POCACITO

european post-carbon cities of tomorrow

TOWARDS A POST-CARBON FUTURE

BENCHMARKING OF 10 EUROPEAN CASE STUDY CITIES

INTELI – INTELLIGENCE IN INNOVATION, INNOVATION CENTRE

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ABSTRACT

Considering the urgency of global climate change and other environmental, social and economic pressures, it is presumed that the current urban system is close to crossing several thresholds of sustainability and that a new system – the post-carbon city – is necessary to prevent the movement into an undesirable state from which it is difficult, if not impossible, to recover.

This article intends to analyse this transition process towards a post-carbon model in 10 European cities (Barcelona, Copenhagen, Malmö, Istanbul, Lisbon, Litoměřice, Milan, Turin, Rostock and Zagreb) based on a set of environmental, economic and social Key Performance Indicators (KPI).

This research work identifies a global trend towards a post-carbon paradigm, besides different urban development stages. Copenhagen and Malmö are at the forefront of this sustainable trajectory. These cities have clear strategic visions in the area of urban sustainability, and are implementing several projects on mobility, energy and climate with positive impacts. Moreover, they are young, qualified and multicultural cities and present a good economic performance in terms of GDP per capita, which emphasises the importance of good framework conditions.

I INTRODUCTION

This article intends to analyze the transition process of 10 European cities - Barcelona, Copenhagen, Malmö, Istanbul, Lisbon, Litoměřice, Milan, Turin, Rostock and Zagreb towards a post-carbon model, based on a set of environmental, economic and social Key Performance Indicators (KPI). The identification of clusters of cities with different stages of development in the achievement of a sustainable future is also an objective of the research, taking in account the diverse territorial specificities.

This work has been developed under the framework of the POCACITO – "Post-carbon Cities of Tomorrow – Foresight for sustainable pathways towards livable, affordable and prospering cities in a world context" project, supported by FP7 of the European Commission (EC). This initiative aims to produce a 2050 roadmap to support the transition of cities to a more sustainable or post-carbon future, through a collaborative research and participatory scenario building. An important step to achieve project's goal is the production of an integrated assessment of case study cities in order to evaluate and make a comparison of their current situation as an input into the scenario development.

The article is divided in the following parts: urban transition and post-carbon cities, methodological framework, overview of the case study cities, case study cities performance, findings and key challenges, and conclusions.

II URBAN TRANSITION AND POST-CARBON CITIES

Cities are complex, adaptive, social-ecological systems (Levin and Harvey 1999; Berkes, Colding and Folke 2003; Gunderson and Holling 2001; Norberg and Cumming 2008; Evans 2008) "characterised by a particular human settlement pattern that associates with its functional or administrative region, a critical mass and density of people, man-made structures and activities" (UNEP 2011).

A significant proportion of global greenhouse gas emissions are attributed to urban areas, with figures ranging from 31 to 80% of global emissions (Duren and Miller 2012; Satterthwaite 2008). It is therefore of pivotal importance that cities, while being the centre of economic and social activities, become crucial players of promoting carbon reduction and sustainable development strategies worldwide.

Since the World Commission on Environment and Development (the "Brundtland Commission") sought to address the problem of conflicts between environment and development goals by formulating a definition of sustainable development in 1987 – "development which meets the needs of the present without compromising the ability of future generations to meet their own needs", many attempts have been made to narrow down the concept to make it applicable to different contexts or to reconcile the three classical pillars – environment, society, and economy.

Mainly based on Keivani (2010) and UN-DESA (2013), Pisano, Lepuschitz, and Berger (2014) undertake a convincing attempt for framing urban sustainable development. They define a diagram for urban sustainable development, which is made up of six blocks.

The social perspective includes urban social inequalities, low income, poverty, crime and social exclusion, which can lead to socially deprived problem areas in urban centres or suburbs. In sequence, the economic development integrates not only the economy, but also municipal finance in order to ensure provision of essential city services as well as social support activities. The environmental aspects are two-fold: on the one hand, cities are the largest contributors of GHG emissions; on the other hand, cities and their citizens suffer from climate instability, floods, heat waves or hurricanes. Furthermore, urbanisation, urban sprawl and industrialisation lead to general environmental pollution, issues of resource management (particularly water) and loss of agricultural land. The fourth component refers to the viewpoint of access to utilities and infrastructure which determines, among others, the degree to which a city can become active in transition processes towards sustainable development since a city has more influence on utilities if they belong to the city or if the municipality is at least a shareholder. Moreover, the connections derived from urban form and spatial developments have consequences for all the pillars of sustainable development and are therefore crucial in the urban context. Urban sustainable development can become reality if a conscious planning towards this end takes place. The inclusion of multi-level governance and institutional development refers to the fact that a city is part of a larger system, e.g., the political system of the nation state. The issues of inter-city linkages or the relationship of the city with the surrounding area – which is usually responsible for delivering renewable energy - is also highly relevant.

