SEVENTH FRAMEWORK PROGRAMME

THEME 6: Environment (including climate change)

Contract for: **Collaborative Project**

D.5.3
Indicators definition report

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Book Captain:	Margaretha Breil (CMCC)
Authors:	Margaretha Breil (CMCC) Jaroslav Mysiak (CMCC) Ainhoa González (TCD)
Contributors:	Judith Klostermann (ALTERRA)
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1 Introduction

1.1 Purpose of the document

This document is the Deliverable 5.3, *Indicators definition report*, within the BRIDGE project, reporting on the activities and achievements within WP5 aiming at the definition of a set of indicators to be used for the assessment of planning alternatives.

1.2 Acronyms

BRIDGE	sustainaBle uRban plannIng Decision support accountinG for urban mEtabolism
CHP	Combined Heat and Power Plant
CoP	Community of Practice
CSI	Core Set of Indicators (EEA)
DPSIR	Driver-Pressure-State-Impact-Response
DSS	Decision Support System
EC	European Community
ECI	European Common Indicators
EEA	European Environment Agency
EU	European Union
GIS	Geographical Information Systems
GHG	Green House Gases
MCA	Multi-Criteria Analysis
MCDM	Multi-Criteria Decision Making
NECD	National Emissions Ceiling Directive
NMVOC	Non-Methane Volatile Organic Compounds
SDI	Sustainable Development Indicators
WP	Work Package
WWTP	Waste Water Treatment Plant

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1.4 Project Overview

Urban metabolism considers a city as a system and distinguishes between energy and material flows. “Metabolic” studies are usually top-down approaches that assess the inputs and outputs of materials, water, energy, etc. from a city, or that compare the metabolic process of several cities. In contrast, bottom-up approaches are based on quantitative estimates of urban metabolism components at local scale, considering the urban metabolism as the 3D exchange and transformation of energy and matter between a city and its environment. Recent advances in biophysical sciences have led to new methods to estimate energy, water, carbon and pollutant fluxes. However, there is poor communication of new knowledge to end-users, such as planners, architects and engineers.

BRIDGE aims to illustrate the advantages of considering environmental issues in urban planning, with particular focus on specific metabolism components (energy, water, carbon, pollutants). BRIDGE’s main goal is to develop a Decision Support System (DSS) which has the potential to propose modifications to the metabolism of urban systems towards sustainability.

BRIDGE is a joint effort of 14 Organizations from 11 EU countries. Helsinki, Athens, London, Firenze and Gliwice have been selected as case study cities. The project uses a “Community of Practice” (CoP) approach, where local stakeholders and BRIDGE scientists meet on a regular basis to learn from each other. The end-users are therefore involved in the project from the start. These meetings are used to discuss and define the key sustainability issues for each city. These provide the basis to determine the sustainability objectives and associated indicators, as well as their relative importance, which would help assess planning alternatives with the overall goal of promoting sustainable development.

The BRIDGE project integrates key environmental and socio-economic considerations into urban planning through Strategic Environmental Assessment. The BRIDGE DSS evaluates how planning alternatives can modify the physical flows of the above urban metabolism components. A Multi-Criteria Decision Making (MCDM) approach has been adopted in the BRIDGE DSS. To cope with the complexity of urban metabolism issues, the indicators measure the intensity of the interactions among the different elements in the system and its environment. The objectives are related to the fluxes of energy, water, carbon and pollutants in the case studies. The evaluation of the performance of each alternative is done in accordance with the developed scales for each criterion to measure the performance of individual alternatives.

The energy and water fluxes are measured and modelled at a local scale. The fluxes of carbon and pollutants are modelled and their spatio-temporal distributions are estimated. These fluxes are simulated in a 3D context and also dynamically by using state-of-the-art numerical models, which normally simulate the complexity of the urban dynamical process exploiting the power and capabilities of modern computer platforms. The output of these models leads to indicators which define the state of the urban environment.

Several studies have addressed urban metabolism issues, but few have integrated the development of numerical tools and methodologies for the analysis of fluxes between a city and its environment with its validation and application in terms of future development alternatives, based on environmental and socio-economic indicators for baseline and proposed situations. The innovation of BRIDGE lies in the development of a DSS integrating the bio-physical observations with socio-economic issues. It allows end-users to evaluate several urban planning alternatives based on their initial identification of sustainability objectives. In this way, sustainable planning strategies will be promoted, based on quantitative evidence in relation to energy, water, carbon and pollutant fluxes.

1.5 The role of indicators within the BRIDGE project

The aim of the BRIDGE project of providing a tool to support decision making based on information on sustainability of the urban metabolism required the definition of a common set indicators to be used as criteria for the assessment of urban planning alternatives. This set of indicators feeds into the BRIDGE DSS which will be used for the assessment of planning alternatives. The set of indicators responds both to the requirements for sustainability indicators of providing meaningful and understandable measures of sustainability, and to the need, within the development of the BRIDGE DSS, of having a limited set of criteria which can be applied in all case studies. It should further more suit further applications of the DSS beyond the end of the project.
The definition of indicators has followed a double bottom-up and top-down approach: In a first step, a bottom-up approach was used for identifying sustainability objectives and indicators during local workshops with stakeholders in each of the case study sites. During these two rounds of meetings, which were organized in collaboration between WP2 (ALTERRA), WP5 and the responsible of each of the study sites, specific sustainability objectives and indicators were discussed with stakeholders gathered during the first and second round of CoP meetings. In addition, a final indicator session was incorporated into the Umbrella CoP meeting, where representatives from the case study cities discussed and agreed a common set of sustainability objectives and indicators. Subsequently a top-down approach was applied to validate the proposed indicators with respect to the modelling capacity existent within the BRIDGE project and with respect to existing indicator sets, used at national European level. This revised set of indicators was verified by WP4 members in order to ensure that the indicators selected respond to the modelling capacities and in order to define the modalities of connecting outputs from models to the indicators used in the DSS.

2 Indicators for assessing and monitoring

Indicators respond to a communication need between scientists and policy-makers, enabling and/or promoting information exchange regarding the issue/s they address (EEA 2005a). This is commonly achieved by a simplification of the observed reality, focussing the data choice on certain aspects which are regarded most relevant and on which data are available, having a significance that goes beyond what is obtained from measured properties (Smeets and Weterings 1999). In other words, the data measured by the indicator normally represents a reality which is broader than the issues measured directly. For example, an indicator measuring a single typical pollutant can represent the more complex problem of air pollution in a certain context, or represent an issue as complex as land use changes due to urbanization measuring two or three single values (urban density, rate of green areas urbanized, and use of brownfields for new developments) illustrating the relevant trends in each of those cases. In order to be useful for decision makers, scientific data needs to be transformed into indicator data, and in some cases grouped according to a given category or criteria based on policy goals – i.e. aggregated into a simple or composite value, which enables the identification of trends correlated to the policy action under assessment.

In the context of the BRIDGE project, indicators are mainly based on outputs from the models used for the simulation of impacts from planning alternatives on the urban metabolism components, so that changes in air pollutant concentration, heat fluxes, and water balance can be explored by end users. These model outputs are integrated with additional indicators addressing those aspects of urban sustainability which are not considered under the urban metabolism approach, namely social and economic concerns of urban development.

All indicators chosen can be used as input information feeding the BRIDGE DSS, which will assist stakeholders, planners and politicians in decision making for urban planning. In particular, it will support decision making in favour of making urban policies more sustainable, by providing outputs from sophisticated models simulating aspects of urban metabolism, which will more accurately predict and, therefore, inform on potential environmental impacts. In this way, the BRIDGE DSS will assist decision makers in understanding and judging potential impacts from urban transformations with regards to urban metabolism, referring also to the wider sustainability considerations: the potential economic and social impacts associated with the assessed urban interventions.

Defining indicators is thus of central importance given their role as criteria for decision-making, and also, because of the potential impact the definition of criteria and indicators for decision making and monitoring on policies (Valentin and Spangenberg 2000). Indicators are in fact frequently based on indications given by legal frameworks, but given the attention paid to them in monitoring or decision-making processes, they are also able to condition policy implementation and to raise the awareness on environmental issues. Selecting indicators is thus a delicate and important task which needs to be supported by local stakeholders and end users as well as by scientific knowledge to ensure that indicators are fit for purpose and address core and relevant issues. Within the BRIDGE project, selection was undertaken through a bottom up approach, in conjunction with the definition of policy objectives and goals during the local CoP meetings, and subsequently adapted to fit data availability and modelling capacity. The indicator selection process and results are described in the BRIDGE Deliverable 5.1 (González et al. 2010a), which presents the content, structure and outcomes of the BRIDGE workshops held in the case study cities.

2.1 Existing indicator sets

It is argued that in the urban context sustainability is difficult or even impossible to achieve (Rees and Wackernagel 1996). However, given the importance of cities' metabolism with respect to natural resources, and due to the opportunities offered by urban density in terms of land consumption, service provision and communication, urban agglomerations represent the "motors for the sustainable development of European regions" (Rotmans et al. 2000). Since the Agenda 21, formulated during the Rio Summit in 1992 (U.N. 1992), urban sustainability has received increasing attention leading to widespread local initiatives striving for urban sustainability. Sustainable development, defined as "paths of progress which meet the needs and aspirations of the present generation without compromising the ability of future generations to meet their needs" (Brundtland et al. 1987) has been translated into urban development goals by a many local initiatives and entered into the European policy agenda through the "Communication on Sustainable Urban Development in the European Union" (EC 2006). In the context of these initiatives, the definition of indicators holds a prominent role because of the importance of indicators as a central tool for policy design, implementation and monitoring, as stated in the Aalborg Charta (1994):

> *"We know that we must base our policy-making and controlling efforts, in particular our environmental monitoring, auditing, impact assessment, accounting, balancing and reporting systems, on different types of indicators, including those of urban environmental quality, urban flows, urban patterns, and, most importantly, indicators of an urban systems sustainability."*

Urban planning and design can have a positive impact on urban sustainability, through the appropriate delivery and management of land, water, energy, transport, and waste, and safeguarding biodiversity, water and air quality; in addition to the promotion of economic prosperity, social equality and human well-being. The integration of all these considerations, taking account the limitations set by the physical and economic characteristics of a given plan or project, is often a complex and challenging endeavour. Appropriate definition of sustainability objectives and associated indicators can assist this integration by addressing core sustainability considerations.

European Sustainability Indicators and BRIDGE

Given the extensive attempts to address the urban sustainability policy goal, a significant number of indicator sets have been made available (EC 2003; Bardos et al. 2009). The advantage of selecting indicators from consolidated existent sets relates to the fact that these indicators are already measured on an ongoing basis and allow for a better cross-national comparability than those provided by ad-hoc constructed indicators or indicator sets. However, such ad-hoc indicators may, on the contrary, measure more precisely, and address more accurately the problem at hand, than the already set "generic" indicators.

At European level there are different sets of indicators measuring environmental, social and economic aspects of sustainability which were used as a reference for the criteria chosen in the CoPs:

- EEA set of core indicators[1] which is actually used for environmental sustainability reporting on European and national level,
- European Set of Sustainability Indicators (SDI)[2] used by Eurostat to monitor the EU Sustainable Development Strategy." (EC 2005; Ledoux et al. 2005)
- Core Set of Indicators used by the European Environmental Agency[3], comprising a set of 37 indicators addressing mainly the status or progress of environmental resources in meeting the targets established in the legislation;
- Set of Structural Indicators[4] which provide an instrument for annual assessments of the progress made towards the Lisbon objectives
- Laeken Indicators, a set of common indicators for the social situation in the countries of the European Union, defined in relation to specific policies for social inclusion (EC 2006)5.

The last two sets of common indicators are cited in the sustainability context. They were not fully applied in BRIDGE due to the urban metabolism focus, but are considered as relevant since they are specifically connected to economic and social goals and policies.

European Common Indicators

Specific urban sustainability issues are monitored in the context of the European Common Indicators (ECI) Initiative[6] which refers explicitly to the local scale of urban policies. The ECI indicator set was launched by the European Commission in the context of the "Thematic Strategy on the Urban Environment" and is closely connected to the experiences made in numerous European cities in the context of local Agenda 21 processes (Ambiente Italia 2003). Thus, compared to the SDI indicator set, some policy areas as public health, poverty, and social exclusion or international relationships are not covered at all, and some others, such as those connected to the theme of economic development are only scarcely considered, as they are beyond the reach of local policies.

