POCACITO

european post-carbon cities of tomorrow

QUANTIFICATION OF THE CASE STUDY CITIES

2050 SCENARIOS

IVL, ECOLOGIC INSTITUTE, FEEM, POLITO, CEPS, AU, UNDP, CUNI

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TABLE OF CONTENTS

1.1.1.1 LIST OF TABLES

1.1.1.2 LIST OF FIGURES

LIST OF ABBREVIATIONS

BAU	Business as usual
EE-MRIO	Environmentally extended multi-regional input output
GDP	Gross domestic product
GVA	Gross value added
IIASA	International Institute for Applied Systems Analysis
MEUR	Million Euros
MRIO	Multi-regional input output
PC 2050	Post carbon scenario for 2050
POCACITO	Post Carbon Cities of Tomorrow
SSP	Shared Socio-economic Pathways
TAPE	Turin Action Plan for Energy
WP	Work Package

1 EXECUTIVE SUMMARY

Developing post carbon cities of tomorrow is fundamental in the challenge of limiting climate change and humanities environmental impacts – particularly in the knowledge that 70-80% of the global population of over 9 billion people will be living in cities by 2050. The POCACITO project aims to facilitate the transition of European cities towards a post-carbon future by defining a Roadmap for the transition. Central to this is the modelling, quantification and comparative analysis of two possible future scenarios in 2050: business as usual (BAU) and post-carbon 2050 (PC 2050).

This report outlines the process, methodology and results of the quantification of 2050 scenarios developed for ten case study cities: Barcelona, Copenhagen, Istanbul, Lisbon, Litoměřice, Malmö, Milan/Turin, Rostock and Zagreb. A series of participatory stakeholder workshops in the case study cities have been central to the project. They have brought together local stakeholders to construct a common post-carbon vision for 2050 (PC 2050) and a set of actions and milestones needed to reach the vision.

Within WP5 two complimentary modelling and impact quantification methods will be performed. The first utilises the information and data already gained during the preceding work packages to focus on the impacts within the city system boundaries (city level assessment). The second will utilise the economic based multi-regional input-output (MRIO) approach to enable the consumption footprint of the cities to also be assessed (supply chain and city). Figure 1 provides an overview of the approach and the tasks that will be conducted for the two deliverables D5.2 and D5.3. This document only reports on the first stage, which is the modelling of the fundamental elements that help to describe the city: population, energy, transport, buildings and housing, GDP/economic development, industry sectors and employment.

The main approach for modelling the scenarios was to build on and utilise the work and data gathered in the previous work packages of the POCACITO project – specifically WP1, WP3 and WP4.

The main stages of the modelling for each city can be summarised as:

1) **Current trends**– developing and understanding the current trends for a set of primarily physical indicators. These are derived from the WP3 assessment and other literature and information;
2) **BAU** – is projected from the current trends, and where appropriate, considers progress made in relevant ongoing and planned projects.
3) **PC 2050** is developed from the qualitative scenarios developed in WP4, and provided in D4.2. Hence translating and expanding the visions, actions and milestones.

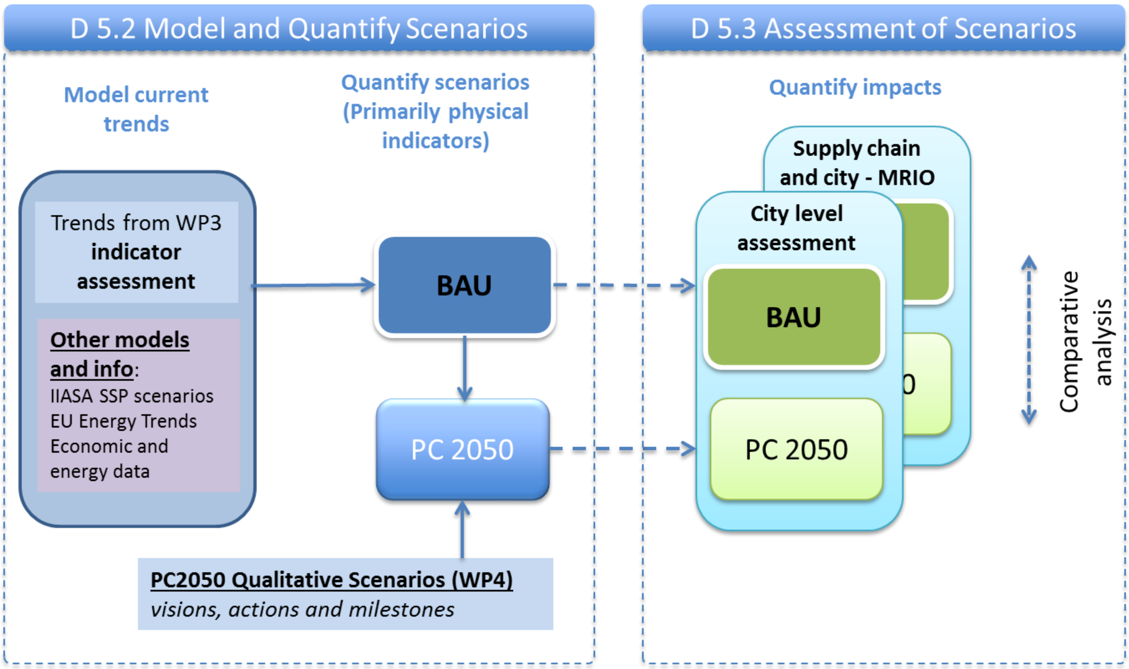


Figure 1: Modelling and quantification processes within WP5

An overview of the calculation approach for each of the main elements in the scenarios is provided in Table 1. A more detailed overview of the methods of modelling the scenarios and defining BAU and PC 2050 is provided in the main report

Table 1: Overview of calculation approach for the main elements

ELEMENT	BRIEF DESCRIPTION OF CALCULATION METHOD
Population	Population projections were based on those provided by data obtained from Oxford Economics, and other data from literature. For the difference between BAU and PC2050, we utilised data from the Shared Socio-Economic Pathways (SSP's) of the International Institute for Applied Systems Analysis.
Energy	Energy use and production used a range of data available from various sources to determine trends for that city. In general we tried to utilise the current trends and projected this with consideration from other factors such as population change, transport, residential sector, business and industry. PC 2050 was determined based on an interpretation of the post carbon scenarios and the associated actions and milestones.
Transport	Various sources were used. The main data from WP3 was on total energy used by the transport sector and the modal share breakdown and trends (available in most cases). A critical aspect for the scenarios is the modal share and the degree of electrification. Various assumptions were needed (outlined in Annex 2) based on the current trends for BAU and for PC 2050 an interpretation of the degree of sustainable transport and the modal share.
Housing and building	In most cases the trends of the residential and service sectors were used as a background to projecting the expected energy use of housing and buildings. This was adjusted depending on other qualitative information such as projects and policies for energy efficiency etc. For PC 2050 an interpretation of the energy efficiency measures, and other actions were considered.
GDP	GDP was calculated from the trends provided by WP3 and supplementary data where required. In addition, the data projections obtained from Oxford Economics.

ELEMENT	BRIEF DESCRIPTION OF CALCULATION METHOD
Business and Industry	Information on the industry mix and employment was highly variable, being very good in some cases, to very sparse in others. Current trends were generally projected to 2050 with some moderation due to expected limits to the trends (i.e. an expected ceiling to the growth of the service sector).

1.1 RESULTS

For the majority of cities, population increases are expected in both scenarios as shown in Figure 2. Litoměřice is the only city expected to decline in both scenarios, although only a small decline is anticipated. Since we had utilised the IIASA SSP scenarios for national projections as background, the PC 2050 population is typically larger. This is accounted for through an increased densification of the cities. An exception is Istanbul where PC 2050 is actually lower than BAU. Although this follows the background provided by the SSP's it can also be seen to be particularly fitting for a sustainable Istanbul. It is suggested that this could be achieved through an increase in sustainable planning which increases densification, limits illegal building, and attempts also to limit the population to sustainable manageable levels.

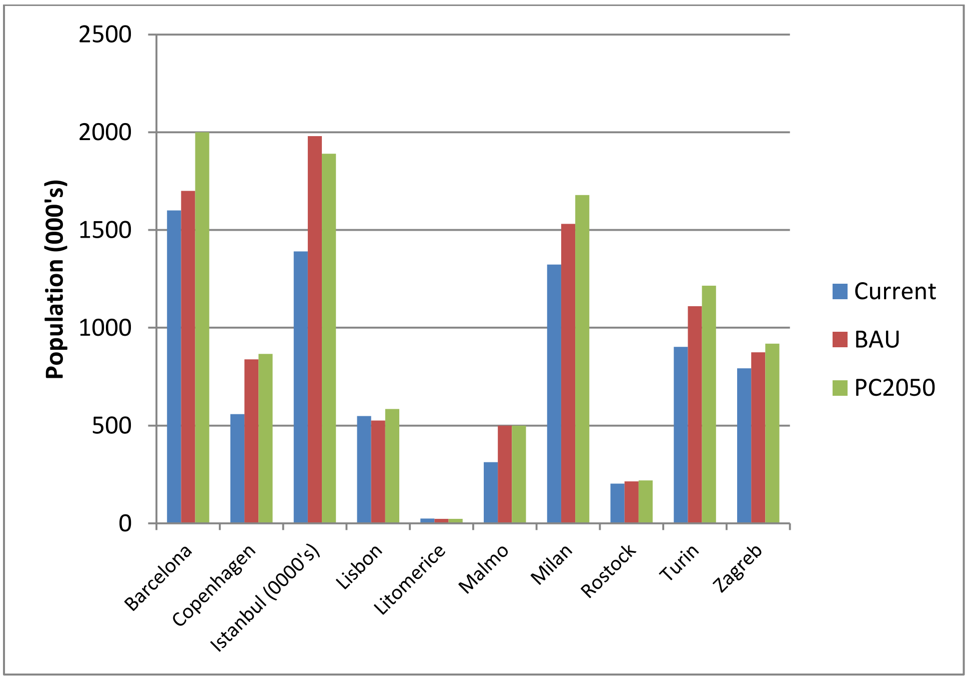


Figure 2: Populations of the cities comparing the scenarios against the current levels

For the majority of the cities energy use is usually higher for BAU than the current situation and PC 2050. This is typically related to the expected population increase with BAU compared to the current situation, and the expected level of energy reduction and efficiency improvements under PC2050. In some cases, energy use and efficiency improvements are also expected to be quite significant in the BAU scenario. Hence in some cases, energy use under BAU is also lower than the current situation despite the population rise, as in the case of Turin and Zagreb. The anticipated improvements are based on current trends, evidence of improvements, but also current projects and policies.

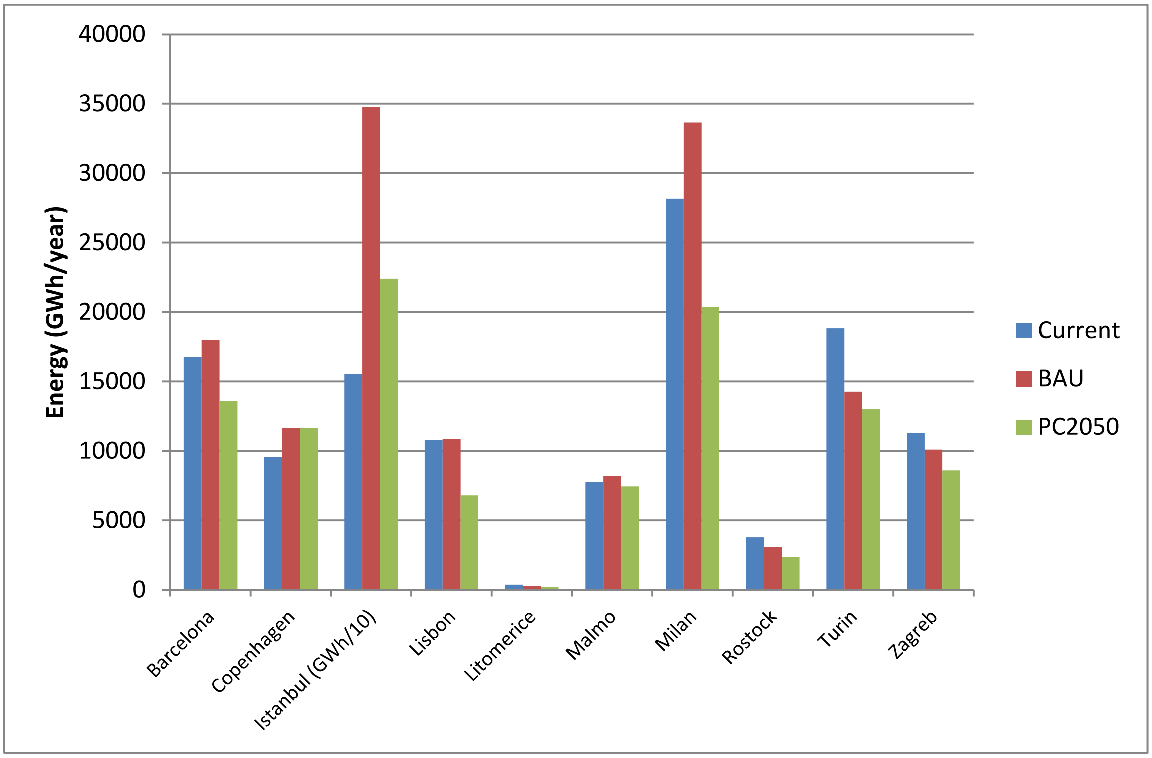


Figure 3: Energy use of the cities comparing the scenarios against the current levels

Figure 3 provides a more focussed perspective by comparing the energy use per capita, which removes the need to concurrently consider population change. This reveals that for 40% of the cities (Barcelona, Istanbul, Lisbon, and Milan) the energy use per capita is projected to grow under BAU whilst for the remaining 60% it is expected to drop. This drop is quite significant in some cases. Under PC 2050 the energy use is expected to drop for all of the cities with three cities, Barcelona, Litoměřice and Zagreb, dropping to under 10 MWh/person/year.

Surprisingly this shows Malmo as quite a significant user of energy on a per capita basis. This could partly be due to the cold climate, but may also to be due to differences in what is included in energy use data, particularly for transport. Of particular concern is Istanbul where in under BAU the energy use per capita is expected to grow significantly to unsustainable levels.

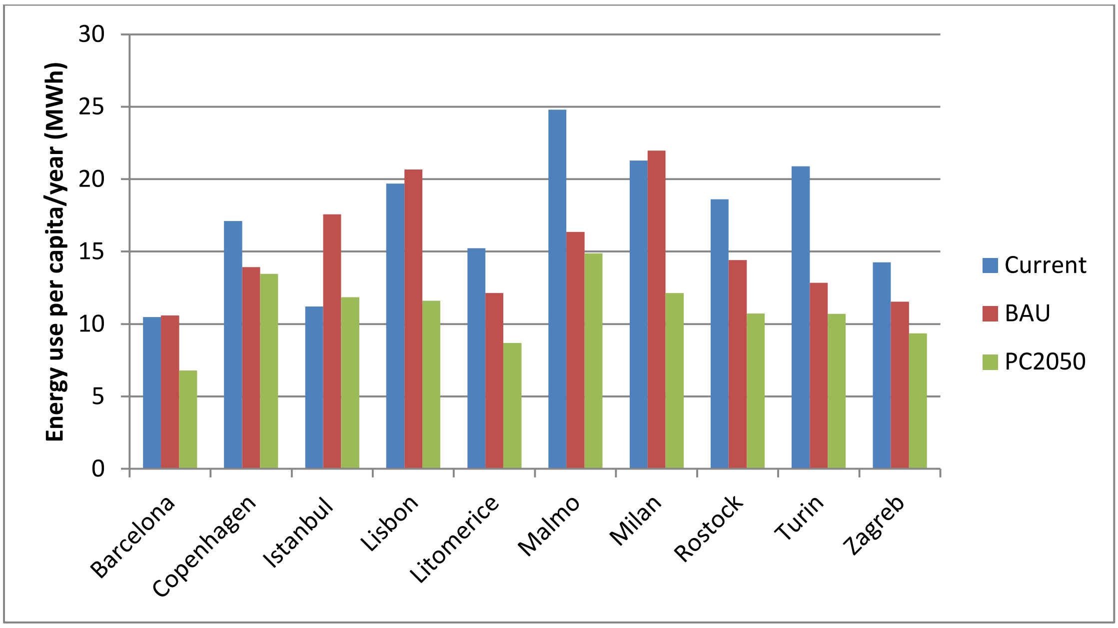


Figure 4: Energy use per capita comparing the scenarios against the current levels

A good indicator of the sustainability of the transport system within the cities is given by the energy used. Figure 5 provides a comparison of the energy use per capita of the city transport systems for the scenarios. It clearly shows that Lisbon has the highest per capita energy use, which is indicative of the high car use due to many residents moving away from the city centre. This is shown to fall significantly in the PC2050 scenario with higher densification, improved public transport and higher electric vehicles use. For the large majority of the cities energy use of transport in PC 2050 is much reduced due primarily to a shift to more sustainable transport modes and electric vehicles. The cities of Milan and Istanbul have notably high BAU values. This may partly be due to the projections being based on limited data that show poor current trends. Istanbul is expected to increase considerably in population, but towards 2050 we also expect increased mobility.

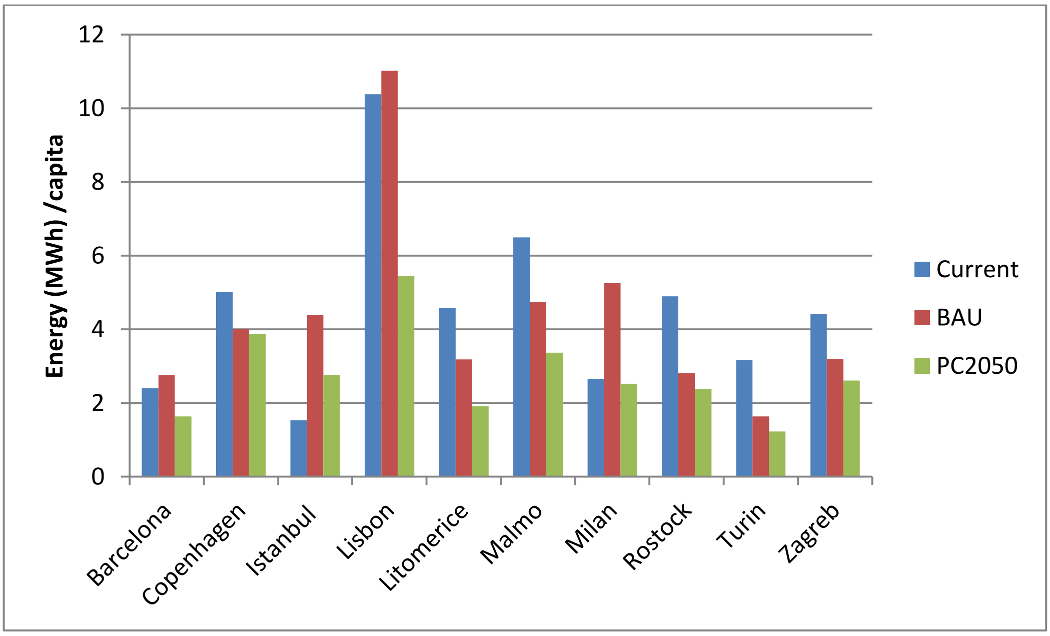


Figure 5: Energy per capita for the city transport systems under different scenarios

The GDP per capita for the scenarios against current levels is shown in Figure 6. This shows large improvements for some cities under both BAU and PC 2050, in particular Malmo, Copenhagen and Lisbon. The difference between BAU and PC 2050 is quite marginal in general.

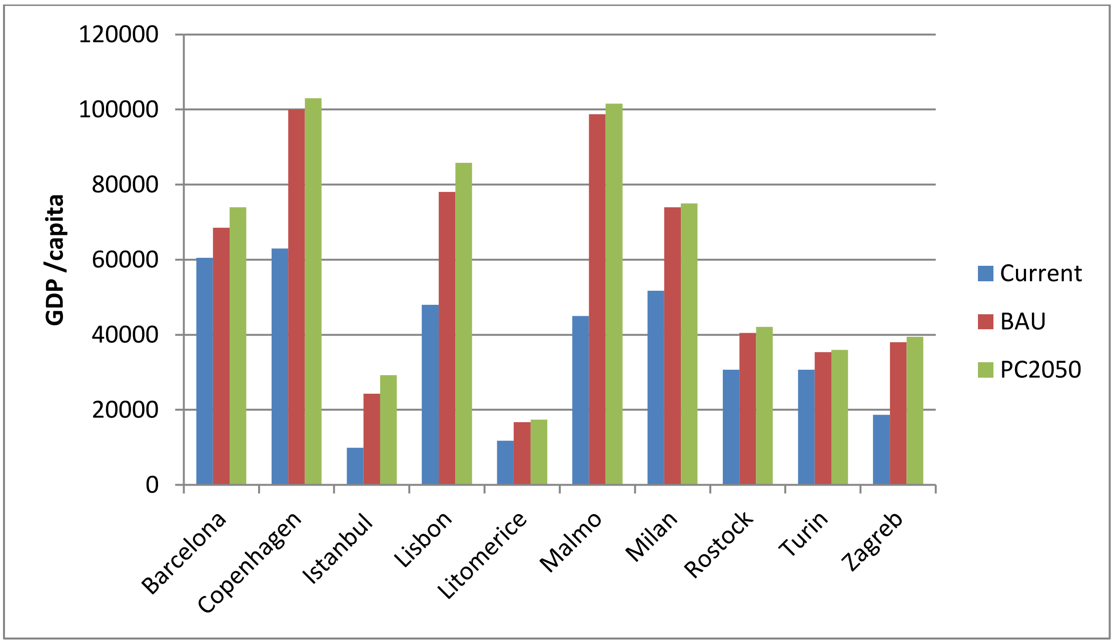


Figure 6: GDP per capita comparing the scenarios against the current levels

1.2 CONCLUSION

Overall, the chosen method was successful in developing the quantified scenarios for all cities, and also provides a solid foundation for the next project steps in WP5 – quantifying the impacts of the scenarios. In addition, this work will now feed into the MRIO work that will quantify the impacts of the city and its supply chain.

As in any modelling process that looks into the future there are several uncertainties and contentious issues. However, it is important to bear in mind that the projections given in this report are not intended as a prediction of the future (although BAU is viewed as a reasonable extrapolation and therefore a prediction of what could happen if no focussed action is taken). They are developed to learn from possible future scenarios about what might happen in BAU, what are the risks and how this compares to a possible post-carbon route. In addition, what are the possible effects and impacts that occur in the different scenarios, the strengths and weaknesses, and any trade-offs that might occur. Finally, what elements are missing in PC 2050 and what measures are required to achieve post-carbon cities?

The results of the modelling and quantification work to date, have shown that nearly all cities are growing. But in many cases energy consumption in the BAU is being decoupled, from both population and economic growth. However, this is generally too weak to make significant progress towards becoming post-carbon by 2050. There are generally significant differences in the energy consumption between the BAU and PC2050 scenarios. It is energy production, however, that will be the most critical in determining the climate change impact. Early indications suggest that the PC 2050 scenarios may not reach complete zero carbon status in many of the case study cities.

It is premature to speculate which cities this might be as the GHG emissions will be calculated in the next phase of the project. However, for nearly all of the PC2050 scenarios the total energy use is still fairly high in most PC2050 scenarios and supplying this energy with renewable/low carbon energy was interpreted as difficult to achieve within the current set of related actions. In other words, although low carbon energy supply is certainly possible to achieve, many of the PC2050 visions and actions are currently too weak to achieve complete post carbon status. Therefore the actions and milestones related to the PC 2050 visions will need to be reviewed and strengthened.

However, aside from the actually energy supply of the city, a further challenge to this is the carbon footprint and environmental impact of the supply chain, or household consumption to the city. Only the city of Malmo, appears to be considering household consumption, both currently in its indicator set, as well as in the post carbon scenario (aside from some sharing schemes, such as bikes and cars). However, it is becoming common for cities to develop bike sharing schemes as in the case of Copenhagen and Milan. Car sharing schemes are also developing as in the case of Barcelona, Lisbon and Milan.

In our desired 2050 low-carbon city, supplied by renewable/low carbon energy, the impacts of household consumption and the supply chain will represent the largest share of environmental impacts and of the carbon footprint, if nothing is done to address it. Hence although it appears to fall outside the radar for many cities, consumption represents a critical future challenge. Understanding the role of the city in addressing this is still in its infancy, but there are many actions that both local and national governments can do to address this. For example, there is the potential to develop standards or restrictions (e.g. for certain products, or develop thresholds to emissions), provide business support (particularly those involved in the circular economy), provide facilities (to encourage repair, reuse and recycling), optimise planning and spatial design, promoting sharing, and education of residents.

1.3 NEXT STEPS

The next steps are to move from quantified scenarios to quantified impacts which will be documented in the deliverable D5.3. The impacts will be quantified using two complementary methodologies the indicator modelling and the MRIO modelling. The former will examine the impacts that are result of activities that occur within the city boundaries. It will focus on the energy supply system and the associated impacts. Socio-economic impacts will also be covered that include social effects of the scenarios, investment costs and a cost-benefit analysis. In addition, the role of eco-system services in the scenarios and the impact on green and blue spaces will be reported. The

MRIO work will account for the resource footprint impacts of the city scenarios by modelling the household consumption and government expenditure.

The analysis will compare and illustrate the gap between the BAU with PC2050 scenarios for the environmental and socio-economic indicators. This will help to identify the most important measures and changes that are required for a transition to a post carbon city. This will then provide vital results for WP7 and the development of the Roadmap.

2 INTRODUCTION

The POCACITO project aims to facilitate the transition of European cities towards a post-carbon future by defining a Roadmap for the transition. The project is working with ten European case study cities: Barcelona, Copenhagen, Istanbul, Lisbon, Litoměřice, Malmö, Milan/Turin, Rostock and Zagreb. Central to this is the modelling, quantification and comparative analysis of two possible future scenarios in 2050 for each of the cities: business as usual (BAU) and post-carbon 2050 (PC 2050). A series of participatory stakeholder workshops in the case study cities brought together local stakeholders to construct a common post-carbon vision for 2050 (PC 2050). They also developed a set of actions and milestones needed to reach the vision. This report outlines the process, methodology and results of the quantification of 2050 the BAU and PC 2050 scenarios for the 10 case study cities[1].

This report is the second report of Work Package 5 (WP5). The aim of WP5 is to model BAU and PC2050 scenarios for each of the case study cities and to quantify the environmental and socio-economic impacts. It will therefore identify the difference between the two scenarios for each city in terms of impacts, and also identify the difference in financial costs of implementation. In order to enable this each of the scenarios must first be quantified in terms of mainly physical elements such as population, energy consumption and production, transport, housing and buildings.

Hence, the objective of this D5.2 report is to quantify these elements for each scenario, in order to provide the foundations for the quantification of the impacts in the next steps of WP5. Previous work packages in the POCACITO project provide a foundation for the WP5 quantification work:

- WP1 developed a common approach and a set of key indicators.
- WP3 provides an initial assessment of each case study city in terms of the developed indicator set.
- In WP4 participatory workshops were conducted with stakeholders from each city to develop visions for a post carbon city and perform a backcasting exercise to identify actions and milestones required to achieve PC 2050.

However, the actual quantification of BAU and PC2050 by utilising the information and data from the previous work was challenging for several reasons. Firstly, the information and data from the WP3 initial assessments was extremely variable in quality and quantity, and was only collected for a limited range of years. This meant developing trends was difficult without further information. Also, data on energy use and production was not adequate for the modelling. In addition, the qualitative scenarios developed in WP4 had limited information and details to enable a quantification of the scenarios. Also the actions and milestones that accompanied these scenarios was limited and had been developed to various degrees of completion and robustness.