When ecological, social, or economic structures make the existing cities unsustainable, it may be necessary to fundamentally change the nature of the system – to transform it. Considering the urgency of global climate change and other environmental, social and economic pressures, it is presumed that the current urban system is close to crossing several thresholds of sustainability and that a new system – the post-carbon city – is necessary to prevent the movement into an undesirable state from which it is difficult, if not impossible, to recover.

In this context, a transition process can be defined as "a gradual, continuous process of change where the structural character of a society (or a complex sub-system of society) transforms (…) transitions are not uniform and nor is the transition process deterministic (…) there are large differences in the scale of change and the period over which it occurs (…) transitions involve a range of possible development paths, whose direction, scale and speed government policy can influence, but never entirely control" (Rotmans et al. 2001). Consequently, transitions are "complex and long-term processes comprising multiple actors" (Geels 2011).

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, and the establishment of new types of cities that are low-carbon as well as environmentally, socially and economically sustainable. The term post-carbon emphasizes 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 adaptive capacity, 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" (Evans 2008; based on Adger 2006; Neil Adger, Arnell, and Tompkins 2005).

This adaptive capacity of urban systems is the ability of stakeholders – i.e., human actors – to improve its resilience (Berkes, Folke, and Colding 2000; Folke et al. 2004; Gallopín 2006; Lebel et al. 2006; Olsson et al. 2006) to fluctuating environmental and socio-economic pressures.

Transitions with regard to sustainability have three characteristics that distinguish them from other transitions (Geels 2011). First, sustainability transitions are goal-oriented. However, since the goal is a collective good, there are hardly any incentives for private actors to engage in sustainability transitions. Sustainable solutions usually do not offer obvious user benefits. Therefore, economic framework conditions need to be changed so that innovations can replace existing systems. This requires changes in policies beforehand to address politics and power struggles, which are likely to emerge since vested interests will probably try to resist these changes. The third characteristic is based on the assumption that it is not incumbent firms, but pioneers who develop innovations and thus help start or implement transitions. Moreover, incumbent firms will probably stick to the old regime. Therefore, innovation and innovative businesses are seen as a driver of transition.

The transition of cities to become more sustainable through the three pillars – environment, society and economy – requires dramatic improvements in energy and water-use efficiency; alternative transportation modes such as walking, bicycling, and mass transit; investments in green infrastructure; waste minimisation (reduced packaging and increased use of composting, waste-to-energy, and recycling); promotion of regional food systems; sustainable housing; as well as other measures in governance or education structures. Along with environmental concerns, policies and planning must also confront key socio-economic issues, such as aging populations, migration, health, poverty and exclusion of the urban poor.

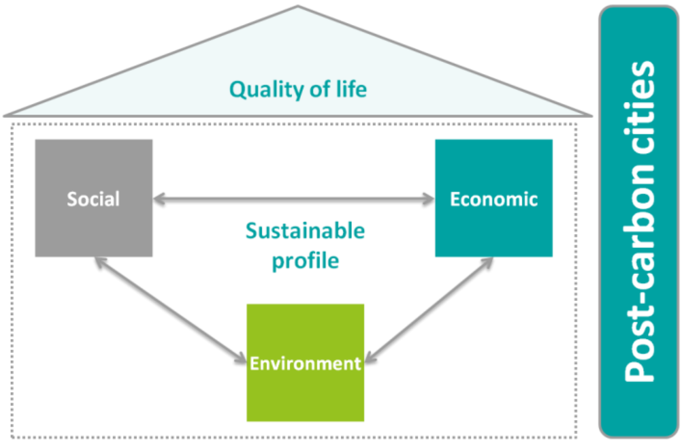
III METHODOLOGICAL FRAMEWORK

III.I DIMENSIONS AND SUB-DIMENSIONS

A description of a city (e.g., the inner system made up of the political and economic system, physical structure, etc.), and an inventory of where most of the GHG emissions stem from, as well as other social and economic problems (the subsystems), help identify what possible measures could lead to a post-carbon transition process.