[1] http://themes.eea.europa.eu/IMS/CSI

[2] http://epp.eurostat.ec.europa.eu/portal/page/portal/sdi/introduction

[3] http://www.eea.europa.eu/data-and-maps/indicators#c7=all&c5=&c0=10&b_start=0&c10=CSI

[4] http://epp.eurostat.ec.europa.eu/portal/page/portal/structural_indicators/introduction

[5] http://ec.europa.eu/employment_social/spsi/common_indicators_en.htm

[6] http://ec.europa.eu/environment/urban/common_indicators.htm

Table 1 Correspondence between European Common indicators and sustainable development indicator themes

European Common Indicators (DG ENV)	Sustainable Development Indicator (SDI) themes
Citizen satisfaction with the local community	Good governance
Local contribution to global climatic change	Climate change and energy
Local mobility and passenger transportation	Transport
Availability of local public open areas and services	Public health
Quality of local ambient air	Management of natural resources
Children's journeys' to and from school	Transport
Sustainable management of the local authority and local business	Good governance
Noise pollution	Management of natural resources
Sustainable land use	Management of natural resources
Products promoting sustainability	Production and consumption patterns
No correspondence	Economic development
	Poverty and social exclusion
	Ageing society
	Global partnership

European Environment Agency Core Set of Indicators (SDI)

The core set of indicators proposed by the European Environment Agency (EEA) addresses mainly the status or progress of environmental resources in meeting the targets established by legislation, thus facilitating environmental reporting both at local and at EU level. This indicator set exclusively addresses environmental issues of sustainability. Further to the aim of monitoring the progress against environmental policy priorities, the definition of the indicator set aims also at improving the quality and coverage of data flows, which will enhance comparability and certainty of information and assessments; and at streamlining contributions to other indicator initiatives in Europe and beyond. The selection of indicators has been undertaken based on their relevance to policy priorities, objectives and targets, the availability of high-quality data over both time and space, and the application of well-founded methods for indicator calculation.

Of these 37 indicators, 6 apply to air pollution and ozone depletion, 4 to climate change, 5 to energy 7 to water resources – the main aspects analysed under the scope of BRIDGE. The remainder of the indicators consider land management and transport, two further important criteria for the assessment of urban sustainability, (which were also raised as critical during the CoP meetings). Additional indicators refer to areas of environmental sustainability which are not within the scope of BRIDGE, such as agriculture and fisheries.

Table 2: EEA SDI indicators relevant for the urban metabolism approach adopted in BRIDGE.

Indicators	Specifications
AIR	
Anthropogenic emissions of acidifying substances (CSI 001)	Concentration of nitrogen oxides – NOx, ammonia – NH_3, and sulphur dioxide – SO_2; Weighted by their acidifying potential; and Classified by sector.
Anthropogenic emissions of ozone precursors (CSI 002)	Concentration of nitrogen oxides – NOx, carbon monoxide – CO, methane – CH_4 and non-methane volatile organic compounds – NMVOCs; Weighted their tropospheric ozone-forming potential; and Classified by sector.
Emissions of primary particulate matter (CSI 003)	Concentration of particulate matter less than 10 µm (PM_{10}); Aggregated according to the particulate formation potential of each precursor; and classified by source sector.
CLIMATE CHANGE	
Greenhouse gas emissions (CSI 010)	Greenhouse gas emissions are expressed in 'million tonnes CO_2-equivalent' (Mt CO_2-eq.)
Annual average temperature (CSI 012)	Annual urban average temperature and winter/summer temperatures; Compared with the 1961–1990 average; and Units are °C.
Projections of GHG concentrations (CSI 011)	Projections of carbon dioxide - CO_2, nitrous oxide – N_2O, and methane - CH4, and fluorinated gases (HFCs, PFCs, and SF6); All data are in million tons CO_2-equivalent; and Global annual averages are considered. and compared to national Kyoto targets (reduction from base year levels)
ENERGY	
Final energy consumption by sector (CSI 027)	Sum of final energy consumption of all sectors; Measured in thousand tons of oil equivalent; and Disaggregated into industry, transport, households, services and agriculture. measured in million TOE and per capita final consumption
Primary energy consumption by fuel (CSI 029)	Disaggregated into fossil fuels (coal, oil, gas) and renewable sources (wind, solar, geothermal, wave/tidal, hydropower, biomass, landfill gas and biogases); Measured in thousand tons of oil equivalent; and the share of each fuel in total energy consumption is presented in the form of a percentage.

European Sustainability Indicators and Policy Objectives and their Relevance in the BRIDGE Case Studies

The policy objectives for air quality in the European Community mainly focus on the reduction of anthropogenic pollutant emissions and the increase of pollutant sinks, in order to protect human health and mitigate the effects of climate change. BRIDGE focuses on carbon and pollutants as components of the urban metabolism process. Therefore, the objective of the project is to promote sustainable land use planning, by identifying the planning alternative that maximizes the reduction of key pollutants in the atmosphere (e.g. CO_2, NOx, SO_2, PM_{10}, $PM_{2.5}$).

European Community initiatives and policies with regards to energy aim at reducing the overall energy consumption and the associated pollutant emissions through an incremental use of renewable energy sources. BRIDGE considers the energy balance in the urban system as a net heat exchange, particularly focusing on the heat island effect (exacerbated by the effects of climate change). Nevertheless, due consideration is given to energy consumption mechanisms through the assessment of planning alternatives that optimize energy efficiency in the urban structure and maximize the use of renewable energy sources.

Several European legislations aim at reducing the loads and impacts of nutrients in water resources. However, water balance measures have only recently been put in place (e.g. flood risk management). BRIDGE looks at the water balance in urban systems, assessing the sustainability of planning alternatives on the basis of their effects on the water cycle.

Taking into account the scope of BRIDGE, the EEA indicators relating to air pollution and ozone depletion can be coupled with the indicators addressing climate change. Similarly, the energy indicators considered by the EEA can be grouped to address the overall consumption by production source and by sector. All the EEA indicators relating to water refer to nutrient load, and therefore, fall outside the scope of BRIDGE. Those EEA indicators relevant to BRIDGE are indicated in Table 2.

2.2 National indicators

EEA Indicator Assessment for BRIDGE Case Study Cities

An overview of the context and the state of the environment in the BRIDGE case study countries is provided in Table 3, based on the indicators used by the EEA for environmental reporting. The EEA indicators have been grouped in the three core areas of BRIDGE (namely carbon and pollutants, energy and the water cycle), to facilitate future comparison. This information has been extracted from the most up to date European Environment Outlook (EEA 2005b), and updated with values obtained from the current EEA dataset[7]. These indicator assessments have been used to validate the baseline environment reported for each city, during the impact assessment stage of the project.

Table 3: Overview of the state of the environment for BRIDGE case study countries.

FINLAND
Carbon and Pollutants
Emissions of Acidifying Substances Emissions have decreased since 1990, with SO_X showing the largest decrease to a level below the NECD ceiling. Air emissions depend on climatological conditions, export/import of electricity, availability of hydropower, and many other factors that cause variation in annual emissions.
Emissions of Ozone Precursors Ground level ozone concentrations are mainly low (and have been decreasing) in Finland and the few occurrences of elevated levels are due to long-range transport of emissions.
GHG Emissions Finland's target is to keep its GHG in the first commitment period at the 1990 level. GHG emissions in Finland depend on many issues: prevailing economic situation, energy intensive industries; volumes of hydro-power produced; imports of energy and renewable sources; and climatic conditions. Finland's greenhouse gas emissions in 2002 exceeded the 1990 level by 9.7 % percent; the energy sector CO_2 emissions having increased 15 %.
Energy
Energy Consumption The energy intensity per capita is rather high in Finland. This is due, among other things, to climate, transport, and energy intensive industry. As much electricity as possible is produced from combined heat and power plants (CHP). Other means include voluntary energy conservation agreements, and promotion of sustainable consumer behaviour.
Renewable Energy The share of renewable energy in electricity production has been increasing substantially and the action plan for renewable energy sources aims at an increase of 30 % by 2010 compared to 2001.
Water
Use of Freshwater Resources Water abstraction per capita in Finland is above average but the abstracted amount of water is a very small proportion of the available water resources. The irrigated agricultural area is very small and the amount of water used for irrigation is only about 2 % of the total abstracted amount.

[7] http://themes.eea.europa.eu/IMS/CSI (data release date: December 2008)

GREECE
Carbon and Pollutants
Emissions of Acidifying Substances Emissions of air pollutants increased following GDP growth with the exception of NO_X and SO_2.
Emissions of Ozone Precursors Between 1990 and 2002 emissions increased, particularly for NO_X and NMVOC, and were above the level that would be needed to meet 2010 NECD targets. Focus for these actions is the energy sector, responsible for the largest part of air quality degradation.
GHG Emissions Greenhouse gas emissions increased steadily during the last decade, the most important gases being CO_2 and CH_4. The production and use of energy, as well as waste disposal and agriculture are the primary sources of emissions. Projections indicate that with a consistent implementation of its 2003 plan Greece will come close to meeting its target.
Energy
Energy Consumption The Greek energy sector is largely dependent on conventional fuels and domestic lignite resources, contributing significantly to the release of atmospheric pollutants. The total operational electrical capacity of natural gas plants will be increased by 52 % by 2010, of hydropower plants by 18 % and of renewables by at least 100 %, while the capacity of lignite plants will be decreased by 3 %.
Renewable Energy Renewable energy sources contributed 5 % of total energy demand in 2003. Two-thirds of the total production comes in the form of heat from biomass and active solar systems, and the remaining third comes from hydropower plants and wind. It must be noted that electricity production from large hydro is largely affected by weather conditions (rainfall) and the availability of water in the reservoirs.
Water
Use of Freshwater Resources The problems of water management mainly concern issues of quantity and not of quality. The uneven distribution of water resources and rainfall creates water availability problems. Agriculture is the most significant water consumer (accounting for over 80% of total water abstractions). The irrigation demand was reduced by about 2.5 % between 1992 and 2002, and further reductions are anticipated. Approximately 70% of the national population was serviced by WWTP in 2004; and 97.6 % of coasts met EU requirements with regards to bathing water quality.

ITALY
Carbon and Pollutants
Emissions of Acidifying Substances Emissions of acidifying substances are diminishing and nearing the European targets. Although close to the desired target, emissions of NH_4 show a slight increase due to the transport sector.
Emissions of Ozone Precursors Emissions of NMVOCs dropped by 37.6 % between 1992 and 2002, close to the European targets.
GHG Emissions Italy has undertaken the commitment to reduce overall national emissions by 6.5 % from the 1990 levels by 2008–2012. However, the total emissions in 2002, in CO_2-equivalent terms are 7% higher and thus far from the fixed target. This increase is closely related to energy consumption.
Energy
Energy Consumption Italian energy system is characterised by a good performance of energy intensity, and a changing energy supply pattern involving increasing use of natural gas, renewable energy and cogeneration.
Renewable Energy Renewable energy contributed only 5.9 % of the total energy produced in 2003, although is showing an increase. Renewable sources include hydroelectricity, biogas, wood and wind energy.
Water
Use of Freshwater Resources The main water consuming sector is agriculture (irrigation), and the main source of water for this purpose remains groundwater. Groundwater bodies are then affected by imbalances in the recharge regime and salt intrusion along the coastline. Reduction of water stress in agriculture is a priority in the national water policy, and relevant actions have been put in place including monitoring of abstraction-treatment-distribution-wastewater treatment and reuse.

POLAND
Carbon and Pollutants
Emissions of Acidifying Substances Poland has already reached its reduction targets for NO_2 set for 2010 in the Gothenburg protocol, is well below the reduction target set for NH_3 and very close to reaching its SO_2 reduction target.
Emissions of Ozone Precursors Emissions of ozone precursors are low in Poland with a continual decrease of CH_4 and CO since 1990. For NMVOCs, Poland is currently well below its emission reduction target set for 2010.
GHG Emissions Total GHG emissions have declined substantially, mainly due to restructuring or closure of heavily polluting and energy intensive industries. Poland has a reduction target of 6 % from the base-year; emission trends and projections show that Poland is on track to meet its Kyoto target.
Energy
Energy Consumption Energy use has decoupled from economic growth in Poland, leading to low energy consumption per capita. Modernization of existing power generation facilities and implementation of eco-efficient technologies is resulting in a successful decrease in energy consumption.
Renewable Energy The share of renewable energy accounts for about 2 % of total electricity consumption in Poland; mostly derived from biomass with a small but increasing number of hydro and wind power plants.
Water
Use of Freshwater Resources The level of water abstraction is decreasing; Poland has low levels of agriculture/irrigation water use in comparison with the EU average, and industry represents the main user.

UNITED KINGDOM
Carbon and Pollutants
Emissions of Acidifying Substances In England 62 % of rivers were of good quality in 2004 compared with 43 % in 1990.
Emissions of Ozone Precursors Background levels of ground level O_3 have doubled over the past 100 years. Ozone production is affected by the weather and by pollutants blown over from mainland Europe. O_3 concentrations are lower in urban areas where it is converted to NO_2 through chemical reaction with NO_X.
GHG Emissions A decrease of about 7 % for CO_2 and about 14 % for the total of GHG were observed between 1990 and 2003. However, the greater use of coal in electricity generation anticipates increases.
Energy
Energy Consumption One of the UK's renewable targets is that 10% of electricity generated should be from renewable sources by 2010. Between 1990 and 2004 the percentage of electricity generated from renewable sources increased from 1.8% to 3.6%, with the largest increase from landfill gas and wind power.
Renewable Energy Between 1980 and 2003 energy use for transport increased by 58 %, mainly as a result of an 80 % increase in road traffic over the same period and a levelling-off of domestic consumption.
Water
Use of Freshwater Resources Water is abstracted under licences, granted on the basis of the reasonable needs of the public, industry and agriculture, and availability of supplies. The amount abstracted has been generally rising; in 2002, 83% of abstracted water was for public water supply and electricity industry.