[1] It should be noted that due to problems arranging a workshop with suitable stakeholders in Copenhagen, the PC2050 scenario for Copenhagen is based on analysis of already existing visions of the city and not developed from Pocacito workshops

2.1.1 STRUCTURE OF THIS REPORT

In this section we introduce WP5 and the context and purpose of deliverable D5.2. Next in Chapter 0 there is an extensive literature review of potential methodologies to model the scenarios, and also to enable the quantification of the impacts of the scenarios. Subsequently, the chosen approach and methodology is presented in Chapter 4. Chapter 5 then provides the main results of the modelling work. A qualitative description of the BAU and PC2050 scenarios is provided for each case study city, before the quantified results for the main scenario elements are provided in tables. The main aspects of quantifying the scenarios and a comparison of the results are then discussed in Chapter 6. Finally, some concluding remarks are discussed in Chapter 7.

2.2 OVERVIEW OF WP5

The objectives of WP5 are to:

1. Collect quantitative information on the qualitative strategic transition and BAU scenarios, respectively defined in WP4 as well as quantitative data on measures needed for the transition described in the case studies.
2. Engage selected stakeholders in a structured way by applying the Sensitivity Model to define the most important factors for quantification, and to define and visualise the causal relations between key factors and semi-quantify the interdependencies. We will select tools and methods for each case study city based on the causal relations.
3. Model and analyse the environmental and socio-economic effects of the post-carbon city scenarios as compared to BAU scenarios.
4. Interpret the results and feed the results of the impact analysis and the conclusions into the Roadmap process of WP7 and into the global knowledge sharing (task 6.4 of WP6).

The application of the Sensitivity Model, developed by Vester (Vester and Hesler, 1982; Vester 2004) was reported in D5.1 (Harris et al, 2015) and addressed the second objective. The Sensitivity Model is a system dynamics approach, designed to help understand the interaction of different system factors on each other. It is a participatory approach that utilises stakeholders to identify and model this interaction and help build up a system model. However, in D5.1 the POCACITO team only used the initial stage of the process, using an impact matrix to model the relationship and impact of the main system elements.

The document herein reports on the intermediate modelling step that begins with the first objective of collecting appropriate data, and then laying the foundations for the final two objectives.

The main tasks of WP5 are to:

1. Select the key factors to be modelled for each case study city – by using the Sensitivity Model.
2. Model BAU and PC 2050 and to quantify the physical elements of the scenarios
3. Quantify the environmental impacts – this involves identifying which indicators to focus on in each case study city and assessing effects on eco-system services.

4. Quantify the socio-economic effects of the scenarios – this includes
    - an assessment of the financial costs of the required investments and the mitigation costs.
    - Socio-economic costs and benefits
    - Monetised externalities and impacts, and effects on ecosystem services
    - Social effects of the scenarios through methods such as the GINI coefficient.
5. Interpret the results and provide an analysis that illustrates the gap between BAU and PC 2050.

The methodology of the original proposal allows some flexibility, particularly in terms of adapting to what is identified by the Sensitivity Model.

The main goals of WP5 are therefore to compare the BAU and PC 2050 scenarios to:

1. Check that the post-carbon future achieves what it aims for.
2. Assess any unintended consequences.
3. Check whether the paths to get to post-carbon status need to be improved.
4. Compare the costs of the paths and compare to the costs of BAU.
5. Inform the Roadmap for post-carbon European cities.

2.3 CHALLENGES IN DEVELOPING A METHODOLOGY

For the POCACITO project the concept of post-carbon cities signifies a rupture in the carbon-dependent urban system, which has led to high levels of anthropogenic greenhouse gases. It recognises the need for the establishment of new types of cities that are low-carbon as well as environmentally, socially and economically sustainable. The term post-carbon emphasises the process of transformation, a shift in paradigm, which is necessary to respond to the multiple challenges of climate change, ecosystem degradation, social equity and economic pressures. Through their embedded flexibility and resilience, post-carbon cities use the threat of climate change "as an opportunity to reduce vulnerability as they restructure human–ecological and human–human relationships toward ecosystem health and a clean energy economy."

However, there remains a challenge in also interpreting what is meant by "business as usual". The main notion with BAU is that it should be a continuation of the current trends to 2050. Several cities though have a number of projects and policies in place, which can greatly affect the current trends.

Another issue is that the data for some indicators within the WP3 case study city assessments is of varying quality and quantity. Some indicators only have two data points 5 years apart, whilst for others there is only reading for a particular year. Using either of these for trend projection is not only a challenge but would have limited scientific robustness. Hence it is necessary to find additional supportive data or information.

A further challenge is to determine how detailed the modelling should be. It is important to remember that POCACITO is a foresight project, intended to inform a Roadmap for post carbon European cities by understanding the impacts of different trajectories. The aim is not to make a prediction of the future.

There is a need to ensure that the level of detail in the assessment of the current situation and the trends are complimentary to the task of modelling the 2050 scenarios. Hence spending too much time focussing on detail and accuracy in the assessment of the current cities may be counterproductive in helping model 2050 scenarios. This is true for two main reasons. Firstly, the goal of WP5 is not to provide a detailed assessment of the current situation. Hence using detailed material flow analysis methods to develop an urban metabolism model would wrongly utilise the project resources. Secondly, this would not provide a suitable foundation for modelling because the range of parameters that would need to be modelled would be too vast.

One aspect that was identified as a critical future challenge for cities and should be incorporated into the project (as it was not included in the original proposal) was a consideration of the impacts of cities footprint. Hence the "upstream" or supply chain impacts of supplying the resources and products that the cities and their occupants consume. This was identified by the POCACITO team, through literature reviews and discussions, to be an important omission. In particular, with the growing awareness of the prominence of consumption impacts, this should be included in some way. In addition, in POCACITO's desired future low-carbon city, supplied by renewable energy, if the carbon footprint of the inputs to the system remains static, then the footprint/consumption is likely to represent the bulk of carbon emissions for the city. Hence, consumption could become one of the key issues and challenges for future cities.

The next section provides a literature review of the possible methodological approaches for the quantification of the case study cities within WP5.

3 LITERATURE REVIEW

The main purpose of this deliverable (D5.2) is to quantify the BAU and PC2050 scenarios for each of the case study cities. In order to do this there is a need to identify a methodology to:

1. model the scenarios, which must facilitate the quantification; but also
2. assess the sustainability impacts of the BAU and PC 2050 scenarios.

Hence although the latter objective is the subject of D5.3 (Quantification of the sustainability impacts of PC2050 compared to BAU) these two aspects must be complementary in nature, and are therefore also considered in this deliverable. In other words, the methodology must contain appropriately detailed indicators to enable an assessment of the current city status that lays the foundation to support the modelling and subsequent assessment of the 2050 scenarios. In particular, the wrong level of detail would not only make the modelling process very cumbersome, it would may also give a false perception of accuracy in the projections of the scenarios.

Therefore this literature review aims to both identify:

1. potential scenario modelling methodologies; and
2. suitable methodologies to assess the sustainability impact of the city scenarios.

These are both covered in the following sections. In the section on sustainability assessment there is more emphasis placed on potential methodologies to quantity the city footprint, because these methods are still emerging and developing, and often require more time and data. It is therefore critical to select the most relevant method.

3.1 SCENARIO MODELLING

This section provides a brief review of what scenarios mean in the context of POCACITO and methods for their assessment. It then provides an overview of some of the modelling and extrapolation techniques which are potentially appropriate for POCACITO.

3.1.1 SCENARIOS AND ASSESSMENT

A scenario can be considered as a hypothetical image of the future that describes how the system functions under certain conditions (Gambelli *et al.*, 2010). Scenarios are not predictions or forecasts but explore how various trajectories of change can result in alternative futures (IPCC, 2008).

Similarly foresight and its analysis do not aim to predict the future but to help build it (EC, 2005). According to the European Commission's Joint Research Centre, foresight is: *action oriented*, supporting actors to actively shape the future; *open to alternative futures,* which are shaped by decisions and actions; *participatory*, involving different stakeholders concerned with the issues; and *multi-disciplinary*, incorporating qualitative and quantitative variables to build a complete a picture as possible (EC, 2005). This is essentially the methodology utilised within the POCACITO project, which is fundamentally participatory, multi-disciplinary and focussed on identifying actions that will guide the cities towards a post-carbon status. Further discussion on scenarios and foresight were provided in the POCACITO report for D4.1 for WP4 (Breil *et al*. 2014).

Due to the many different circumstances and ways scenarios can be utilised there are a range of approaches that depend on the type of information and data used (Börjeson et al., 2006; Mahmoud et al., 2009). Gambelli et al (2010) provide a simple scenario classification based on the aim, type of data and methods:

1) Intuitive logic - explorative or forecasting, and anticipatory or backcasting scenarios. Hence starting either at the current situation or the desired situation and exploring strategies.
2) Trend impact analysis - Based on the nature of the source of information, such as participatory/expert based scenarios and desk-analysis scenarios.
3) Complex systems interaction – developed according to different methodological approaches, from less formalised to more structured methods.

Each of these have their strengths and weaknesses as highlighted in Table 2.

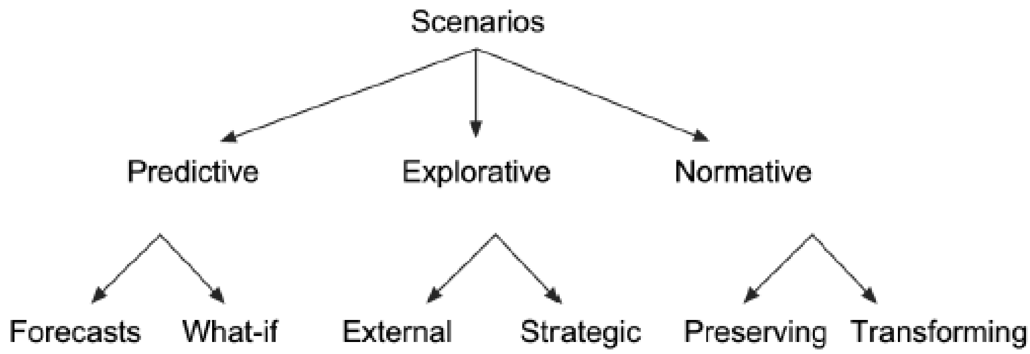
METHODOLOGICAL APPROACH	STRENGTH	WEAKNESS
Intuitive logic	Flexibility, simplicity, intuitive and creative perspective, integrate traditional forecasting techniques	High subjectivity, low methodological formalisation
Trend impact analysis	Combination of traditional and qualitative forecasting techniques, focus on exogenous shocks/ impact factors	Low formalisation of exogenous shocks/ impacts identification, requires time-series data for trend extrapolation, does not take into consideration events interactions
Complex interaction systems	List of relevant variables, variable interactions, measurement of links between variables	Complex, time consuming, theoretical and practical problems for managing expert assessments in a formalised way

(Source: Gambelli et al. 2010)

Table 2: Methodological approaches for SA

Another perspective is provided by Börjeson et al. (2006) who categorised scenario techniques into either:

- Predictive – what will happen?)
- Explorative – what can happen?
- Normative – how can a specific target be reached?



(Source: Börjeson, 2006)

Figure 7: Typology of scenario techniques

In addition, different modelling methods are required depending on whether the modelling is qualitative or quantitative. For instance quantitative approaches lend themselves to mathematical models, whereas qualitative approaches result in narrative/literary techniques (Kosow and Gasner, 2008). In WP5 a combination of methods is likely to be required because there is both qualitative and quantitative information to utilise from WP3 and WP4.

It is suggested in the POCACITO proposal to utilise the WP3 indicators as a basis for the scenario modelling. Therefore trend analysis and extrapolation is of particular interest and will be discussed in the next sections. After that combining methods for scenario analysis is discussed.

3.1.2 TREND ANALYSIS AND TREND EXTRAPOLATION

Trend analysis and trend extrapolation consist of past trend analysis and extrapolating it into the future (Kosow and Gasner, 2008). Quantitative trend analysis is used in areas such as demography, technology and economics, but requires data that extends far enough into the past to enable a suitable projection (Kosow and Gasner, 2008). The normal procedure is to collect data, identify the trend and develop a statistical projection into the future. The advantage is that the calculation is relatively simple and verifiable based on past data, and it is possible to perform reliability tests.

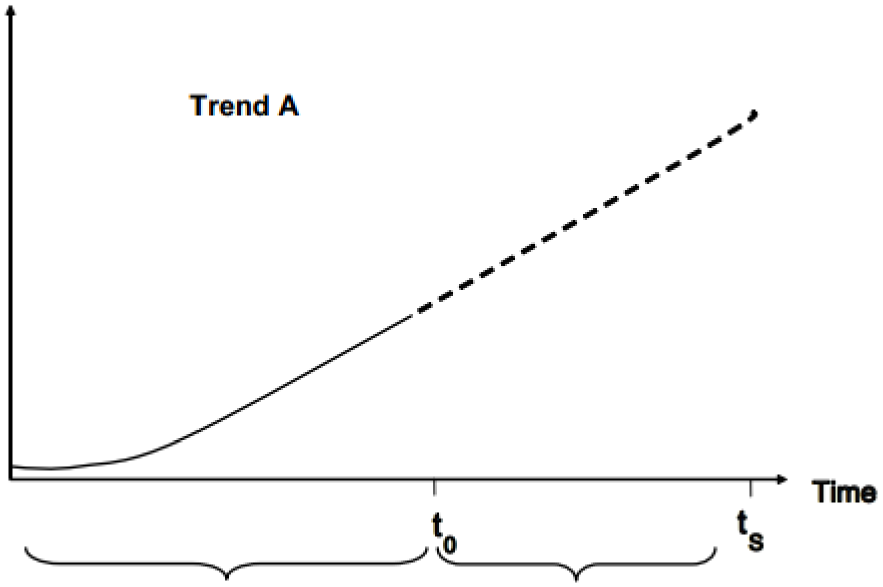
A major disadvantage can be that they communicate a sense of greater objectivity than they are actually capable of (Kosow and Gasner, 2008). In addition, the time period selected for observation and analysis (day trader versus historian perspective) and the criteria for projection can have a considerable effect on the outcome.

When there is no quantitative data available and/or quantitative projections are possible but not adequate, qualitative trend analysis is used. It is typically used for softer factors such as social aspects or institutional and political aspects. A normal procedure is to identify influence factors of importance and develop a theoretical underpinning as to the development, and further strengthened with all available information to accurately describe the future (Kosow and Gasner, 2008).

It is not automatic that a scenario funnel opens up when trend extrapolations of scenarios are constructed. Often only a single development, the most probable comes under observation (Kosow and Gasner, 2008; see *(Source: Kosow and Gasner, 2008)*

Figure 8).

Trend extrapolation that relies too strongly on a prolongation of the past, especially with too narrow a chronological time horizon has been likened to driving a car by looking into the rear view mirror (Minx and Böhlke, 2006). Hence trend extrapolation is often supported by other approaches and techniques, typically qualitative trend analysis.



(Source: Kosow and Gasner, 2008)

Figure 8: Trend extrapolation, forecast, "business as usual" (BAU)

Trend impact analysis is used to assess alternative scenarios and was developed to compensate for the weakness of extrapolations in that they do not take into account future unexpected events. In the method, trend extrapolation is first used to calculate a surprise free future, before surveying experts to identify potential future events. If they happen the events would results in a significant change somewhere in the projected trend. Hence the strength of the potential influence and the other possible directions that the events might foster are also calculated alongside the estimated likelihood. Therefore the technique combines creativity with a formalised process (see Mietzner and Reger 2004, 54). However, because of the subjectivity of the future events, being based on expert viewpoints, and that it requires a solid data basis, TIA is rarely used in scenario work (Kosow, 2008).

3.1.3 THE TECHNIQUE OF COMBINING METHODS

In practice, the modelling of the future often requires combining and integrating scenario techniques which can be a very productive approach (Kosow 2008). Three such method combinations were highlighted by Kosow (2008): the combination of scenarios with other modelling techniques, with Delphi surveys and with roadmapping techniques. Three main methods are utilised in future studies: system dynamics models, agent based modelling methods, and special qualitative methods.

With a multi-disciplinary project such as POCACITO involving 10 individual case studies, with varying amounts of data quality and quantity, it is likely that additional supportive data will need to be utilised. This will limit the amount of modelling work required and support any assumptions.

For example, the EU project called OPEN used the following data sources in order to develop carbon, ecological and water footprints (Roelich et al., 2011):

- “Europe’s Share of the Climate Challenge” (Heaps et al., 2009) – which examines how Europe can rapidly reduce emissions of GHG. It presents a sector by sector mitigation scenario for EU27 countries to reduce emissions by 40% in 2020 and 90% in 2050, relative to 1990 levels.
- 2050 Pathway Analysis (DECC, 2010) – which examined four trajectories for the UK energy system ranging from little effort to reduce emissions or save energy to extremely ambitious changes.
- Efficiency improvements within the air and water transport sectors were taken from Energy Technology Perspectives (IEA, 2010).

Simulations or computer based modelling are often used to support the development of potential scenarios and is a way to promote credibility and robustness of the scenarios (Vidalenc 2014). For instance Vidalenc (2014) used the IMACLIM model, a hybrid macro-economic model, to assess the extent to which local measures can impact upon national objectives for CO2 reductions.

Vester’s Sensitivity Model, which was partly used in the early WP5 POCACITO work (Harris, 2015), is a systemic-formalised scenario technique for impact analysis (Kosow, 2008). The technique can also be considered as a complex systems approach. One of the weaknesses of this is the complexity and time consuming nature of its approach, which requires extensive interaction with participants as well as multiple iterations of the computer based model.

It is also becoming more common to utilise modelling systems that have been developed in European research projects. Energy modelling systems such as GAINS and PRIMES are widely used in EU research (e.g. Capros et al. (2014) utilised the PRIMES model). In developing scenarios to explore how the EU can take action to reduce GHG emissions, Heaps et al. (2009) used SEI’s LEAP energy modelling system that is freely available together with the data (www.energycommunity.org). This can be a useful approach to greatly increase the speed of the modelling process, but also to add a level of perceived robustness to the modelling.

However, many of these modelling systems are aimed at the national level and are not suitable for the POCACITO project. In addition, the need to cover not only the physical aspects, but also the socio-economic indictors adds a further complexity.

3.2 ASSESSMENT OF SUSTAINABILITY IMPACTS

The use of the term sustainability is now prevalent across many fields and is therefore subject to various interpretations. Similarly the term sustainability assessment can have different emphasis and meanings for different fields. In ecology, the emphasis is naturally skewed to the environment whereas for urban development the approach can be more qualitative than quantitative. One definition for a sustainability assessment is the process of identifying, measuring and evaluating the potential impacts of alternatives for sustainability (Devuyst 2000).

Within POCACITO the aim is to quantify and compare the environmental, social and economic impacts of the BAU and PC 2050 scenarios. This section briefly discusses the various tools available to enable this comparison. For POCACITO the suitability of an assessment methodology is also dependent on the modelling approach. A further challenge is to identify a methodology to assess the supply chain and consumption based impacts.

Ness et al. (2007) categorised sustainability assessment tools into three types:

1. Indicators /indices – subdivided into non-integrated (environmental pressure indicators) and integrated (such as ecological footprint, well-being index, and human development index).
2. Product related assessments – including LCA, life cycle costing, material and energy flow analysis.
3. Integrated assessment – which includes multi-criteria analysis, cost benefit analysis, and impact assessment methods.

A number of methodologies exist for measuring the sustainability performance of companies. Methodologies such as those developed by the World Business Council for Sustainable Development (WBCSD, 1997), the Global Reporting Initiative (GRI, 2002a and GRI, 2002b) and development of standards (OECD, 2002) were fundamental in promoting sustainability within industry.

The Driving Force Pressure State Impact Response (DPSIR) model is a comprehensive framework for sustainability indicators that extended the Pressure State Response (PSR) framework developed by Holmberg and Karlsson (1992). It was adopted by the European Environmental Agency (EEA) and the European Statistical Office in 1997.

In terms of environmental assessment, the approach provided by life cycle assessment (LCA) is becoming increasingly prevalent across many disciplines. For example, LCA recently became the basis for PAS 2070:2013, which is the standard for assessing greenhouse gas emissions of a city, including the direct emissions as well as the supply chain and consumption based impacts (BSI, 2013).

For cities however, sustainability indexes such as the Siemens Green City Index, are the most widely used and publicised methods, and are typically used in a retrospective assessment. However, multi-criteria sustainability assessments and sustainability appraisals are qualitative and semi-quantitative methods that are more often used in the planning phase (e.g. Masterplan developments) or strategy and policy assessment.

Assessment techniques such as BREEAM and LEED that were originally developed for the assessment of buildings have been extended into tools to assess the sustainability of urban development. The resulting methods including BREEAM for Communities, LEED for Neighbourhood Development and CASBEE for Urban Development (Berardi 2013) are used for master-planning projects, infrastructure, as well as buildings. These methods develop a score for different criteria which is then collated into a final score for the development. Berardi (2013) highlighted some deficiencies in these methods in that the systems often allow a prioritisation of other priorities over the use of natural resources. Berardi (2013) also suggested that there were a number of missing criteria particularly within the social and economic dimensions.

The sustainability assessment of communities or cities has been shown to be much more complex than simply the summation of individual buildings and infrastructure, due to the interactions of various criteria (Haapio 2012; Mori and Christodoulou 2012).

Hence assessment techniques have gone from the assessment of sustainable buildings to the assessment of sustainable communities, but there is now a need to consider the city as an entire system with inputs and outputs, and a functioning inner core. How a city effects consumption and behaviour is therefore also important.

A critical aspect is the choice of indicators, which depend on the focus and goal of the research or study (Kates et al., 2001). However, aligning the goal with suitable indicators is a challenging task, and is more difficult if several dimensions are aggregated into a single score (Kuik and Gilbert, 1999). Methods that attempt to provide a single score are generally more communicable to a general audience, but can be less transparent, and their robustness has been questioned and criticised (see for example Zamagni et al. 2008). Research has also shown that the timing of assessment and the views of the assessor can have a strong influence in the assessment because they influence the choice of indicators and many indicators have a subjective dimension (Devuyst 2000; Martens 2006).

Reviews of the available indicators have shown that many of the current indicator sets for measuring sustainability have a bias towards an environmental approach (Pope et al. (2004) and Tanguay et al. (2010). This is apparent in the emergence of many of the well-known assessment methodologies such as the Ecological Footprint, the Water Footprint, the Carbon footprint and assessment of eco-system services. This is because the preservation of natural resources is fundamental to the well-being of humanity and ensuring sustainability. It is increasingly recognised that environmental sustainability is strongly inter-related to social sustainability and well-being (Vallance et al. 2011).

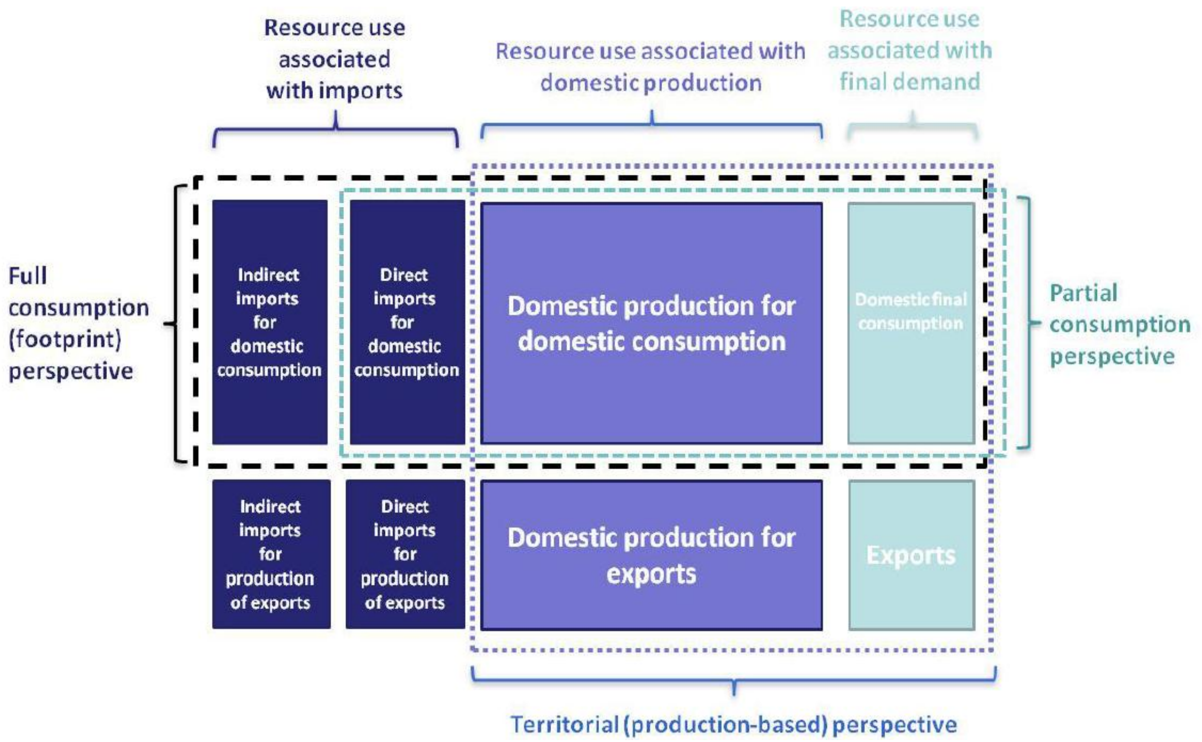
A further challenge in conducting a sustainability assessment of a city is defining where the boundaries of the city and therefore the assessment are. The boundaries can be identified in terms of land-use, infrastructure or population density (UN-Habitat, 2006). Continuing urban sprawl around many cities also complicates the issue, and how this should be accounted for. Bithas and Christofakis (2006) therefore emphasised that impacts on external aspects should be considered in sustainability assessments.

In particular the flows of materials, energy and water into the city need to be considered and is the focus of the next section.

3.2.1 POTENTIAL WAYS TO MEASURE CONSUMPTION

There are several methods available to assess the impacts of resource use and its supply chain. These include life cycle assessment, economic input-output analysis and material flow analysis methods such as urban metabolism. These can be termed footprint methods (SERI 2013). It is common to apply these at the national level but their application, apart from urban metabolism, has been less common at the city level. The various footprint methods have the potential to be utilised to help assess the supply chain and consumption impacts, but most only addresses a single indicator such as carbon, material, land or water. Figure 1 illustrates three options with different boundaries to calculate resource use. These perspectives are the territorial or production, partial consumption and full consumption or footprint.

In this literature review we consider the following three main methods that are relevant for use within the POCACITO project, and are discussed in the next sections:



(Source: SERI, 2013)

Figure 9: A framework for consumption-oriented versus production-oriented accounting of resources

1. Economic based
    a. Utilising economic input-output analysis tables. The most appropriate form being environmentally extended multi-regional input-output analysis (EE-MRIO)
2. Material flow based
    a. Using material flow accounts such as those available on EUROSTAT combined with LCA
    b. Urban metabolism – which can be combined with LCA
3. Measurement of selected consumption parameters using footprint methods such as carbon footprint or ecological footprint.

3.2.1.1 ECONOMIC BASED METHODS

The economic methods are based on utilising economic input-output tables, which document the sale and purchase relationship between producers and consumers of an economy (OECD 2015).

Input-output analysis is an analytical framework developed by Wassily Leontief in the 1930's (Miller and Blair, 2009). The input-output matrix documents the interdependencies between different sectors of a national economy or regional economies. They are models that integrate economic data for a whole country or several countries and quantify the specific inter-sectoral relationships..