To achieve this objective, a theoretical model was developed based on the concepts of 'urban sustainability' and 'post-carbon cities' comprising the environmental, social and economic dimensions. Instead of analysing these three components as silos, a comprehensive and holistic approach that assesses the relationships among factors and feedback loops of the entire system was adopted. A systems thinking approach was used in order to analyse the dynamics of urban systems and to identify key features of post-carbon city transitions.

Figure 1: Conceptual model

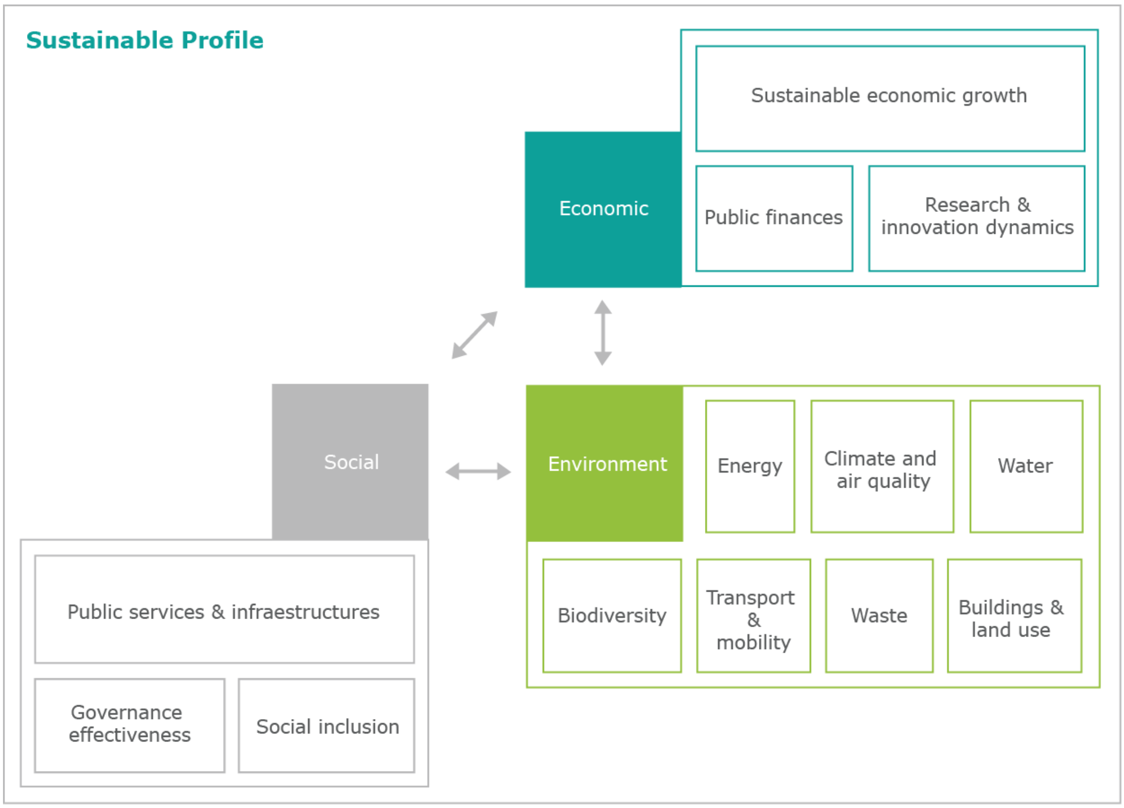


The environment dimension investigates the sustainable profile of the cities and assesses not only the current impacts on the environment, but also during the transition processes, evaluating the environmental resilience of the cities. It is important to continuously adapt the strategies to follow in order to mitigate the negative impacts on the environment during the transition process. The environmental dimension covers the energy sector in general in order to promote not only the final energy efficiency but also the resources depletion associated with energy consumption. Post-carbon cities pay special attention to GHG emission and its contribution to climate change. Some energy intensive sectors are empathised, such as transportation/mobility and the buildings stock. Biodiversity and air quality are critical themes that are also integrated in this dimension. The concerns regarding waste and water are also evaluated.