Sustainability Indicators in the BRIDGE Case Study Cities

The sustainability indicators commonly applied at national level are reviewed in this section to facilitate the validation of the indicators proposed at the CoPs, as well as to determine the availability of relevant datasets.

Athens, Greece

Sustainable development indicators are only available at the national level in Greece. These are provided by the National Centre for Environment and Sustainable Development, and the most up to date data was published in 2003 (NCESDG 2003). The indicators that are suitable for BRIDGE are summarised in Table 4 below; however, this list constituted a comprehensive proposal and not all of them are being measured hence.

Table 4: Sustainability indicators in Greece relevant to BRIDGE.

Dimension	Indicators
AIR	• Evolution of air pollutants emissions according to EU Directive 2001/81 • Progress in decoupling economic growth from the emissions of air pollutants • Sectoral analysis of air pollutants • Per capita SO_2 and NO_x emissions • Air quality in the urban environment
CLIMATE	• Evolution of greenhouse gas emissions and deviations from the Kyoto target • Progress in decoupling economic growth from greenhouse gas emissions • Sectoral analysis of greenhouse gas emissions • Contribution of the energy sector to CO_2 emissions
ENERGY	• Evolution of primary energy demand • Evolution of final energy consumption • Per capita energy consumption and CO_2 emissions • Contribution of the energy sector to total emissions • Decoupling the economy from energy demand and pollutants emissions • Energy intensity • Relative evolution of energy and electricity demand • Composition of the electricity production mix • Participation of Renewable Energy Sources (RES) in electricity production • Electricity production from RES excluding large hydroelectric facilities • Installation of solar collectors for water heating
WATER	• Water uptakes • Per capita water demand • Sectoral analysis of water demand • Intensity of water use in agriculture

Firenze, Italy

Environmental reporting in Italy, under Agenda 21 activities, is commonly undertaken by contrasting the European common urban indicators for local sustainability (Ambiente Italia 2003).

Table 5: European common indicators for urban sustainability.

Indicators	Units
Citizen satisfaction at the local level	Personal security (% of satisfied population) Natural environment (% of satisfied population) Urban environment (% of satisfied population) Services (culture and arts) (% of satisfied population)
Local contribution to climate change	CO_2 emissions per capita per sector
Mobility and transport	% of private car use and % of other transport modes
Accessibility to green areas and services	% of population that lives 300m away from a green area >5,000m^2
Air quality	Net overexposure to PM_{10}
Transport of kids	Home-school travel: % of kids brought to school by private car
Sustainable management of local authorities and local enterprise	% of environmental certificates in relation to total number of businesses (per business type).
Noise impacts	% of population exposed to noise night levels L>55dB(A)
Sustainable use of land	% of protected/urbanized areas in relation to the total of the administrative area
Sustainable products	% of sustainable products acquired
Waste	% of waste produced and type

Additional indicators have been developed at the regional level. The Tuscany Region has established a system for measuring sustainability at the local level; with an inventory of over 1,000 indicators (CDF 2008) that can be selected and applied to the local context (e.g. suited to the urban or rural characteristics of the area). The indicators are categorised according to the sustainability objectives and their dimension:

- Economic Dimension – Objective: to create a solidary economy.
- Institutional and Social Dimension – Objective: to build a sustainable community.
- Environmental Dimension – Objective: conserve and improve the quality of environmental resources.

Within this set, the 90 indicators that are applicable to monitor the sustainability of Firenze (PDF 2005) are embedded. Table 6 lists those indicators (from the 90 core set of indicators for urban sustainability) that are relevant to BRIDGE, for which the last data update took place in 2007.

Table 6: Sustainability indicators in Firenze relevant to BRIDGE.

Dimension	**Indicators & Units**
AIR	
Environmental Dimension	Emissions to the atmosphere – mg/m^3
	Contribution to GHG/climate change effects – tones CO_2-equivalent/year
	Air quality (NO_2 and PM_{10}) – mg/m^3
ENERGY	
Economic Dimension	Energy intensity/consumption per capita – MW/sector/year or KW/capita/year
WATER	
Environmental Dimension	Water consumption – l/capita or m^3/year per sector
	Exposure to extreme events (floods, draughts) – Number of occurrences (% of population affected)
SOCIO-ECONOMIC	
Economic Dimension	Employment/unemployment – % of population
Institutional and Social Dimension	Land use per capita – m^2/capita
	Private car ownership – Number/100 persons
	Accessibility of public transport – % of population
	Public transport – Number of persons/year
	Immigration – % of population
	Population density – Number of persons/Km^2
OTHER	
Environmental Dimension	Land use – % /type
	Protected area surface – m^2, % of total
	Ecologic infrastructure – m^2, % of total
	Recovered areas – % of total

Gliwice, Poland

The National Environmental Policy (CMRP 2009) sets the measures and actions to protect natural resources and improve environmental quality and safety. Although there is no official list of sustainable development indicators in the country, monitoring the implementation of the Environmental Policy will have regard to:

- Nature conservation;
- Protection and sustainable development of forests;
- Rational management of water resources;
- Land protection;
- Managing geological resources;
- The environment and human health;
- Air quality;
- Water protection;
- Waste management;
- Noise and electromagnetic field impacts; and
- Chemicals in the environment.

Helsinki, Finland

The national sustainable development indicators in Finland are grouped according to the strategic subject areas within the national strategy for sustainable development (FNCSD, 2009), which include the 'balance between use and protection of natural resources'. The indicators under this strategic heading are:

- Greenhouse gas emissions;
- Total energy consumption;
- Use of renewable energy sources;
- Endangered species;

- Energy and natural resource consumption in relation to economic growth;
- Environmental loading in relation to economic growth;
- Development of total material requirement;
- Proportion of household expenditures on services; and
- Eutrophicating discharges into Baltic Sea.

In addition, the list in Table 7 presents the sustainability indicators used by the 6 biggest cities in Finland (i.e. Helsinki, Espoo, Vantaa, Tampere, Turku, Oulu – CH 2007).

Table 7: Sustainable indicators for major urban areas in Finland.

Indicator	Units
Greenhouse gas emissions	tons/resident/year
Share of buildings and dwellings built in the city plan area	Percentage
Proportion of nature protection areas and reserves of the land area	Percentage
Proportion of nature protection and reserves of the total surface area	Percentage
Community electricity consumption	kWh/resident/year
Community water consumption	l/resident/year
Heating needs covered by district heating	Percentage
Specific consumption of heat in city owned buildings	kWh/m^3
Specific consumption of electricity in city owned buildings	kWh/m^3
Air quality, PM10 exceeding the daily limit values (35 allowed)	Days
Community air quality, bad and very bad day according to the index	% of hours
Community wastewater load, phosphorus,	g/resident/day
Community wastewater load, nitrogen	g/resident/day
Community wastewater load, BOD7	g/resident/day
Amount of community waste for final placement	kg/resident/year
Amount of waste utilized, biowaste	kg/resident/year
Number of cars/1,000 residents	Number
Number of public transport journeys	journeys/resident/day
Cycle path network	m/resident
Copy paper consumption in City departments	A4sheets/employee/year
Green flag schools and kindergartens	Number
Participation in environmental education arranged by the city	% of Helsinki residents

Based on the indicators above, the Helsinki Environment Center (HEC 2009) provides a more comprehensive list to monitor the state of the environment. Table 8 illustrates the indicators currently monitored by the Environment Center that are relevant to BRIDGE, and for which numerical data is available up to 2008.

Table 8: Environmental indicators in Finland relevant to BRIDGE.

Group & Units	Indicators
AIR	
Air Quality ($\mu g/m^3$)	• Air quality in Helsinki city centre. • Annual nitrogen dioxide concentration averages. • Number of cases where the numeric value for the NO_2 limit (200 $\mu g/m^3$) was exceeded. • Annual averages for thoracic particle (PM_{10}) and fine particle ($PM_{2.5}$) concentrations. • Number of days where the limiting value for thoracic particles was exceeded. • Highest hourly average ozone concentration values.
CLIMATE CHANGE	
Weather and climate (^oC)	• Mean monthly and annual temperatures measured at Kaisaniemi weather station.
Greenhouse gases (metric tons of CO_2-equivalent)	• Consumption-based greenhouse gas emissions (district heating, electrical heating, individual property heating, consumer electricity, industry and machinery, transportation, waste and wastewater treatment, agriculture). • Helsingin Energia specific energy production emissions (CO_2, SO_2 , NO_x, PM). • Energy production facility emissions (CO_2, SO_2 , NO_x, PM).
ENERGY	
Energy consumption (KWh/GWh)	• Total consumption of energy by type of consumption (electricity, district heating, transportation, individual property heating, industry and work machinery). Energy consumption per resident. • Consumption of electricity, by consumer segment (household, services, processing). • Specific consumption of district heating. • Specific heat consumption of district heated buildings (total buildings stock, industrial, service and public buildings, residential apartment blocks). • Heat consumption of properties monitored by the City of Helsinki (residential houses, service buildings).
Energy production (KWh/GWh)	• Percentage of renewable energy in the district heating and cooling (natural gas, renewable, oil, coal, nuclear power). • Energy production emissions (CO_2, NOx, SO_2, PM).
WATER	
Water consumption (l/resident/day)	• Water consumption in Helsinki by consumer segment (households, services, industry).

London, United Kingdom

A framework for sustainable development is shared by the UK Government and the devolved administrations in Scotland, Wales and Northern Ireland (DEFRA 2009). Twenty ‘UK Framework indicators’ cover key impacts and outcomes that reflect the priority areas shared across the UK. These priority areas are:

- Sustainable consumption and production;
- Climate change and energy;
- Protecting natural resources and enhancing the environment; and
- Creating sustainable communities and a fairer world.

These 20 indicators are included in the UK’s 68 national sustainable indicators supporting the Government’s Sustainable Development Strategy, which address issues such as health, housing, jobs, crime, education and the environment (DEFRA 2009). Table 9 illustrates the national sustainable indicators that are relevant to BRIDGE, for which data is available up to 2008.

Table 9: Environmental indicators in the UK relevant to BRIDGE.

Subgroup	Indicators
AIR	
Carbon dioxide emissions by end user	• CO_2 emissions by end-user (business, residential, transport, aviation and shipping).
Electricity generation	• Electricity generated, CO_2, NO_x and SO_2 emissions by electricity generators and GDP.
Household energy use	• Domestic CO_2 emissions, domestic energy consumption and household spending.
Road transport	• CO_2, NO_x, PM_{10} emissions and Gross Domestic Product.
Private cars	• Private car CO_2 emissions and car-kilometres and household spending.
Road freight	• Heavy Goods Vehicle (HGV) CO_2 emissions, freight moved and Gross Domestic Product.
Manufacturing sector	• CO_2, NO_x, SO_2, PM_{10} emissions and output.
Service sector	• CO_2, NO_x emissions and output.
Public sector	• CO_2, NO_x emissions and output.
Ecological impacts of air pollution	• Area of sensitive UK habitats exceeding critical loads for acidification and eutrophication.
Emissions of air pollutants	• NH_3, NO_x, PM_{10} and SO_2 emissions and GDP.
Air quality and health	• Annual levels of particles and ozone. • Days when air pollution is moderate or higher. • Urban population exposure to ozone. • Urban population exposure to particulate matter.
CLIMATE CHANGE	
Greenhouse gas emissions	• Greenhouse gases (from energy use, production of goods, and transportation – differentiating also aviation and shipping). • Emissions of the basket of six GHG per capita. • CO_2 emissions gases (from energy use, production of goods, and transportation – differentiating also aviation and shipping).
ENERGY	
Energy supply	• UK indigenous energy production and gross inland energy consumption.
Renewable energy	• Renewable energy generated as percentage of total electricity
WATER	
Water resource use	• Total abstractions from non-tidal surface and ground water, leakage losses and Gross Domestic Product.
Domestic water consumption	• Liters per person per day.
Water stress	• Resource availability status at low flows for units of surface water and/or surface water combined with groundwater.
Flooding	• Number of properties in areas at risk of flooding.
SOCIO-ECONOMIC	
Housing density	• Average density of new housing.
Demography	• Population and population of working age.
Employment	• People of working age in employment.
Economic growth	• Gross Domestic Product.