The input-output models come either as single region input-output (SRIO) models (representing one country or an aggregated region such as the EU) or multi-region input output (MRIO) models (SERI 2013). SRIO models have the advantage of being much simpler and easier to handle technically, with a limited amount of data. However, the major disadvantage is that the models can have difficulties to accurately assess the resource requirements of imports. MRIO models link the IO tables of several countries or regions, and hence the data requirements and complexity is much larger. They have the advantage of incorporating international supply chains and therefore can take into account the different resource intensities of production in different countries (Tukker et al, 2013a).

The IO tables have been extended to enable environmental analysis since the 1960's, for example to account for pollution increases associated with industrial production as a result of changes in final demand (Scott et al. 2013). This is known as Environmentally Extended Input-Output model (EE-IOM). These models contain additional columns and row vectors to help calculate the sectoral emissions.

Hoekstra (2010) reviewed the literature on EEIO analysis and showed that 90% of the papers since 1995 focus on single countries. A wide variety of environmental issues have been covered since 1995, whereas previously the focus was almost exclusively on energy use.

Wiedmann et al. (2006) allocated ecological footprints to final consumption categories using input-output analysis. They detailed a method that allows the disaggregation of national Ecological Footprints by economic sectors, final demand category, sub-national area or socio-economic group (Wiedmann et al. 2006).

In recent years several projects have refined input-output tables and multi-regional input-output systems to provide databases that enable the calculation of supply chain and consumption impacts (Tukker and Dietzenbacher, 2013). Examples include: FP7: CREEA (www.creea.eu), FP6: EXIOPOL (www.feem-project.net/exiopol), FORWAST (forwast.brgm.fr), OPEN-EU (www.oneplaneteconomynetwork.org). DESIRE, WIOD (www.wiod.org). Some of these and others are compared in Table 3.

Table 3: Comparison of EE-MRIO models

MODEL	SECTOR COVERAGE	COUNTRY COVERAGE	YEARS AVAILABLE	POTENTIAL UPDATES	REFERENCE(S)
Eora	Varies by country from 26 to 515 sectors	187	1990 – 2010	Annual updates with 2 year time lag	Lenzen et al. (2012)
GTAP	57	127 (yr '07); 113 (yr '04); 87 (yr '01)	2001, 2004, 2007	3 year intervals with a 4 year lag	Peters et al. (2011)
EXIOPOL	130	44 (EU27, 16 others + ROW)	2000	Funding dependent	Tukker et al (2009)
EXIOBASE	163	43, and 5 RoW regions	2000, 2007	Funding dependent	Tukker et al. (2014)
WIOD	35 industries, 59 products	41 (27 EU, 13 others + RoW)	1995 – 2009	Funding dependent	Timmer et al (2012)

MODEL	SECTOR COVERAGE	COUNTRY COVERAGE	YEARS AVAILABLE	POTENTIAL UPDATES	REFERENCE(S)
AIIOT	76	11 (9 Asian, USA and ROW)	1985, 1990, 1995, 2000, 2005	Every 5 years	Zhou and Kojima (2009)

(Source: adapted from Scott et al. 2013)

These methods and databases therefore have the potential to be utilised in the analysis of cities, by combining with household consumption data. This could be performed either by utilising national data on household consumption and adjusting for the size of the city, or through collecting and incorporating city or regional based data. The latter would provide a much more representative and accurate picture if the data is available for the ten POCACITO cities.

One of the major criticisms of MRIO is that it is based on economic units and not actual physical data. It therefore assumes proportionality in the allocation of resource flows to monetary structures (Bruckner et al, 2012). Hence the resource use related to trade and consumption in western countries, with high value to weight ratios, can be underestimated in comparison to emerging economies (Bruckner et al, 2012). For example, Steen-Olsen (2014) examined four of the most important global MRIO systems and found considerable sensitivity to background system detail and that sub-sectors within an aggregate MRIO sector can have widely ranging carbon multipliers.

Physical input-output tables, incorporating for example mass, are possible but not yet widely utilised or consistent in structure (Giljum and Hubacek, 2009). They therefore do not currently allow the study of supply chains and impacts. An alternative to provide the physical approach is the methodology provided by urban metabolism studies which is discussed in the next section.

3.2.1.2 MATERIAL FLOW BASED METHODS

Material flow analysis (MFA) is typically used to study the flows of materials within an industrial system. It can be used at several system levels including: products and services on a life cycle basis; companies; sectors and branches; and communities, regions and national economies (Bringezu 2003). It is the latter application of MFA that is of interest to the POCACITO study and has led to the field of urban metabolism studies.

The Urban Metabolism field originates in the 1960's when Abel Wolman compared the flows of resources in and out of a city to those of an organism. The metabolic inputs of energy and resources are requirements for existence and these are ultimately emitted into the environment as waste. Hence the urban metabolism concept aims to assess these flows into and out of the urban system. There are three basic types of flows (Minx et al. 2010):

- Direct extraction and releases of resources within the urban system boundaries.
- Imports and exports.
- Indirect flows associated with the imports and exports.

It is the third type of flows that are overlooked by many common city indicator assessments that only include indicators for impacts within the city system. Hence in an urban metabolism study the systems approach provides a complete description on the metabolic resource flows and has global system boundaries and consumption based accounting (Minx et al, 2010). The data requirements are therefore extensive and present a large challenge to any study.

Accounting for the accumulation of stock is a further challenge for of urban metabolism studies and is particularly relevant for scenario analysis as the accumulation is related to delays in the outflows of resources from the urban metabolism.

Many studies however have focussed solely on the material flows across the city boundaries and have not accounted for the indirect material used (e.g. Browne et al. 2009; Niza et al. 2009). In addition, accounting for the impacts of these flows has only recently begun to be addressed. However, the majority of studies that related metabolic flows to impacts focus only on one aspect such as GHG emissions (e.g. Ramaswami et al. 2008; Kennedy et al. 2009; Minx et al. 2009; Hillman and Ramaswami 2010; Kennedy et al. 2010).

However, as far back as the late 1990's Newman proposed the extension of the metabolism model to include the indicators of employment, income, health, education, leisure, housing and community activities (Newman, 1999; Newman et al 1996).

Combining UM and LCA facilitates the quantification of upstream and downstream environmental impacts of cities, but requires extensive data. Research has only recently begun to address this, extending the resource flow approach to include impacts. Goldstein et al (2013) applied the approach to five global cities (Beijing, Cape Town, Hong Kong, London and Toronto) to identify the dominant sources of a city's environmental footprint. They also combined the outputs with socioeconomic data to give an indication of how these variables influenced the footprints of the case study cities. The footprints of wealthier cities were more associated with personal consumption whilst poorer ones were more affected by local impacts.

The study however was limited by its methodology and the available data. It utilised data from previous urban metabolism studies and used data of quite low resolution. The method also lacked a certain amount of precision due to the simplified method of selecting LCA data to represent the products of the cities.

Recently in a study of Lisbon, Rosado et al. (2014) attempted to address some of the gaps reported in the literature including lack of a unified methodology (e.g. Niza et al. 2009; Barles 2010; Weisz and Steinberger 2010) and the lack of data (Kennedy et al. 2011). In addition, they examined the life cycle of the materials and products accumulating within the city system over 2003-2009 and modelled the temporal scale of when different materials may become obsolete. This for example, showed large waste quantities could arise after 2032 and grow exponentially, just from this material. Per capita material consumption in Lisbon was 10.40 tonnes/person, which correlates well with an average of 10.42 tonnes/person when compared to other regions.

3.2.2 CALCULATION OF SELECTED IMPACTS

The approaches within this category have been termed "coefficient approaches" (SERI, 2013) as they utilise process analysis or similar methods (such as LCA).

The approach is bottom up as opposed to economic input-output analysis which is top down, and starts the calculation from the single product level or product groups. This method has been applied at the level of the city system in various forms to calculate various indicators including carbon, water, materials and ecological footprint.

The most common indicator covered is that of energy and GHG emissions (e.g. Ramaswami et al. 2008; Druckman et al. 2008; Minx et al. 2009; Kennedy et al. 2009; Kennedy et al. 2010; Hillman and Ramaswami 2010) and has culminated in the production of the PAS 2070.

In a study that calculated greenhouse gas emission footprints and energy use for eight US Cities, Hillman and Ramaswami (2010) used a hybrid LCA approach. It was found that the activities occurring outside of the city contributed an average of 47% more than the GHG emissions within the city boundaries. The method used covered the end use of energy, embodied energy of four urban materials (food, water, fuels and concrete, calculated using LCA) and airline/freight transport. It was found that the inclusion of these six aspects produced a per capita GHG emission that was similar to the national level, suggesting that inclusion of only these 6 may be enough to provide a good estimation of GHG emissions.

The water footprint methodology has also been applied at various spatial levels including the city level, but is still being refined in its application. One study that compared the water footprints for Berlin, Delhi and Lagos showed large differences in the footprints and origins of water use (Hoff et al. 2014.

Similarly the ecological footprint of cities has been calculated at the city level. For example, Rees and Wackernagel (1996) calculated that the area needed to support the city of Vancouver was over 200 times the actual area of the city. Whilst another study estimated London's ecological footprint for food, forest products and carbon assimilation to be 120 times the area of the city (IIED 1995).

However the aggregation level and methodology of the ecological footprint method was deemed unsuitable for the POCACITO project. This is because the single indicator of land use does not provide enough detail to provide sufficient lessons, or comparability between cities or the scenarios. In addition, there are several criticism of the methodology that suggest its robustness is not satisfactory (Fiala 2008: DEFRA 2010).

Some studies cover the POCACITO cities and are relevant for comparison and data acquisition. The life cycle energy and GHG emissions for the urban water cycle of Turin Metropolitan area was the subject of research by Zappone et al. (2014). In this study life cycle assessment was combined with material flow analysis. Minx et al (2010) included Barcelona and Malmö in a study that developed a methodology to assessing urban metabolism in Europe. Rosado (2014) performed a comprehensive material flow accounting study of Lisbon using the urban metabolism model, whist Shafie (2013) studied the urban metabolism of Barcelona using economic input-output analysis.

3.3 SUMMARY

The literature aimed to identify a methodology to model and quantify the scenarios, and a method to assess the sustainability impacts of the BAU and PC 2050 scenarios. The method of sustainability impacts also needs to support the assessment of the city footprint.

The review shows that there are a range of approaches to scenario analysis. The most appropriate for WP5 appears to be the use of trend extrapolation supported with qualitative trend analysis. Two different variations of this technique are required in principal. This is because the modelling of BAU is based on an extrapolation of current trends of the indicator set, whereas PC2050 is quantified from a qualitative scenario. However, the modelling of BAU will also support the construction of a quantified PC2050 scenario by providing a baseline scenario.

The sustainability assessment techniques will need to use a range of techniques applicable to the individual indicators. In addition the MRIO appears to be the most appropriate technique for assessment of the scenario’s footprint, due to the greater availability of datasets and supportive tools such as EXIOBASE.

4 QUANTIFICATION AND MODELLING METHODOLOGY FOR WP5

4.1 OVERVIEW OF APPROACH

This chapter discusses the choice of methodology to model the scenarios. Following the review of literature and data from WP3, the key factors determining the choice of methodology were:

- **Need to cover a range of indicators** – meaning a high level of complexity and interaction.
- **Quantification of qualitative scenarios** – the PC2050 scenario was produced by the case study teams and stakeholders only in a qualitative description. They each contain milestones and actions, but these are quite limited for many case studies.
- **Limited data availability** – which varied in quantity and quality between the cities. The "trends" available from the WP3 assessment were sometimes very limited, and sometimes non-existent.
- **Long-time scan required for modelling –** meaning any projection would have a high degree of uncertainty and
- **A need to consider consumption aspects** – which meant that a method needed to be selected that could account for the supply chain and consumption aspects of the cities.

However, these challenges were tempered with the knowledge that the overriding aim of POCACITO is not to predict the future, but to learn about potential impacts of the BAU and PC2050 scenarios, and inform a roadmap to be developed in WP7.

Despite data difficulties from the WP3 assessment, a large and useful quantity of data was nonetheless available and provided a useful start to develop an understanding of current trends. It is therefore prudent to utilise this data as much as possible. However, it was also strongly preferred to address the consumption component and so an additional approach and additional data would be needed. Although the urban metabolism approach combined with LCA provides a potential robust and relevant approach, the extensive data and time requirements meant that it was simply not possible to apply to ten cities within the scope of POCACITO. Even if the approach was dramatically simplified and streamlined, much of the basic data on resource flows into the city did not appear to be available following the WP3 work. A much more viable approach seemed to be the EE-MRIO approach where database systems were already available.

Hence two complimentary modelling and impact quantification methods will be used. The first will utilise the information and data already gained during the preceding work packages providing an indicator based estimate of costs and benefits of decarbonisation measures, whilst the second will utilise a MRIO approach to enable the consumption component to also be considered. The indicator assessment approach will also provide a foundation for the MRIO analysis by providing qualitative and quantitative information and trends for the scenarios.

The first stage to enable this is to understand the current situation in each city and to model and quantify the scenarios. This refers mainly to the physical elements of the scenarios such as population, energy use, transport and the main indicators, which will then lay the foundations for the impacts to be calculated in subsequent stages. Figure 10 provides an overview of the approach and the tasks that will be conducted for the two deliverables D5.2 and D5.3.

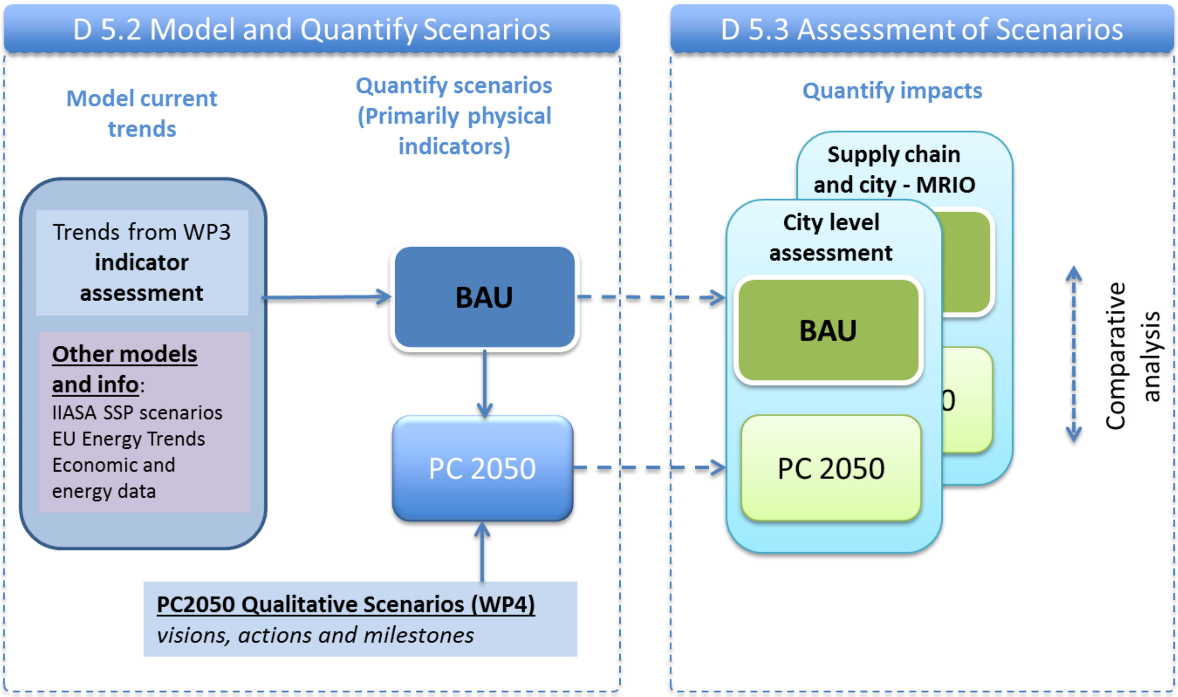


Figure 10: Modelling and quantification processes within WP5

The final quantification of the impacts within WP5 therefore has two components:

1. **Modelling and quantification of scenarios (D5.2)** – utilising the information from previous work packages, other literature, data and models, to develop qualitative and quantitative BAU and PC 2050 scenarios for each city. The outcomes are quantitative descriptions of the scenarios that provide the foundations for an assessment of the impacts.
2. **Assessment of the impacts of the scenarios (D5.3)**
    a. City-level impact assessment – building directly on stage 1, this will convert the scenarios into impacts
    b. City footprint, the supply chain and city assessment – this task will first develop assessments of the current impacts for each city and its supply chain, using the environmentally extended MRIO database CREAA (Tukker et al. 2013a). To enable this, household consumption and government expenditure data will be collected. The next phase will then utilise information and data from stage 1 above to model the BAU and PC 2050 scenarios. This will involve developing technological coefficients and adjusting the household consumption and government expenditure within different spending categories.

It is only the first stage that is the focus of this report and is described in more detail below. The next report D5.3 will describe the assessment of these scenarios.

4.2 MODELLING AND QUANTIFICATION OF SCENARIOS

The main approach for modelling the scenarios was to build on and utilise the work and data gathered in the previous work packages of the POCACITO project – specifically WP1, WP3 and WP4.

The main stages of the modelling for each city can be summarised as:

1) **Current trends**– developing and understanding the current trends for a set of primarily physical indicators. These are derived from the WP3 assessment and other info;
2) **BAU** – is then projected from the current trends, and where appropriate considers progress made in relevant ongoing and planned projects.
3) **PC 2050** is developed from the qualitative scenarios developed in WP4, and provided in D4.2. Hence translating and expanding the visions, actions and milestones.

However, utilising the previous POCACITO work had its own set of challenges. Firstly, the information and data from the WP3 initial assessments was extremely variable in quality and quantity, and was only collected for a limited range of years. This meant developing trends was difficult without further information. Also, data on energy use and production was not adequate for the modelling. In addition, many of the qualitative scenarios developed in WP4 have limited information and details to enable a quantification of the PC 2050 scenarios. Also the actions and milestones that accompanied these scenarios was limited and had been developed to various degrees of completion and robustness. Therefore to support the modelling and projection additional data and research was required.

In order to model the quantified scenarios a set of "elements" were developed to represent the basic building blocks and foundations of the scenarios. The primary elements were: population, energy, transport, buildings and housing, GDP/economic development, industry sectors and employment.

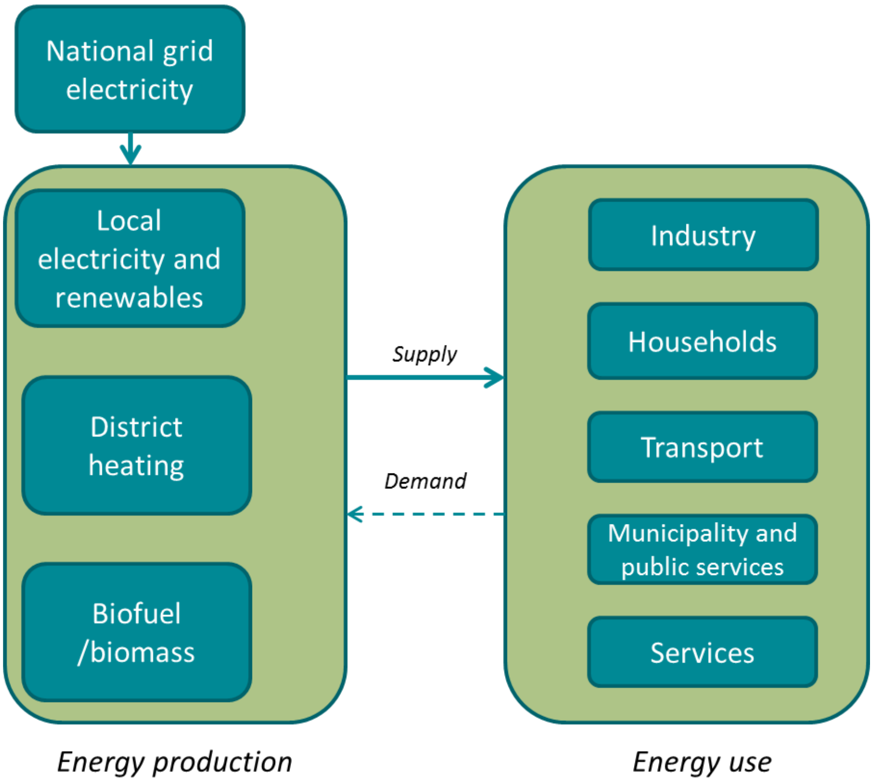
The basic approach is to understand the current and inter-related trends of these elements to understand how this can develop into the different scenarios. Of central importance is how these interrelated elements affect energy production and its use. Figure 11 illustrates the interrelationships between some of the critical energy factors of the modelling. This was also affected by the change in population and development of economic sectors that was projected to occur within the scenarios.

Hence the first task is to summarise the current trends and identify patterns and any discernible trends where possible. This can then be used to project how this might change in each scenario utilising data from various sources.

The modelling approach can be described as quantitative triangulation supported by qualitative information, evidence and research. It should be noted that:

- The degree of complexity varies depending on the level of data available for each city.
- Cities and regions report data in many different forms and in varying levels of detail.
- A separate model was effectively built for each city.

The different modelling stages are described below.



(Source: author's illustration)

Figure 11: Relationships between the different sectors in the model

4.2.1 CURRENT TRENDS

The starting point for developing the current trends for each of the case study cities is the information gathered for the initial assessments in WP3 for the set of indicators.

This data was provided in varying degrees of quality and quantity, and in some cases only available for a single year. Developing trends from these data points is of dubious scientific robustness, unless supported by additional quantitative and/or qualitative information.

Therefore the initial stage was gathering extensive additional quantitative and qualitative data on the city to understand the current situation and trend with the variables.

As mentioned above, as scenarios aim fora post carbon future, it was felt that a larger emphasis on energy production and consumption was needed than provided by the initial assessments (WP3). Obtaining improved data on this and understanding the trends (if possible) was therefore a major focus. This is fundamental in understanding whether post-carbon status can actually be achieved.

4.2.2 MODELLING BAU

The second stage is to construct a BAU scenario based on a projection of current trends, but supported by qualitative analysis. Also of importance are the ongoing projects and policies that may affect the elements being modelled, for example energy efficiency projects and recent achievements. The interaction of these elements must also be considered, for example development of a particular industrial sector may strongly influence the energy use of the city. In many European cities there is a move away from traditional energy intensive industries towards the service industry. In summary, developing projections for BAU is therefore based on following four aspects:

1. Current trends - and their most likely projection.
2. Qualitative factors – how have other factors influenced the current developments and past trends. E.g. has immigration been strong; has there been an exodus from the city centre to surrounding suburbs?
3. Interaction of indicators, how the trends influence one another and evidence of correlation. E.g. has the rise of energy use been in line with a rise in population; or is a decrease due to a move away from energy intensive manufacturing towards the service sector (or due to the economic crisis?)..
4. Current and ongoing policies and projects -for example, many cities have projects and policies, in place or planned, which need to be considered. However, where no evidence of their success or failure existed then it is not sensible or robust to include these as influences on the BAU.

It should be remembered that the main aim is after all to assess the difference between the current path and a new post-carbon path rather than to assess the likely success of freshly implemented projects or policies.

The calculation of the indicators is now discussed in more detail below. These were selected partly from the indicator set of WP3 and integrated with further elements that help to describe the cities basic function. The initial calculations were sent out to the city case study teams for review. In some cases the values were reviewed as there was some question over whether for example the population would increase or decrease. The data was then rechecked and the final values were supported by further explanation or data.

4.2.2.1 POPULATION

Population is the most important trend and fundamentally determines the scale of other aspects.

BAU population is calculated both from an examination of the past trends by the POCACITO team, information from the literature and data and projections obtained from Oxford Economics. Data was obtained from Oxford Economics on household consumption for the EE-MRIO work and included projections on several indicators until 2030. Hence this was used to inform the projections (see Appendix 1).

4.2.2.2 ENERGY

Energy use and its production were reviewed for trends and compared to trends of the other indicators for correlation. For example, is the past change in energy use consistent to population changes, or linked to improvements in energy efficiency or economic changes?

It was desirable to obtain as much specific information on the city energy use as possible, rather than use national based data. This included:

1. Energy production – was reported simply as heating energy, and electricity. But some cities have much better information including: electricity imported, electricity produced in the city, gas, incineration, biofuel, diesel and petrol etc.

2. Energy use – in some cases this was provided in the initial assessment (WP3) but only as a percentage breakdown of aggregated sectors (e.g. industry, service, apartments, houses, transport). Hence, more data was sought to help understand how the energy is being used within the cities, and hence how changes in use and efficiency might affect overall energy use. Data came from literature sources as well as the Covenant of Mayors (covenantofmayors.eu) website and reports. Hence where possible triangulation was used to verify, or improve the calculations.

3. Information on the trends – for some cities energy use by sector was reported from 2003-2011. Additional information, both quantitative and qualitative was required to understand longer term trends and influences.

The key document for providing a background reference scenario for BAU national energy use and production is the reference scenarios developed in the report for the European Commission "*EU Energy, Transport and GHG Emissions. Trends to 2050*" (Capros et al. 2014). This document provides detailed projections for each of the EU 27 countries using the PRIMES modelling software (E3Mlab, 2011). This was used for the electricity grid mix for the BAU scenarios for the case study cities.

The document also provides projections for the expected content of renewable energy (this was only used to predict electricity obtained from the national grid and not the actual mix of renewable energy produced in the cities). In addition, the document provides a reference for changes within each country for other factors related to energy use and production including: transport, production, electricity generation, quantity of energy provided by electricity, thermal generation, energy use by sector and GHG emissions,

4.2.2.3 TRANSPORT

Transport is a significant part of the energy equation and hence understanding the transport trends was critical. The main data from WP3 was on total energy used by the transport sector and the modal share breakdown and trends (available in most cases).

In addition to the modal share, one of the most critical aspects for BAU calculation is the degree of electrification of vehicles in 2050. This is especially crucial for energy use and the comparison with PC2050. Several studies have attempted to provide projections but many are on the national level (EC, 2014; WEC, 2011). SOU (2013) provides more relevant projections for cities following a review of recent literature. As a basic assumption we assumed that 10% of vehicles were propelled by electricity in 2050. This is based on a review of the literature for projections for national levels which project electric propulsion to account for 3-4% (WEC, 2011) and assuming that cities would have a greater share due to shorter trips. Further detail is provided in Annex II.

4.2.2.4 HOUSING AND BUILDINGS

The quality of housing and buildings are also fundamental the energy use and carbon emissions as well as affecting softer elements such as aesthetics. Unfortunately, the data availability for this was quite poor, but in some cases some qualitative information was available. For example, the upgradability of the buildings in terms of energy efficiency could be influenced by the age and historical significance of the buildings.

In general however, limited information was available but in any case the current trends on energy use in the residential sector provided most of the required information to develop the scenarios.

4.2.2.5 GDP

GDP was calculated from the trends provided by WP3 and supplementary data where required. In addition, the data projections obtained from Oxford Economics. GDP values are based on constant 2010 prices.

4.2.2.6 BUSINESS/INDUSTRY MIX AND EMPLOYMENT

Information on the industry mix and employment was highly variable, being very good in some cases, to very sparse in others. Current trends were generally projected to 2050 with some moderation due to expected limits to the trends. For example, in most European cities the service sector has shown strong growth, with manufacturing continuing to decline. However, we can also expect that there is a ceiling to this growth of around 80%. For example, by 2050 it is expected that services will account for 78% of gross added value for the EU (Capros 2014).

4.2.2.7 WATER USE

Data availability on water use was not reported in the WP3 assessment and the scope within WP5 did not facilitate the water use trends. In addition water use was not identified as an issue of major concern by any of the cities in the PCIA work (see Harris, 2015).

