Work Package 2

Executive Summary:

D2.3 ‘Analysis of current and projected energy flows within the city’

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Executive Summary

Deliverable aims and objectives

This deliverable seeks to identify and analyse current and projected energy flows and energy infrastructure within the partner cities. In doing so, the city and its future energy consumption and related CO_2 emissions can be better understood, issues and opportunities for action can be assessed and innovative cross-sector opportunities can be identified. This will directly support the development and implementation of enhanced SEAPs in the cities. A key part of this deliverable is to demonstrate the best practice approaches to working with energy flow analysis within the cities. The deliverable uses a consistent, analytical and science based process, conducts detailed energy system analysis and collects best practice knowledge and experiences within the partner cities.

City approaches

Partner cities have conducted an assessment of patterns of energy use and production by sector and geographical area, understanding how this pattern changes for each city over different timescales. This analysis has been conducted in different ways by the cities, using different reference years, with some following the Covenant of Mayors' approach to carbon accounting and others going beyond this scope. For example, in Ghent, the energy consumption of EU ETS companies and shipping has been included as this makes a large contribution to the city's energy consumption and therefore the city sees it as an important part of a thorough assessment of energy flows.

An inventory and analysis of existing energy systems and infrastructure in the cities has been completed, and the potential for renewable energy resources has been understood. This has helped cities start to identify issues and opportunities for future sustainable energy infrastructure development in their enhanced SEAPs, to be explored further later in the STEP UP project.

Energy flows in all cities are demonstrated by high level Sankey diagrams, visually representing various energy inputs, outputs, losses and energy stored. This helps to illustrate which energy flows represent useful energy, which flows are responsible for CO_2 emissions and to what extent.

The partners took different approaches to analyse energy consumption patterns in geographical form. The deliverable was designed to present a series of data sets and diagrams showing current and future energy flows and energy infrastructure (including the potential of renewable energy resources) linked to Geographic Information System (GIS) maps. In reality, some partners, in particular Glasgow and Ghent, have been able to present a detailed application of GIS tools for energy infrastructure analysis, mapping energy demand and renewable energy potential within the city. Gothenburg and Riga have used these tools to a lesser extent.

The task of forecasting projected energy flows under BAU and alternative scenarios has been approached by the cities in different ways. The main challenges for this task relate to the cities' understanding of the definition of a 'scenario' and how to build different scenarios, including the types of data needed and the interpretation and application of national level data for city-level scenario modelling. Despite this, the results and learnings from this sub-task will provide useful input when the cities consider three different socio-economic scenarios and their impacts on planned energy targets and actions (D2.6).

The cities have used CO_2 emissions per capita as an indicator of the efficiency of energy use when comparing their cities to other similar cities. However, this indicator provides aggregate information on the contribution of two factors – energy efficiency and renewables – which cannot be distinguished separately. To avoid misleading results, an alternative approach could be to use annual CO_2 emissions per capita, attributed to specific sectors, and to compare it to the equivalent values for cities which share similar climate and economic structure.

To identify opportunities going forward, partner cities have also reviewed known development proposals and third party studies on local energy infrastructure development. Some partners, in particular Glasgow, have conducted a more thorough assessment than others, in part due to the availability of these types of studies or the relevance they are seen to have. This has helped the partners understand the relevance of these proposals and plans for the development of their enhanced SEAPs, as well as the importance of ensuring that various development proposals, plans and strategies are inter-linked with each other in order to develop a comprehensive energy system aligned with the long-term vision of the city.

Key findings

The table below presents a comparison of partner cities in terms of the formative components of final energy supply. The role of electricity and district heating in particular has been identified, in Gothenburg and Riga in particular. In Gothenburg the district heating network is predominantly supplied by waste and residual heat, whereas in Riga this is predominantly natural gas.

	Ghent*	Glasgow	Gothenburg	Riga
Annual final energy consumption, GWh	28,800**	12,500	15,650	12,260
Year of reference	2009	2011	2010	2012
Major energy source in energy supply	Cokes (including ETS and shipping); Natural gas (excluding ETS and shipping)	Natural gas	Liquid fossil fuels	Natural gas
Share of electricity	~ 9.5%	~ 25%	~ 35%	~ 21%
Share of district heat	~ 2.3%	<1%	~ 26%	~ 20%
Share of renewables	~ 2.2%	<1%	~ 1.9%	~ 10%

*including ETS and shipping unless explicitly mentioned otherwise

**final energy consumption data excluding ETS and shipping is not available due to data privacy reasons

The following table presents a comparison of partner cities in terms of formative components of final energy demand. This shows the share of energy consumption of principal sectors: industry, tertiary, residential and transport.