3 BRIDGE indicators for Urban Sustainability

The European indicator sets, with exception of the common indicators, (ECI described above) refer to progress towards sustainability objectives at national levels, aiming at monitoring and comparison across EU member states, and refer to sustainability objectives relevant for national policies. In the case of the ECI set, the level of reference is the urban scale. The policy concerns expressed in these indicator sets are highly relevant in the urban contexts considered by BRIDGE, and were congruent with the issues and concerns of urban sustainability defined by local end-users throughout all meetings in the CoP groups (see Table 11). The translation of these sustainability issues and objectives into policy measures and planning interventions to be assessed with the support of the BRIDGE DSS implied a further downscaling and specification of policy objectives. In fact, the planning interventions to be assessed by the DSS cover only a part of the city areas, and tackle only some and not all the sustainability objectives defined at city level. Therefore, the indicators selected during the first round of the CoP meetings (which addressed city-wide sustainability considerations) were revised during the second round of CoP meetings to more specifically address sustainability criteria associated with the proposed planning alternatives at the local level.

3.1 Scale considerations

Whereas policy objectives expressed by the categories for indicators in the generic European indicator sets fitted well the stakeholder's concerns with respect to urban sustainable development as defined during the first round of CoPs, planning alternatives focussed on smaller parts of the respective city areas and therefore were not able to fully address all the sustainability objectives defined at city level. However, as already mentioned, the objectives formulated during the first round with reference to the city level were translated into more detailed measurements in the second round of CoPs, in order to be meaningful in the assessment of the alternatives proposed.

Once planning alternatives were chosen for the testing of the BRIDGE DSS and the corresponding model outputs checked against measurement units and time scales used for the indicators, limitations with regards to the measurement of some indicators became obvious. In fact, when considering the planning alternatives, it became obvious that the contribution of each alternative to the overall sustainability goal, for instance in terms of contribution to the overall air quality conditions at city level, or to the city's carbon emissions, might not always be measurable or significant, albeit differences between planning alternatives, measured at the scale of the planning area, were quite significant, or showed an important variability throughout the planning area. With regards to time scales, qualitative differences between different policy alternatives under exam might be difficult to be acknowledged on the basis of annual medium values, which are normally used for monitoring urban sustainability because of the reduced entity of relative change, whereas daily changes may be important under some specific conditions. The project team has carefully addressed spatial scale considerations during a technical meeting. Where possible, indicator values will be provided in spatial format (i.e. map form) to be able to identify spatial distributions and patterns. This will potentially help end-users identifying hot-spots or concentration of planning issues (e.g. cumulative impacts) and, thus, assist them defining localised and specific remedial actions. To standardise modelling operations and provide comparable spatial datasets, a geographical extent of 5.4x 5.4 Km has been adopted in BRIDGE – which covers the study area of the planning alternatives for all the cities except for London where the Central Activity Zone has a larger extent. The adopted spatial resolution is 200x200m, which is considered to provide sufficient detail at both strategic and local planning level. Because of the limitations of certain models, this resolution has been extended to 1000x1000m as in the case of the LUMPS model. Nevertheless, every effort has been made to adopt consistent geographical scales and, in this way, provide comparable model outputs and facilitate their integration in the DSS.

Similarly, time scale considerations have been addressed, as far as practicable, in the BRIDGE project. Several indicators (particularly those associated with air quality) have very specific time scales set in the relevant EU or national legislation (e.g. a concentration of 50 $\mu g/m^3$ of PM_{10} cannot exceeded more than 35 times a calendar year). Therefore, it is vital for the BRIDGE DSS to provide end users with information on an hourly or daily basis for evaluating any potential changes on indicator values and, enabling them thus to determine whether a given planning alternative fulfils legislative requirements.

Due to data availability constraints, the DSS prototype will be run with 2008 datasets and will, therefore, assess planning alternatives against the baseline environment for that year. When comparing planning alternatives, the DSS will produce annual mean values for the different indicators (which will also entail a mean spatial value for the study area). This will facilitate strategic comparison of assessment outcomes. However, to address temporal variation and determine fulfilment of EU and national requirements, the end-user will also be able to retrieve indicator values on an hourly basis, to examine trends and daily/seasonal variations. In all cases, the provision of an absolute value (which is commonly an annual average, but could also refer to maximum or minimum values or deviations) is essential to enable the aggregation of indicators to calculate the performance index of each planning alternatives (refer to González et al. 2010b for further detail). It must be noted that qualitative indicators are, to some extent, difficult to examine spatially or on the basis of annual medium values or any other temporal scales and, therefore, overall values are provided for such indicators.

The potential shortcoming of this focalization on very local issues in the planning alternatives lies in the difficulty in inverting the process, impeding upscaling the scores of indicators according to their performance in the planning intervention to higher hierarchic levels of the urban planning system as well as the consideration of trade-offs which manifest themselves at higher scales of urban policies, which are likely to differ from those considered in the assessment of planning alternatives. To address this spatial scale issue and, consequently, link different urban planning scales, Cellular Automata models are being applied within BRIDGE. These models enable to anticipate land uses changes and, therefore, will be used to build land use changes associated with and resulting from the planning interventions (e.g. resulting increase in housing in the surrounding environs due to the planned development of a technology campus). In doing this, the DSS end-user will be able to explore localised impacts as well as city-wide effects of planning alternatives.

3.2 Indicators and Modelling Capacities

The appropriate incorporation of the indicators resulting from the CoP meetings into the DSS is partially constrained by the models available. Modelling capabilities have not limited indicator selection as such, but a clear differentiation has been made between those indicators that can be modelled within BRIDGE and those for which values need to be provided by the end-user. In this way, a subset of the sustainability indicators (i.e. those associated with air pollutants, water balance and energy fluxes) is automatically calculated by online and offline models and provided to the end-user, while the end-user is prompted to input the value of the rest of the indicators (e.g. socio-economic), where information is available, before the assessment. Further details on the methodology can be found in Deliverable 5.2 (González et al. 2010b).

Time and resources, as well as lack of data in some instances, affect the implementation of modelling tools within BRIDGE. Therefore, not all models available are applied to all the case study cities and not all the case study cities are subject to the same modelling operations (Table 10). To optimise their application, models have been incorporated online into the DSS, but several models have remained offline due to their high computer demand. In this case, the outputs of offline models are automatically integrated into the DSS so the end-user has ready access to them. Offline models exist for modelling air pollution, energy fluxes and water balance in all the case study cities (through WRF/UCM and WRF/CHEM). Additional offline models (i.e. CMAQ and MM5/CAMx) calculate pollutant concentrations for several cities, and WRF/ACASA is providing energy fluxes and water balance calculations for Firenze. In the case of online models, an attempt has been made to ensure that these are as applicable to as many case studies as possible, but difficulties with data gathering and limited resources have resulted in URBAIR air pollution modelling being applied and made accessible in the DSS for all the case studies while LUMPS, SIMGRO and SURFEX for modelling energy fluxes and water balance, are available only for a limited number of cities.

Table 10: The application of BRIDGE models to the case study cities.

	MODELS	OUTPUTS	CASE STUDIES				
ONLINE			Athens	Firenze	Gliwice	Helsinki	London
	URBAIR	air pollutants concentrations	x	x	x	x	x
	LUMPS	water and energy balance					x
	SIMGRO	water and energy balance				X(W)	
	SURFEX	energy balance + energy consumption, water balance	x			X (E)	
OFFLINE							
	WRF/UCM	meteo + energy and water balance	x	x	x	x	x
	WRF/CHEM	Pollutants concentrations	x	x	x	x	x
	CMAQ	Pollutants concentrations	x	x			
	MM5/CAMX	Pollutants concentrations			x	x	x
	WRF/ACASA	energy and water balance + CO2 fluxes		x			

3.3 Uncertainty

The use of model outputs as information for the assessment of planning alternatives requires communication of uncertainties implicit in physical modelling to end-users and decision-makers. Lipshitz and Strauss, (1997) describe three principal forms of perception of uncertainty by decision-makers: a) inadequate understanding (a sense of having an insufficiently coherent situation awareness); b) lack of information (a sense of having incomplete, ambiguous, or unreliable information); and c) conflicted alternatives (a sense that available alternatives are insufficiently differentiated). In order to ease the understanding of uncertainty connected to the model outputs , the BRIDGE DSS presents mean indicator values based on single model's output, and as ranges where alternative models exist. The indicators values based on modelling outputs will be provided in the DSS in spatial format. Where more than one model exists for measuring the same indicator, the results will be presented as ranges rather than as single absolute values, illustrating maximum, minimum and mean values to account for uncertainty.

3.4 Limitations within BRIDGE

The domain of interest of BRIDGE is sustainable urban development, to be analysed within a set of boundaries determined by the scope of the project focussing on urban metabolism: carbon and pollutants, energy and water. These boundaries constrain the detailed assessment of additional sustainability issues (such as mobility and human well-being identified during the CoPs) and other relevant socio-economic considerations.

The use of models, which are associated with different scientific contexts and have been designed for modelling operations commonly not tailored for use in urban planning renders a number of limitations to the calculation of indicator value such as spatial and time scale considerations. Certain limitations, such as those related to uncertainty, are implicit to any form of modelling, independently from the scientific area, and will not be completely eliminated by an increase in scientific knowledge or calculating capacity. The need to obtain and use aggregated values in the BRIDGE DSS entails loosing spatial and temporal variation detail.

Moreover, constraints associated with the application of certain models to certain case studies limits the potential of the DSS

Other limitations are of a more technical nature, such as the lack or excess of space and time detail from model outputs, which need to be reduced to an aggregated value to be used in the BRIDGE DSS, loosing as little information as possible.

The linking of different urban scales represents thus a crucial issue for the assessment of urban metabolism, to be tackled during the application of the BRIDGE DSS, which requires the design of different sets of indicators at different spatial levels of a city. These need to be used in parallel, in order to avoid a piecemeal erosion of city wide sustainability goals by the reliance on spatially (and thus thematically) limited sets of criteria and spatial focus.

A further limitation within BRIDGE, connected to the issue of scale, is due to the network character and functional interconnection between city areas, so that decisions and transformations in one area will easily cause changes not only in the immediate surroundings, but also in farther areas, as for instance, the increase of housing in a periphery area will have impacts on central urban areas which will not be captured by a set of indicators measuring sustainability at the level of the single planning intervention.

4 Results

4.1 Common set of indicators

The definition of the final set of indicators started with the creation of a first set of indicators connected to the relevant sustainable development aspects for the city in question (Table 11) during the kick-off Meetings of the CoPs. During these meetings, the planning priorities were established and the core sustainability objectives determined for each case study. In the majority of cases, preliminary indicators were also discussed; in some of the cases these preliminary indicators were proposed by WP5 based on the established objectives. These indicators were further discussed during the second CoP meetings and adjusted to the specific requirements of the planning alternatives to be analysed.

The results in Table 11 show a clear correspondence between sustainability concerns between the cities in relation to some of the sustainability objectives. Air quality was considered to be one of the key objectives (with particular emphasis in reducing emissions from health-damaging contaminants such as particulate matter), followed by the need for the improvement of energy efficiency (mostly related to the bad insulation and poor energy performance of aging built infrastructure), and the mitigation of climate change effects (in relation to both temperatures increases and flooding events). A majority of the case studies also highlighted mobility and green space issues, highlighting the need to improve such aspects to promote sustainability.

Due to the existing correlation between objectives, there was also a significant overlap in the proposed indicators. In terms of air quality, key pollutant emissions and concentrations, together with their relative sectoral share, were proposed as indicators. Energy consumption and demand, as well as percentage of supply coming from renewable sources, were the most common indicators suggested to monitor energy performance. Flood risk was the most widely suggested indicator to monitor water balance whereas water supply and consumption, were rarely viewed as issues during the CoPs, given that these issues do not depend essentially on choices related to urban design but on the management of distribution networks and individual behaviour.

The specific characteristics of the case studies (refer to Gonzáles et al. (2010a) for further detail) required a revision of the initial set of sustainability objectives and indicators. The urban development alternatives considered as case studies produced a discussion, in relation to all case study areas, on the criteria to be applied to the assessment. From the results, it can be concluded that certain environmental and socio-economic considerations remain common to all the cities. These include improving air quality (and the associated concentration and distribution of pollutants as indicators), improving energy efficiency (with energy demand/consumption and percentage of renewable energy sources as indicators) and ensuring social inclusion/comfort (with use/appreciation of services and social composition as key indicators).

Table 11: Sustainability goals and indicator sets defined during the kick-off CoP meetings.