4.2.3 MODELLING PC2050

The starting points for modelling PC2050 are the qualitative scenarios developed in WP4 and presented in D4.2. In principle, each element was calculated by considering the current trends and the BAU scenario quantification alongside the visions, actions and milestones. Hence a qualitative judgement was made on what the targets of the scenarios would achieve (e.g. in terms of reduction in greenhouse gas emissions) and whether the actions and milestones were likely to achieve the targets.

The POCACITO document D4.1 (Breil et al. 2014) proposed the Shared Socio-economic Pathways (SSP), produced for the fifth IPCC assessment report, as a reference for outlining the POCACITO background scenario. In this sense, the national projections from SSP with aspects such as the population, urbanisation and economic (GDP) projections are utilised as background information in the development of the city scenarios.

The calculation of the elements for PC2050 is now discussed in more detail below. These were selected partly from the indicator set of WP3 and partly because they are the essential elements that help to describe the cities basic function.

4.2.3.1 POPULATION

The population for PC2050 used the BAU projections as a starting point and then adjusted them based on the projections of SSP for national population growth and the level of urbanisation.

This was performed unless a figure for population was provided in the PC2050 visions as in the case of Malmo. Hence from the SSP scenarios we first calculated the percentage difference in population between the middle of the road (BAU) and sustainability (PC2050) scenarios. This was also performed for the urbanisation. These percentage factors were then applied to the BAU quantity to calculate the PC2050 value.

4.2.3.2 ENERGY

The energy calculation was based on a range of considerations, both quantitative and qualitative. Firstly, the PC2050 vision from the workshops was interpreted on which elements were represented and what the goals and targets were. This was compared alongside the current trends and BAU scenarios, and consideration of the actions and milestones (from the workshops). Hence, the calculation considered how the actions and measures would impact the main energy related elements (i.e. energy use, production, transport, buildings and housing, etc) and how and whether the goals and targets might be reached. Hence a judgement was made on whether the targets could actually be achieved based on the actions and measures but also the current trends and situation of the case study city. For example, it was not enough just to say 100% renewable energy, there also needed to be some associated actions and realistic way identified of achieving this.

4.2.3.3 TRANSPORT

The calculation of the PC 2050 transport was performed in a similar method to the energy. It was based on an examination of the current modal share and energy use of transport trends, against the PC2050 vision, its targets and stated actions. Again it was not enough to say 100% fossil free cars. There needed to also be some method and proposal to support this, such as milestones for electric car charging points and actions such as banning fossil fuel based vehicles in the city.

4.2.3.4 HOUSING AND BUILDINGS

The calculation of housing and buildings was based on a consideration of the current trends (e.g. energy use of housing, residential, service sector – depending on how the individual city categorised and recorded energy use), and the PC2050 visions and actions, such as energy efficiency measures.

4.2.3.5 GDP

In a similar way to the calculation of PC2050 population levels, the GDP was calculated using BAU as a basis. It was then adjusted by a percentage factor found from calculating the difference between the SSP middle of the road and sustainability scenarios.

4.2.3.6 BUSINESS/INDUSTRY MIX AND EMPLOYMENT

The calculation of the PC2050 business and industry profile of the cities took BAU as a starting point and adjusted it based on the PC2050 vision and actions. This mainly occurred if for instance a city had the vision of a localised circular economy, which would increase the prominence of the manufacturing sector to refurbish and remanufacture products.

Employment was generally not calculated and will be included in the quantitative assessment of impacts in the next WP5 deliverable D5.3.

5 RESULTS

The following sections provide the initial quantification results for the BAU and PC 2050 scenarios for each case study city. These contain only the main physical elements and where possible other indicators such as GDP, and not the quantified impacts of the scenarios. Further elaboration will be made in the next task of WP5 where the impacts that result from these scenarios will be quantified.

The main results in this chapter are displayed in tablature form consisting of three columns one each for the current situation, BAU and PC 2050 scenarios. Each section first begins with a qualitative description the BAU and PC 2050 scenarios for each city.

The BAU qualitative description is shorter and less detailed than the PC2050. This is because the BAU description is only intended as an overview of the main points of the results and what is contained in the tables and the assumptions in Appendix 2. A more detailed PC2050 description is provided for the reader to summarise the vision and results of the workshop, which has not been provided in previous POCACITO reports (other than the workshop reports provided in D4.2 –see Nunez Ferrer et al, 2014).

5.1 BARCELONA

5.1.1 BAU

In the BAU 2050 scenario the population of Barcelona municipality has risen only slightly to 1.7 million. Energy use is at a similar level to what it was before the financial crisis. Following a return to growth in GDP after 2014 Barcelona's energy consumption continued to grow again. This growth was countered by energy efficiency policies to a certain extent, but a continuing electrification of society almost cancelled these out. However, energy production has improved with an increase of renewable and local energy sources. Transport efficiency per km has improved due to a shift to electric mobility but transport volumes have risen slightly. An early ambition to attain 100% renewable energy was not met with concerted action and there was a tendency to rely on regional nuclear energy, which still supplies over 50% of the electricity supply.

5.1.2 PC 2050

Barcelona in the PC 2050 scenario is a city that has undergone a remarkable transformation with the majority of buildings being extremely energy efficient and adorned with solar panels. A focus on increasing density and incentives to relocate from the suburbs has increased the population to 2 million inhabitants. Transport energy has declined due to public transport network and electric/hydrogen only transport. A fossil fuel ban on city transport in 2035 saw a shift to predominantly electric mobility.

5.1.3 QUANTIFICATION OF SCENARIOS FOR BARCELONA

The overview of the quantified scenarios is shown in Table 4.

Table 4: Quantification of the main elements of the scenarios for Barcelona

Element	Current	BAU 2050	PC 2050
Population	Province: 5.5 million Metropolitan area: 3.24 million (5,500 per km^2) Municipality: 1.6 million (16,000 per km^2) 18% above 65 years, 16% below 15 year	Population of City remains fairly stable: at 1.7 million Oxford Economics projection on the province level shows slow decline after 2011 from a peak of 5.51 million to 5.314 in 2030. SSP projection for Spain show continued national growth from 46 million (2010) to 52.8 million in 2050	More densification in the centre leads to a population of 2 million. According to IIASA SSP scenarios, compared to BAU, sustainability has 2.9% higher population in Spain and 4% more urbanisation.
Energy	**Energy use (city level)** 16782 GWh Improved energy intensity but energy use has declined almost in line with financial crisis Hence a downward trend seems to be due to falling economic activity. 9% overall energy reduction from 2003 GDP share shifted largely to the service (+14.6 sector from industry (GWh) 2003 2012 Change % Residential 5034 4913 -2.4 Services 4780 4874 1.97 Industry 3797 2990 -21.25 Transport 4683 3833 -18.16 **Energy production** In 2008, renewables including waste make up 291.53 GWh, or 1.7% of the total.	**Energy use** 18,000 GWh Consumption has risen steadily since 1994 until 2005. The energy use by sector is: Residential 27% Services 27% Industry 20% Transport 26% **Energy production** Local renewable energy production of energy has risen to 2.6%. Electricity use rises to 52.5%. Energy consumption by energy source is as follows: **Source** **%** Electricity 52.5 Natural gas 25 Diesel 14 Petrol 7 LPG 1 nat gas (auto) 0.5	**Energy use** 13,600 GWh With all buildings renovated the energy efficiency greatly increases. Demand for space heating and cooling decreases significantly, and the energy use in residential and services declines by 40%. Transport energy declines due to public transport network and electric/hydrogen only transport. Residential 26% Services 25% Industry 25% Transport 24% **Energy production** Solar energy and other renewables provide 65% of the electricity. **Source** **%** Electricity 80

Element	Current	BAU 2050	PC 2050
	According to the Energy and climate plan: electricity share has increased from 37.2% to 44.3% (1999-2008) **Projects:** Strategy to reduce CO2 emissions Energy, climate change and environmental quality plan (2011) - push for solar thermal	National electricity mix, shifting to primarily wind, solar and gas: 2010 / 2050 Nuclear energy: 20.70% / 14.80% Solids: 8.50% / 3.50% Oil: 5.50% / 0.10% Gas: 32.50% / 22.00% Biomass/waste: 1.60% / 3.90% Hydro: 14.10% / 9.00% Wind: 14.70% / 32.10% Solar: 2.10% / 14.30% Geo & other: 0.20% / 0.30%	Natural gas 8 Diesel 0 Petrol 0 LPG 1 Bio-mass and fuels 10 Hydrogen 1 **Actions and milestones** Renewable energy self sufficiency Smart grid with 80% renewables by 2025 – is not seen as achievable in the POCACITO modelling
Transport	From 2004 to 2014 Public transport: 34.9% to 39.7% Private: 33.3% to 26.1% Walk and cycle: 31.7% to 34.1%	**Transport balance:** Public: 42% Private: 23% Walk and cycle: 35% Private transport decline has slowed and is expected to remain relatively the same. Public transport has also seen a decline in recent years. Electric cars and other non-fossil fuels represent 10% of the total. **Projects:** Electric mobility New bus network	**Transport balance:** Public transport: 50% Private: 12% Walking and cycling: 38% Electric, biofuels and hydrogen transport greatly increases from 2025. In 2035 there is no fossil fuels transport within the city. Electric cars are dominant as private transport, whilst public transport use increases markedly **Actions and milestones** Public transport needs to be efficient, accessible and clean. Radial design and in the form of a net to increase connect-ability. By 2035 no fossil fuel transport in the city, due to new law, phased in since 2025

Element	Current	BAU 2050	PC 2050
Housing	Dense city		All buildings renovated and energy efficient
Building	279,998 energy efficiency certificates, but only published in 2013		All buildings renovated and energy efficient With all buildings renovated the energy efficiency greatly increases. Demand for space heating and cooling decreases significantly, and the energy use in residential and services declines by 40%.
Water use	Water use reduced 2001 to 2014 129.6 to 101.1 L/cap/day	Potential further reductions to 2050 possible	Not discussed
Food and Consumption	No data	No data	Not considered
Air quality	Reduction in number of days of exceeding limits by 89.9%	Projects: SIIUR project No exceedances expected by 2050	No exceedances expected by 2050
Waste	From 2003 to 2014 1.44-1.26 kg/person and day	BAU = 0.81 kg Goals of the “Pla de prevencio de residus 2012 – 2020” of Barcelona is to reduce waste generation per capita 10% by 2018 (as compared to the reference year, 2006). This goal is already achieved.	All waste treated and recycled
Economic			
GDP	2003- 2012 Growth from 55,707 to 60,540 EUR 35,191 to 37, 347 GDP/capita (EUR)	68,537 GDP/capita (EUR) Continuing Oxford Economics projections for Barcelona Province, GDP rises from 26,177 EUR in 2012 to 48,039 EUR in 2050. (83.5% increase). The figure is then adjusted by the same % difference as currently exists between the Province and the city.	73,952 GDP/capita (EUR) According to IIASA the sustainability scenario has 7.9% higher GDP/capita.
Business/Industry mix	Growth rate of 8% whilst service sector grew by 24.6%, industry declined 20% Further shift from industry to service (2003-12) Agriculture: 1.28 to 0.93% Industry: 34.4 to 25.5% Services: 64.3 to 73.8%	Continued growth of the service sector, with some recovery of industry, until service industry represents 80%.	Large SME presence in the city – proximity shops and services preserved. Increased training and support for businesses and entrepreneurs.

Element	Current	BAU 2050	PC 2050
Employment	Large increase in unemployment		

5.2 COPENHAGEN

5.2.1 BAU

In the Copenhagen BAU scenario the population has continued to increase and the dense city centre now has a population of 838,000. The housing and buildings are all heated through district heating which is fuelled almost entirely by biomass. The biomass is combusted in combined heat and power plants which also supply more than a third of the electricity. The remainder being supplied by wind energy, with an excess of electricity being supplied to the grid, whilst some is stored in storage facilities for peak loads. Transport are the only major emissions of the city and is still dominated by private cars, although cycling is a close second,.

5.2.2 PC 2050[2]

The Copenhagen visions '*Eco-Metropolis Copenhagen*' and '*CPH CO2 Neutral by 2025*' imagines the City of Copenhagen to be CO2-neutral by 2025 and be the most sustainable capital in the world. The vision is of a strong metropolitan area where sustainable urbanism is integrated into all urban areas and policies. The population growth is addressed through increased density rather than sprawl, opening new options for low-carbon urban design and transport. In PC2050, the quality of life is central and is promoted by nurturing blue and green spaces, low carbon mobility, safe neighbourhoods, sustainable built infrastructure, smart technology and novel forms of participation that jointly invite citizens to have active urban lives and shared activities in city spaces. Copenhagen is also a regional city, with strong networks to adjacent cities on Zealand and in Scandinavia, in particular Malmo.

This encourages and underpins innovative approaches to business and urban policy, and helps build a strong cohesion of local communities, promotes safe and amiable daily lives through e.g. reduced crime, flood proofing and enhanced traffic safety, and enhances the health of diverse population groups in the city. Copenhagen's location by the coast and the harbour areas provides recreational areas for the citizens, tourists and businesses. Moreover, this approach fosters Copenhagen to be a people friendly, active, knowledge based, vibrant and green city. Equally, sustainable urbanism is integrated in green growth and Copenhagen at the global scene demonstrates how being a sustainable and low-carbon city is good business.

The city's growth is addressed through environmental and energy efficient solutions, whilst promoting a safer and more efficient public transport system. Mobility increases for the labour force and business. This together with the high liveability of the city encourages international businesses to locate in Copenhagen, to take advantage of the city's high level of education, calm conditions and well-connected international networks.

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[2] It should be noted that a workshop was not held for the Copenhagen study and the PC2050 scenario is therefore based on an interpretation of current visions and plans extended to 2050.

5.2.2.1 URBAN DESIGN, URBAN NATURE AND BUILT ENVIRONMENT

Copenhagen is designed for people and different cultures, and the city hosts its new citizens and has more housing for people with different dwelling preferences. Use of land and built environment is highly sustainable, with green and recreational areas mixed with multifunctional use of public buildings and redevelopment of former industrial areas. The citizens of Copenhagen together with the City of Copenhagen have shared responsibility for maintenance of green spaces and increased temporary use of spaces. Climate proofing Copenhagen protects the city against flooding and adds to liveability of public and private spaces.

The city has coherent urban areas where new and old neighbourhoods are integrated. A special focus on areas with many social problems and social cohesion is supported through socially balanced neighbourhoods, location of education and public services in residential areas and extended multi-modal transport infrastructure

5.2.2.2 URBAN LIFE

Liveability is high and diverse in Copenhagen which attracts families, a skilled work force, students and different cultures. Urban green/blue spaces are integrated into urban areas, meaning that the short distance from residences stimulates active travel modes such as walking, running and cycling. Public spaces and buildings are used flexibly and for multiple functions. Citizen and stakeholder participation is leading to increased ownership and community cohesion.

Copenhagen is widely known globally and regionally as an example for urban climate adaptation that generates benefits for the city and citizens. The greener and healthy environment for Copenhageners prompts reduced social inequality in health across urban neighbourhoods, where especially vulnerable children benefit.

5.2.2.3 TRANSPORT

Urban transport in Copenhagen is sustainable and public transport is CO2 neutral. Cycling, walking and public transport are widespread in everyday transport. Cars and busses are electrical and add to pleasant and accessible urban environments for all. The city's design motivates cycling and walking and the cycle network is safe, pleasant and integrated with the public transport system.

The dense city enables good public transport. Smart transport systems supported by ICT monitoring reduces emissions and energy use and prevent congestion on roads as well as cycle tracks. Road transport is regulated through a congestion scheme, while cycle infrastructures and public transport are extended, convenient and of high quality. The city centre is calmed due to the traffic tunnels directing road transport away from streetscapes. Transport networks also support Copenhagen as a strong player in city-regional development, and connect the city to the region, including Malmo, Europe and CPH Airport.

5.2.2.4 ENERGY

In 2050, Copenhagen is CO2-neutral and the green transition of the city's energy production is complete. Energy consumption is heavily reduced and green mobility dominates and prompts continued green and integrated innovations in energy and transport. Existing housing has been renovated to be energy efficient and Copenhagen's energy system has been transformed to be primarily based on renewable energy, e.g. wind energy, solar panels and energy storage. Copenhagen exports sustainable and/or renewable energy solutions.

5.2.2.5 INDUSTRY AND BUSINESS

Copenhagen's businesses are central to the green growth of the city. Businesses take advantage of the high level of education and the high quality of life in Copenhagen attracts people and businesses. The innovative business environment is sustained by collaborative networks with participation of businesses, private partners and leading R&D milieus for future sustainable solutions. The regional position as an international hub and metropolitan city provides critical labour. Green growth happens without increased pressure on the environment, but with increased demand for new technology in energy and environment.

5.2.2.6 WASTE

Nearly all resources are recycled and the least possible volume is led to incineration. Generation of waste is reduced through direct reuse, less wastage, and by supporting the development of cleaner products through partnerships with industry and waste management companies. Source separation takes place at all public institutions and all homes have access to separation of the most ordinary types of waste nearby. Waste is collected in a sustainable manner with 100 % of the city's collection vehicles fuelled with electricity or bio fuels.

5.2.3 QUANTIFICATION OF SCENARIOS FOR COPENHAGEN

The overview of the quantified scenarios is shown in Table 5.

Table 5: Quantification of the main elements of the scenario's for Copenhagen

Element	Current	BAU 2050	PC 2050
Population	11.4 % increase of the population in Copenhagen, from 502,362 inhabitants in 2005 to 559,440 in 2013 100,000 more by 2025	838,000 Following a yearly growth rate of 1.05%. Oxford Economics also has a similar growth rate for Byen Copenhagen.	866,000 According to IIASA SSP data the population in the sustainability scenario is about 3.3% more. With the urbanisation rate being the same 91% in both.
Energy/renewable mix etc	**Energy Use** Total 9,569 GWh (2013) Share of electricity 2287 GWh and heating 4482 GWh Transport estimated at: 2800 GWh By sector for share of electricity and heating Public institutions – 21.1% and 7.9% Private households – 28.7% and 66.8% Trade and services – 41.3% and 21.9% Industry- 6.6% and 3.3% Building and construction – 2.2 % and 0% Electricity use per capita in households has declined by 14.6% in 6 years (2008 -2013). Whereas heating has fluctuated but remained fairly constant overall. **Energy Production** Data and information do not clearly indicate how energy is supplied in Copenhagen. In the City 97% of heating is supplied by the district heating network which is powered by a combined heat and power plant, fed by waste and fossil fuels. The fuel source will convert to biomass, but will still use oil and gas at peak times. The aim is that renewable energy production will by 2025 compensate for any fossil fuels from traffic, wastewater management and industrial processes Renewable share of district heating was almost 50%	**Energy Use** Total: 11,665 GWh Assuming that there is an increase of energy needed for the growing population. New housing is needed as well as an increase in energy in services due to increased employment. Carbon neutral district heating through use of biomass. Biogas to be investigated. Sector – GWh – % Public institutions – 1006.8 – 8.6% private households – 4565 – 39.1% Trade and services – 2313.6 – 19.8% Industry – 360 – 3.1% Building and construction – 60 – 0.5% Transport – 3360 – 28.8% **Total** – **11665.4** **Energy Production** Insufficient data available But the trend is fairly clear that all electricity should be generated by wind and biomass (via CHP systems, combined with the district heating).	**Energy Use** 11,665 GWh It should be noted that a workshop was not held for the Copenhagen study and the PC2050 scenario is therefore based on an interpretation of current visions and plans extended to 2050. We therefore assume that the energy use is the same as for the BAU scenario, with reduced energy for the transport, due to an increased move to electric vehicles. It is likely that the district heating will be continued and extended. **Energy Production** It can be expected that further renewable energy is added.

Element	Current	BAU 2050	PC 2050
	in 2010. In 2005, electricity supply came from: • Fossil fuels – 73% • Wind – 13% • Biofuels – 9% • Waste – 5%	Transport however represents a potential pitfall, with cars representing 31% of the modal balance. **Projects** Wind turbines are part of Copenhagen's goal to install 360 megawatt from 100 wind turbines by 2025. Wind turbines are one of the largest contributors to achieving CO2 neutrality by 2025. This will produce around 1150 GWh of electricity	
GHG	Carbon emission intensity reduced from 4.69 to 3.35 t/cap, from 2005-2013 (29% reduction) The total reduction in the period 2005 to 2014 is calculated at 31%. This is realized in spite of a population growth of 14% in the same period. Although if 2013 figures are used the reduction is only 20.6%. This took place within a 11.4% population increase. Total (kton CO_2): 2358 (2005) to 1874 (2012) Change (kton CO_2 2005 to 2012: • Work machines and tools: 50 - 74 • Industry and energy: 734 - 1158 • Road transport: 489 - 348 • Transport: 45.6 – 25.3	Expected continued decrease in overall emissions. This to be calculated in next project task. Emissions in 2025 are expected to still be 400,000 tCO_2 which accounts for the traffic. But this will be offset	To be calculated in the next phase of the project.
Transport	For work and study, bicycling has increased from 32% to 36%. For all trips cars are 33%, cycle 26%, bus, train 21% and walking 20% (2011) Vehicle traffic rose 16.9% since 1990. But has dropped from 2007.	Transport will continue to be shifted to electric, hybrid and some hydrogen powered vehicles. Light rail and metro lines will form a small share of transport, reducing car use. Predicted model share is therefore: Cars 31%, cycle 26%, bus and train 23, walking 20%	Due to fossil fuel cars being banned in the city, the use of public transport increases and electric cars compete with cycling as the next popular form of transport.
Building and buildings	By 2025 6.8 million m^2 of new buildings 100,000 new residents and 20,000 jobs Plans to make existing buildings more efficient. Reduction of 84,000 tons of CO2 per year	Goals for 2025 • 20 % reduction in heat consumption. • 20 % reduction of electricity consumption in commercial and service companies. • 10 % reduction of electricity consumption in	Assumed the same as BAU

Element	Current	BAU 2050	PC 2050
		households. • Installation of solar cells corresponding to 1 % of electricity consumption in 2025.	
Water use	No data	No data	No data
Food and Consumption	No data	No data	No data
Air quality	Challenges with NO2 which is 50-56 µg/m3 compared to EU limit of 40.	No exceedances expected	No exceedances expected
Waste	Reduced from 1.77 t/cap to 1.56 t/cap from 2007 to 2010. Recycling increased from 55% to 58% (2006-2012) Incineration 41% to 37% (2006-2012) General trend is that there is very little variation in recycling over the past ten years or so.		Not discussed
Economic			
GDP	GDP/cap 2003 to 2013 (EUR) Capitol Region – 42,000 to 56,000 Municipality – 49,000 to 63,000 GDP by sector for Denmark (CIA World Factbook): • agriculture: 1.5% • industry: 21.7% • services: 76.8% (2013 estimate)	GDP/cap = 100,000 Euro According to Oxford Economics Copenhagen returns to a steady growth in GDP until 2030 after 2015 of 1.7-1.8% per year. Extending this trend until 2050 gives a GDP/capita of 100,000 Euro.	GDP/cap = 103,000 Euro According to IIASA SSP sustainability scenario GDP is 3.2% higher than business as usual.
Business/industry mix	(From Wiki) Service based economy, with focus on research and development within biotechnology and life science sectors. Medicon Valley is being developed as a central sector across the Öresund region, supported by Sweden. Transport, communications, trade and finance are the biggest employers.	In BAU Copenhagen continues as a service based economy with a strong research industry.	In PC 2050 Copenhagen continues as a service based economy with a strong research industry.
Employment	Less than 10,000 in manufacturing Public sector including education and healthcare employ 110,000 Biggest growth in the 2009 to 2013 period was in hotels and restaurants (21.9%), education (13.5%), research and development (9.3%) and consultancy	Manufacturing continues to be a small employer.	Assumed the same as BAU

Element	Current	BAU 2050	PC 2050
	(9.2%). Biggest losers were building and construction (-14.9%), transport (-13.1%), and telecommunications (-9.8%)		

5.3 ISTANBUL

5.3.1 BAU

In the 2050 BAU scenario Istanbul is a mega-city with a population of 19.8 million. Since 2010 energy use has more than doubled and electricity use continued to grow exponentially as more consumers came online. Congestion is still a challenge in Istanbul despite several infrastructure projects.

Many housing and building projects were developed with poor standards of energy efficiency, which remains a legacy of a pre-2030 unrestricted construction boom. Despite ongoing renovations and retrofitting, overall energy use remains high. Unemployment has remained fairly high at 10% due in part to a continued influx of new residents.

5.3.2 PC 2050

Istanbul 2050 is: *"A dynamic, innovative, self-sufficient, sustainable city having high level of life quality and good governance that able to compete at the global level".* Listed below for each thematic area identified in the vision workshop are the desired endpoints, obstacles, opportunities, milestones, interim objectives and actions, and actors.

5.3.2.1 QUALITY OF LIFE

In 2050, Istanbul is among the international top 10 for quality of life indexes; has a low crime rate, with effective usage of waterfronts. There has been an increased quality of inner and outer space through urban renewal and transformation movement.

5.3.2.2 GOVERNANCE

There is increased coordination between central and local governments; participation of citizens in all processes. The city has adapted well to EU adaptation process and there is active involvement of NGOs in rising awareness of citizens and increasing transparency and major technological improvements (simulations, technical support systems etc.)

5.3.2.3 ENVIRONMENT AND NATURAL RESOURCES

Green buildings are commonplace within the city and there is integration of built and natural environment, thereby protecting ecologically and biologically important areas. EU environmental policies have been adopted protecting natural resources Agriculture is ecologic and all forested areas are protected. The water supply and wastewater are managed in a sustainable way.

5.3.2.4 ENERGY

Renewable technology is the foundation for transportation, buildings and industry, resulting in an energy efficient society moving towards zero CO_2 emissions. The use of solar panels on buildings and hybrid and electric cars are common.

5.3.2.5 GLOBAL COMPETITIVENESS

Industry and services have a focus on global competitiveness. Istanbul fully utilises the opportunities provided by the urban renewal/transformation movement; democratic and economic potential; EU adaptation process; and young population and qualified employees.

5.3.3 QUANTIFICATION OF SCENARIOS FOR ISTANBUL

The overview of the quantified scenarios is shown in Table 6.

