle, a region or city can implement its own, unique quantification methodology in the tool and continue using it for GHG quantification, but this would then mean that the opportunity of comparison would be lost.

The **version control system** is a solution applied by almost all software developers. It allows users to view changes and go back to earlier versions of the tool, this gives access to the full history of changes made to the code. The version control system allows the developers to remove problematic changes, track issues, and merge changes made by multiple developers to the same files in the code base.

Code repository is the physical manifestation of the version control system, containing the current code version and all its historical incremental iterations.

Git is the most popular free open source, and arguably the most sophisticated version control system available. Git is used to manage the changes in the code, this is used by large organisations and is even used in small open source projects. It is a means of managing code in a safe and coordinated manner, sharing and collaborating on the same codebase.

Github is at the time of writing the most popular platform for hosting Git code repositories. It offers the users an easy way to set up a Git repository for their code, and share the repository with other developers. A typical Github repository is an open source project that has been created to solve a problem, and then the solution can be shared with everyone. Github allows the developer to set up a project website to communicate the project and to publish documentation. What often happens is that users who benefit from this open source project come up with a solution to improve it, and contribute to the project. Github offers mechanics for this, so that users can submit issues, and/or solutions to them, and the "owner" of the project can review and merge these improvements into the project, after validating them.

Github is completely free to use for public repositories, and utilising it creates no permanent dependency for the users, as a developer downloads the repository from the Github, it is always a complete copy of the Git repository, with its full history and documentation etc. Github also offers the developer a safe backup "in the cloud" so that the code is never stored only in one location which might be lost.

A platform like Github can offer the project a location where the code can be safely stored and shared, documentation published. It should be noted that the tool is not operable in Github, but only the code can be accessed through Github. So the calculator software needs a hosting environment where it is operated.

A hosting environment for a web application is essentially a server that runs a database, the code from the repository and web server software that serves the web page (UI) to the user from the web address. The database on the server holds any data the project administrator have input, this is usually information that is required by the software to function (e.g. CO_2 emission factors), and captures any saved changes made by the users (eg. calculation projects, results etc). The code running on the server is responsible for this and executes calculations for the user, or processes saved data from the database.

An open source repository needs an operator who takes responsibility and maintains the repository. Despite it being transparent, in practise it is not feasible to allow everyone to make changes how they want, as unfortunately, there might be developers who would use the opportunity to hide malicious code (virus) in the project, in order to gather sensitive information. The maintainer of the open source project acts as the moderator and gatekeeper for any such unwanted changes, and reviews any “change requests” and takes care of physically updating the code repository with only the changes that actually benefit the project.

To function in this role, and keep the code base stable and safe for both developers and users of the software, the maintainer needs to have a good understanding of the code base and the functionality the program offers. Therefore, typically the maintainer is the original developer and/or main contributor of the open source product.

The software, as described earlier, a web-based GHG emissions calculator, runs in the hosting environment. This environment is like any machine – it needs to be operated, and maintained.. An error may occur, the application halts and needs to be restarted. Even more importantly, every single online system is under constant bombardment from automated hacking attempts. Since essentially all end-user facing software developed is based on some other software, security holes found in them (e.g. the database engine, server’s operating system etc) potentially compromises every application utilising them. A compromised system can result in users’ personal information like passwords being lost to the hackers, and often this information can be used to break into other, more sensitive services used by the same users. Therefore, every online system needs constant updates to keep secure.

Outside “everyday” stability and security maintenance, there is always a need to update the software itself (eg. calculator). If a user notices a bug in the software, they can check the source code in Github, locate the reason, and submit a change request to the repository maintainer, to update the code base with the fix. If the maintainer does this then the code repository is updated, but not the software running the code that the users are using online. It is up to the software operator to deploy a new version of the code to the server (hosting environment), in order to get an updated version of the software up and running. The same applies for the data in the database, if it contains false information or there is a new set of data, this needs to be input into the database (eg. new type of emission factors as part of a new module etc).

There are good tools for hosting, and even for automating some error recovery and update scenarios, but these are for the sake of efficiency and saving time and effort. In any scenario, the live software requires someone that is responsible for its stability, security and updates

The research team proposes that collecting relevant, accumulative regional and local data would be done by the users of the tool, generating an open database available for all users. For accurate results, use of local datasets should be preferred. As the number of European territories, cities and municipalities is so high, any project aiming at producing datasets for all of them would not be feasible.

The responsibilities of the owner of the software are

- To arrange the hosting of the tool as described above;
- To update annually the European datasets (mainly from Exiobase and Eurostat databases) to keep the quantification model up-to-date, according to the instructions provided in the video guide.

The service provider wishes that ESPON promotes the tool and launches a continuation project to develop the tool functionalities further with additional and/or more advanced quantification modules and to increase the number of local set-ups in the tool. It would be also important to keep up the discussion on the European harmonization considering the GHG quantification in spatial planning and the role of SEA as an important GHG mitigation mechanism.

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