	AIR		ENERGY	
	Objectives	**Indicators**	**Objectives**	**Indicators**
ATHENS	**Improve Air Quality**	• Concentration of pollutants (NOx, SOx, PM_{10}, $PM_{2.5}$). • Number of days above established air quality thresholds.	**Improve Energy Efficiency**	• Energy consumption per capita. • % of energy from renewable sources.
	Reduce CO_2 Emissions	• CO_2 concentration. • % of CO_2 emissions from anthropogenic sources. • Effects of meteorological conditions on concentrations.	**Reduce Thermal Discomfort**	• Average outdoor temperature (surface and air). • Average indoor temperature (particularly in old buildings).
FIRENZE	**Improve Air Quality**	• Concentration of pollutants (PM_{10}, CO_2, NO_x, SO_x, CO, etc.).	**Improve Energy Efficiency**	• Kw (or %) produced from renewable sources. • % of energy consumed (and saved) per capita. • Number of properties with passive heating. • Number of properties with insulation improvements. • Urban temperature indoors/outdoors.
GLIWICE	**Improve Air Quality**	• Concentration of pollutants (PM_{10}, CO_2, NO_x, SO_x, CO, etc.). • Contribution of 'low emissions' to the total emissions. • Energy consumption for low emission stoves (% change)	**Optimise Energy Efficiency**	• Energy losses (GJ/MW tonnes/m3/y/). • Number (%) or modernized/insulated old buildings. • Number or surface area of buildings in relation to total urban area. • Length of newly built heating systems/year. • Number of newly adjoined beneficent/year.
HELSINKI	**Improve Air Quality**	• Concentration of pollutants (O_3, NOx, SOx, PM_{10}, $PM_{2.5}$). • Greenhouse gases and CO_2 emissions per capita and sectoral split. • Emissions from transport and split per type (private and public).	**Optimize Energy Consumption**	• Electricity consumption per capita and sectoral split. • Energy ratings and heating in buildings. • % of energy from renewable sources.
LONDON	**Improve Air Quality**	• Concentration of pollutants (Benzene, NOx, SOx, PM_{10}, $PM_{2.5}$). • Number of days above established air quality thresholds.	**Decrease Heat Island Effect**	• Average outdoor temperature (surface and air).
	Reduce CO_2 Emissions	• CO_2 concentration. • % of emissions from anthropogenic sources. • Effects of meteorological conditions on concentrations.		

	WATER		OTHERS	
	Objectives	**Indicators**	**Objectives**	**Indicators**
ATHENS			**Improve the Built Fabric**	• Building characteristics. • Number of dwellings where insulation improvements have taken place.
			Increase Green Space Areas	• Area (ha) of urban green space. • Number of trees planted. • Coverage (m^2) of green infrastructure (from new plantations and growth). • % of urban green space of total urban area.
			Increase Mobility	• Number of municipal passenger transport services. • % of population using public transport. • Number of new car-parking spaces.
FIRENZE			**Improve Mobility**	• Car ownership. • Public transport use (%).
			Increase and Improve Green Space Areas	• Number of trees/per person/hectare. • Density of green areas (m^2/capita). • Number of green roofs/green walls. • Accessibility (distance and number of public transport links). • Number of service/person/green area. • Volume of irrigation (or %) coming from rainwater.
GLIWICE	**Improve Water Mgmt.**	• Volume of water used by sector. • % of population connected to waste water treatment.	**Promote Controlled Expansion of Urban Areas**	• Number of newly elaborated land use plans. • % of surface covered by land use plans. • Daily travel time to/back from the city centre. • Number of services in the city centre. • Increases on taxation.
			Improve Mobility	• Car ownership. • Public transport use (%). • Number of new roads built. • Number of cycle-ways provided.
HELSINKI	**Protect the Water Balance**	• Water balance: precipitation, surface run-off, evapotranspiration, filtration, and flooding events. • Water quantity and quality (i.e. BOD, N, P load) at discharge point.	**Enhance human well-being in the city**	• Number of new developments in brownfield sites versus number of developments in greenfield sites; • Density of developments (persons/m^2). • Population exposure to air pollutants.
LONDON	**Reduce Flooding**	• Flood events.	**Promote Integrated Decision-making**	• Public participation and effectiveness. • Quantitative character of SEA/EIA/HIA reports. • Number of interdepartmental consultations. • Number of processes/aspects being studied.
			Increase Canopy Cover	• Number of trees planted. • Coverage (m^2) of green infrastructure (from new plantations and growth).

The sustainability objectives defined during the first CoP meetings in each city have been redefined during the second round of meetings in the light of the specific characteristics of the planning alternatives to be considered.

Table 12: Results of the second CoP meetings for environmental objectives and indicators.

	ENVIRONMENT	
	Objectives	**Indicators**
ATHENS	**Reduce Thermal Discomfort**	• Average outdoor temperature (air) and humidity; • Average surface temperature (roads, buildings, etc.); and • Wind speed.
ATHENS	**Improve Air Quality and Reduce Emissions**	• Concentration of pollutants (NOx, SOx, PM_{10}, $PM_{2.5}$); • CO_2 concentration; • Source of emissions (% per building/sector type); • Number of days above established air quality thresholds; and • Effects of meteorological conditions (e.g. temperature) on concentrations.
ATHENS	**Increase Green Space Areas**	• Area (% or m^2) of urban green space; • Number of trees planted; and • Types of trees planted.
ATHENS	**Optimize Water Use**	• Volume of water used (for irrigation).
ATHENS	**Improve Energy Efficiency**	• Energy consumption for lighting the avenue; and • % of energy from renewable sources (i.e. solar panels).
ATHENS	**Optimize Quality of Materials Used**	• Solar reflectance of materials used.
FIRENZE	**Improve Energy Efficiency**	• Urban temperature outdoors (compared to rural temperatures), and • Potential renewable energy from the volume of biomass produced.
FIRENZE	**Increase and Improve Green Space Areas**	• Number of trees/per person/hectare (and number of trees planted); • Density of green areas (m^2/inhabitant); • Accessibility (distance by foot/bike, and number of public transport links); • Number of services per person in the green area; and • Biodiversity (plant species, pollen season, etc.)
FIRENZE	**Improve Air Quality**	• Concentration of pollutants (PM_{10}, $PM_{2.5}$, NOx, CO).
GLIWICE	**Improve Air Quality**	• Distribution of pollutants (PM_{10}, $PM_{2.5}$, NOx, SOx, CO, CO_2); • Contribution of 'low emissions' (from single boilers located in the low residential dwellings) to the total emissions; • Total emissions (% change); and • Relationship between pollutant concentrations and wind direction.
GLIWICE	**Improve Energy Efficiency**	• Energy demand (kW/h/m^2 or % change); • Heating demand (kW/h/m^2 or % change); and • % and structure of thermo-insulation.
GLIWICE	**Improve Water Management**	• Urban water use; • Urban water supply; • % of waste water treated; • River capacity (both quality – BOD, and quantity - volume); • WFD quality values; • % of "solid" area (and % of change); • Flooding zones; • Sewage capacity (volume); • % of houses connected to the WWT; and • Volume of discharge.
HELSINKI	**Optimise Energy Consumption**	• Energy demand (i.e. electricity consumption per dwelling); • Energy balance in buildings (i.e. energy heating); and • Percentage of energy from renewable sources.
HELSINKI	**Protect the Water Balance**	• Water balance: surface run-off, evapotranspiration, and filtration.
HELSINKI	**Improve Air Quality**	• Concentration of pollutants (ozone and particulate matter); • Greenhouse gases and CO_2 emissions per capita; and • Emissions from transport and split per type (private and public).

	ENVIRONMENT	
	Objectives	**Indicators**
	Enhance Human Well-being	• Density of developments (persons/m^2); and • Population exposure to air pollutants.
	Anticipating Climate Change	• Carbon intake (i.e. removal of carbon sinks); • Material reuse (e.g. soils); and • Number of zero-carbon buildings.
LONDON	**Improve Air Quality**	• Concentrations of PM_{10}, $PM_{2.5}$, NOx, NO_2 and O_3; and • Number of days above established air quality thresholds.
LONDON	**Reduce Surface Water Flood Risk**	• Number and extension of "hot spots".
LONDON	**Mitigate Heat Islands Effect**	• Ambient temperature (at 1m above street level); and • Number of days above 33°C /per area ("heat waves").
LONDON	**Decentralize Energy Generation**	• % of energy created; and • Additional heat generated.
LONDON	**Increase Urban Greening**	• Canopy surface newly created; and • Accessibility to green areas.

Table 13: Results of the second CoP meetings for socio-economic objectives and indicators.

	SOCIO-ECONOMICS	
	Objectives	**Indicators**
ATHENS	**Improve Mobility**	• Road traffic intensity; • Quality of pedestrian sideways; and • Number of parking slots.
ATHENS	**Maintain Public Health and Safety**	• Number and severity of road accidents and pedestrian injuries; • Number of people suffering from short term effect of air pollution (upper respiratory infections such as bronchitis and pneumonia, allergic reactions); and • Number of people suffering from long term effects of air pollution (e.g. chronic respiratory disease, lung cancer, heart disease).
ATHENS	**Promote Social Inclusion**	• Extent to which roads and sideways can be used by disabled or differently able people and groups (e.g. number of safe-street-crossing points, number of repose places along the street); and • Local community composition – compared to other areas: % of elderly people, foreigners, low-income families etc.
ATHENS	**Promote Place Identity**	• Aesthetic value of the area and changes due to planning intervention.
ATHENS	**Ensure Economic Viability**	• Financial costs of the interventions; and • Estimated side-effects on local economy.
FIRENZE	**Promote Social Comfort**	• Usability of the park (number, time and type of uses); • Public appreciation of the park; • Increase/decrease on public parking spaces; and • Number of illegal activities (crime events).
FIRENZE	**Ensure Economic Viability**	• Cost associated to maintenance and pruning; and • Benefits perceived by private economic activities
GLIWICE	**Improve Mobility**	• Number of pedestrian streets (Km); • Public transport use (%); • Length of new roads built (Km); • Length of cycle-ways provided (Km); and • Number of parking places built up.
GLIWICE	**Controlled Expansion of Urban Areas**	• Number of administrative decisions; • Accessibility of district from Silesia metropolitan area (hours to/from); • Number of specific services in the district; • % of new public space; and • Increase on incomes.
	Cater for Housing	• Number and type of dwellings;

	SOCIO-ECONOMICS	
	Objectives	**Indicators**
LONDON	**Demand**	• Population growth; • Demand for housing types; and • Percentage of owned/rented dwellings.
	Promote Social Inclusion	• Access to housing; • Social class/ethnical group; • Age group of residents; and • Number of family households.
	Optimise Accessibility	• Travel time to work; and • Use of public transport.
	Improve Human Well-being	• Number of health impacts derived from "heat waves" and air pollution; and • Number of residents affected by flash flooding.
	Ensure Economic Viability	• Cost of maintenance of green areas; • Cost of drainage; and • Value at risk of flooding.

Focussing the selection of indicator sets on the assessment criteria of planning alternatives drew the exercise away from measuring and comparing progress towards sustainability at city level or between different cities. It was nevertheless registered that planning alternatives proposed by the end-users for the case study applications reflect well every-day planning issues throughout European cities and the decisions to be taken correspond to sustainability issues discussed at international level. Criteria chosen in the single case studies significantly overlapped, indicating that common sustainability issues and correlating indicators enabled the creation of a common set of indicators, to be used in all case studies for the application and validation of the DSS (see Tables 13 and 14).

The definition of this common set of indicators was made by case study representatives at the Umbrella CoP after BRIDGE researchers reviewed and validated the city-specific indicators in terms of their applicability and data availability. The overview of planning and sustainability issues in each of the cities and the shared understanding of sustainability goals facilitated the identification of the common and most critical objectives across all the cities. The results correlate with the findings of the first and second CoP meetings. Those sustainability objectives identified in every city (i.e. improving air quality and energy efficiency and optimising water balance, including the reduction of flooding effects) were perceived as being critical in promoting sustainable urban development. There was consensus among participants for the ready incorporation of such considerations and the relevant indicators into the final set and, therefore, the DSS. The rest of relevant objectives and associated indicators were classified as secondary, not for their lack of significance but rather for their city-specific nature. Thermal comfort was not considered an issue in both Firenze and Gliwice; the type of materials used was deemed irrelevant in Firenze and London and green spaces were not a priority in Helsinki or Gliwice. Therefore, it was proposed that these city-specific (or discretionary) objectives will not be available by default in the BRIDGE DSS. Nevertheless, the end-user will be able to incorporate them if deemed appropriate. (see Table 14)

Although consensus was also reached when defining the core socio-economic objectives, certain indicators (e.g. the length of roads, associated with mobility) were subject to lengthy debate as a result of the differing planning and development approaches between the case studies and will be used as city-specific (i.e. discretionary) indicators in the DSS.

Table 14: Results of the Umbrella CoP meetings.