Table 6: Quantification of the main elements of the scenario's for Istanbul

Element	Current	BAU 2050	PC 2050
Physical Elements			
Population	About 13.9 million (18.3% of Turkey's population). +1.7% per year. Population increase and immigration are key issues according to the case study report. High density of population: 2666 inhabitants/km^2	19.8 million According to Oxford Economics the population growth will drop to just under 0.9% by 2022 and then continue fairly steady until 2030. Continuing this projection until 2050 gives 19.8 million.	18.9 million IIASA projections for the sustainability scenario show Turkey's population at 8.9% lower than BAU. The urbanisation data however is 4.9% higher, meaning the difference between PC and BAU is 4.5% lower
Energy	**Energy use (based on national data)** 155,700 GWh (2010) Unknown mix and total amount. Toe/euro decreased by 13% in 2008-2012. Probably increasing in total numbers due to increase in population and GDP. Energy by sector for Turkey was: Turkey: 2003 / 2008 Industry: 33.0% / 32.0% Services+ Residential: 24.0% / 36.0% Transports: 16.0% / 20.0% Agriculture: 4.0% / 7.0% Others: 23.0% / 5.0% Electricity consumption in Istanbul was reported to be greatly increasing in 2013 to: 36,800 GWh (estimated at 21% of total)	**Energy use** 347,800 GWh **Istanbul: 2050** Industry: 23% Services+ Residential: 50% Transports: 25% Others: 2% Electricity 30%	**Energy use** 224,000 GWh **Istanbul: 2050** Industry: 29% Services+ Residential: 47% Transports: 23% Others: 1% Electricity 50% **Actions, milestones and targets** 70% clean energy in industry Energy efficient urban development Self-production in urban development

Transport	54% sustainable transport. Trends unknown. Congestion is identified as a major problem. Major investments in public transport may be needed due to increasing population. Projects: - Improvement in public transport and popularization of usage: increasing the ratio of railway systems - Airport carbon accreditation – 4.6% decrease in total carbon emissions	Better data needed to make a BAU scenario	Unlikely to be completely CO2 free transportation. Although potentially strong electrification could occur. **Actions, milestones and targets** CO2 free transportation
Housing and building	Urban renewal is ongoing in Istanbul: old and risky buildings are being rebuilt. Data is missing on energy performance of existing and new buildings. Unknown for how much time new buildings are built to last.	Better data needed to make a BAU scenario	Energy efficient urban development Self-production in urban development
Water use	Challenges in maintaining water quality, with illegal construction near reservoirs.	Increased water use due to population and affluence, is expected to put a strain on local supplies.	Overall water use and management has greatly improved with high quality sewage treatment and recovery of water.
Food and Consumption	No data. Low GDP per capita compared to the other cities. GDP and standard of living increasing.	Increase due to assumed continued GDP growth.	Not discussed in vision.
Air quality	Improvement in NO2, no difference in PM10 (2010-2012). No data on source of pollutants.	Expected exceedances of air quality thresholds	Much improved air quality with rare exceedances
Waste	Waste amounts increasing. Low rate of waste recovery (2.6% 2011). Unknown amount per capita.	Continued increase due to assumed continued GDP growth	Not greatly discussed in vision. Waste management will be well organised, but levels of recycling are still low compared to European standards.
Economic			
GDP	9922 Euro per capita (2008)	24,300 Euro/capita Extending trend forecast provided by Oxford Economics model.	29,200 Euro/capita According to IIASA SSP scenarios the sustainability scenario is 20% higher in GDP.
Business/industry mix and employment	829 119 companies in Istanbul. Services dominant sector (73.1%), followed by industry (26.7%) and agriculture (0.2%). Unemployment rate is 11.3%	Services remain the major driving force of the economy. Unemployment is still high at around 10%	Services account for nearly 80% of the GDP, and unemployment has fallen

5.4 LISBON

5.4.1 BAU

In 2050 BAU the population of Lisbon has continued to decline and there are now 526,000 residents in the municipality, whilst greater Lisbon has also declined from 2.02 million in 2014 to 1.96 million. Energy use has increased only marginally and is still dominated by the transport and service sectors.

5.4.2 PC 2050

Lisbon 2050 is a carbon neutral smart city with more people, more jobs and an excellent quality of life. It is an attractive, creative, sustainable and start-up city with 585,000 inhabitants (municipality).

It is a city growing in density and increasing energy productivity. The total energy use has decreased considerably due to 50% of vehicles being electric and, improved building efficiency by 30% in the services and residential sectors. Electric vehicles account for about 50% of the motor transport, but oil is still widely used and accounts for 28% of the final energy demand.

5.4.2.1 ECONOMY

Lisbon is a city open to the world and a European Atlantic Hub, in close relation with Latin American, African and Asian countries and regions. Allowing access to 750 million consumers from Europe and Portuguese-speaking countries, Lisbon has been attracting companies wishing to manage and prepare its exports or investment ventures in these markets. The capital has also been the place for the location of Competence and Research Centres of multinational companies and high value shared services centres. In fact, Lisbon can guarantee human resources with availability, qualifications, flexibility, creativity and multilingual skills.

Moreover, Lisbon has been attracting students, talents, entrepreneurs and businesses, due to a strong entrepreneurship policy, namely the creation of incubators, co-working spaces and fab labs and launching of incentive programs (funding, contests, coaching, etc.). For example, a fab lab is installed in each city neighbourhood.

Lisbon is an important economic and financial hub, the services sector being the predominant sector (about 80%) and the one that holds the largest share of GVA. Key urban clusters are ICT, web and mobile, creative industries, maritime economy, tourism and health and wellbeing.

5.4.2.2 TRANSPORT

Sustainable transport is the main transport mode in Lisbon (but it was impossible to achieve a share of 100%). Electric mobility is very important for the city, being adopted by the municipality, service operators' and companies' fleets. The use of driverless cars is also a reality (the use of 6 million autonomous cars is foreseen in Europe in 2030).

Shared mobility increased exponentially and the biking lane network encourages biking for all citizens, both for work and leisure purposes.

On-demand mobility organises urban transport around user needs and offers new service solutions in the city. Furthermore, electric cargo bikes are facilitating micro-logistics in Lisbon and surroundings.

Cars have been forbidden in the historic city centre, contributing to reductions in carbon emissions and improving air quality, and providing pedestrian areas and shared public spaces to the citizens.

An Integrated Operations Centre has been created, providing real-time information on traffic (and other areas such as civil protection) to the city authority, services' operators and citizens. The objective is to support decision-making processes and anticipate urban disasters.

5.4.2.3 ENERGY AND AIR QUALITY

Almost 100% of the city's energy comes from renewable energy. Thermal and solar PV systems have been installed in buildings all over the city, potential that was identified by the "Lisbon Solar Potential Map". Public lighting is totally controlled by intelligent systems and LED.

A smart grids project was implemented in Lisbon allowing a two way energy flow where many users supply the grid at high demand times through electric cars and renewable energy production.

Air quality has been improved in Lisbon's downtown, but not as much as desirable. A monitoring centre was installed in order to collect real-time information on air quality and to produce knowledge oriented to support decision-making processes.

5.4.2.4 BUILDINGS AND URBAN REGENERATION

Several smart and green neighbourhoods have been created in the city centre. The pilot initiative was the rehabilitation of the downtown area supported by the European lighthouse project "Sharing Cities" 2016-2020 (in partnership with London and Milan). The zone was completely renewed in terms of sustainable mobility, energy efficiency and urban rehabilitation. In this context, urban districts are generating more energy than they need without additional costs, and new decentralised energy grids have been established.

For new constructions, the share of 100% Nearly-Zero Energy Buildings (NZEB) has been achieved, contributing to promoting energy efficiency and carbon emissions' reduction. Energy management systems are implemented in several buildings, as well as other smart technologies and solutions (integration with electric vehicles, intelligent water and waste management, remote control of basic functions, etc.).

Green roofs are installed in some buildings such as public buildings, industry and retail, supplying residents daily with fresh vegetables and other food. Urban agriculture has increased, as well as small farms and micro-producers.

5.4.2.5 INCLUSION AND PARTICIPATION

Lisbon is promoting itself as a healthy and age friendly city, providing adequate facilities for elderly people, such as ICT home care and telemedicine. Technology is also used to support emergency management systems and to prevent and fight criminality and natural disasters.

Open governance is a characteristic of Lisbon. Several instruments are at the disposal of citizens to promote their involvement in the resolution of urban problems and in the definition of the city's future (participatory budget, digital platforms, etc.).

Sharing economy is growing in different areas, such as working, housing and transport. Information and communication technologies and social networks are supporting this movement.

Migrants and refugees are socially integrated in urban daily life, Lisbon being characterized by cultural diversity.

5.4.3 QUANTIFICATION OF SCENARIOS FOR LISBON

The overview of the quantified scenarios is shown in Table 7.

Table 7: Quantification of the main elements of the scenario's for Lisbon

Element	Current	BAU 2050	PC 2050
Population	547,733 (2 000 000 in Greater Lisbon) Aging population Large influx of commuters	526,000 For greater Lisbon, Oxford Economics predicts a peak of 2.02m in 2014, declining to 1.96m in 2030. For BAU we assume that the population declines to 2030 by 4% and has a similar value in 2050. The IIASA SSP scenarios predict an increase in population for Portugal from 10.7 (2010) to 11.3 in 2050, with urbanisation rising from 61% to 77%.	585,000 The IIASA SSP scenarios predict an increase in population for Portugal from 10.7 (2010) to 11.6 in 2050, with urbanisation rising from 61% to 85%. Population is 3% higher and urbanisation is 8% more. Therefore PC2050 is 11% higher than BAU – in the absence of particular goals and policies to increase the density of the city and encourage a population return from the suburbs.
Energy/renewable mix etc	**Energy use** 10786 GWh (2012) City of Lisbon (12% increase from 2008 (9638) Greater Lisbon (2003-2012) 27200 – 28400 GWh 0.68 – 0.62 GWh/MEUR +4.3% in total numbers, -9.9% in GWh/Euro Energy use increasing in three sectors. No change in services, residential use decreased. Variation rate/current trend (2008-2012): (blank) / 2008 / 2012 / (blank) Transport / 4535.553 / 5688.13 / +25% Services / 3353.519 / 3368.751 / 0% Residential / 1448.439 / 1295.844 / -11% Industry / 258.3683 / 376.8028 / +46% Agriculture / 42.504 / 56.01457 / +32% **Total** / **9638** / **10786** /	**Energy use** 10,869 GWh (935 ktoe) Sector distribution: Transport 53.3% Services 30.5% Residential 12.0% Industry 3.6% Agriculture 0.5% This is calculated by applying the national trends to each sector from 2010 to 2050 in EC Energy Trends (2014), and then adjusting for population decline of 4%, applied to residential and transport sectors. From 2008 to 2012 energy consumption increased by 12%, whilst the population increased by 8.4%. Despite limited data we assume a correlation between energy and population for the BAU scenario. Several assumptions are required, due to limited data: • although industry has increased dramatically	**Energy use** 6795 GWh Total energy use has decreased considerably due to 50% of vehicles being electric and, improved building efficient in services and residential by 30%. The sector energy mix is as follows: Transport 46.9% Services 34.2% Residential 13.5% Industry 4.6% Agriculture 0.8% Electricity is 60% of the final energy demand, but oil still accounts for 28%. **Actions and milestones** (workshop): - Solar panels in 90% of the buildings stock - smart grids - intelligent public lighting

Element	Current	BAU 2050	PC 2050
	Projects and targets: Lisbon solar potential map -20% CO2 emissions until 2020 (target)	since 2004 the energy use increased by 3.6% in line with the EU trends projections for Portugal (EC 2014) • The other sectors are also modelled based on the EU trends projections: transport 5%; services -1.5%; residential 4.1%. Electricity use increases by 29.5%, meaning it is predicted to be 36% of the total energy consumption. Renewables account for 44.3% of final energy demand. (following national projections).	-increase bike lanes, and bike share scheme - tolls for entering city centre - cars banned in historic centre.
Transport	The transport sector represents the largest share of energy consumption and has a huge responsibility in terms of air pollutant emissions and urban noise. Several initiatives have been launched by the Lisbon City Council in the area of sustainable mobility (such as electric mobility, car-sharing, bicycle lanes, improvement of public transport, etc.), but the share of sustainable transportation has been decreasing. **The most important projects that are being carried out to improve sustainable mobility are:** • Electric mobility program • Mob carsharing • Bicycle lane network • ZER – Reduced emissions areas	The projected transport mix in 2050 under BAU is: Car 44% Motorcycle 1% Public Transport (Bus+Metro) 33% Train 2% Bicycles 1% Walking 18% Other 1% Although there is only limited data and trends available, the projection is based on the following observations and information:: • population moving from the city to the suburbs • several projects are already aimed at increasing sustainable transport modes and have only recently begun; hence it is too early to assess the effects of these. However, we assume here a positive influence.	Electric mobility has increased to 50% greatly improving the total efficiency of the transport. However, the transport modes share is similar to the BAU. **Actions and milestones** (workshop): No car traffic in historic city centre Encourage walking and cycling. Sharing car, bikes and car pooling Electric cars are well supported - Use of virtual technologies to avoid travel - Use of autonomous cars (6 million autonomous cars in Europe in 2030)
Housing	6,247.5 inhabitants /km^2 Declining density due to movement to suburbs	The main national targets related to housing policies are: • Total eradication of family households without health and comfort conditions (National Housing Strategy 2011-2031); • Increase the number of leases in historic centres by 25% by 2030 (National Commitment to Green Growth 2020-2030).	Due to limited data the assumptions used to design the desired 2050 housing scenario include: • Continuous development of pilot projects centred on neighbourhoods' rehabilitation in historic zones of the city;

Element	Current	BAU 2050	PC 2050
			• Surpass the 25% target of leases in historic centres defined for 2030; • Creation of new spatial management mechanisms to force lease and building permits in historic or deprived city areas, thereby contributing to urban regeneration and renewal.
Building	Limited data.	Urban rehabilitation of 7000 buildings until 2014	Energy efficient and smart buildings, including net zero energy buildings. **Actions and milestones (workshop):** - 100% of NZEB – Nearly net zero energy buildings - 30% of buildings with green roofs
Water use	No data	Not enough data to make BAU scenario	Not considered.
Food and Consumption	No data		Not considered.
Air quality	Significant improvement 2003-2012	Occasional exceedance of thresholds	No exceedances of thresholds expected.
Waste	No data	The main political commitments to improve waste management fix the national and municipal targets for 2015 and 2020	Considering the mentioned aspects, the main actions identified in visioning waste management scenario for 2050 are: • Achieve lower amounts of waste production per inhabitant; • Surpass the recycling and energy recovery waste rates expected for 2020; • Launching alert systems oriented to inform citizens about the increasing rates of waste production; • Release new technologies to support citizens on waste production control.
Economic			
GDP	About 48,000 MEUR – 52,000 MEUR (2004-2012; maximum in 2008-2010) for Greater Lisbon. Increased from 18,400 to 19,500 Euro/cap (2004-12). Represents 31% of national GDP	41664 Eur/cap Total GDP: 78,010 MEUR	44580 Euro/cap Total GDP: 85,811 MEUR

Element	Current	BAU 2050	PC 2050
	(Greater Lisbon 2011). By sector (2003-2012): Industry: 17 -14% Services: 83-86% Agriculture: 0.21 -0-20% GVA Greater Lisbon 37,635 MEUR (2010) GVA Lisbon Municipality 22,745 MEUR (2010) 25.8% of country's GVA	Oxford Economics projections shows the GDP of Greater Lisbon recovering in 2014 to a positive trend through to 2030. Extending this same trend until 2050 gives a GDP of: 78,010 MEUR. Per capita is found by extending the trends from 2030 given by Oxford Economics for population and GDP: 41664 Eur/cap Projected by sector: Industry: 9.8% Services: 90% Agriculture: 0.20% The National Commitment to Green Growth 2020-2030 establishes some targets in the area of green economy: Increase green GDP by 5%/year; Increase green sectors' exports by 5%/year	The IIASA SSP projections show that the GDP for Portugal is 10% higher for the sustainability scenario, and 7% higher per capita. Projected by sector: Industry: 14% Services: 85% Agriculture: 1% Increase in industry compared to BAU due to circular economy.
Business /industry mix	Main city is home to 96 731 companies (8.7% of national share). Services 86% of GDP and increasing Projects: Stimulate the "creative economy" in Lisbon until 2020. Startup Lisboa Fab lab Lisboa Co-working spaces	Being a major hub for GDP, location of agriculture may be assumed to be elsewhere	Services expected to dominate providing 85% of the GDP.
Employment	Employment 2003-2011: About 1 190 000 – 1 190 000 (peak in 2008 of about 1 230 000 people employed in Greater Lisbon) Main city: about 600,000 employed	No trends available to make a BAU scenario. High-level political decisions and trends (e.g. automation, jobs moving to low-income regions) may have a large impact	High employment

5.5 LITOMĚŘICE

5.5.1 BAU

In the BAU 2050 scenario Litoměřice declines slightly in population to 23,500. A geothermal plant supplies all of the heating required to the city and some electricity, greatly reducing the carbon emissions of the energy supply. The service sector is the driving force of the local economy, but the GDP/capita at €16,700 is low by national standards of €31,700.

5.5.2 PC 2050

LITOMĚŘICE 2050 is an emission neutral and energy self-sufficient city. It is a compact city, not sprawling in the country side around. It is a green and cultural city that integrates its rich historical heritage with today's lifestyles. Its motto declares "a city for the people – people for the city".

The city is still rather small allowing for implementation of diverse transport modes. Most daily routes are done by walking, cycling and public transport. Individual car traffic has been expelled from the city centre.

5.5.2.1 SUSTAINABLE TRANSPORT AND MOBILITY: A CLEAN CITY WITH DIVERSE MODES OF TRANSPORT

Transport in Litoměřice city is safe and accessible. Individual car traffic is limited in the city centre and other modes of transport are primarily used, with walking, cycling and public transport encouraged. The transport infrastructure is tailored to enable flexibility of choice of diverse transport modes. Motorized transport in general is minimised, while ensuring sufficient levels of mobility. Vehicles use primarily ecological fuels and energy from local renewables. There is minimum noise from the traffic.

5.5.2.2 SUSTAINABLE ENERGY: ENERGY SELF-SUFFICIENT AND CARBON FREE CITY

The city is energy self-sufficient. It uses local renewable energy sources and the most of its energy demand is covered by a geothermal power plant in the city´s ownership. The potential of decentralized energy production is fully utilized. The energy use is highly effective and the energy performance of buildings is high. The energy system of the city is based on local and renewable energy sources and energy flows are optimised. The city has its own independent distribution network.

5.5.2.3 URBANISM AND PUBLIC SPACES: A CITY OF SHORT DISTANCES

The city is compact with dense development. It is spatially interconnected, creating opportunities and spaces for encounters and intergenerational cognition. As a city with a valuable historic city centre, it has managed to integrate its historical city centre into everyday life and it is actively utilized with respect to current needs of citizens as well as the historical value of the architecture. The city is green, stressing the development, conservation and functionality of green areas and corridors with low energy and water intensity. The city has managed to adapt to threatening impacts of climate change, especially floods.

5.5.2.4 CIVIL SOCIETY AND PUBLIC SERVICES: A CITY FOR THE PEOPLE, PEOPLE FOR THE CITY – A LIVEABLE CITY

To live in the city means to live in an active, safe and resilient community. The city provides sufficient space, facilities and background for cultural and leisure activities. It takes care about its citizens - it provide quality, accessible and innovative training and education, ensures a dignified life to all generations, there are equal conditions in access to employment for women and men, public services provided by the city are accessible to all and the city´s functioning is transparent. While doing so, the citizens on the other hand take care about their city.

5.5.2.5 ECONOMY: A CITY ATTRACTIVE AND OPEN TO INVESTMENTS

The city is open and attractive to investments and tourism still constitutes a significant contribution to the local economy. However local production and consumption create the basis of the city´s economy; local agriculture is done on ecological principals. Negative impacts on environment from industrial operations in the city are minimised.

5.5.3 QUANTIFICATION OF SCENARIOS FOR LITOMĚŘICE

The overview of the quantified scenarios is shown in Table 8.

Table 8: Quantification of the main elements of the scenario's for Litoměřice

Element	Current	BAU 2050	PC 2050
Population	Small city: 24,136 (2013) Average age: 41. 14% under 15 years, 15.2% over 65 years.	23,500 Regional projections from Oxford Economics show the region of Ustecky Kraj reached a peak in 2009/10 and will continue to decline to 2030.	23,500 Despite the IIASA sustainability scenario for the Czech Republic being higher than BAU for population growth and urbanisation, there is little evidence to suggest Litoměřice will grow more in the PC 2050 is scenario.
Energy/renewable mix etc.	**Energy use** 365 GWh **MWh** Electricity 63 926 Elec local 370 Heating 79596 Other 111968 Transport 109650 **Total** **365510** % GWh Industry 39 100.9 Housing 50 129.4 Other 11 28.5 Total 258.8 By carbon emissions (2013): Industry: 29.7% Transport: 23.0% Housing: 36.7% Other: 10.6% Pioneering city at energy efficiency and renewable energy production. Aiming for self-sufficiency with geothermal plant.	**Energy use** 285 GWh **MWh** Electricity 22911 Elec local 25836 Heating 61999 Other 99967 Transport 74733 **Total** **285445** Geothermal energy to supply heat (317 TJ/year) and electricity (25,8 GWh/year) In EU Energy trends scenarios national energy in the Czech Republic by final energy demand rises by 11%, and electricity's share of this rises from 18 to 22%. Electricity generation is projected as follows: Nuclearenergy 57.9% Solids 22.0% Oil 0.1% Gas 8.2% Biomass-waste 5.1% Hydro 3.9% Wind 0.7%	**Energy use** 204 GWh **MWh** Electricity 0 Elec local 48066 Heating 38749 Other 68722 Transport 46053 **Total** **204365** **Actions and milestones:** Energy self-sufficiency through local renewable energy. Geothermal plant could provide the majority of heating needed through a district heating network. Over 90% of the city is energy self-sufficient.

Element	Current	BAU 2050	PC 2050
		Solar 2.2%	
Transport	High share of sustainable transportation. Unknown trend. Walk 58.9 Car-driver 25.5 Bus 6.4 Train 4.4 Bicycle 4.8	BAU is projected to be similar to today's transport modes.	The use of motorised transport is reduced by 30%, whilst efficiency of the transport is improved overall by 40%. **Actions and milestones:** Limited individual car traffic. Walking, cycling and using public transport is encouraged. The city is designed as interconnected and compact. Emission free individual transport- e.g. hydrogen or electric. 30% non-motorised transport 40% public transport 50% of households do not own a car
Housing and buildings	1342 inhabitants/km^2 2% of public buildings were energy efficient in 2013, jumping to 14% in 2014. But this was the result of increased registration.	Electricity use decreases by 80% mostly due to	Assume 50% reduction in heating on a city basis due to new stock of buildings, but some older ones remain. Electricity use decreases by 60% mostly due to energy efficient appliances. **Actions and milestones:** Energy demand lowered and efficiency increased. 100% of public buildings are passive 80% of flats are passive 50% of city is energy self sufficient
Water use	No data	No data	**Actions and milestones:** Rainwater tanks for 50% of family houses.
Food and Consumption	No data	No data	No data
Air quality	Improvements 2010-2012	No exceedances expected	No exceedances expected
Waste	General decrease in waste amounts		
Economic			

Element	Current	BAU 2050	PC 2050
GDP	€11 800 per capita (2011) Rise from (2002-2011) 6,500 to 11,800	16,700 EUR Based on adjusting IIASA SSP projections for BAU for the Czech Republic for Litoměřice 2010, which has a GDP of 65% of national GDP.	17,400 EUR Based on adjusting IIASA SSP projections for sustainability for the Czech Republic for Litoměřice 2010, which has a GDP of 65% of national GDP.
Business/ industry mix	6 693 enterprises. Typical: cultivation of crops, fruit and viticulture, but also chemical and paper industries. Most of the enterprises are active in commerce and services and construction industry. GDP sector balance 2003-2012 Agriculture: 1.7 – 1.76% Industry: 39.0 – 40.9 % Services: 48.8 – 48.0 %	Increasing service sector Sector balance: Agriculture: 2% Industry: 36% Services: 52 %	Sector balance: Agriculture: 2% Industry: 36% Services: 52 %
Employment	58.9 employed in services 1.4% in agriculture From 2003-2012: Agriculture: -28.9% Industry: -13.8% Services: +20.5%		

5.6 MALMÖ

5.6.1 BAU MALMO

Malmo in 2050 BAU is a vibrant and dense city with a population of 500,000. In terms of energy, Malmo continues to perform generally well with new buildings and developments continuing to be low in energy and carbon use. However, due to the significant population growth and increasing electrification of society energy use has grown in total by almost 10% since 2013. The energy supply system is reasonably low in carbon with 41% of energy derived from renewable sources. There is a strong service sector that accounts for almost 80% of the GDP.

5.6.2 PC 2050 MALMO

Sustainable Malmö 2050 is a dense, yet green and attractive city with around 500,000 inhabitants. In Malmö it is easy to live a long, happy and climate smart life, due to supportive infrastructure and facilities. The three sustainability dimensions: economy, ecology and social, are integrated and play an equal role in the city development. Development and implementation of smart technology are major factors in building this city. Malmö has capitalised on its primary location to become Sweden's gateway to Europe, which has strengthened its diverse economy. The citizens are amongst the lowest carbon emitters in Europe, emitting only 1-2 tons of CO_2/person/year, including the carbon footprint of their consumption.

5.6.2.1 TRANSPORT

The city has excellent public transport and infrastructure for cycling and walking, making sustainable-transport the dominant transport mode. There is reduced demand for individual travel and car ownership within the city due to the increased density and infrastructure for sustainable mobility. A growing amount of travel takes place in driverless electric vehicles, which are linked with public transport nodes, increasing the usability and desirability of public transport. The station nodes have become the backbone of the city, enabling meeting places, and investment in new housing and services. The biking lane network has a high priority and encourages biking for all citizens year round with shelter provided on some exposed cycling lanes.

5.6.2.2 ENERGY

A large portion of the city's energy comes from local renewable energy, but the desired 100% goal was not possible to achieve. A large portion of energy is derived from the national grid which is low in carbon (and has therefore discouraged local investment). An advanced smart grid allows a two way energy flow where many users supply the grid at high demand times through plug-in cars and renewable energy production. This results in low overall costs for many energy users. These measures mean that renewable energy supplies about 62% of Malmo's needs.

5.6.2.3 INDUSTRY AND BUSINESS

Malmo's physical connection to Europe through the Öresund bridge and Fehmarn Belt Fixed Link has bolstered its economy, through manufacturing and the service industry. This has been aided by local initiatives that support and facilitate new economic models, which has allowed a diversified and creative business environment. The service sector is the predominant sector and contributes most to the above average GDP. But a new mind-set has developed that has enabled a strong transition to a circular economy, with a strong culture of shared consumption. Through this sharing and a standardisation of products the overall resource use of consumption per person has been reduced by almost 50%.

City gardening and farming is thriving and has combined with social media to provide an innovative sub-culture food supply network. Other forms of social entrepreneurship are supported and have led to innovative businesses.

The use of arable land is optimised by producing food in a resource efficient and large-scale manner outside the city and in small scale inside the city. This enhances green space in the city. Industrial symbiosis is standard and excess energy from industrial production is utilised in facilities such as greenhouse growing of tomatoes and energy crops. Apart from farming, green plants have taken over roofs, walls and public spaces and help reduce noise in the quiet city.

5.6.2.4 LIFE

The new development has created new jobs with a distribution amongst citizens that allows a high employment rate. This has encouraged inclusion and participation in society, whilst people work less in their primary job, allowing more time for meeting and helping people. This together with efforts to limit housing segregation and support social inclusion, have developed a "borderless" city where differences between suburbs are minimal. This has increased security and greatly reduced crime.

5.6.3 QUANTIFICATION OF SCENARIOS FOR MALMO

The overview of the quantified scenarios is shown in Table 9.