	Ghent*	Glasgow	Gothenburg	Riga
Annual final energy consumption, GWh	28,800	12,500	15,650	12,260
Year of reference	2009	2011	2010	2012
Share of industry	79%	38%	19%	15%
Share of tertiary (services) sector	7.2%	2%	23%	25%
Share of residential sector	7.7%	34%	27%	36%
Share of transport sector	5.7%	26%	24%	24%
Current CO_2 emissions (tonnes) (most recent available data)	1,438,578 (2011)	3,425,200 (2011)	3,702,799 (2010)	2,118,000 (2011)

Ghent

As can be seen in the tables above, Ghent's final energy consumption in 2009 was 28,800 GWh. As the EU Emissions Trading Scheme (EU ETS) sector has been included in the city's energy consumption calculations to date, cokes are the major source in Ghent's energy supply, with the industry sector being responsible for the majority of energy consumption. The residential, tertiary and transport sectors all make a much less significant contribution. These findings are heavily influence by one ETS company (steel sector) which, if excluded, would lead to reduction in final energy consumption by approximately 68% and would result in natural gas being the major source of energy (42%). In this situation, the share of industry in total energy consumption would fall to 34%, followed closely by the residential (25%) and tertiary (23%) sectors.

In the city of Ghent in 2009, more than 18 PJ (5,083 GWh) of electricity was produced, of which 13 PJ (3,503 GWh) was consumed in the city. A small amount of renewable electricity was also produced locally (wind and solar), and a small amount of residual heat from the energy production sector, which was also used locally.

Primary energy consumption in the 2030 business as usual scenario is expected to be 3% lower than in 2009, amounting to 131 PJ (36,281 GWh), with industry making up 73% of this total. Consumption in the industry and transport sectors is expected to increase, but the residential, tertiary and energy production sectors are all expected to see a decrease. To assess an alternative scenario, measures have been ranked on an abatement cost curve, which shows that by implementing the most cost effective measures consumption will decrease by a further 1.3 PJ (369 GWh) in 2030 compared to BAU.

Partners in Ghent recognise that the industry sector, in particular EU ETS companies, represent a large share of the city's energy consumption. The City of Ghent is also aware that as a local authority it has little impact on the decisions made by those companies. As a result, ETS companies and shipping wil not be including in the city's enhanced SEAP. At the same time there is recognition that it will be difficult to realise the potential consumption reductions identified in the alternative 2030 scenario as this relies on large investment in existing buildings, as well as current energy and transport systems. However, Ghent has found significant potential to increase the share of renewable sources in its system, including through solar PV, solar thermal and wind. The city is also exploring the scope to expand its existing steam energy network, working with a local waste incineration plant, and to re-use waste flows in the harbour area. At the same time, Ghent is working with the wider Flemish region to ensure the city's visions are aligned with regional energy ambitions.

Glasgow

The tables above show that Glasgow consumed approximately 12,500 GWh of energy in 2011, the largest share of which came from natural gas (45%). 72% of Glasgow's total energy use is attributable to two sectors – the industrial and commercial sector (38%) and the residential sector (34%), with road transport accounting for 24% of energy use. Energy use in buildings accounts for 70% of all energy consumed, highlighting the need for the enhanced SEAP to focus on this area. As a result of this, and in light of difficulties modelling energy demands associated with transport and waste, Glasgow's analysis focuses on energy flow in buildings.

Glasgow's mapping has shown that high concentrations of energy consumption can be found in the city centre where there is high-density, non-residential development, followed by high-density residential development in the areas just outside the city centre. The mapping exercise highlights priority areas for efficiency and energy use improvements to be made to buildings, and at the same time helps identify key energy consumers in the city. Individual premises have been identified where energy consumption is particularly high, including a university, drinks factory, hospital and shipbuilding yard. The capacity of all primary sub-stations has also been assessed, with potential future network constraints identified, including in the city centre, along the River Clyde and in the West End.

Significant existing generators have been identified, as well as plans for new energy from waste centres and district heating networks, including the potential for a city centre district heating network linking together several smaller networks. Very little renewable energy is currently produced in Glasgow, but the city is now exploring options to develop this further, including through solar PV, wind and biomass.

Two future energy demand scenarios have been assessed; 'Slow Progression' and 'Gone Green'. Under both, energy demand in residential and non-residential buildings is expected to increase, at a similar magnitude and spatial distribution. Both scenarios show a growth in electricity demand, but this is noticeably higher in the 'Gone Green' scenario, suggesting that a greater proportion of future domestic energy demand will be met by electricity.

Using these findings, opportunities for buildings in the city centre and beyond, large energy consumers and the electricity distribution network have been identified. Partners have prioritised improvements in energy efficiency, expansion of district heating schemes, development of energy from waste plants, and innovative smart grid solutions to reinforce the electricity distribution network.