ENVIRONMENT	
Objectives	**Indicators**
Common Aspects (Core)	
Improve Air Quality	• Concentration of pollutants (PM, O_3, NOx) • GHG and CO_2 emissions

ENVIRONMENT	
Objectives	**Indicators**
	• Number of days above established thresholds
Improve Energy Efficiency	• Energy demand (kw per hour per m^2) • Potential for renewable energy • Additional heat generated • % of energy created (renewables)
Anticipate CC (Flooding)	• Flooding zones (m^2) & hot spots
Optimize Water Use & Mgmt	• Surface runoff, evapotranspiration and filtration • Water consumption per capita
City-Specific Aspects (Discretionary)	
Increase Green Space Areas	• Density of green areas (m^2 per habitant) • Canopy/green surface or area newly created • Accessibility to green areas
Thermal comfort	• Ambient & surface air temperature (^oC) • Number of days above established thresholds
Optimize Materials Used	• Volume of material reuse
SOCIO-ECONOMICS	
Objectives	**Indicators**
Common Aspects (Core)	
Urban land use	• New urbanized areas (land use changes) • Number of brownfields re-used • Density of development
Ensure Economic Viability	• Cost of intervention • Effects on local economy
Improve Mobility & accessibility	• Quality of pedestrian sideways • Length of cycleways provided • Length of new roads provided • Use of public transport • Number of persons close to public transport
City-Specific Aspects (Discretionary)	
Promote Social Inclusion	• Access to housing and services
Maintain Public Health/Safety Enhance Human Well-being	• Number of persons affected by flash flooding • Number of persons affected by heat waves & air pollution

4.2 Creation of the final indicator set

Whereas the feedback between proposed sustainability indicators and verification of their feasibility in terms of data availability and representation in international indicator sets was undertaken, and the final set of indicators was agreed by stakeholders and end users during the Umbrella CoP meeting, a further review and indicator tailoring exercise was undertaken in conjunction with WP4 to fine-tune the final indicator set with the modelling capacities (Annex I).

The definition of measurement units and the adaptation of modelling outputs for those indicators was achieved at a technical meeting between WP5, WP4 and WP6 researchers, responsible for modelling and DSS design within the BRIDGE project. The refinement process was subsequently continued on the basis of further inputs from researchers responsible for modelling.

5 Conclusions and recommendations

The final set of indicators to be implemented in the DSS includes indicators covering a wide range of sustainability issues which are relevant for decision-making in urban planning. The specific scope adopted by the BRIDGE project implied a major stress on those sustainability issues related to urban metabolism. Based on the modelling capabilities within the project, a significant number of indicators referred in particular to air quality. In order to integrate these urban metabolism considerations with those relating to other sustainability concerns (e.g. social inclusion or economic development), additional indicators have been incorporated.

The values of the final indicators will be provided in different ways:

- Based on the outcomes of modelling, single indicator values are represented in a GIS connected to the DSS and used for exploring their spatial or temporal distribution throughout the planning area;
- Based on modelling outcomes, absolute indicator values will be provided, subsequently used for the generation of scores in the MCA procedure;
- Relative indicator values will also be used to examine exceedance of legally defined thresholds; and
- Based on the combination of environmental and socio-economic single indicator values, a composite index will be provided to evaluate the overall sustainability of a planning alternative when compared to another.

During the DSS assessment exercise, indicators need to be selected by the end users, in order to specifically address all sustainability objectives in the assessment and in order to keep the number of indicators within a feasible limit to facilitate the MCA weighting process.

5.1 Research needs

During the collaboration between modellers and planners some problems emerged which are mainly connected to different time, and, to a smaller extend, space scales, used within each of these two communities. Although urban planners are highly interested in accurate and reliable data to support decision making, the time frames presented by the scientific models were not congruent, if for example models consider small time intervals much inferior to one day, whereas urban policies need to take decision with much longer time frames. These discrepancies in scales need to be bridged if results from scientific modelling shall be adopted in every day policy making. The design of the DSS and the integration of modelling results have shown a possible path for this integrations as proved by the indicator sets which are the outcome of a mutual learning process between scientists and practitioners.

6 Annex I: Final Set of Indicators

Indicator Name	Offline Model	Online Model	Model Output Units	Indicator Units (for comparing between alternatives)	Threshold Target	Indicator Estimation	Indicator value computation steps	Notes
Pollutants and Carbon								
Green House Gases								
Biogenic and anthropogenic Carbon Dioxide (CO_2) emissions	EMIMO (UPM)		Kg/h per grid cell	Total kg/h (or tonnes per year)	**Reference value (i.e. baseline or reference alternative)*	Direct model spatial output (map) showing hourly emissions per grid cell; indicator value represented as the total concentration for the area.	1. Sum values for the area (for each hour); 2. Sum the results for the whole month; 3. Sum the results for the whole year	Under development. Will be available for all 5 case studies offline.
Carbon Dioxide (CO_2) flux	ACASA (CMCC) WRF/ACASA (CMCC)	URBAIR (UAVR)	µg/m^2/sec per grid cell	Total µg/m^2/sec	**Reference value*	Direct model spatial output (map) showing hourly fluxes per grid cell; indicator value expressed as the total sum of fluxes for the area.	1. Sum values for the area (for each hour); 2. Sum the results for the whole month; 3. Sum the results for the whole year	It derives from plant and urban canopy element sources and turbulent micro-environment. Available for all 5 case studies online; offline (as values only) for Firenze and Helsinki. CO_2 flux maps may be produced for Firenze and Helsinki (once WRF-ACASA are coupled).
Methane (CH_4) emissions	EMIMO (UPM)		Kg/h per grid cell	Total kg/h (or tonnes per year)	**Reference value*	Direct model spatial output (map) showing hourly emissions per grid cell; indicator value expressed as the total sum of emissions for the area.	1. Sum values for the area (for each hour); 2. Sum the results for the whole month; 3. Sum the results for the whole year	Available for all 5 case studies online and offline.

Indicator Name	Offline Model	Online Model	Model Output Units	Indicator Units (for comparing between alternatives)	Threshold Target	Indicator Estimation	Indicator value computation steps	Notes
Pollutant Concentrations								
Nitrogen Dioxide (NO_2) concentration	CMAQ (UPM) CAMx (UAVR) WRF/chem. (UPM)	URBAIR (UAVR)	µg/m^3 per grid cell	Hourly average µg/m^3	200 µg/m^3	Direct model spatial output (map) showing hourly concentration per grid cell; indicator value expressed as average hourly concentration for the area.	1. Average values for the area (for each hour); 2. Average the results for the whole year	CMAQ modelling Firenze and Athens; CAMx modelling London, Gliwice, Helsinki. Available for all 5 case studies online and offline.
Nitrogen Dioxide (NO_2) concentration limit	CMAQ (UPM) CAMx (UAVR) WRF/chem. (UPM)	URBAIR (UAVR)	µg/m^3 per grid cell	Max. µg/m^3	400 µg/m^3 for 3 consecutive hours (alert)	Direct model spatial output (map) showing 3-hourly average NO_2 concentrations at surface level; indicator value expressed as the maximum value for the area.	1. Max value for the area (for each 3-hours); 2. Max of the results for the whole year	CMAQ modelling Firenze and Athens; CAMx modelling London, Gliwice, Helsinki. Available for all 5 case studies online and offline. This limit relate to the relevant exceedance indicator below.
Thoracic particle (PM_{10}) concentration	CMAQ (UPM) CAMx (UAVR) WRF/chem. (UPM)	URBAIR (UAVR)	µg/m^3 per grid cell	Daily average µg/m^3	50 µg/m^3	Direct model spatial output (map) showing daily concentration per grid cell; indicator value expressed as average hourly concentration for the area.	1. Average values for the area (for each day); 2. Average the results for the whole year	CMAQ modelling Firenze and Athens; CAMx modelling London, Gliwice, Helsinki. Available for all 5 case studies online and offline.
Thoracic particle (PM_{10}) concentration limit	CMAQ (UPM) CAMx (UAVR) WRF/chem. (UPM)	URBAIR (UAVR)	µg/m^3 per grid cell	Max. µg/m^3	48 µg/m^3 (50 + 20% tolerance)	Direct model spatial output (map) showing daily average PM_{10} concentrations at surface level; indicator value expressed as the average hourly concentration for the area.	1. Max value for the area; 2. Max of the results for the whole year	CMAQ modelling Firenze and Athens; CAMx modelling London, Gliwice, Helsinki. Available for all 5 case studies online and offline. This limit relate to the relevant exceedance indicator below.

Indicator Name	Offline Model	Online Model	Model Output Units	Indicator Units (for comparing between alternatives)	Threshold Target	Indicator Estimation	Indicator value computation steps	Notes
Fine particle ($PM_{2.5}$) concentration	CMAQ (UPM) CAMx (UAVR) WRF/chem. (UPM)		µg/m^3 per grid cell	Hourly average µg/m^3	*No limit defined.*	Direct model spatial output (map) showing hourly concentration per grid cell; indicator value represented as the average hourly concentration for the area.	1. Average values for the area (for each hour); 2. Average the results for the whole year	CMAQ modelling Firenze and Athens; CAMx modelling London, Gliwice, Helsinki. Available for all 5 case studies online and offline.
Ozone (O_3) concentration	CMAQ (UPM) CAMx (UAVR) WRF/chem. (UPM)		µg/m^3 per grid cell	Hourly average µg/m^3	120 µg/m^3	Direct model spatial output (map) showing hourly concentration per grid cell; indicator value represented as the average hourly concentration for the area.	1. Average values for the area (for each hour); 2. Average the results for the whole year	CMAQ modelling Firenze and Athens; CAMx modelling London, Gliwice, Helsinki. Available for all 5 case studies offline.
Ozone (O_3) concentration limit	CMAQ (UPM) CAMx (UAVR) WRF/chem. (UPM)		µg/m^3 per grid cell	Max. µg/m^3	120 µg/m^3 for 8 consecutive hours	Direct model spatial output (map) showing 8-hourly average emissions at surface level; indicator value expressed as the maximum value for the area.	1. Max value for the area (for each 8-hours); 2. Max of the results for the whole year	CMAQ modelling Firenze and Athens; CAMx modelling London, Gliwice, Helsinki. Available for all 5 case studies offline. This limit relate to the relevant exceedance indicator below.
Carbon monoxide (CO) concentration	CAMx (UAVR)	URBAIR (UAVR)	µg/m^3 per grid cell	Hourly average µg/m^3	10000 µg/m^3	Direct model spatial output (map) showing hourly CO concentrations at surface level; indicator value expressed as the average hourly concentration for the area.	1. Average values for the area (for each hour); 2. Average the results for the whole year	CAMx modelling London, Gliwice, Helsinki. Available for all 5 case studies online and offline. This limit relate to the relevant exceedance indicator below.

Indicator Name	Offline Model	Online Model	Model Output Units	Indicator Units (for comparing between alternatives)	Threshold Target	Indicator Estimation	Indicator value computation steps	Notes
Carbon monoxide (CO) concentration limit	CAMx (UAVR)	URBAIR (UAVR)	µg/m^3 per grid cell	Max. µg/m^3	10 000 µg/m^3 for 8 consecutive hours	Direct model spatial output (map) showing hourly concentration per grid cell; indicator value represented as the averaged maximum 8-hourly concentration for the area.	1. Average the hourly values for each cell for 8-hours (moving average). 2. Determine the maximum daily value for the area; max of the results for the whole year	CAMx modelling London, Gliwice, Helsinki. Available for all 5 case studies online and offline.
Sulphur dioxide (SO_2) concentration		URBAIR (UAVR)	µg/m^3 per grid cell	Hourly average µg/m^3	350 µg/m^3	Direct model spatial output (map) showing SO_2 hourly concentration per grid cell; indicator value represented as the average hourly concentration for the area.	1. Average values for the area (for each hour); 2. Average the results for the whole year	Available for all 5 case studies offline. This limit relate to the relevant exceedance indicator below.
Sulphur dioxide (SO_2) concentration limit		URBAIR (UAVR)	µg/m^3 per grid cell	Max. µg/m^3	500 µg/m^3 (350 + 150 tolerance)	Direct model spatial output (map) showing hourly concentration per grid cell; indicator value expressed as the maximum value for the area.	1. Max value for the area; 2. Max of the results for the whole year	Available for all 5 case studies offline.
Ambient Concentrations								
Number of exceedances of NO_2	CMAQ (UPM) CAMx (UAVR) WRF/chem. (UPM)	URBAIR (UAVR)	µg/m^3 per grid cell - hourly	Total No. of exceedances (more than 18 times above threshold) in the grid	200 µg/m^3 not to be exceeded more than 18 times a calendar year	Direct model spatial output (map) showing the average hourly concentrations; indicator value expressed as the sum over the number of exceedances per grid cell (number of times above threshold).	1. Count how many times a year the hourly average (model output) is >200 µg/m^3 for each cell; 2. If more than 18 times then cell value is 1; 3. Spatial Sum	CMAQ modelling Firenze and Athens; CAMx modelling London, Gliwice, Helsinki. Available for all 5 case studies online and offline.