Table 9: Quantification of the main elements of the scenario's for Malmo

Element	Current	BAU 2050	PC 2050
Population	313,000	500,000	500,000
Energy	**Energy use** 7259 GWh (2013) (produced) 8230 GWh 7196 Gwh (2008). Hence, 2003-2013, +8.8%. However, it fluctuated up and down since 1990, staying around 7000 Gwh/year. Energy intensity improved but overall energy use also grew 9.5% or 9% comparing 2003-2013 The consumption of energy by sector (2003-2012 %): Household 33-31 Industry and construction 11-11 Public sector 9-9 Transport 27-28 Other services 20-21 Despite the population increasing by 34% since 1990, energy use has remained fairly stable. Goal of 100% renewable. Has not increased from 2008 to 2014, suggesting a slow transition in BAU All food waste is already collected separately in Malmö for biogas From energy strategy 2009, energy use from 1990 to 2006 decreased by 3%, or 18% per person (as population rose substantially). This can be attributed to a reduction in the use of oil. Electricity use however rose 4%.	**Energy use** 8175 GWh (produced 9044 GWh) Total energy remains fairly stable increasing by only 10% to 2050, to approximately 7900 GWh This is due to a balance between energy efficiency and a increase in population. The service sector continues to grow Household density continues to increase. New developments are almost climate neutral... Efficiency gains are cancelled by population increases and increasing electrification of society. However, due to increasing use of electric vehicles, energy use in the transport sector decreases, this is cancelled to some degree by the rebound effect, which sees increasing numbers of electrically propelled transportation. The sector balance remains similar : **Sector** — **%** Household — 30% Industry and construction — 10%	**Energy use** 7440 GWh (produced 8230 GWh) Total energy remains stable at 8230 GWh due to the competing influence of population growth, energy efficiency and energy consumption. The effect of being a smart city on energy could not be calculated due to insufficient data. **Sector** — **%** Household — 33.7% Industry and construction — 9.8% Public sector — 8.8% Transport — 22.6% Other services — 26.2% **Energy production** With an increasingly circular economy incineration of waste has largely decreased. Therefore energy production from wind and solar has greatly increased to fill this gap. Now only 4-5% of energy comes from waste. Malmo's desire for a 100% renewable energy system is difficult to achieve within the current set of milestones, and since the grid represents a very low carbon alternative, this will still provide a large

Element	Current	BAU 2050	PC 2050
	Energy production Renewable 21% in 2013[3] if energy "recovery" from waste incineration is included. But if waste is not included in this then the figure is only 6.4% Wind and solar account for 5.1% of energy and 15.1% of electricity. Electricity accounts for 30% of production and is: • hydro 44.1%, nuclear 40.5%, biofuels and waste 8.5%, wind 4%, natural gas 1.2%, coal 0.8%, oil 0.5%, peat 0.4% (IEA, 2013) Therefore elect. renewables – 56.6% Total for Malmö total recycled energy is 36.8%	Public sector 9% Transport 29% Other services 22% **Energy production** Goal of 100% renewable. Has not increased from 2008 to 2014, suggesting a slow transition in BAU Electricity use increases, the increase being provided by an increase in locally produced wind and solar energy. - Electricity from grid 26% (hydro 44%, nuclear 40.5%) - Wind and solar – 12% - Gas – 18% - Waste – 14% - Waste heat – 2% - Biofuel – 8% - Oil – 0.1% - Diesel/petrol 19.6% Renewables therefore provide 40.7% of Malmo's energy.	proportion of energy. - Electricity from grid 27.9% - Wind and solar – 40% - Gas – 5% - Waste – 7% - Waste heat – 2% - Biofuel – 8% - Oil – 0.1% - Diesel/petrol - 10% Renewables therefore provide 62.8% of Malmo's energy (this assumes waste is considered "renewable" and includes renewables within the national grid). Some energy is provided via a gasification plant and the growth of the city as a smart city with a smart grid allows households to produce their own electricity and feed it back into the grid. 50% of households contribute energy to the smart grid Increasingly homes are becoming carbon neutral. Fossil free district heating by 2025 The goal of 30% solar is not seen as realistic.
GHG	Carbon emissions +27% in 11 years Despite CO2 intensity -23.5% Öresundsverket, the gas fuelled energy power plant complicates the picture – and is removed for the analysis, since most electricity is supplied outside of the Malmo region	**To be completed in the next phase**	**To be completed in the next phase** **Goal:** In 2050, the citizens of Malmö only emit 1-2 tons of carbon dioxide per person and year, including the carbon footprint of their consumption.

[3] http://miljobarometern.malmo.se/miljomal/sveriges-klimatsmartaste-stad/mer-fornybar-energi/info1/

Element	Current	BAU 2050	PC 2050
Transport	Modal share change (2003-13) (%) 2003 2013 % Change Car 52 40 -12% Bus 10 14 +4% Train 3 7 +4% Bicycle 20 22 +2% Walking 14 15 +1% Other 1 2 +1%	Modal share is projected as: Car: 32% Bus: 15% Train: 9% Bicycle: 24% Walking: 18% Other: 2% Overall transport increases due to increasing population and economic activity. However, based on the stable trend it is assumed that transport energy remains stable. Malmo's "Traffic Program" aims for the share of pedestrian, bike and public transport to increase so that a maximum of 30% of all travel and half the commuting into the city is made by car in 2030. 30% biking by 2018. This appears difficult to fully achieve as the rise in biking appears to have levelled off from 2008 to 2013 at 22%. However, due to the increasing densification, and more people, the ratio of car use will decrease as walking and public transport become more attractive options.	The transport balance is therefore predicted as: Car 32% Bus 15% Train 9% Bicycle 24% Walking 18% Other 2% Driverless electric cars increase the use of public transport by increasing the efficiency of connections and car use has decreased. However, the move to public transport has been countered to some degree, by the perception that electric cars are low impact (i.e.re bound effect). **Actions and milestones from workshop** Trams Car /mobility pool for most residents Driverless vehicles are integrated with public transport Well-developed logistics from nodes Public transport covers all areas 24 hours Smart transport
Housing	Density 1.97% increase from 3458-3527 in densest area, and up by 40% in some regions (Södra Klagshamn). New developments such as Västra Hamnen have aimed for close to zero carbon emissions and local renewable energy and storage.	Assumed that new developments follow Västra Hamnen design.	Shared accommodation KPI on energy/m2 – 40% less living area Energy efficiency in buildings decreases electricity use by 33% (IEA[4]). Household – more shared accommodation, reduced

[4] https://www.iea.org/textbase/npsum/etp.pdf

Element	Current	BAU 2050	PC 2050
			living space per person. • 80% energy efficiency of Malmö achieved
Building	Current building stock is fairly high quality with good efficiency in terms of insulation overall.	Assumed that new developments follow Västra Hamnen design	Assumed that new developments are increasingly energy efficient
Food and Consumption	Malmö has indicators and targets around a few food items.		30% of food produced within city limits (not enough data to know if this is achievable) Due to the thriving local circular economy system consumption of imported goods has decreased, with reuse, refurbishment and remanufacturing
Air quality	Threshold exceedances occurring up to 136 days in streetscapes	Threshold exceedances decrease by 50% up to 70 days in streetscapes.	Faster improvement in air quality due to quicker transition to non-fossil transport, and there are no exceedances of threshold levels, despite new regulations having lowered the threshold levels.
Waste		Decreasing waste, food waste collected separately. C&I waste needed for CO2 later?	Large-scale logistics systems for recycling are established.
Economic			
GDP	45,400 EUR (2011) The trend over the past 9 years has been an average of 2.94% annual growth. This can be considered the result of the move to more of a service industry and perhaps the result of better trade routes to Europe with the opening of Öresund Bridge. 2003-2011: 35990-45400 Euro (+26.1%)	98,700 EUR Using either IIASA projections (for Sweden) or Oxford Economics (for Skåne) and adjusting for Malmo based on % difference for Malmo gives a similar result for 2050 BAU.	101,600 EUR IIASA projections show sustainability scenario to be 2.9% higher than BAU.
Business/industry mix	Increasing services and less manufacturing Gross regional product (Malmo snapshot 2014; pg 13) in SEK billion • Services 66.5 (SEK) • Goods 19.5 • Public auth. and household non-profit org – 21.5 • Other – 17.5	Increasing services and less manufacturing. Services 78% by 2050 of gross added value for EU (from EU energy trends 2050 (Capros 2014)). Therefore service sector in Malmö is likely to be about 70-80%	Due to a focus on circular economy manufacturing, and remanufacturing contribute more to the local economy than in BAU. Services are also a strong feature.

Element	Current	BAU 2050	PC 2050
	Percentage services – 57.3% By wages Percentage services– 57%		
Employment	Workforce of 161,172, + 19% in 10 years Last 10 years primarily business services and education that have increased. Workforce structure (main categories only): Business services: 15.7% Commerce: 14.6% Healthcare and social services: 13.7% Education 9.3 % Manufacturing – 6.7% (compared to 13% for Sweden)	Increase in "green jobs", with e.g. operation and maintenance of renewable energy. Circular economy jobs, such as repair and refurbishment, But majority of jobs continue to develop in the service, IT, hotels, and health sectors. Manufacturing is still a minor sector.	Approximately 600 jobs from green energy. (0.5 jobs per MW) Increase in local agriculture due to emphasis on local food production. The manufacturing sector has also made an increase due to the emergence of a strong circular economy culture and infrastructure.

5.7 MILAN

5.7.1 BAU MILAN

In the Milan BAU scenario both the population and the overall energy use continues to grow to 2050. The population has grown to over 1.5 million and is supplied by 31% renewable energy. The district heating network has grown to supply more than 10% of the city's heating needs and is connected to the waste incineration plants. The industrial sector declined and the service sector now supplies almost 80% of GDP.

5.7.2 PC 2050 MILAN

Milan is dense, spacious, green and rich in biodiversity, suitable for pedestrians, and uses carbon free transport. The energy sources are renewable, with energy efficient technologies employed. In Milan, people are sensitive to environmental issues and use accessible services with a low carbon footprint. The city has experienced a general change in direction from previous patterns of carbon intensive consumption and emissions. Milan has a green economy, with continuously enhancing economic, environmental, and social well-being. This success has been achieved by setting short term goals – once one is achieved, the next goal is set, to limit costs and maintain momentum.

5.7.2.1 TRANSPORT

Milan is easily accessible and usable without a car due to a carbon-free and well integrated transport system. Public transport services have become more convenient than private transport, as Milan is a pedestrian and cycling friendly city where streets have been transformed in shared public spaces. It is a city of sharing, where services are accessible even through alternative or complementary forms of carbon-free private transport. The city also manages an efficient logistic system for the distribution of goods within the city thus limiting commercial transport and emissions. Public services are offered online and/or in a decentralized manner in order to ease access to services and reduce travel needs.

5.7.2.2 ENERGY

Milan has achieved a very high level of energy efficiency and all energy needed for the city to function is produced from renewable sources. A large share of buildings are designed to consume few energy (increase of passive house buildings both for new buildings and for reconstruction), and energy consumption by transport is declining, too, both contributing to the decline of overall energy consumption. The use of fossil fuels is tending towards zero, due to reduced consumption and increasing use of renewable energy sources, with an energy network being transformed towards decentralized and smart networks. Many buildings are able to produce energy and to feed energy into the system through the smart grid. All households commercial and public buildings are connected to district heating and cooling provided renewable energy sources. The extension of the district heating system was facilitated by initial projects using the residual heat from an industrial plant for feeding a growing net for district heating. The obstacle of individual heating plants for households was slowly overcome using public subsidies and energy efficiency norms which drove individual heating plants gradually out of the market and encouraged households to connect first to the public heating, and from the 2030's on to the public cooling system. The conversion of public buildings proceeded in a faster pace as these were used as demonstration objects promoted in the local energy plan, as well as in the area of commercial buildings due to their more rapid overturn and shorter investment cycles.

5.7.2.3 INDUSTRY AND BUSINESS

The technology systems and networks are integrated and clearly and effectively support all aspects of citizens' daily life. These systems allow a large share of telecommuting, favouring access to services so that the need to travel is reduced. Milano and Turin remain the drivers of innovation, with a high collaboration for development and implementation of innovative technologies which create synergies and represent a success factor for both urban economies while reducing energy needs and the carbon footprint in industrial production

5.7.2.4 LIFE

People are sensitive to environmental and energy issues and have a high awareness of their consumption and behaviour and of their responsibilities with respect to the environmental quality and the climate, transforming lifestyles and personal decisions. The awareness has been raised by the events around the expo furthermore, by the activities connected to the city's participation in international projects like Mayors Adapt and "100 resilient cities". Public services have been decentralised so that citizens can find all services nearby with a greater reach and usability. Also they take part in a participative urban society that is open to the world and recognizes the advantages deriving from exchanges. As a result, all citizens are able to enjoy a more liveable city.

Changes in the urban planning scheme contribute to making the city more liveable: further to services that are offered at neighbourhood levels at short distances, dense urban areas are interrupted by green public areas improving urban climate. Milan has significant green space that contributes to a reduced urban heat island effect and preserves a rich biodiversity. Green spaces are integrated into the urban fabric and connect to the territory. Milan is dense but spacious and has a highly populated urban area with a high rate of permeable surfaces. Citizens are not only consumers but also guardians and custodians of the urban and peri-urban territory. Many neighbourhoods "adopt" open spaces and use them for urban gardening and for creating new urban greening on former street surfaces.

5.7.2.4.1 CONSUMPTION

Industry and research create a system of reuse and recycling of materials moving spread towards a fully circular economy although this goal is not yet completely achieved by 2050.

5.7.2.4.2 TRANSPORT

The transformation of the transport system represented the most challenging area for transition as the mostly car oriented transport system was favoured by a patchy and uncoordinated public transport and by long commuting distances between the city and the periphery dominated by urban sprawl. Urban planning reduced and re-densified urban areas, and also increased the attractiveness of public transport. This contributed to a sharp decline in the share of private cars. In addition, the success of the 2012 traffic ban in the central area, promoted its extension to other parts of the city.

The second phase of the PUMS (local traffic plan (2025-2035) provided the foundations to a major change in the transport of goods and commercial traffic in the city, introducing electric vehicles and overcoming the fragmentation of the sector in different private enterprises.

5.7.3 QUANTIFICATION OF SCENARIOS FOR MILAN

The overview of the quantified scenarios is shown in Table 10.

Table 10: Quantification of the main elements of the scenario's for Milan

Element	Current	BAU 2050	PC 2050
Population	Milan City: 1,324,169; 7271 inhabitants/km^2. 23% older than 65. Province of Milan (NUTS 3) has 3,176,180 over 1580 km^2. (2010 inhabitants/ km^2)	Milan City: 1,532,000 Based on continued recent growth at about 4.1% per year.	Milan City: 1,678,000 Enhanced growth based on difference with SSP scenarios: 3.3% higher growth with sustainability scenario compared to BAU (from 2010 to 2050). In addition, urbanisation is about 6% higher. Therefore PC 2050 population is 9.4% higher than BAU.
Energy/ renewable mix etc.	**Energy use (2005)** 28,167 GWh Domestic uses 9.0% Domestic heating 44.3% Industry and tertiary 21.5% Public lighting 0.4% Private transport 23.1% Public transport 0.8% Metro 0.8% **TOTAL 28,167 GWh** **Energy Production** (2005) GWh % Natural gas 10502 25.9% Diesel 7245 17.9% Petrol 3315 8.2% Oil, biodiesel LPG 291 0.7% Electricity 17864 44.1% Waste 1314 3.2% **Total 40531** Energy intensity reduced from 67 to 61 toe/M€	**Energy Use** 33,663 GWh Figures for Milan show energy use grew 4.1% from 2005 to 2010. However, 2013 figures show a slight decline. We assume this to be at least in part, due to financial crisis, or other factors, and apply a nominal growth rate of 2% every 5 years to 2050. The energy increases but the energy share remains the same: Domestic uses 9.0% Domestic heating 44.3% Industry and tertiary 21.5% Public lighting 0.4% Private transport 23.1% Public transport 0.8% Metro 0.8% **TOTAL 33663 GWh** **Energy production** Share of electricity is expected to rise. PRIMES projects share of electric for Italy will rise from 19.2% to 27.8%. However, Milan's share of electricity is already very high, so it can be expected to rise only 3-4% under BAU.	**Energy Use** 20376 GWh Key points (See below for details derived from vision and backcasting workshop): • Integrated and efficient transport system • Low energy buildings with district heating and cooling • Shift from industry to services **Energy Use** Energy use is reduced significantly due to a range of reduction and efficiency measures: private transport accounts for 20% of the transport modal balance and is 65% electric vehicles, building and housing efficiency. GWh % Domestic uses 2547 10.3% Domestic heating 7494 30.4% Industry and tertiary 5793 28.2% Public lighting 94 0.5% Private transport 3943 16.0% Public transport 282 1.4% Metro 222 1.1% **Total 20376**

Element	Current	BAU 2050	PC 2050
	(2003-2010)	GWh % Natural gas 9757 20.0 Diesel 7193 14.7 Petrol 4012 8.2 LPG 968 2.0 Electricity 20733 42.5 Waste 2439 5.0 Solar 1464 3.0 Wind 488 1.0 Geothermal 488 1.0 Biofuel 1245 2.6 **Total** **48787** Renewables provide 31% (36% including waste) of Milan's energy. **Projects:** Action Plan for Sustainable Energy and Climate Plan of Action for Sustainable Energy (PAES) and its Strategic Environmental Assessment (SEA), which identified the following areas of intervention: • Buildings (Heritage public sector and residential) • Lighting • Mobility and transport • Production of energy from renewable sources • Tertiary sector and services • Trash	**Energy Production** There is a large increase in the share of electricity, which accounts for about 70% of the total energy. About 55% of total energy comes from the national grid. GWh % Natural gas 3066 10.0 Diesel 563 1.7 Petrol 282 0.9 LPG, CNG 563 1.7 Electricity 18413 60.0 Waste 2523 7.7 Solar 3069 10.0 Wind 921 3.0 Geothermal 614 2.0 Biofuel 921 3.0 **Total** **30689** Renewables provide 51% (59% including waste) of Milan's energy.
Transport	Transport energy in Milan municipality increased by 20% from 2005 to 2010. Population only increased by 2 or 3% GDP increased about 26.3%	**Projects:** • Sustainable Urban Mobility Plan • AREA C (low emission zone) • Turin-Lyon high-speed railway line	**Actions and Milestones from vision:** • City of sharing, that makes services accessible even through alternative or complementary forms of private transport

Element	Current	BAU 2050	PC 2050
		• Metropolitan railway system An obstacle identified was that there is no long term plan or strategy for 2050 National targets for 2020: •10% transport consumption met by renewable energy	• Pedestrian friendly city with shared spaces • Accessible and usable without a car • Carbon-free integrated transport systems • Public transport faster, cheaper and more convenient than private transport. • Creation of an integrated public transport system. • A more widespread network of public transport, including extension of the circular lines to connect outlying areas. • Bike network – bike sharing. • Smart park and ride facilities. • New urban freight logistics • Extend road pricing to encourage use of public transport and discourage private car use. • Electric cars • Substitute municipal vehicle fleets with new ones that use clean technologies. • Add more electric car charging points (serviced by renewably produced energy).
Housing	No data	No data	• Low energy buildings, in the direction of the passive house • District heating and cooling with renewable energy sources for all households
Building	No data	No data	• High energy efficiency • Energy needed for the city to function is produced from renewable sources • Low energy buildings, in the direction of the passive house • Many buildings able to produce energy feed it back into the system through the smart grid • District heating and cooling with renewable energy sources for all households. • Linked CHP network with industry so that waste heat is utilised • Micro tri-generation (heating, cooling, and energy

Element	Current	BAU 2050	PC 2050
			production) plants as pilot projects for big public and private energy users (hospitals, schools, etc.). • Measures of energy recovery from the integrated water cycle using heat pumps to heat buildings near (or in) industrial wastewater treatment plants • Goal of 100% of new buildings that are zero energy or carbon neutral.
Water use	No data	No data	No notable actions
Food and Consumption		Projects: EXPO	No notable actions
Air quality	Air quality is a critical issue. With over 100 days (or just below for 2010) of exceedances for PM10's throughout 2009 to 2012. Exceedance in ozone and nitrous oxide were also registered.	Reduced exceedances but some exceedances may still occur.	Due to the transport measures, there are not expected exceedances for air quality in PC 2050.
Waste		Increase waste sorting PAES Increase energy recovery of waste (PAES)	No notable actions
Economic			
GDP	On the Province level 45600 EUR (2011) PPP/capita GDP is 51754 EUR (Oxford Economics)	74,000 EUR Continuing trend projection by Oxford Economics.	75,000 EUR IIASA SSP projections show similar GDP for BAU and sustainability
Business/industry mix	Milan: main industrial and commercial city in Italy. Main banking centre. Fashion and design. 1% commodities, 5% construction, 33% business and finance, 21% manufacturing, 16% local non-markets, 15% trade and tourism, 6% transport, 3% utilities.		

5.8 ROSTOCK

5.8.1 BAU ROSTOCK

After declining in population in recent years, Rostock grew steadily until 2030, when it slowed to reach a population of 215,000 in 2050. Overall energy use is only slightly less than it was in 2010, partly due to the population growth, but also due to an increase in electricity use. The largest reduction of energy use was realised in the transport sector due to an increase in the use of electric cars and improved public transport.

5.8.2 PC 2050 ROSTOCK

Sustainable Rostock 2050 is a compact city of short distances hosting a thriving green economy. Using the regenerative energy potentials fully, Rostock is adding value to the region. Its 220,000 inhabitants have integrated new arrivals and together reached a good quality of life. In Rostock it is easy to live a healthy and decelerated life. Regional products are accessible and self-sufficiency is supported. A culture of care for old and young and alternative working time models have established. Generations are mixing and living space is affordable and sustainable.

Transport

Rostock has become the green infrastructure axis of the region. The city provides easily accessible public transport and infrastructure for cycling and walking, and the distances are short. Car-sharing fuelled by electricity or gas is the main individual transport option. The city train is electric and has been extended to the region so that commuters' use of public transport has increased. An extensive network of bike pathway provides quick and diverse access to recreation.

Energy

After the dismantling of the coal-fired plant, Rostock is primarily powered by renewable energy from off-shore wind, bio-gas and geothermal energy (95 % is planned). The cogeneration plant is running most efficiently with all redundant grids dismantled. The storage capacity of renewable has been increased and energy cooperatives have led civil society and business to further increase the share of renewable energy. Small wind energy plants and solar panels on roofs contribute to a resilient city. Furthermore, hydrogen based cycles are utilizing waste heating. Ships that are entering the harbour of Rostock are running on liquid gas only.

Industry and business

The assembly especially of cranes and wind power has been established as a strong sector in Rostock. Furthermore, the agriculture and tourism businesses are thriving just as the traditional sector of fishery and harbour operation which adds to the maritime atmosphere. Energy services have strengthened renewable energy and natural building material has been used throughout and beyond the city. Research is a backbone of the city development and well supported by the University of Rostock.

Life

In Rostock a good quality of life has been reached for all citizens. The city centre is car-free. Diverse rehabilitation spaces and cultural options are enriching citizens' lives. In a meeting centre per district, different generations can mix and learn from each other. Supervision and care for young and old citizens is easily accessible. Alternative working time models like a 30-hour week and home office have become widely established.

The demographic change of an increasingly old population and poverty in old age has been averted. New people arrived and have been welcomed and well integrated, leading to a heterogeneous mix of citizens.

Living space in Rostock is affordable. Multigenerational living has established as a popular social living arrangement. The city has developed compact, ecologic and energy efficient housing. Green roofs throughout the city with gardens and solar panels, both improve quality of life and renewable energy production. A majority of buildings are energy-plus houses or have had energy refurbishment.

Consumption & Waste Management

The citizens of Rostock have easy access to healthy food and vegetarian diets have been encouraged. Self-sufficiency is easy through the many allotment gardens of Rostock. Regional products are available throughout the city and add value to the region. Waste and water cycles have been fully closed improving the sustainable management of resources.

5.8.3 QUANTIFICATION OF SCENARIOS FOR ROSTOCK

The overview of the quantified scenarios is shown in Table 11.

Table 11: Quantification of the main elements of the scenario's for Rostock

Element	Current	BAU 2050	PC 2050
Population	203,673 23% more than 65 years old, 11% younger than 15 years.	215,000 Oxford Economics predicts a small rise of 1-2 thousand inhabitants per year until 2018, where it hovers around 211-212,000 until 2030. Based on the IIASA SSP national projections we adjust for a decrease in population, but also an increase in urbanisation.	220,000 The IIASA SSP national projections sustainability scenario suggest a 0.4% drop in population in Germany from 2030, but urbanisation increases by 4.8%.
Energy/renewable mix etc.	Small increase in total energy use from 2002 to 2012, but energy productivity has increased with a 18% decrease in energy use per euro. **Energy use** 3776 GWh (2010) Energy breakdown for 2010 GWh Heating 2010 Electricity consumption 773 Transport 993 **Total 3776** Trend (but only including regional mobility) (GWh) Year 1990 2005 2012 Heating 2990 1813 1950 Energy 650 705 795 Regional Transport 380 550 480 **Total 4020 3068 3225** Per resident (climate adjusted): 1990 2005 2012 MWh/resident 17.4 16.17 16.15	**Energy use** GWh Heating 1904 Electricity consumption 1094 Transport 604 **Total 3602** **Corresponding CO2 -emissions** **CO2 kt** Heating 287 Electricity consumption 161 Transport 138 **Total 585** **= 2.72 t/capita**	**Energy use** GWh Heating 1540 Electricity consumption 741 Transport 524 **Total 2805** **Corresponding CO2 -emissions** **CO2 kt** Heating 198 Electricity consumption 50 Transport 113 **Total 362** **= 1,65 t/capita** (compared to = 0.46 t/inhabitant, if the production would be 100% renewable) **Projects:** - 50% reduction of CO_2 emissions in 2010 compared to 1987 Masterplan 100% climate protection targets: - Reduction of energy demand by 50% by 2050 and

Element	Current	BAU 2050	PC 2050
	Renewable energy capacity trend total: Year 1995: 8 GW 2002: 32.8 2013: 117 GW Produced Renewable Electricity (Feed in tariff – EEG) in the city of Rostock 2010: Wind: 11.9 GW/ Solar: 3.9 GW / Biomass: 9.1 GW = **total: 24.9 GW** (Masterplan Ist-Zustand, p. 21)		CO_2 emissions by 95%
Transport	65% sustainable transport with positive trend. Share of traffic year 2010: Walking 4% Bike 9% Public transport 28% Private transport 59% **Transport** **Energy (GWh)** Car 896.94 Motorcycle 4.72 Bus 25.28 Tram 23.33 Rail transport 29.44 Distance rail 13.06 **Total** **992.77**	Following the cities Masterplan for the "Trend" scenario: 604 GWh/a in 2050. Public transport has improved and participation rates have followed.	Following the cities Masterplan for the "Ambitious" scenario: 524 GWh/a in 2050. Share of traffic: walking: 4% bike: 12% Public transport: 49% Private transport: 35%
Housing and buildings		Reduction of: **Households (energy, total: -0.8%):** Heating -17% total Hot Water +15% total Electricity +1% p.a. =+49% total (2010-2050) **Municipal & Service sector (energy total -5%):** Heating - 15% Electricity +1% p.a. =+49% total (2010-2050)	Reduction of: **Households (energy, total: -27%):** Heating -36% total Hot Water -20% total Electricity +0% p.a. =+0% total (2010-2050) **Municipal & Service sector (energy total -21%):** Heating - 30% Electricity +0% p.a. =+0% total (2010-2050)

Element	Current	BAU 2050	PC 2050
		Industry (energy, total: -25%): Electricity -0.4% p.a. =-15% total (2010-2050) Heating ca. -1% p.a. =- 33% total (2010-2050).	**Industry (energy, total: -45%):** Electricity -1.5% p.a. =-45% total (2010-2050) Heating ca. -1.5% p.a. =- 45% total (2010-2050).
Food and Consumption	No data		
Air quality	Improvements 2010-2012	No exceedances expected	No exceedances expected
Waste	General decrease in waste amounts	Continued decrease and increased recycling	
Economic			
GDP	30 628 EUR (2012)	40,454 EUR Based on IIASA SSP scenarios and adjusted based on Rostock being 17% higher than Germany base GDP. Also correlates with projections from Oxford Economics.	42,079 EUR Based on IIASA SSP scenarios and adjusted based on Rostock being 17% higher than Germany base GDP.
Business/industry mix	Main economic sectors: tourism, services and technologies. **Sector by GDP:** 2003 2012 Agriculture 0.1% 0.05% Industry 15.9% 18.4% Services 84 % 81.5%	**Sector by GDP:** Agriculture: 0.05% Industry: 18.5% Services: 82%	**Sector by GDP:** Agriculture: 0.05% Industry: 18.5% Services: 82%
Employment	High levels of about 15%. Significant annual variations.	8-9% unemployment	8% unemployment

5.9 TURIN

5.9.1 BAU TURIN

Turin in 2050 has recovered from a 3 decade long decline to one of rising economic growth. Despite an increase in population to 1.1 million the energy use of the city has declined. Car use is still high and represents a larger modal share than public transport. However, electric vehicle use is increasing. Many buildings have undergone energy efficiency renovations and solar cells are common, resulting in lower energy use in the residential sector despite a population increase.