The economic dimension emphasises the sustainable economic growth based on the wealth of the cities and their inhabitants. It recognises that investments are crucial to promoting post-carbon cities, in particular the ones related to sustainable facilities. The labour market and the life of the companies are taken into account to demonstrate the dynamics of a post-carbon economy in a green economy paradigm. Public finances are also analysed because the cities with a lower level of indebtedness are more prepared to face the challenges during the transition process towards a post-carbon city. This dimension also includes the R&D expenditure because no city can become a post-carbon city without innovation.

The social dimension is concerned about equity both in the current generation and between generations during the transition process to post-carbon cities, which is expected to be smooth for all citizens. The benefits for inhabitants that come out of living in a reduced carbon city are highlighted, showing that these cities are places where it is pleasant to live in and the values of equity and social inclusion are present. Special attention has been given to standards of living related to essential aspects such as education and health (for example, life expectancy and wellbeing). Unemployment rates and poverty are also issues addressed on the context of post-carbon cities. Public services and infrastructures that are available for citizens are analysed, as well as aspects of governance and civic society, promoting the positive sense of culture and community.

Figure 2: Dimensions and sub-dimensions



For each dimension and sub-dimension, a set of indicators has been selected which allows a uniform collection of data, improves the comparison and supports the identification of good practices.

III.II KEY PERFORMANCE INDICATORS

The development of KPIs was supported by an in-depth analysis of several existing index systems related to sustainability (Vivid Economics 2013; Economist Intelligence Unit 2012; OECD/LEED 2013; Marcelino et al. 2007; Columbia University, Joint Research Centre European Commission, World Economic Forum 2012).

The indicators selection was based on mapping exercises through an iterative process comprising discussions with stakeholders, as most relationships are not straightforward and dynamic in nature. Criteria of relevance, clear message, data availability and data quality were taken in account.

Table 1: List of Key Performance Indicators (KPI)

DIMENSION	SUB-DIMENSION	INDICATOR	UNIT
SOCIAL	Social Inclusion	Unemployment level (by gender)	Percentage
		Poverty level	Percentage
		Tertiary education level (by gender)	Percentage
		Average life expectancy	Nº
	Public services and Infrastructures	Green space availability	Percentage
	Governance effectiveness	Existence of monitoring system for emissions reductions	Yes/No Description
ENVIRONMENT	Biodiversity	Ecosystem protected areas	Percentage
	Energy	Energy intensity	Toe/euro
		Energy consumption by sectors	Percentage
	Climate and Air Quality	Carbon emissions intensity	Ton CO_2/euro
		Carbon emissions by sectors	Percentage
		Exceedance rate of air quality limit values	Nº
	Transport and mobility	Share of sustainable transportation	Percentage
	Waste	Urban waste generation	Kg/person/year
		Urban waste recovery	Percentage
	Water	Water losses	m^3/person/year

DIMENSION	SUB-DIMENSION	INDICATOR	UNIT
	Buildings and Land Use	Energy-efficient buildings	**Percentage**
		Urban building density	**Nº/ km²**
ECONOMY	**Sustainable economic growth**	Wealth per capita	**eur/person**
		GDP by sectors	**Percentage**
		Employment by sectors	**Percentage**
		Business survival	**Percentage**
	Public Finances	Budget deficit	**Percentage of city's GDP**
		Indebtedness level	**Percentage of city's GDP**
	Research & Innovation dynamics	R&D intensity	**Percentage**

The development of KPIs was founded on the approach that monitoring the sustainability profile of cities will promote the adjustment of urban policies accordingly and will stimulate adaptive (or flexible) policy processes (National Research Council, 2014). Jointly, monitoring the sustainability performance will thus in a medium and long term perspective enhance quality of life for urban citizens and sustainable growth of cities.

III.III DATA COLLECTION

In order to quantify the KPI in each case study city, the selected methods for data gathering and collection have comprised the following approaches:

- Top-down approach – completion of the indicators list according to a review of main statistical findings, existing relevant strategic and planning documents, and legislation to assure an accurate quantitative data collection;
- Bottom-up approach – discussions with local authorities and other selected stakeholders to complement the collection of quantitative data and enrich the contents of the case study analysis.

In general, most of the required data can be retrieved by national/regional statistical offices, government departments, environment and energy agencies, research institutes and non-governmental organisations. The data collection process depends on the availability of high quality and relevant data.

Moreover, all the indicators should be collected for both years 2003 and 2012 in order to compare their evolution throughout this period (sometimes, mainly for some economic and social indicators, time series were required). Whenever data is not available for those years, one should collect the earliest and the most recent years between 2003 and 2012.