Indicator Name	Offline Model	Online Model	Model Output Units	Indicator Units (for comparing between alternatives)	Threshold Target	Indicator Estimation	Indicator value computation steps	Notes
Number of exceedances of PM_{10}	CMAQ (UPM) CAMx (UAVR) WRF/chem. (UPM)	URBAIR (UAVR)	µg/m³ per grid cell - daily	Total No. of exceedances (more than 35 times above threshold) in the grid	50 µg/m³ not to be exceeded more than 35 times a calendar year	Direct model spatial output (map) showing the average hourly concentrations; indicator value expressed as the sum over the number of exceedances per grid cell (number of times above threshold).	1. Compute daily average per cell; 2. Count how many times a year the daily average is >50 µg/m³ for each cell; 3. If more than 35 times then cell value is 1; 4. Spatial Sum	CMAQ modelling Firenze and Athens; CAMx modelling London, Gliwice, Helsinki. Available for all 5 case studies online and offline.
Number of exceedances of O_3	CMAQ (UPM) CAMx (UAVR) WRF/chem. (UPM)		µg/m³ per grid cell - 8-hours	Total No. of exceedances (more than 25 times above threshold) in the grid	120 µg/m³ for 8- hours no more than 25 times a year	Direct model spatial output (map) showing the average hourly concentrations; indicator value expressed as the sum over the number of exceedances per grid cell (number of times above threshold).	1. Compute 8-hour moving average*(See directive); 2. Compute the daily max for each cell; 3. Count how many times a year the daily value is >120 µg/m³ for each cell; 3. If more than 25 times then cell value is 1; 4. Spatial Sum	CMAQ modelling Firenze and Athens; CAMx modelling London, Gliwice, Helsinki. Available for all 5 case studies offline.
Number of exceedances of SO_2		URBAIR (UAVR)	µg/m³ per grid cell - hourly	Total No. of exceedances (more than 24 times above threshold) in the grid	350 µg/m³ not to be exceeded more than 24 times a calendar year	Direct model spatial output (map) showing the average hourly concentrations; indicator value expressed as the sum over the number of exceedances per grid cell (number of times above threshold).	1. Count how many times a year the hourly value is >350 µg/m³ for each cell; 2. If more than 24 times then cell value is 1; ; 3. Spatial Sum	Available for all 5 case studies offline.

Indicator Name	Offline Model	Online Model	Model Output Units	Indicator Units (for comparing between alternatives)	Threshold Target	Indicator Estimation	Indicator value computation steps	Notes
Population exposure to air pollution								
Number of inhabitants exposed to NO_2 concentrations above the threshold	CMAQ (UPM) CAMx (UAVR) WRF/chem. (UPM)	URBAIR (UAVR)	µg/m^3 per grid cell	No. of inhabitants exposed	200 µg/m^3 no more than 18 times a year	Calculated based on pollutant concentration areas above thresholds and population in those areas, based on GIS computation.	Previous indicator (Number of exceedances) will be used; 1. Sum the #inhabitants for all the cells in previous indicator having a value of 1	Pollutant concentrations above thresholds can be obtained from online and offline models (i.e. URBAIR, WRFChem, CMAQ, CAMx).
Number of inhabitants exposed to PM_{10} concentrations above the threshold	CMAQ (UPM) CAMx (UAVR) WRF/chem. (UPM)	URBAIR (UAVR)	µg/m^3 per grid cell	No. of inhabitants exposed	50 µg/m^3 no more than 35 times a year	Calculated based on pollutant concentration areas above thresholds and population in those areas, based on GIS computation.	Previous indicator (Number of exceedances) will be used; 1. Sum the #inhabitants for all the cells in previous indicator having a value of 1	Pollutant concentrations above thresholds can be obtained from online and offline models (i.e. URBAIR, WRFChem, CMAQ, CAMx).
Number of inhabitants exposed to 0_3 concentrations above the threshold	CMAQ (UPM) CAMx (UAVR) WRF/chem. (UPM)		µg/m^3 per grid cell	No. of inhabitants exposed	120 µg/m^3 for 8 hours no more than 25 times a year	Calculated based on pollutant concentration areas above thresholds and population in those areas, based on GIS computation.	Previous indicator (Number of exceedances) will be used; 1. Sum the #inhabitants for all the cells in previous indicator having a value of 1	Pollutant concentrations above thresholds can be obtained from online and offline models (i.e. URBAIR, WRFChem, CMAQ, CAMx).
Energy								
Energy consumption in the building sector for air conditioning (cooling/heating in buildings)		SURFEX (CNRM)	kWh/m^2 per grid	Total KWh/m^2	**Reference value*	Direct model spatial output showing hourly average consumption for built areas; indicator value expressed as sum of the total for the area (hourly value).	1. Monthly sum for each cell; 2. Yearly sum for each cell; 3. Spatial sum	In some cases data may be provided by case studies. Model outputs available online only for Helsinki and Athens.

Indicator Name	Offline Model	Online Model	Model Output Units	Indicator Units (for comparing between alternatives)	Threshold Target	Indicator Estimation	Indicator value computation steps	Notes
Anthropogenic heat flux		LUMPS (KCL) SURFEX (CNRM)	W/m^2 per grid	Total W/m^2	**Reference value*	Direct model spatial output showing Q_F (hourly heat loss); indicator value expressed as sum of the total for the area (hourly value).	1. Monthly sum for each cell; 2. Yearly sum for each cell; 3. Spatial sum	The model outputs include net radiation, sensitive and latent heat fluxes and net storage. This indicator may be omitted to avoid duplication. Model outputs available online only for Firenze;
Sensible Heat Flux and Latent heat Flux (Bowen Ratio)	WRF/UCM (UPM) WRF-ACASA (CMCC)	LUMPS (KCL) SURFEX (CNRM)	Bowen Ratio per grid	Bowen ratio	**Reference value*	Direct model spatial output showing hourly flux (Bowen ratio); indicator value expressed as the ratio for the total for the area (hourly value).	1. Monthly ratio for each cell; 2. Yearly ratio for each cell	Model outputs available online only for London, Athens and Helsinki; offline for all 5 cities.
Percentage of energy from renewable energy sources	N/A	N/A	N/A	% (KWh) of total	**Reference value or national targets.*	Direct values. Reference and alternative values to be provided by end-user.		
Water Balance								
Water consumption per capita	N/A	N/A	N/A	Total m^3/capita/year	**Reference value*	Direct values. Reference and alternative values to be provided by end-user.		
Water consumption (external)		LUMPS V6 SUEWS (KCL)	mm per grid	Total mm^3/year	**Reference value*	Direct model spatial output showing hourly consumption per grid; indicator value expressed as hourly total for the area.	1. Spatial Sum. 2. Monthly Sum. 3. Yearly sum.	Model outputs available online only for London.

Indicator Name	Offline Model	Online Model	Model Output Units	Indicator Units (for comparing between alternatives)	Threshold Target	Indicator Estimation	Indicator value computation steps	Notes
Evapotranspiration	WRF/UCM (UPM) WRF-ACASA (CMCC)	LUMPS (KCL) SIMGRO (ALTERRA) SURFEX (CNRM)	mm^3/m^2 per grid cell	Total mm^3/m^2	**Reference value*	Direct model spatial output showing hourly flux per grid; indicator value expressed as hourly total for the area.	1. Monthly sum for each cell; 2. Yearly spattial sum.	Model outputs available online only for London, Athens and Helsinki; offline for all 5 cities.
Infiltration (in green surface areas)	WRF/UCM (UPM) WRF-ACASA (CMCC)	SIMGRO (ALTERRA) SURFEX (CNRM)	mm^3/m^2 per grid cell	Total mm^3/m^2	**Reference value*	Direct model spatial output showing hourly flux per grid; indicator value expressed as hourly total for the area.	1. Monthly sum for each cell; 2. Yearly spattial sum.	Model outputs available online only for London, Athens and Helsinki; offline for all 5 cities.
Surface run-off	WRF/UCM (UPM) WRF/ACASA (CMCC)	LUMPS (KCL) SIMGRO (ALTERRA) SURFEX (CNRM)	mm^3/m^2 per grid cell	Total mm^3/m^2	**Reference value*	Direct model spatial output showing hourly flux per grid; indicator value expressed as hourly total for the area.	1. Monthly sum for each cell; 2. Yearly spattial sum.	Model outputs available online only for London, Athens and Helsinki; offline for all 5 cities.
Potential flood risk		SIMGRO (ALTERRA)	Peak mm^3/m^2 discharges per grid cell	Total mm^3/m^2	0	Direct model spatial output showing hourly peak discharges; indicator value expressed as 24-hour sum for the area.	1. 24-hours spatial sum; 2. Monthly sum. 3. Yearly sum.	Peak run-off discharges will be used as PROXY data. Online model available only for Helsinki
Thermal Comfort								
Thermal Comfort (CP)	WRF/UCM (UPM)		wind at 2m (m/s), temperature at 2m (° C)	No. of times of thermal discomfort per grid	*0*	CP = (0.421 + 0.087*Wind)*(36.5 - Temperature)	1. Having wind and temperature, compute CP for every cell for every hour; 2. If CP < 5 or CP > 10.5 value is 1 (discomfort); 3. Time sum for each cell for the whole year; 4. Devide each value cell by 24*365; 5. Spatial Sum.	

Indicator Name	Offline Model	Online Model	Model Output Units	Indicator Units (for comparing between alternatives)	Threshold Target	Indicator Estimation	Indicator value computation steps	Notes
Air Temperature (outdoors) at 2m above ground	WRF/UCM (UPM) WRF/ACASA (CMCC)	LUMPS (KCL) SURFEX (CNRM)	°C per grid cell	°C	**Reference value or national thresholds.*	Direct model spatial output showing hourly temperature at 2m heigh; indicator value expressed as the maximum deviation for the area.	1. Daily min and max for every cell; 2. Monthly min and max for every cell. 3. Yearly min and max for the area.	Offline model available for all 5 cities; online models for London, Athens and Helsinki only.
Number of days above established thresholds	WRF/UCM (UPM) WRF/ACASA (CMCC)	LUMPS (KCL) SURFEX (CNRM)	°C per grid cell	Days (cumulative)	**National thresholds.*	Direct model spatial output showing hourly temperature above threshold; indicator value expressed as the sum of days above threshold.	1. Daily max for the area. 2. Count how many times a year this daily max is higher than a threshold specific for each city, to be provided ny the user.	Indicator to be computed on an annual basis. Offline model available for all 5 cities; online models for London, Athens and Helsinki only.
Green Spaces								
Number of inhabitants per green area	N/A	N/A	N/A	inhabitants/m^2	**Reference value or national targets.*	Calculated as direct computation from land use data (reference alternative). Alternative values to be provided by end-user.	1. Compute area of green spaces (in m^2) for the whole area; 2. Devide this number by total number of inhabitants	
Newly created canopy surface or green area	N/A	N/A	N/A	m^2	**Reference value*	Calculated as direct computation from land use data (reference alternative). Alternative values to be provided by end-user.		
Number of inhabitants with access to green areas	N/A	N/A	N/A	No. of inhabitants (within 500m of green area)	**Reference value*	Calculated based on land use data and population in the area, based on GIS computation.		
Materials								
Volume of material re-used (recycled)	N/A	N/A	N/A	m^3 of total	**Reference value*	Direct values. Alternative values to be provided by end-user.		

Indicator Name	Offline Model	Online Model	Model Output Units	Indicator Units (for comparing between alternatives)	Threshold Target	Indicator Estimation	Indicator value computation steps	Notes
Land Use								
New urbanized areas (land use changes including greenfield and brownfield)	N/A	N/A	N/A	m^2 (or % change)	**Reference value*	Calculated as direct computations (i.e. CORINE). Alternative values to be provided by end-user.	1. Compute the area (m^2) of urban space; 2. Compare existing urbanised area with that of the alternative to compute % change.	
Brownfields re-used	N/A	N/A	N/A	m^2 (or % of total)	**Reference value or national targets.*	Direct values. Reference and alternative values to be provided by end-user.		
Density of development	N/A	N/A	N/A	built m^2/total m^2	**Reference value or national targets.*	Direct values. Alternative values to be provided by end-user.		
Economic Viability								
Cost of proposed development	N/A	N/A	N/A	€ (or €/m^2)	**Reference value*	Direct values. Reference and alternative values to be provided by end-user.		
Effects on local economy (employment)	N/A	N/A	N/A	No. of new jobs created	**Reference value*	Direct values. Reference and alternative values to be provided by end-user.		
Effects on local economy (revenue)	N/A	N/A	N/A	€ (or €/m^2)	**Reference value*	Direct values. Reference and alternative values to be provided by end-user.		
Mobility/ Accessibility								
Quality of pedestrian sideways	N/A	N/A	N/A	N/A (qualitative)	**Reference value or national targets.*	Direct values. Reference and alternative values to be provided by end-user.		