5.9.2 PC 2050 TURIN

The 2050 post-carbon vision for Turin that emerged in the participatory workshops is built around the following three key concepts:

5.9.2.1 DIFFERENTIATION

- The economic base is structured in a few specialized sectors (for example, automotive, tourism, ICT etc.) and they represent the strengths that make the city competitive and more resilient to economic crisis;
- The mobility system at metropolitan level is organized to be multimodal; people (residents, tourists and business people) are less dependent on private motorization and can easily move by more sustainable modes. Emissions from transport are reduced through the introduction of a congestion charge, fostering telecommuting, and cutting the use of private cars through promotion of more sustainable mode of transport.

5.9.2.2 IDENTITY

- Even if deeply differentiated, Turin will keep and enhance its identity thanks to strong social integration, high quality of life, promotion of initiatives for young people and start ups. The challenges of an ageing population are faced by enhancing social housing, developing user-friendly technologies, and improving welfare through ICT.
- Spatial resources, cultural heritage and landscape are recognized and developed as having critical value. Soil consumption is reduced, preserving natural and agricultural soils, by re-naturalizing abandoned built areas, and promoting the utilisation of existing empty space within the city.

5.9.2.3 SMARTNESS

- Technology is systematically developed to connect people, both inside the city and globally. New jobs are created from green technology through several approaches including: cooperation between universities and local companies; innovative financial tools for R&D and start-ups; promotion of renewable energy sources; and enhancement of tertiary education in scientific issues. The impact from buildings is minimised through stringent energy performance standards and certification, as well as incentives for building renovation.

- Sharing is a new key paradigm, for granting services (first of all, mobility) but also as an opportunity for economic innovation and new business. New models of education and training are defined, as well as innovative tools and resources for welfare.

5.9.3 QUANTIFICATION OF SCENARIOS FOR TURIN

The overview of the quantified scenarios is shown in Table 12.

Table 12: Quantification of the main elements of the scenario's for Turin

<table>
<tr><th>Element</th><th>Current</th><th>BAU 2050</th><th>PC 2050</th></tr>
<tr><td>Population</td><td>902137;
6939 inhabitants/km^2.25% older than 65.
Province of Turin (NUTS 3) 2'297'917 inhabitants in an area of 6'827 km^2, (336 inhabitants/km^2.)</td><td>1,110,000
Based on continued recent growth of 0.62%/year. Oxford Economics projects Turin province population will peak in 2019 with 2.31 million and then decline to 2.27 in 2030. IIASA/SSP predicts Italy 2050 population will only be marginal greater, whilst those living in urban areas rises from 68% to 80%.</td><td>1,215,000
Enhanced growth based on difference with SSP scenarios: 3.3% higher growth with sustainability scenario compared to BAU (from 2010 to 2050). In addition, urbanisation is about 6% higher. Therefore PC 2050 population is 9.4% higher than BAU.</td></tr>
<tr><td>Energy</td><td>Energy use
18 841 GWh (2005)
Energy intensity of Province of Turin has decreased between 2002 and 2011 from 87 to 63 Toe/M€. Energy consumption declined by 13% whilst GDP increased by 20%.
<table>
<tr><th>GWh</th><th>1991</th><th>2005</th></tr>
<tr><td>1.1 Municipal</td><td>607</td><td>375</td></tr>
<tr><td>1.2 Tertiary</td><td>2 417</td><td>2 745</td></tr>
<tr><td>1.3 Residential</td><td>9 644</td><td>7 939</td></tr>
<tr><td>1.4 Lighting public</td><td>70</td><td>87</td></tr>
<tr><td>2. Industry</td><td>6 552</td><td>4 839</td></tr>
<tr><td>3. Transport.</td><td>3 364</td><td>2 856</td></tr>
<tr><td>TOTAL</td><td>22 654</td><td>18 841</td></tr>
</table>
% change by sector (only available for 2003-2011): :

Residential: 0.1%
Industry: -32%
Transport: -15%
Services: 14%
Agriculture: 18%

This cannot be explained for instance by GDP as industry did not shrink in proportion to the energy reduction.</td><td>Energy use
14263 GWh

Energy use
The BAU energy use is:
<table>
<tr><th>GWh</th><th>2050</th></tr>
<tr><td>1.1 Municipal</td><td>575</td></tr>
<tr><td>1.2 Tertiary</td><td>2342</td></tr>
<tr><td>1.3 Residential</td><td>5971</td></tr>
<tr><td>1.4 Lighting public</td><td>68</td></tr>
<tr><td>2. Industry</td><td>3596</td></tr>
<tr><td>3. Transport</td><td>1811</td></tr>
<tr><td>TOTAL</td><td>14263</td></tr>
</table>
(Note: due to limited data available the robustness of this estimate is limited)
This assumes that the commitments in TAPE are achieved and that similar reductions from 1991 to 2020 can be made up until 2050.</td><td>Energy use
13006 GWh

The BAU energy use is:
<table>
<tr><th>GWh</th><th>2050</th></tr>
<tr><td>1.1 Municipal</td><td>429</td></tr>
<tr><td>1.2 Tertiary</td><td>1831</td></tr>
<tr><td>1.3 Residential</td><td>5602</td></tr>
<tr><td>1.4 Lighting public</td><td>61</td></tr>
<tr><td>2. Industry</td><td>3596</td></tr>
<tr><td>3. Transport</td><td>1487</td></tr>
<tr><td>TOTAL</td><td>13006</td></tr>
</table>
(Note: due to limited data available the robustness of this estimate is limited)</td></tr>
</table>

Element	Current	BAU 2050	PC 2050
	Energy Production In the Province Total energy consumed: Renewable 13% Petroleum products 21% Natural gas 66% 35 % of electricity consumed is derived from renewable energy. Whilst electricity accounts for 18.0% of final energy use. For the Province the energy source of final use is (%): Heat 6.7 Renewable heat 5.4 Renewable electricity 7.9 Coal 13.2 Natural gas 41.2 Petroleum 25.7 However, the balance within Turin City is (2020 expected) : Electricity 26.5% Combustible fossil 71.5% Renewable sources 2.2%	**Energy production** The balance within Turin City is projected as: Electricity 32% Combustible fossil 71.5% Renewable sources 5% The national electricity mix is expected to be (based on EU energy trends): Solids 15.5% Oil 1.2% Gas 28.2% Biomass-waste 8.9% Hydro 11.1% Wind 13.2% Solar 19.3% Geothermal 2.7% Hence 55.2% of electricity from grid is renewable electricity. **Projects:** Action Plan for Sustainable Energy and Climate Turin Action Plan for Energy – for 2020	**Energy production** The balance within Turin City is projected as: Electricity 30% Combustible fossil 45% Renewable sources 25% (This is not as low carbon as possible due to limited actions and milestones within the WP4 report) **Actions and Milestones** Promote renewable energy sources.
Transport	2000- 2010 Public transport : 26 to 23% Car: 44 to 45% Foot: 28 to 27% Bikes and motorbikes:3 to 3%	Despite improved public transport there is still a high level of car use. **Projects**: Sustainable Urban Mobility Plan AREA C (low emission zone) Turin-Lyon high-speed railway line Metropolitan railway system	Public transport. 50% reduction of transport emissions. Halve use of private cars through promotion of more sustainable transport modes. Introduction of congestion charge from 2035 Foster telecommuting

Element	Current	BAU 2050	PC 2050
		Expected reduction of 248 GWh expected through transport measures (pg 69 TAPE). E.g. completion of metro lines, updated public transport vehicles, burying of railway that divided the city, increasing bicycle mobility, electric vehicle charging points, subsidies for conversion to LPG for 5000 resident cars.	Transport system for goods and passengers will be fully integrated.
Housing and buildings		TAPE - For the residential sector expected reduction of 718 GWh: Energy efficiency of existing buildings, high-efficiency generators, redevelopment of existing residential buildings, tax deduction for energy upgrading, energy certification, incentives for integration of solar PV in residential buildings; diffusion of solar thermal, redevelopment District via Arquata, and increased volumes connected to district heating	20% reduction of emissions from buildings Spread adoption of certifications of energy performance Adopt incentives to building renovation
Food and Consumption		**Projects**: EXPO	
Air quality	Poor. Over 100 days in 2013 for PM 10 exceedance and 30-40 for NO2 and O3. Although air quality has improved since 2004 when exceedances for PM10's were over 200.	Based on recent improvements the air quality is expected to be without any exceedances of threshold values in 2050	
Waste	16% lower in 2012 than in 2002, from 600 to just over 500 kg /capita Waste recovery over the same period increased from 20% to 43%.		
Economic			
GDP	PPP 26,500 EUR (2002) to 28,900 EUR in 2011 GDP/ capita 30716 EUR	35,400 EUR Recovery in GDP after 2015 following Oxford Economics projections.	36,000 EUR IIASA SSP projections show similar GDP for BAU and sustainability (1% higher in latter)
Business/ industry mix	Turin is the most specialized area of Italy in industrial activities: it hosts design offices and factories of Fiat (now FCA – Fiat Chrysler Automobiles); other important industrial sectors are mechanics, aerospace, ICT, telecommunications. Gross value added: manufacturing for 18%, construction (5%), wholesale and retail trade, transport, accommodation and food service activities (19%), ICT (7%),	Services are expected to continue to dominate, whilst further decline in industrial activities is highly likely.	New jobs from green tech Increase cooperation between universities and local companies Innovate financial tools for R&D and start-ups Promote renewable energy sources Enhance tertiary education in scientific issues

Element	Current	BAU 2050	PC 2050
	real estate (14%), financial and insurance activities (6%), professional, scientific and technical activities (10%), public administration, defence, education, human health and social work activities (14%), arts, entertainment and recreation (4%). In Province of Turin (2003-2011) Services: 72.2% to 74% Industry: 27% to 25.4% Agriculture: 0.8% to 0.6%		
Employment	Unemployment increased from 4% to 11% over 2004 to 2013.		

5.10 ZAGREB

5.10.1 BAU ZAGREB

In BAU 2050 Zagreb the population has continued to grow strongly and has reached 875,000 people. Public transport has improved and represents the major form of transport, although the car is still a strong second option. Energy use per person is lower than in 2010 and despite the increase in population, the overall energy use of the city has been reduced by almost 11%.

5.10.2 PC 2050 ZAGREB

Zagreb 2050 is a city of 919,000 healthy and united citizens who fully enjoy sustainable lifestyles. The city has a near zero footprint and sources many resources locally. Organic food is produced locally in and around the city, the water resources are clean and reused, materials are constantly recycled, and a significant share of energy is produced from renewable sources. Zagreb city management has changed dramatically, with citizens and communities participating in decision making and the budgeting process (following the socio-political trends all over the world). The economy is driven by social innovations that stimulate new job opportunities and business models.

Transport

The motorized traffic has been significantly reduced, with the majority of citizens commuting by bike as this is the fastest, easiest and most convenient way of transport. Biking lanes are spread all over the city and cycling became dominant over car for shorter distances. There is a lower demand for individual car usage and ownership while the majority of cars are plug-in hybrids and battery electric cars. Public transportation is very efficient, affordable and popular. In addition, it operates exclusively on either biogas or electric energy. Due to attractive public spaces, lively streets and a trend of healthy lifestyles, many citizens prefer walking. After the new Sava channel was constructed the river became navigable for cargo vessels so the number of heavy vehicles is much lower. Local production and distribution networks have further decreased carbon emissions.

Energy

New hydro power plants were constructed along the Sava river channel and became one of the main electricity providers for the city. PV panels on roofs, urban biogas power plants and urban wind turbines are covering electricity needs for households and enterprises. In some parts of the city, domestic heating with biomass and geothermal energy has been introduced. All buildings built before 2000 were energy retrofitted and many new houses are energy positive. The energy market is more flexible and two way grids are installed together with monitoring system which allows energy trading. Consumption of energy decreased after the introduction of energy efficiency measures and smart technology systems and products. A significant share of citizens are supplied by green energy from local energy cooperatives.

Industry and business

A change in the overriding economic model of the city was accompanied by a boom of localisation, which has resulted in improved services and the development of new ones. Cultural and creative industries are a fully developed and revived city industry. Lively streets and strengthened neighbourhood affiliation have greatly encouraged deployment of diverse small enterprises. Formerly unused urban areas were regenerated and within them are university facilities, modern factories and business hubs. The social innovation industry is very advanced and has been exported to other cities, and many young people are involved in social entrepreneurship.

Life

The general city image is improved and the city is ranked among the top ten most liveable cities in Europe. Unemployment has decreased significantly as many people were employed in green jobs and new industries. Public spaces are revitalized and biodiversity systems are restored. The city is fully connected with the Medvednica mountain and Sava river, where citizens and tourists spend a lot of time doing sports or recreation. A much improved tertiary education rate has raised ecological and social awareness among citizens. Citizens are very active in communities and their initiatives are taken seriously by the city management. People are less concerned about making big earnings and are more focused on the quality of their life and life of their fellow citizens.

5.10.3 QUANTIFICATION OF SCENARIOS FOR ZAGREB

The overview of the quantified scenarios is shown in Table 13.

Table 13: Quantification of the main elements of the scenario's for Zagreb

Element	Current	BAU 2050	PC 2050
Population	About 793,000 (City of Zagreb) 2011, 1.2 M in metropolitan area. 1237 inhabitants/km2 (3121 in urban area) Population pyramid in indicator assessment report	875,000 Based on recent trends and a continuation of 2030 projection by Oxford Economics	919,000 IIASA SSP scenarios show a population decrease of 7.8% from 2010 to 2050 for the BAU scenario for Croatia, with the sustainability scenario being a further 2.9% decrease. Urbanisation is 8.2% higher in the sustainability scenario. Therefore we use a scaling factor of (0.971x1.082) 5% more in the sustainability/PC2050 scenario.
Energy/renewable mix etc.	**Energy use** 11,300 GWh Declining energy intensity 1.17 to 0.92 GWh/euro (2006-2008) Energy by sector: **TWh** / **2008** / **2013** Municipal 0.5 0.5 Tertiary 2 1.7 Residential 5 5.45 Transport 4 3.5 Public lighting 0.1 0.15 **Total** **11.5** **11.3** Carbon [kt CO2]: Buildings 1,007 Transportation 1,731 Illumination 29.1 Industry 3,555	**Energy use** 10,100 GWh Energy by sector **TWh** **BAU** Municipal 0.5 Tertiary 1.3 Residential 5.4 Transport 2.8 Public lighting 0.1 **Total** **10.1**	**Energy use** 8,600 GWh Energy by sector **TWh** **PC2050** Municipal 0.5 Tertiary 1.2 Residential 4.4 Transport 2.4 Public lighting 0.1 **Total** **8.6** **Actions and milestones** • 50% renewable energy. • Biogas production • Investment in local renewable energy sources • 4 hydroelectric power stations • Energy production in the household, use of low carbon technology • 2050 – 95% food and energy production
Transport	Modal share:	In BAU car use remains very high, whilst cycling continues to also increase. Modal share:	Due to a well-developed network of cycle lanes, cycling has greatly increased to 20%. Modal share: **2050 BAU**

Element	Current	BAU 2050	PC 2050
	2001 2011 Public transport 36.80% 35% Walking 25.40% 25% Cycling 0.70% 3.00% Car 37% 37%	2050 BAU Public transport 36% Walking 25% Cycling 8% Car 31%	Public transport 38% Walking 20% Cycling 20% Car 22% **Actions and milestones** • Biking network
Housing and buildings	Several actions are noted in the SEAP plan as part of the participation in the Covenant of Mayors: reducing energy consumption in buildings and improving energy independence.	Energy of residential sector has increased from 2008 to 2013. However, we assume a slight overall decrease of 10% based on improvements up to 2050.	**Actions and milestones** • Investment in energy efficiency • Energy production in the household • Use of low carbon technology • Investment in energy efficiency
Water use	Very high water losses were recorded in 2008 of 48% Water use was 71.7 million m^3 (2008) Corresponding to about 250 litres/person/day which is quite high.	Anticipate improvement, although limited data make it impossible to model improvements in water use or losses. However, based on the current data it appears that water could become a particular challenge for Zagreb particularly with consideration to climate change.	Not mentioned. Therefore it is also anticipated that water could become a particular challenge also with the PC 2050 scenario.
Food and Consumption	No data	No data to develop a projection	**Actions and milestones** • "Healthy food" • Produce 40% of the cities food locally • Increasing areas for food production and urban gardens, with local composting • 2050 – 95% food and energy production
Air quality	No data	No data	No exceedances expected.
Waste	Improving waste recovery but limited data available on trends	Not possible to project based on available data	**Actions and milestones** • Regulations on obligatory sorting of waste and sorting stations • Zero waste and circular economy • Conversion of existing unused urban spaces for start-up business • Breaking the monopoly and creating the conditions for socio-

Element	Current	BAU 2050	PC 2050
			green businesses • Survey of available local resources and new technologies for circular economy
Economic			
GDP	18,645 EUR (2010)	38,000 EUR Based on adjusting Croatia IIASA SSP projections for BAU. In 2010 Zagreb was 50.3% higher than national average.	39,500 EUR Based on adjusting Croatia IIASA SSP projections for sustainability. In 2010 Zagreb was 50.3% higher than national average.
Business/industry mix	Most important branches of industry are: production of electric machines and devices, chemical, pharmaceutical, textile, food and drink processing. GDP share by sector (2003-2009): Forestry: 5.7 - 5.9% Industry: 18 - 16.7% Commercial: 11.8 - 9.5% Tourism: 3.6 - 3.9% Business sector: 17 – 21.3%	Industry is expected to continue to decline whilst the tertiary sectors will continue to develop.	Industry is expected to continue to decline whilst the tertiary sectors will continue to develop.
Employment	Unemployment:9.5% (2012) Employment by sector (2009-2012):: Agriculture: 0.4 – 0.43% Industry: 23.8 – 20.22% Services: 75.7 – 79.3%	Services are expected to dominate providing 80-85% of the employment.	Green jobs are anticipated but are not anticipated to be substantial in numbers.
Circular economy	No awareness of any movement	No awareness of any movement.	Mentioned as a strategic goal. Education and change in society.

6 ANALYSIS AND DISCUSSION

6.1 MAIN FINDINGS

This section provides a comparison of the main elements for the cities for each of the scenarios.

6.1.1 POPULATION

For the majority of cities, population increases are expected in both scenarios as shown in Figure 12. Litoměřice is the only city expected to decline in both scenarios, although only a small decline is anticipated. Since we had utilised the IIASA SSP scenarios for national projections as background, the PC 2050 population is typically larger. This is accounted for through an increased densification of the cities. An exception is Istanbul where PC 2050 is actually lower than BAU. Although this follows the background provided by the SSP's, it can also be seen to be particularly fitting for a sustainable Istanbul. It is suggested that this could be achieved through an increase in sustainable planning which increases densification, limits illegal building, and attempts also to limit the population to sustainable manageable levels.

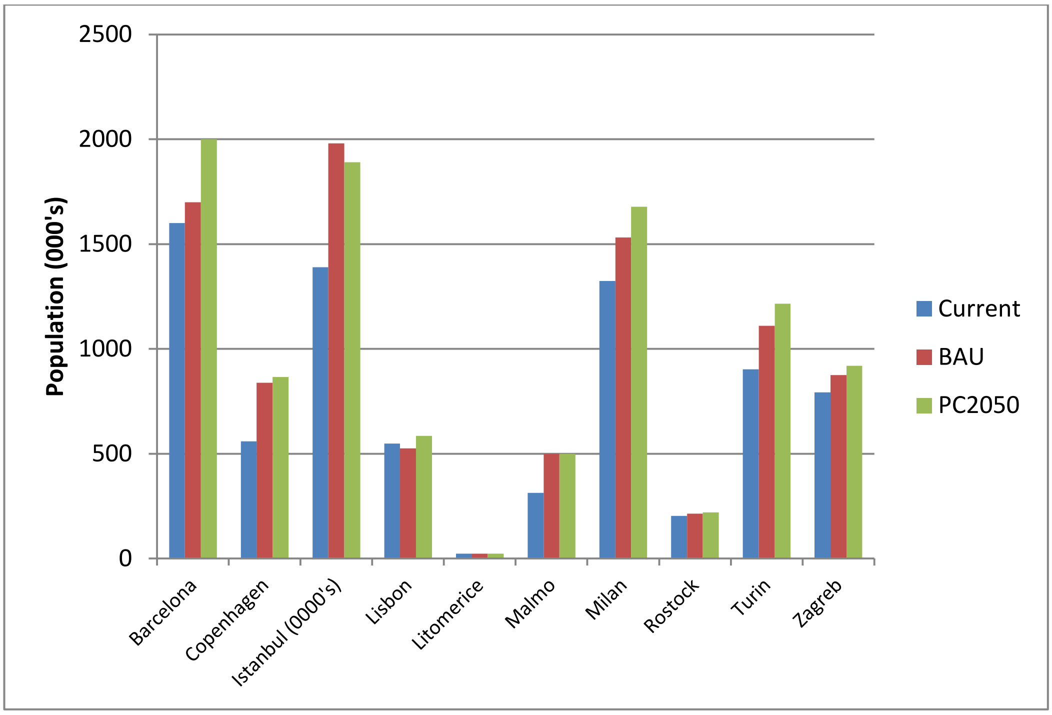

Figure 12: Populations of the cities comparing the scenarios against the current levels

6.1.2 ENERGY USE

For the majority of the cities energy use is usually higher for BAU than the current situation and PC 2050. This is typically related to the expected population increase with BAU compared to the current situation, and the expected level of energy reduction and efficiency improvements under PC2050. In some cases, energy use and efficiency improvements are also expected to be quite significant in the BAU scenario. Hence in some cases, energy use under BAU is also lower than the current situation despite the population rise, as in the case of Turin and Zagreb. The anticipated improvements are based on current trends, evidence of improvements, but also current projects and policies.

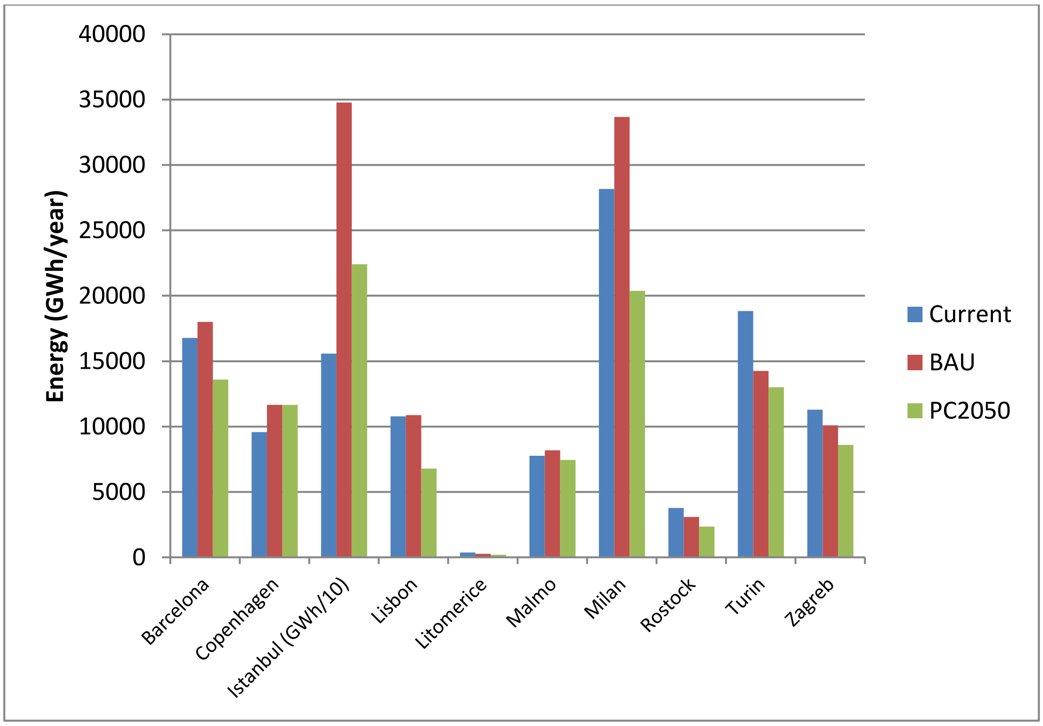

Figure 13: Energy use of the cities comparing the scenarios against the current levels

Figure 14 provides a more focussed perspective by comparing the energy use per capita, which removes the need to concurrently consider population change. This reveals that for 40% of the cities (Barcelona, Istanbul, Lisbon, and Milan) the energy use per capita is projected to grow under BAU whilst for the remaining 60% it is expected to drop. This drop is quite significant in some cases. Under PC 2050 the energy use is expected to drop for all of the cities with three cities, Barcelona, Litoměřice and Zagreb, dropping to under 10 MWh/person/year.

Surprisingly this shows Malmo as quite a significant user of energy on a per capita basis. This could partly be due to the cold climate, but may also be due to differences in what is included in energy use data, particularly for transport.

Of particular concern is Istanbul where in under BAU the energy use per capita is expected to grow significantly to unsustainable levels.

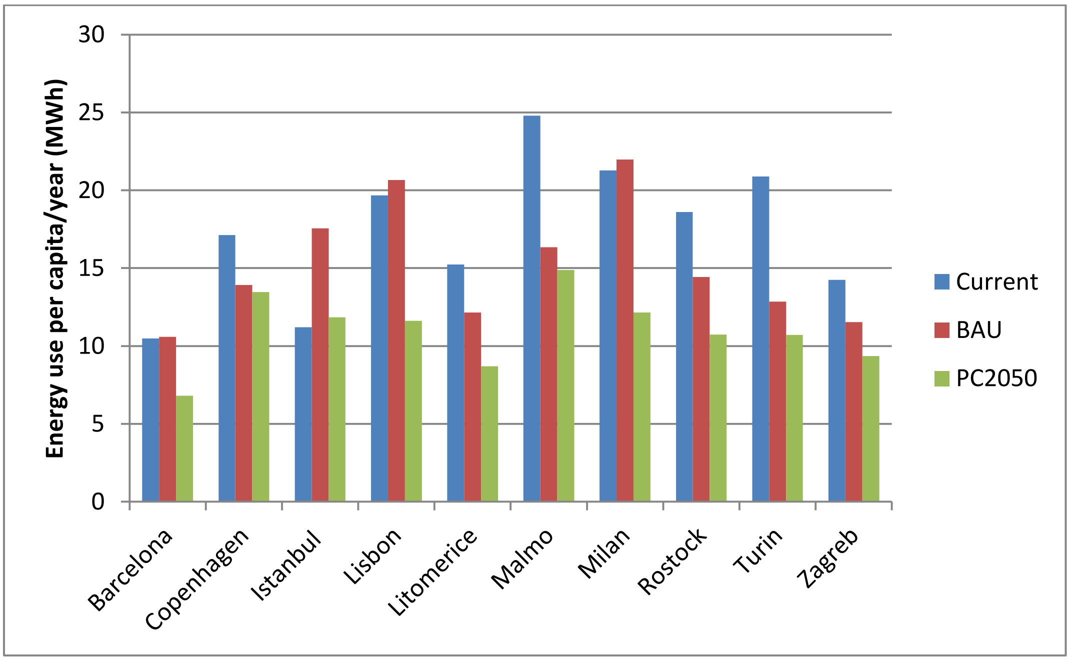

Figure 14: Energy use per capita comparing the scenarios against the current levels

6.1.3 TRANSPORT

A good indicator of the sustainability of the transport system within the cities is given by the total energy used per person, per year. Figure 15 provides a comparison of the energy use per capita of the city transport systems for the scenarios. It clearly shows that Lisbon has the highest per capita energy use, which is indicative of the high car use due to many residents moving away from the city centre.