Gothenburg

Gothenburg consumes around 15,650 GWh of energy per annum. The major sources of energy used in 2010 were electricity (~35%), liquid fossil fuels (~30%) and district heat (~26%). The sectors responsible for the most energy use in Gothenburg in 2010 were residential (~27%), followed by transport (~24%) and services (both public and commercial, ~23%). Emissions from energy use have also been calculated, with transport responsible for the largest share. The industry sector is seen to be a major consumer, and provider, of energy.

District heating plays an important role in the city, with 25% of it coming from residual heat from the refinery industry, 25% from waste incineration and the rest from CHP plants and heat boilers, especially during the winter months. The use of natural gas is high in Gothenburg compared to many Swedish cities, due to the gas pipeline that is located on the Swedish west coast. Natural gas is used for electricity and heat production, as well as directly in industries. Although there are some wind turbines in the city's territory, partners have identified good potential for an increase in wind power locally.

Energy flows in 2030 and 2050 under the BAU scenario have been estimated, in which emissions from energy use are expected to increase by almost 30% by 2030 and by more than 70% by 2050. Energy use in the industry sector is assumed to increase by 2% per year, giving a total increase of nearly 50% to 2030 and of 120% from 2010-2050. Energy use in the public sector is expected to increase by about 25% by 2030 and 60% by 2050, in line with population growth. The amount of traffic is expected to increase by almost 23% from 2010-2030, and by 45% by 2050. For the alternative scenario, an amended Sankey diagram has been produced, showing the changes in energy flows if a number of the city's proposed 2030 energy goals are implemented. This shows that renewables and energy from waste will play a much greater role in the city's energy system in the future, resulting in lower CO_2 emissions and energy use.

Gothenburg has been unable to complete some of the energy flows analysis, as a model is currently being developed in the city that will help the city model the energy balance of the city in a realistic way, taking into account variations in energy demand on a daily and seasonal basis, and enabling the simulation of different energy scenarios and their impacts. The city will use this to complete the remaining tasks and further develop its enhanced SEAP once the model is ready in the summer of 2014.

Riga

In Riga, final energy consumption in 2012 was 12,260 GWh. Natural gas has the largest share in energy supply (26.2%), with renewables constituting ~10% of the total energy supply. The residential sector is responsible for the highest share of consumption (36%), followed by the tertiary sector (25%) and then transport (24%). Industry makes up only 15% of final energy consumption. The largest individual energy consumers have been identified as industrial enterprises, in particular wood-processing companies. Emissions in Riga decreased by 9.6% in 2012 compared to 2008. This shows the city has increased its energy efficiency, though no comparisons to other cities have been made as other Latvian cities are much smaller.

Almost 27% of total final energy consumption is by district heating, and district heating provides more than 70% of the total heat energy consumed in the city. A number of the heat generating facilities used for the network have CHP units installed. With big fluctuations in heat demand during the year, Riga partners have identified the importance of choosing technologies that are flexible and robust in order to minimise efficiency losses. An increasing share of renewable sources is being used in energy generation plants, in particular biomass. However, natural gas continues to make up the majority of fuel used.

Electricity demand in Riga is also significant, currently at 21% of final energy consumption. The projection of electricity demand to 2020 under a BAU scenario anticipates an increase in consumption by 16% between 2010 and 2020. In turn, district heat consumption is expected to increase by 20% in that period, outstripping growth in electricity consumption. This projection is based on the anticipated building of a significant number of new residential and office buildings and their connection to a district heating network. However, current development trends clearly show that this forecast is over-optimistic and economic recession has strongly influenced development activities. In comparison with alternative scenarios (minimum, optimum and maximum based on the implementation rate of emissions-reducing measures), the lowest emissions reductions are projected under the BAU scenario, as would be expected. The greatest reductions are projected under the maximum scenario, under which the most effective CO_2 emissions reduction measures would be implemented.

Some opportunities for Riga have been identified, including increasing the efficiency of the district heating network, increasing use of biomass in energy generation, the application of trigeneration technology to provide energy for the cooling of premises, expanding remote data reading systems for the reading and transmission of other consumption data (for example, gas, electricity or water), enhancing energy consumption management in multi-dwelling residential buildings, and other innovative building solutions that integrate energy management and ICT.