Indicator Name	Offline Model	Online Model	Model Output Units	Indicator Units (for comparing between alternatives)	Threshold Target	Indicator Estimation	Indicator value computation steps	Notes
Length of cycle-ways provided	N/A	N/A	N/A	m	**Reference value*	Direct values. Reference and alternative values to be provided by end-user.		
Length of new roads provided	N/A	N/A	N/A	m	**Reference value*	Direct values. Reference and alternative values to be provided by end-user.		
Use of public transport	N/A	N/A	N/A	% of total population	**Reference value or national targets.*	Direct values. Reference and alternative values to be provided by end-user.		
Number of inhabitants with access to public transport	N/A	N/A	N/A	No. of inhabitants (within 500m of public transport node)	**Reference value*	Calculated based on location and population in the area, based on GIS computation.		
Social Inclusion								
Number of inhabitants with access to social housing	N/A	N/A	N/A	No. of inhabitants (% of total)	**Reference value*	Direct values. Reference and alternative values to be provided by end-user.		
Number of inhabitants with access to services	N/A	N/A	N/A	Number of services/m^2 (or number of inhabitants/servic e)	**Reference value*	Direct values. Reference and alternative values to be provided by end-user.		
Human Well-being								

Indicator Name	Offline Model	Online Model	Model Output Units	Indicator Units (for comparing between alternatives)	Threshold Target	Indicator Estimation	Indicator value computation steps	Notes
Number of inhabitants affected by flash flooding	N/A	N/A	N/A	No. of inhabitants	0	Calculated based on flood risk (based on peak surface run-off) and contrasting this against the population in the area, based on GIS computation.		Flood risk to be provided by SIMGRO?
Number of inhabitants affected by heat waves	N/A	N/A	N/A	No. of inhabitants	0	Calculated based on thermal comfort and contrasting this against the population in the area, based on GIS computation.		Air quality index to be provided by air quality models?
Number of inhabitants affected by air pollution (see above re: population exposure to air pollutants)	N/A	N/A	N/A	No. of inhabitants	0	Calculated based on an air quality index (combining all air pollution parameters) and contrasting this against the population in the area, based on GIS computation.		Air quality index to be provided by air quality models?

7 Annex II: Glossary of Indicators

Indicator		Policy area	Policy issue
CO_2	Carbon Dioxide	Greenhouse gases	CO_2 and MH_4 represent the most important greenhouse gasses responsible for global warming. Households and commercial activities contribute with approx. 20% to the overall production of this atmospheric pollutant, mainly by heating and consumption of electric energy. CO_2 contributes to 80%, MH_4 to 9% of total EU emissions of greenhouse gases. The Kyoto Protocol requires the EC (consisting of the 15 Member States of before May 2004) to reduce greenhouse gas emissions by 8% below 1990 levels by 2008-2012. Most of the 10 new Member States have the same target whereas the target for Hungary and Poland is -6% while Cyprus and Malta are no Annex-I Parties to the UNFCCC and thus have no target.
MH_4	Methane		
NO_2	Nitrogen Dioxide	Air pollution	While most pollutants have been abated substantially since the 1990ies, fine particulate matter and ground-level ozone remain still at sginificant levels and are now generally recognised as the most significant in terms of health impacts. Long-term and peak exposure can lead to a variety of health effects, ranging from minor effects on the respiratory system to premature mortality. Since 1997, up to 45 % of Europe's urban population may have been exposed to ambient concentrations of particulate matter above the EU limit set to protect human health; and up to 60 % may have been exposed to levels of ozone that exceed the EU target value. It has been estimated that PM2.5 (fine particulate matter) in air has reduced statistical life expectancy in the EU by more than eight months (EEA, http://www.eea.europa.eu/themes/air/about-air-pollution, assessed on November, 17th, 2010). Further to the 1996 Air Quality Framework Directive (Council Directive 96/62/EC), the EU Directive on Ambient Air Quality and Cleaner Air for Europe (Directive 2008/50/EC), is one of the key measures in place to address air pollution. It is the first EU directive to include limits on ambient concentrations of PM2.5 (fine particulate matter). It also consolidates various existing pieces of air quality legislation into a single directive.
PM_{10}	Thoracic particle		
$PM_{2.5}$	Fine particle		
O_3	Ozone		
CO	Carbon monoxide		
SO_2	Sulphur dioxide		
Anthropogenic heat loss		Thermal comfort	Urban heat islands The term "heat island" describes built up areas that are hotter than nearby rural areas. The annual mean air temperature of a city with 1 million people or more can be 1–3°C warmer than its surroundings. In the evening, the difference can be as high as 12°C. Heat waves have caused significant mortality in Europe, especially in urban aras, due to the "heat island" effect. In fact urban areas have higher mean temperatures as surrounding agricultural areas, and do not cool down as well as green areas to. Heat directly affects the human health as for elderly persons and those suffering from cardiovascular diseases find it difficult to adapt to heat stress leading to death from heat stroke, heart failure etc . The heat island effect has further impacts on summertime peak energy demand, air
Sensible Heat Flux			
Latent Heat Flux			
Air Temperature (outdoors)			

Indicator	Policy area	Policy issue
Air Humidity (outdoors/relative humidity)		conditioning costs, air pollution and greenhouse gas emissions. With rising temperatures following climate change, the phenomena of heat islands in urban areas is bound to increase health problems for urban population. In April 2009 the European Commission presented a White Paper on the framework for adaptation policies and measures to reduce the European Union's vulnerability to the impacts of climate change (01/04/2009 - COM/2009/0147). The aim is to increase the resilience to climate change, also with regards to human health. Further to human health, the heat islands affects communities by increasing energy demand for cooling, air pollution and greenhouse gas emissions.
Thermal Comfort (CP		
Energy demand for cooling/heating	Energy consumption	Renewable sources of energy are alternatives to fossile fuels with contributing, inter alia, to a reduction of emmissions of greenhous gas emission. With the new directive on renewable Energy, the European Community has defined a target of 20% of renewable energy to be reached in 2020 (Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009)
Percentage of energy from renewable energy sources		
Water consumption	Water Balance	According to the 2007 flood risk directive[2], member states need to undertake a preliminary flood risk assessment within 2011, and for those areas interested by real risks of flood damage, flood hazard maps and flood risk maps shall be developed by 2013. These maps will identify areas with a medium likely hood of flooding (at least a 1 in 100 year event) and extreme events or low likelihood events, in which expected water depths should be indicated. In the areas identified as being at risk the number of inhabitants potentially at risk, the economic activity and the environmental damage potential needs to be indicated. Finally, by 2015 flood risk management plans must be drawn up flood risk zones, including measures to reduce the probability of flooding and its potential consequences. They will address all phases of the flood risk management cycle but focus particularly on prevention (i.e. adapting future developments to the risk of flooding), protection (by taking measures to reduce the likelihood of floods and/or the impact of floods in a specific location such as restoring flood plains and wetlands) and preparedness (e.g. providing instructions to the public on what to do in the event of flooding)[8].
Evapotranspiration		
Infiltration		
Flood risk		
Green areas	Social inclusion, public health	Access to public green and/ or open areas (including freely accessible sports facilities) are considered essential for quality of life.

[8] Directive 2007/60/EC on the Assessment and Management of Flood.

Indicator	Policy area	Policy issue
Volume of material re-used	Waste management	Reutilization of resources and recycling is an important issue for sustainability policies both for the reduced need for new resources and for the reduction of needs for environmental resources such as land fill capacity for waste. A report to the European commission from 1999 quantified that, in the EU, "arisings of construction and demolition waste amounted to around 180 million tonnes each year …. This is over 480kg per person per year, and only about 28% across the EU-15 as a whole is re-used or recycled. Landfilling the other 72% (some 130 million tonnes a year)" (EC 1999). Recycling of waste in the construction sector is thus one of the priority waste streams considered by the European Waste Strategy and the respective EU - Directive[4] . (Directive 2006/12/EC of the European Parliament and of the Council of 5 April 2006)
Newly urbanized areas	Land Use Changes	Land use changes due to increase in urbanized areas are considered a major cause of environmental degradation, and, if loss of trees is involved, causes an increase of Greenhouse gases.Containing urban sprawl is a sustainability goal as more compact cities favour alternative transport systems. In this context, high urban density supports the rational use of services and mass transport facilities and contributes to limiting consumption of further non-urbanized land. and the re-use of brownfields is a strategy for limiting the increase of urbanized areas, limiting thus the consumption of landscape.
Density of development		
Brownfields re-used		
Cost of proposed intervention	Economic viability	The costs of development to be borne by the community represent the use of economic resources. the assessment needs to take into consideration both direct costs generated by the new development for the community and indirect costs in terms of maintenance etc during the lifetime of the project developed. These costs need to be put in relation to costs and benefits generated in terms of environmental impacts, social and economic opportunities.
Effects on local economy (revenue)		One part of the benefits the community derives from the development can be measured in terms of new economic activities and new working places created in a sustainable manner. This figure must neither include economic activities interested by relocation from other city areas nor the work force and economic activities employed during the construction process. During the assessment, the absolute term rather than the value of the surface needs to be employed.
Quality of pedestrian sideways	Sustainable mobility	The transport sector has a major environmental impact and a large carbon footprint. Currently, transport accounts for 32% of Europe's energy consumption and 28% of its total CO_2 emissions. In addition, by 2010, it is expected to have accounted for 90% of the forecast increase in CO_2 emissions since 1990 (http://ec.europa.eu/research/transport/issues_chalenges/urban_en.cfm) Public and private transport presents a number of challenges in the urban environment, including the need for cleaner, quieter, and
Length of cycle-ways provided		
Length of new roads provided		

Indicator	Policy area	Policy issue
Use of public transport		more effective transport solutions, better cohesion and response to rapid demographic changes. These challenges need to be addressed both at EU and regional levels, with the engagement and support of public authorities, municipalities and representatives of civil society. Integration between urban planning and transport planning are among the key issues in this field. (http://ec.europa.eu/research/transport/news/article_8727_en.html) The quality of pedestrian ways in a city influences the quality of life of their inhabitants especially more vulnerable parts of the population as elderly, families with children, etc. At the same time it influences the environmental impact generated by mobility. Good quality of spaces for pedestrian mobility can potentially contribute to a reduction of individual motorised mobility. The length of cycle-ways in a city influences the quality of life of their inhabitants and influence the environmental impact generated by mobility. Good quality of spaces for pedestrian mobility can potentially contribute to a reduction of individual motorised mobility. Good quality of road infrastructure can represent a condition for economic development in specific local situations, increasing the comparative advantage of a specific city in a competitive regional situation. Citizen's mobility determines both the quality of life (mobility, safety, urban landscape) and the environmental pressures generated by emissions from transport. A good acceptance of public transport facilities will reduce the use of private transport. The current way of measurement of use of public transport is based on the number of persons, (computing either the share of trips or of the length of trips) between public transport services and other forms of transportation. The modal split (%) is commonly used in local environmental reporting as well as in reporting by the EEA. In the case of strategic assessment, the potential use needs to be approximated, using the distance from the service facility (bus stop, metro station, etc.)
Access to housing	Social inclusion	Access to decent housing represents a condition for combating social exclusion and is one of the five policy lines adopted by the EC to combat poverty. Low- cost housing is generally provided under the form of social housing, the percentage of social housing offered in a neighbourhood can be used as a proxy for the accessibility of this sector of the housing market, taking into account that high percentages of social housing in single housing estates might lead to situations of ghetto, which further promote social exclusion of their inhabitants.
Access to services		The access to basic (social) services must be considered an essential condition for social inclusion and for economic viability, furthermore, having basic services close to home reduces the demand for mobility. In the UK, the absence of shops selling fresh fruit or vegetables is considered an indicator for social exclusion (European Commission (EC) 2002).
Human well being (the single indicators used for the construction of these composite indicators have already been described above		

Indicator	Policy area	Policy issue
Number of persons close to public transport	Sustainable mobility	The ECI set defines accessibility to public transport, in terms of spatial distance, by the time residents need to reach a public transport facility. The walking distance of 500 m, which corresponds to 300m measured “as the crow flies” or to 15 min. of walk for an elderly person.
Persons affected by heat waves		The indicator is calculated onn the basisi of values on thermal comfort, puit into relation oh the population affected, usina na overlay between maps on urban heat flows and residential functions.
Persons affected by flood risk	Water balance	Calculated delimiting the area interested by flood risk on the basis of peak surface run-offs and g this against the population in the area, based on GIS computation.

8 Annex III: Scales of measurement

area	Square meter	m^2
length	metre (meter in this report)	m
power	kilowatt	W (kg m2 s^{-3} = J s^{-1})
temperature	degrees Celsius	Temperature differences are given in C rather than the more correct form of "Celsius degrees"
time	second	s
weight (mass)	kilogram	kg
weight	tonne (ton)	T (10^3 kg)
weight	gram	g (10^{-3} kg)
weight	Microgram (µg, ug)	µg (10^{-9} kg = 10^{-6} g)