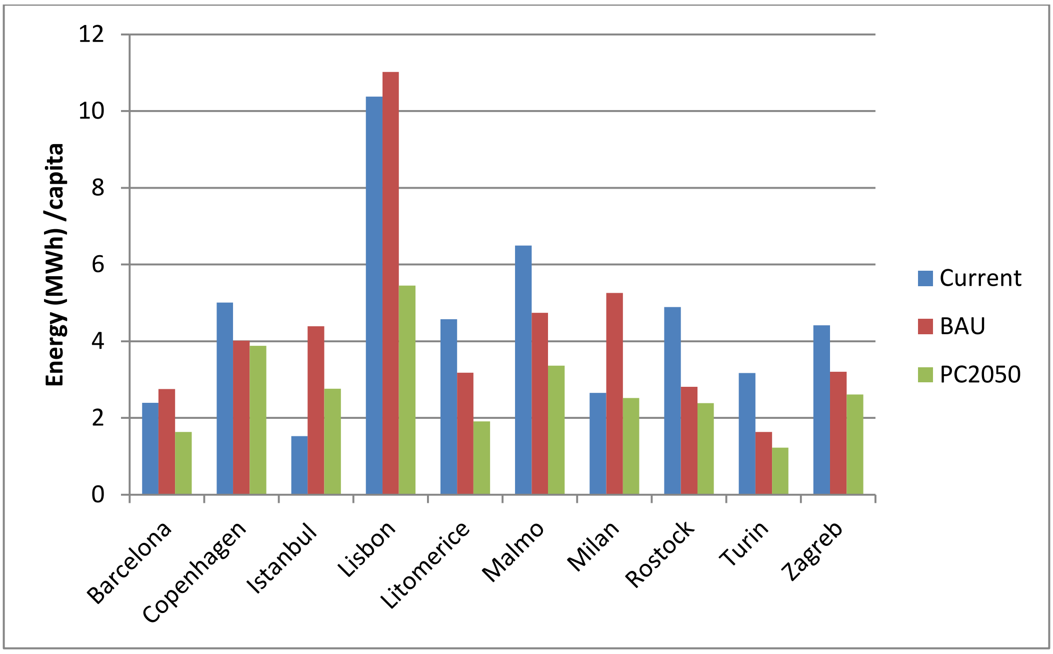

Figure 15: Energy per capita for the city transport systems under different scenarios

This is shown to fall significantly in the PC2050 scenario with higher densification, improved public transport and higher electric vehicles use. For the large majority of the cities energy use of transport in PC 2050 is much reduced due primarily to a shift to more sustainable transport modes and electric vehicles. The cities of Milan and Istanbul have notably high BAU values. This may partly be due to the projections being based on limited data that show poor current trends. Istanbul is expected to increase considerably in population, but towards 2050 we also expect increased mobility.

6.1.4 ECONOMY

The GDP per capita for the scenarios against current levels is shown in Figure 16. This shows large improvements for some cities under both BAU and PC 2050, in particular Malmo, Copenhagen and Lisbon. The difference between BAU and PC 2050 is quite marginal in general. These factors are largely a result of the underlying methodology provided by the SSP scenarios.

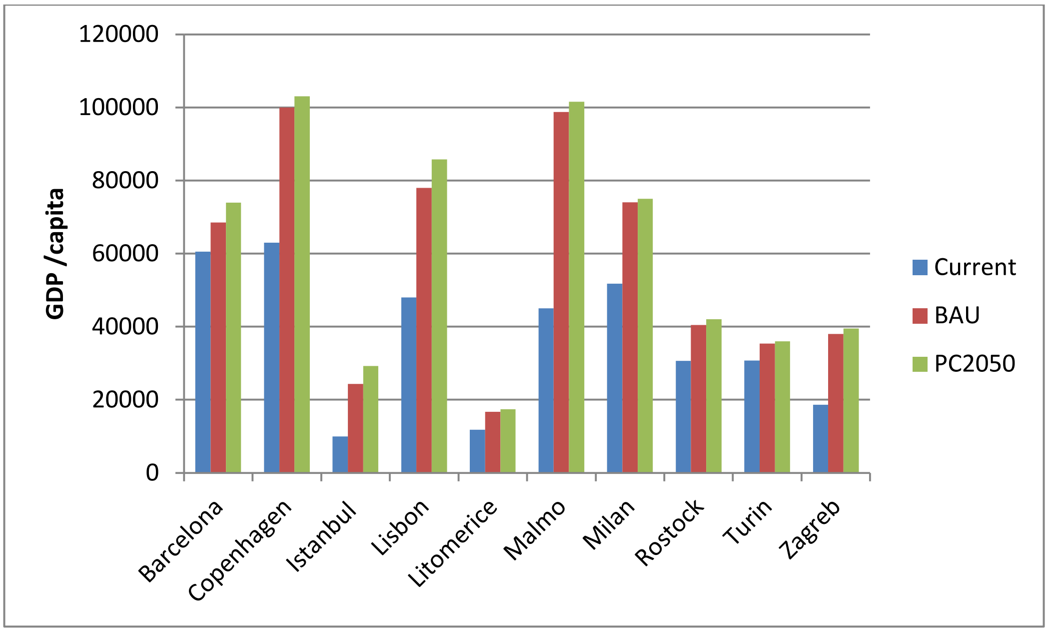

Figure 16: GDP per capita comparing the scenarios against the current levels

6.2 THE MODELLING PROCESS

The modelling process was challenging due to both the variations in data availability and quality, but also due to large inconsistencies in methods of reporting data, particularly energy use/production. Therefore a considerable amount of time was spent understanding how the energy data was structured, what was included and how it could be utilised in the modelling process.

Consistency in the modelling process was therefore impossible due to the inconsistency of data scope and reporting methods. It was judged to be more important to provide as comprehensive a modelling process as possible, on a case by case basis, rather than standardising and thus simplifying for all. This would therefore have meant a less comprehensive modelling for all.

A major challenge was to understand whether the level of detail for each of the modelled elements was appropriate. Too much detail could give a false sense of accuracy, whilst being time consuming and actually not providing any better projection due to the long time scale of the modelling (and because the main aim is "simply" to compare two scenarios for each city). For example, fairly detailed for data was available for Malmo on both energy sources and uses. This provided a basis for a detailed model with more parameters e.g. for sources it included electricity, waste heat, biofuel, oil, diesel, petrol, and ethanol. These could then be adjusted individually allowing more flexibility in response to trends observed in BAU or actions stipulated in the PC2050 vision. However, for other cities such as Istanbul, data for the city could only be obtained for electricity and gas, and needed to be calculated from national data.

None of the cities provided climate adjusted data apart from Rostock. This only made a small difference to understanding the trend and therefore the impact on the modelling process.

7 CONCLUSION

This deliverable has described the process of developing a modelling and quantification methodology, and how this was applied to the cities. It has also provided a qualitative description and basic quantification that describes the BAU and PC 2050 scenarios for each city. Overall, the chosen method was successful in developing the quantified scenarios for all cities, and also provides a solid foundation for the next project steps in WP5 – quantifying the impacts of the scenarios. In addition, this work will now feed into the MRIO work that will quantify the impacts of the city and its supply chain.

As in any modelling process that looks into the future there are several uncertainties and contentious issues. However, it is important to bear in mind that the projections given in this report are not intended as a prediction of the future (although BAU is viewed as a reasonable extrapolation and therefore a prediction of what could happen if no focussed action is taken). They are developed to learn from possible future scenarios about what might happen in BAU, what are the risks and how this compares to a possible post-carbon route. In addition, what are the possible effects and impacts that occur in the different scenarios, the strengths and weaknesses, and any trade-offs that might occur. Finally, what elements are missing in PC 2050 and what measures are required to achieve post-carbon cities?

One key and important uncertainty is the structure of the future transport systems, its efficiency in comparison to today and its energy supply. There are also uncertainties over the future share of transport modes, particularly in terms of the balance between public transport and car use. In addition, whether the move towards cycling and public transport will reach a peak in some cases. The role of the electric or low carbon car, its energy use in 2050 and whether there will be a rebound effect, i.e. increasing car use, due to the perception of low impact.

The issue of how to view the city boundaries is also one of contention. In the analysis in this report we have focussed on the central, municipality, primarily because this is where the “city” has control over and where the data was available.

The results of the modelling and quantification work to date, have shown that nearly all cities are growing. But in many cases energy consumption in the BAU is being decoupled, from both population and economic growth. However, this is generally too weak to make significant progress towards becoming post-carbon by 2050. There are generally significant differences in the energy consumption between the BAU and PC2050 scenarios. It is energy production, however, that will be the most critical in determining the climate change impact. Early indications suggest that the PC 2050 scenarios may not reach complete zero carbon status in many of the case study cities.

It is premature to speculate which cities this might be as the GHG emissions will be calculated in the next phase of the project. However, for nearly all of the PC2050 scenarios the total energy use is still fairly high and supplying this energy with renewable/low carbon energy was interpreted as difficult to achieve within the current set of related actions. In other words, although low carbon energy supply is certainly possible to achieve, many of the PC2050 visions and actions are currently too weak to achieve complete post carbon status. Therefore the actions and milestones related to the PC 2050 visions will need to be reviewed and strengthened.

A conservative approach was used when interpreting the visions and actions into quantified scenarios. Hence it was not enough to state "100% solar" energy without some indication that it was possible from actions, other literature/evidence (i.e. that it was physical and technically possible, hence sunny enough) or even current trends. Therefore some of the apparent "failure" of the PC2050 scenario to achieve a complete post-carbon status is due to the project process, where not enough workshops and follow-up work were conducted to produce a robust visions and set of actions.

It also seems particularly challenging to supply adequate low carbon energy within the system boundaries of the cities. The cities of Malmo and Copenhagen for instance have the advantage of being able to utilise offshore wind power, which could be viewed as somewhat outside the city boundaries. All cities have been modelled with an increase of electric energy and this is based on the current trends. Some cities such as Barcelona and Malmo already have electricity as 30-45% of supply, and this is projected to increase to 50-60%, or even 80% as in the case of Barcelona PC2050. Many cities will likely need to rely, to a certain extent, on electricity supplied from the regional or national grids, and so the post-carbon status depends also on the projected national supply.

Transport is a particular challenge due to the private car often being a large portion of the modal share and energy use. This will require inducing a shift in technology used by the consumer. This could be achieved through either a charge on fossil fuelled vehicles or outright bans on entering the city. It will also require the provision of the necessary infrastructure such as alternative fuelling points and charging stations. Nonetheless, it will require an increase in the supply of electricity.

The improvements that are required to the PC2050 scenarios will be the subject of the gap analysis, which is also in the next phase of the project. This will then inform the Roadmaps or post carbon strategies of what is required to reach post carbon status by 2050.

However, aside from the actually energy supply of the city, a further challenge to this is the carbon footprint and environmental impact of the supply chain, or household consumption to the city. Only the city of Malmo, appears to be considering household consumption, both currently in its indicator set, as well as in the post carbon scenario (aside from some sharing schemes, such as bikes and cars). However, it is becoming common for cities to develop bike sharing schemes as in the case of Copenhagen and Milan. Car sharing schemes are also developing as in the case of Barcelona, Lisbon and Milan.

In our desired 2050 low-carbon city, supplied by renewable/low carbon energy, the impacts of household consumption and the supply chain will represent the largest share of environmental impacts and of the carbon footprint, if nothing is done to address it. Hence although it appears to fall outside the radar for many cities, consumption represents a critical future challenge. Understanding the role of the city in addressing this is still in its infancy, but there are many actions that both local and national governments can do to address this. For example, there is the potential to develop standards or restrictions (e.g. for certain products, or develop thresholds to emissions), provide business support (particularly those involved in the circular economy), provide facilities (to encourage repair, reuse and recycling), optimise planning and spatial design, promoting sharing, and education of residents.

7.1 NEXT STEPS

The next steps are to move from quantified scenarios to quantified impacts which will be documented in the deliverable D5.3. The impacts will be quantified using two complementary methodologies: the indicator modelling and the MRIO modelling. The former will examine the impacts that are results of activities that occur within the city boundaries. It will focus on the energy supply system and the associated impacts. Socio-economic impacts will also be covered, that include social effects of the scenarios, investment costs and a cost-benefit analysis. In addition, the role of eco-system services in the scenarios and the impact on green and blue spaces will be reported. The MRIO work will account for the resource footprint impacts of the city scenarios by modelling the household consumption and government expenditure.

The analysis will compare and illustrate the gap between the BAU with PC2050 scenarios for the environmental and socio-economic indicators. This will help to identify the most important measures and changes that are required for a transition to a post carbon city. This will then provide vital results for WP7 and the development of the Roadmap.

8 REFERENCES

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9 APPENDIX 1: OXFORD ECONOMICS BACKGROUND PROJECTCIONS

Data on household consumption was purchased primarily for the MRIO analysis (to be reported in D5.3). But since it provided projections to 2030 for population change, GDP and employment, these were utilised as background data and the projections extended to 2050 (as discussed in section 4.2).

A brief explanation is provided below, written by Oxford Economics, on the methods used within its forecasting process for consumer spending by COICOP categories. Further detail cannot be provided due to the commercial sensitivity of the methodology.

9.1.1 NATIONAL SPENDING

Both current and constant price spending by COICOP data for most countries comes from Eurostat, with time series generally ranging between 1980 and 2014, depending on the country. Before any forecasting takes place, data is checked for sensibility and some data points are removed or replaced with more appropriate estimated figures. The forecasts are then produced in four steps:

1) First, we estimate price equations for the 12 broad categories and forecast them to 2030 using national total consumption deflators and world commodity prices from our Global Model as drivers.

2) Once we have the price forecasts we then produce forecasts for the volumes of spending (i.e. at constant prices) by using total national consumption, population and the price forecast of each category. As a result, in each broad category the volumes are driven by their relative prices with an adjustment for the evolution of its historical share of total consumption.

3) The price deflators for each of the 12 broad categories are then applied to the constant price spending, producing current price spending.

4) Finally, spending in each of the detailed sub-category is forecast using a shirt-share model against its corresponding broad category.

9.1.2 REGIONAL/CITY SPENDING

Oxford Economics have collected and incorporated regional/city level data into the historical series where it exists. However, data is significantly sparser at the sub-national level if not missing altogether (especially for developing countries). Therefore estimation of the historical series plays a greater role at the regional level. The approach adopted in producing regional estimates and forecasts considers the importance (i.e. share) of spending on a particular good/service in the region *relative to the country*. This “relative importance” is related to a series of economic and demographic factors which were analysed for a panel of countries with national and sub-national data:

1) Relative total consumption per capita: As total consumption per capita increases (due to rising average incomes) the share of spending on particular goods/services falls, while the share of spending on other goods/services rises. For example spending on food, a significant proportion of which would be classed as “necessities”, falls as total consumption rises. Conversely, spending on more “luxury” items such as recreational services and hotels & restaurants see their shares rise as total consumption rises. Thus, higher total consumption per capita in a region relative to the whole country results in a lower share of total expenditure on food in the region compared with the country, with the opposite being true for categories such as recreational services.

2) Relative share of population aged 18-34: A higher proportion of 18-34 year olds in the region’s population (relative to the country) drives a higher share of spending on items such as education and hotels & catering in some countries.

3) Relative population density: A higher population density in the region leads to a greater share of spending on recreational services, and a lower share in transport services in some countries.

10 APPENDIX 2: ASSUMPTIONS FOR INDIVIDUAL CITIES

This Appendix provides additional information on the assumptions and modelling methods used for the energy calculations.

10.1 BARCELONA

10.1.1 BAU

The current trends cannot be used without caution because they closely follow potential fallout from the financial crisis. The energy use was actually growing until 2006. After 2008 the GDP dropped. The energy growth is consistent with the population growth 2001 in the municipality.

- Oxford economics shows that GDP returns to steady growth in 2014.
- Most energy decline was experienced in the transport and industry sectors, which again could be the result of the financial crisis. This is in line with the Province as well. This could also suggest that people travelled less to the city from the provinces.
- (http://www.diba.cat/documents/471041/24663576/emissions+in+Barcelona_july+14.pdf/34110b21-ca61-4da6-acc2-d4f83695fc2a). GDP by sector shows that the service sector has grown by almost 10% points, whilst industry has declined.
- This leads us to suggest that with a recovering GDP, energy consumption could increase again. Transport share could also increase to that similar to the financial crisis.
- Due to lack of data therefore we suggest that BAU energy consumption by sector is similar to 2005 with a greater share covered by the service sector.
- Service sector has continued to grow GDP whilst decreasing energy
- Population does not grow for Province any further according to OE.
- EU energy trends predicts Spain's energy to be similar per resident as growth in final energy demand is similar to population.
- Thus we assume that:
    - service sector continues to grow to 2050 but improves efficiency - therefore similar energy in total;
    - industry recovers to 2005 levels with slightly increased efficiency 5%;
    - residential - increase electrification cancels out efficiency increases therefore remaining fairly similar.
- According to the Barcelona Energy and Climate Plan: electricity share has increased from 37,2% to 44.3% (http://w110.bcn.cat/MediAmbient/Continguts/Vectors_Ambientals/Energia_i_qualitat_ambiental/Documents/Traduccions/PECQ_english_def01.pdf).

10.1.2 PC2050 BARCELONA

The following assumptions were applied to the

- Residential: considers a 40% improvement in energy efficiency according to IEA
- Services: also 40% efficiency
- Industry: 20% efficiency improvement
- Transport: shift to electric 60% of energy use

10.2 COPENHAGEN

10.2.1 BAU

There is insignificant data and information available to identify a trend. The trend from 2005 to 2014 suggests no overall change in energy use, despite 2014 being somewhat lower. Carbon emissions show a clear decline however.

Heating use has remained more or less stable but electricity seems to have been reduced. This could be due to milder weather according to energy and carbon review/ green account. http://kk.sites.itera.dk/apps/kk_pub2/pdf/1393_x6fHiBE3UX.pdf

In addition, the data is only available from 2008 to 2013 and therefore could be affected by the financial crisis.

Therefore the current projections have taken into account the projected population rise (54%) and assumed a modest energy efficiency increase of 22% – resulting in an average increase of 20% in energy.

Transport energy was not available and was calculated from the reported GHG emissions, by converting from a similar example (Malmo).

10.2.2 PC2050 COPENHAGEN

Because a visioning workshop was not held in Copenhagen, the basis for the projection is the current 2025 carbon neutral vision of the city. The major difference is that we assume that the transport is also carbon neutral.

10.3 ISTANBUL

There was insufficient data on energy use and production, and the current trends for Istanbul. However, enough data did exist to construct a reasonable approximation. To enable this, additional data from national trends, available in literature and from Eurostat was used.

Electricity use for Istanbul was only available for the year 2013, but there were clear qualitative reports that electricity use has greatly increased, of the order of 78% over the previous decade.

10.3.1 BAU

National data and trends of energy use was used as a basis and projected to 2050. This was then converted to energy use per capita. Istanbul energy was then calculated for 2013 based on the per capita figure. Using the known electricity use, the % of electricity could then be estimated.

Figures were available from WP3 on the percentage share of energy used for each sector (industry, services, transport, agriculture and others) for 2003 and 2008 – which was then used to calculate the energy use of each sector. These percentages were also used to estimate a trend for the sectors and the share of the total energy for BAU 2050.

The share of electricity could be estimated for 2013 from the available data and then projected to 2050.

10.3.2 PC2050

To calculate the energy for PC2050, the BAU figures were used as a basis and the following assumptions were applied to each sector:

- Residential: considers a 40% improvement in energy efficiency
- Services: also 40% efficiency
- Industry: 20% efficiency
- Transport: shift to electric 60% of energy use

These basic assumptions were derived from IEA suggestions on potential, combined with an assumed large potential for improvement within Istanbul. From this the total figure was arrived at.

10.4 LISBON

Data was available by sector for 2008 and 2012 for Lisbon city. This showed an increase in energy use.

10.4.1 BAU

The following assumptions were applied in the calculation of energy:

- industry has increased since 2004 but remains static through to 2050 (it is generally expected that services will increase in European countries).
- Energy use per person increases to 2050 in line with EU trends projections for Portugal (Capros 2014) at 3%.
- Whilst electricity use increases by 29.5%
- The current trends for energy use in the sectors are used as a basis and then adjusted by population.
- Population declines by 4%.

10.4.2 PC2050

BAU energy use is used as a basis with the following assumptions:

- 50% of traffic is electric (using 40% of total traffic energy).
- Assume that efficiency of electric is 0.4% of current.
- Whilst fossil fuel vehicles use 70% of the energy today.
- Energy efficiency of buildings is 70% of today for services and residential .
- Industry improves efficiency by 20%.

10.5 LITOMĚŘICE

10.5.1 BAU

- Geothermal supplies all of the heating. This is seen as feasible as work is progressing well in drilling and investigations.
- Assume 20% improvement in building heating efficiency, and 20% improvement in energy efficiency of household appliances.
- Transport in PC 2050 uses 40% of the energy, but also energy using traffic is reduced by 30%.
- New hydroelectric power plant supplies 30 GWh.
- There are no data on energy consumed in transport, but there is an assessment of CO2 produced from transport based on regional values. This is used to estimate the energy for the transport sector.

10.5.2 PC2050

- Geothermal supplies all of the heating and most of the electricity.
- Passive housing and buildings are the main focus from the PC vision.
  Hence heating of buildings and houses in the city as a whole is reduced by 50%. This is because some older buildings would remain.
- Electricity use decreases mostly due to appliances in BAU (80%) and 60% in PC.
- Due to success of geothermal power, a second plant is installed for heating
- Assumed improved efficiency in use of natural gas.

10.6 MALMO

For energy calculations, good data on sources and use was available for 2005 from Malmo Energi Strategi (2009). This was converted to 2013 using additional data, which then formed the basis for the calculation of the BAU and PC2050 scenarios.

10.6.1 BAU

Total energy has remained fairly stable since 1990, hovering around 7000 GWh, although with a spike in 2005 and 2006. This occurred despite the population increasing by about 34% from 1990 to 2013.

Despite the energy remaining fairly stable there appears to be a moderate increase of about 8-10% over the last 10 years.

With a similar population growth rate predicted until 2050, we therefore used this trend to suggest a conservative growth in total energy of 10% despite the population expected to increase by 60%. Thus we expect a considerable improvement in energy use of both existing buildings and new buildings. Recent developments such as Västra Hamen and Hyllie suggest that standards for energy efficiency are high and continually improving, thereby supporting this assumption.

The electricity share of energy will rise to 38% in 2050 following a similar trend to the national projection by Capros et al. (2014).

10.6.2 PC2050

The share of electricity will rise to 67.8%

For energy use

- Housing has a 30% efficiency improvement on current stock and new accommodation for residents uses 40% of current energy.
- Industry and construction: 30% more efficient but 30% more manufacturing. Due to more innovation, location, population and circular economy.
- Transport: 1.3 more travellers using energy mode traffic, roughly half the new population. But traffic is 40 more efficient.
- Increase in services based on population factor but 20% more efficient.

10.7 MILAN

Milan's Sustainable Energy and Climate Action Plan (SEAP – produced for the Covenant of Mayors) was used as a basis, and supported with additional data from WP3, that provided figures for 2005 and 2010 for the sectors energy use.

According to Milan's energy plan (SEAP) expected growth without actions would be about 4.5% every 5 years for the municipality. Figures for Milan show energy use grew 4.1% from 2005 to 2010. However, 2013 figures show a slight decline. We assume this to be due to financial crisis and apply a nominal energy growth rate of 2% every 5 years to 2050.

10.7.1 BAU

The following assumptions or effects were applied:

- Electricity use efficiency cancels increase.
- District heating network grows.

- Service grows but industry decreases at same rate.
- Transport stays similar.

10.7.2 PC2050

The following assumptions or effects were applied:

- Residential: existing becomes 60% more efficiency whilst new dwellings use only 40% of energy as before.
- Industry and tertiary: efficiency improves 30%.
- Private transport is 20% of total energy and efficiency of electric cars is 60%.
- Public transport: 20% more efficient than BAU due to focus on electric and smart technology, but (65/51) 27% more volume.
- 20% more efficient.

For transport:

- Energy reduced in transport system by 20%.
- Public transport increases to 65%.
- Bicycles are 15% of modal share.
- 80% of cars are electric or PHEV.

10.8 ROSTOCK

For Rostock the city's Masterplan (Masterplan 100% Klimaschutz für die Hansestadt Rostock, Gicon, 2013) was used as a basis for the calculations and the scenarios "Trend" used for BAU and "Ambitious" used for PC2050.

However, the energy use was adjusted using the POCACITO population projections as these were viewed as more realistic. Rostock's Masterplan was calculated on an assumed decline in population. But according to Oxford Economics projections and consultation with the case study team, the population is now expected to increase.

10.9 TURIN

The trends in Turin's Action Programme for Energy were used as a basis for the calculations. The calculation assumes that the commitments in TAPE are achieved and that similar reductions from 1991 to 2020 can be made up until 2050.

10.9.1 BAU

The following energy efficiency assumptions were applied to the sectors:

- Municipal and lighting – 10% improvement
- Residential and tertiary – 30% improvement
- Industry and transport – 20%

10.9.2 PC2050

The following energy efficiency assumptions were applied to the sectors:

- Municipal and lighting – 10% improvement
- Residential - 40% improvement
- Tertiary – 50% improvement
- Industry – 20% improvement
- Transport – 60% improvement

10.10 ZAGREB

Basic data was available for Zagreb for energy consumption by sector for 2008 and 2013. These were obtained from the Zagreb Sustainable Energy and Climate Action Plan (SEAP – produced for the Covenant of Mayors).

10.10.1 BAU

Due to the limited amount of data and information on current trends and energy related projects only some basic assumptions could be applied and limited improvements assumed.

The trend of each sector from 2008 to 2013 was extrapolated and the energy consumption adjusted based on a percentage factor calculated by the expected population growth to 2050 (10.4% for BAU and 15.9% for PC2050), and the following assumptions for energy efficiency:

- Municipal: assumed to stay the same for all scenarios. Energy efficiency improvements are cancelled by an increased need for services due to population growth.
- Tertiary: 30% improvement in energy efficiency.
- Residential: limited to a 10% energy efficiency improvement due to limited information on current trend and situation
- Transport: basic 30% improvement.
- Public lighting: the same as 2008, hence improvement in efficiency is cancelled by increased lighting for increased population.

A general assumption was first applied that there was a 30% improvement in overall energy use (based on current trend and assumed technological improvements suggested by IEA), which was then adjusted by a factor according to the expected population change.

10.10.2 PC2050

The calculation was repeated as in BAU but with the following assumptions, derived from the PC2050 scenario:

- Municipal: assumed to stay the same for all scenarios. Energy efficiency improvements are cancelled by an increased need for services due to population growth.

- Tertiary: 40% improvement in energy efficiency.
- Residential: limited to a 30% energy efficiency improvement due to limited information on current trend and situation.
- Transport: basic 40% improvement. There was only limited mention of electric cars in the PC2050 scenario and hence we assume only limited improvements.

Public lighting: the same as 2008, hence improvement in efficiency is cancelled by increased lighting for increased population.