Challenges and learning points

The key challenges and learning points that have emerged from this deliverable can be summarised as follows:

- **Scope of, and approach towards, energy flow analysis**: not all cities have followed the scope of the Covenant of Mayors, with some measuring CO_2 and others CO_2e, some including ETS sectors and others not, and some including emissions from local energy production and others not. This relates to the wider issue of there being no consistent

European or international carbon accounting framework for use in all cities. In addition, the level of detail that different cities have gone into for different tasks has also varied, which suggests some cities have found the exercise more difficult to complete, for example due to the timing of it, limited access to required data, or lack of sufficient skills and resources. The impact this has on city energy flows analysis and the ability for cities to learn from each other needs to be understood, and taken into account when comparisons are made between different cities.

- **Data availability and quality**: accessing up to date, accurate and reliable data for energy flow analysis has proved difficult for all cities, which could have impacts on understanding both current and projected energy flows, and potential opportunities.
- **Analysing energy consumption data by sector or purpose:** this has been challenging, especially where cities have not been able to gather city level data. Estimates for the residential and tertiary sector are often based on national level data interpreted for the city level, which may introduce uncertainty in consumption figures. Detailed energy consumption data has been easier to access where utilities have been more closely involved, but there are still challenges where individual consumer data is confidential. Gathering accurate data has been particularly difficult for the transport sector (with different approaches taken in different cities), and at the sub-sector level.
- **Visualising results and identifying opportunities**: mapping tools have been used in different ways by different cities, and those cities that haven't used mapping tools may benefit from skills development in this area. Although some cities have started to use maps to identify opportunities, it is not clear how much mapping and projecting energy flows has really helped cities to identify new innovative cross-sector opportunities so far. This should to be explored further in the project in deliverables 2.5 'Inventory and assessment of energy actions', 2.8 'Implementation plan dealing with prioritising actions, monitoring and review' and 3.4 'Inventory of pipeline projects and windows of opportunity in each focus district'.
- **Selecting indicators of efficiency**: this has proved difficult as a number of factors affect a city's energy use, and general indicators may provide misleading results.
- **Understanding and defining scenarios:** cities have interpreted the definition of 'scenario' in different ways, and have used different timescales. At the same time, the challenges of interpreting and extrapolating national level data to make future energy flow projections, under both BAU and alternative scenarios, have become apparent.

Key recommendations

The best practice approaches and learning points that have emerged from this analysis provide the background for the following recommendations for cities that are developing enhanced SEAPs:

- **A clear, consistent framework for cities to measure carbon emissions and energy consumption is needed**, to ensure that approaches are aligned in all cities and to make it easier for comparisons to be made and lessons to be learned between cities of similar economies and climates. To make optimal use of this framework, local authorities may benefit from investing in training to improve the carbon accounting knowledge and skills of their staff.

- **National level data needs to be gathered and used with clear assumptions, with local level data used where possible**, given the uncertainties that result from interpreting or extrapolating national data to the local level.

- **The importance of considering all relevant sectors needs to be better recognised in energy flows analysis**. Buildings, the focus of much of this report, are a key contributor to a city's emissions but give an incomplete picture. Cities need to recognise the role of transport, waste, industry, etc. and find ways to improve access to emissions and consumption data for these sectors, particularly where they make up a high percentage of emissions.

- **Cities should seek to involve energy utilities in assessing and projecting energy flows as much as possible,** in order to benefit from access to more detailed or accurate data, and any models or maps that the companies have already developed.

- **Cities would benefit from developing mapping skills**, to further understand energy consumption at the spatial level and assist with sustainable energy project planning in different city districts. However, tools need to be appropriate for the audience and valuable to different stakeholders (including responsible city departments and utilities). For example, GIS may be too detailed in some instances, and Sankey diagrams may only help to provide summary level information on energy inputs, outputs and losses.

- **Cities should review known development proposals and third party studies relating to energy infrastructure development where possible**, to understand their relevance for the city and its enhanced SEAP, as well as ensuring that various plans and strategies are inter-linked to develop a comprehensive energy system that is aligned with the long term vision of the city.

- **Potential future opportunities and scenarios need to be considered in the context of the smart cities agenda** (the current state of smart city development and what the city is aiming towards), and the potential to incorporate smart technologies alongside other policy instruments.

- **More consideration needs to be given in the cities to the fairest way to compare efficiency with other cities**, and whether this provides the city with useful information on its own efficiency and how this can be improved.

- **Cities need to further develop their understanding of a scenario analysis**, including what factors should be considered (economic, environmental, social, technological, political, legal), how the analysis should be done and how this helps cities to understand potential future energy flows. In the STEP UP project this is being explored in more detail in the scenario analysis in D2.6. Ideally future energy flow projections, under BAU and alternative scenarios, should be based on the synergy of national and local level data.

The above recommendations will help ensure that energy flows in the cities are assessed in such a manner that necessary infrastructure investment requirements are identified to enable the development and implementation of innovative and effective sustainable energy measures.