The geographical boundaries of the assessment should be defined according to the limitations of data availability. All indicators should be collected for the one geographical level, being privileged the municipality level. If an indicator is not available at this geographical level, then it could be collected for NUT III or NUT II. If the data is only available at the national level, it is considered that it is not representative of the city, so it should be discarded.

Data collection limitations were centred in the following issues:

- Some data was collected for different time periods due to unavailability of data;
- Some data was collected for different geographical scales due to unavailability of data;
- Different data sources used for different years, which can cause comparison problems;
- Absence of data for the quantification of some indicators.

Because of the referred limitations, the integration of data was difficult. However, all the methodological problems are indicated in the analysis.

IV OVERVIEW OF THE CASE STUDY CITIES

IV.I CASE STUDY CITIES SELECTION

Due to the diversity of cities and local circumstances, features of post-carbon cities will vary according to each city. Thus, for analysing the transition process towards a post-carbon future, 10 case study cities were selected, namely: Barcelona, Spain; Copenhagen, Denmark; Malmö, Sweden; Istanbul, Turkey; Lisbon, Portugal; Litoměřice, Check Republic; Milan and Turin, Italy; Rostock, Germany; and Zagreb, Croatia.

The selection of case-studies was developed according to a matrix crossing the following criteria, being privileged their diversity:

- Economic, social and ecological flows under the following themes: water, waste, energy, transport, food, green infrastructure and adaptation to climate change;
- Territorial (cross border, mountain areas, inland, central and coastal regions) and geographical (Northern, Southern, East and Central Europe, and Nordic Countries) location according to the ESPON regional typology database 2013.

Figure 3: Case study cities

The spatial boundaries selected for each case study are identified in the following table:

Table 2: Case studies geographical level

CASE STUDY CITY	GEOGRAPHICAL LEVEL
Barcelona	Metropolitan Area
Copenhagen	Municipality
Istanbul	Municipality
Lisbon	Municipality
Litoměřice	City
Malmö	Municipality
Milan	Municipality
Turin	Municipality
Rostock	City
Zagreb	Municipality

IV.II CASE STUDY CITIES PROFILE

The characteristics of the case studies differ widely according to size, density, wealth, climate as well as governance and economic structures.

Table 3: Geopolitical elements

CASE STUDY CITIES	GEOPOLITICAL ELEMENTS
Barcelona	2nd largest city in Spain, capital of Catalonia 2nd economic centre in Spain, after Madrid Relevant port city Important cultural centre in Europe Touristic destination
Copenhagen	Capital city (Denmark) Located by the coast of Oresund, it is situated on the island of Zealand and the small island of Amager in the south western part of Denmark Oresund bridge connects Copenhagen to Malmö Important harbour area
Istanbul	Capital city (Turkey), mega city Strategic location: Istanbul extends over 2 continents – Asia and Europe; 4th Pan European Corridor ends in Istanbul Two important ports Cultural, economic and demographic dynamics

CASE STUDY CITIES	GEOPOLITICAL ELEMENTS
Lisbon	Capital city and the largest city in Portugal Westernmost city in Europe, along the Atlantic coast Coastal city and touristic destination Strategic location: relation with Latin America, Africa and Asia, allowing access to 750 million consumers from Europe and Portuguese-speaking countries
Litoměřice	Small city Northern part of Czech Republic 60 km North of the capital Prague
Malmö	3rd largest city in Sweden Southwest coast of Sweden Direct connection to Denmark via the Öresund bridge
Milan	2nd largest city in Italy, after Rome Administrative centre of the Lombardy region Northern part of Italy, midway between Po river and the foothills of the Alps Main industrial and commercial city in Italy Artistic and cultural centre
Turin	4th largest city in Italy Administrative centre of the Piedmont region Western part of the Po river, at the foothills of the Alps 3rd area in Italy in terms of GDP
Rostock	Medium-sized city North-east of Germany by the Baltic sea Geographical region Northern Lowland Can be accessed by highway from Hamburg and Berlin in around 2 hours
Zagreb	Capital city and the largest city in Croatia Northwest of the country, along the Sava river Excellent traffic connection between Central Europe and Adriatic Sea

Istanbul has the biggest territorial area, followed by Zagreb and Malmö. The smallest municipalities are Lisbon, Copenhagen and Litoměřice. However, Barcelona is the municipality with higher urban density, followed by Milan and Turin. Less dense municipalities are Rostock and Malmö.

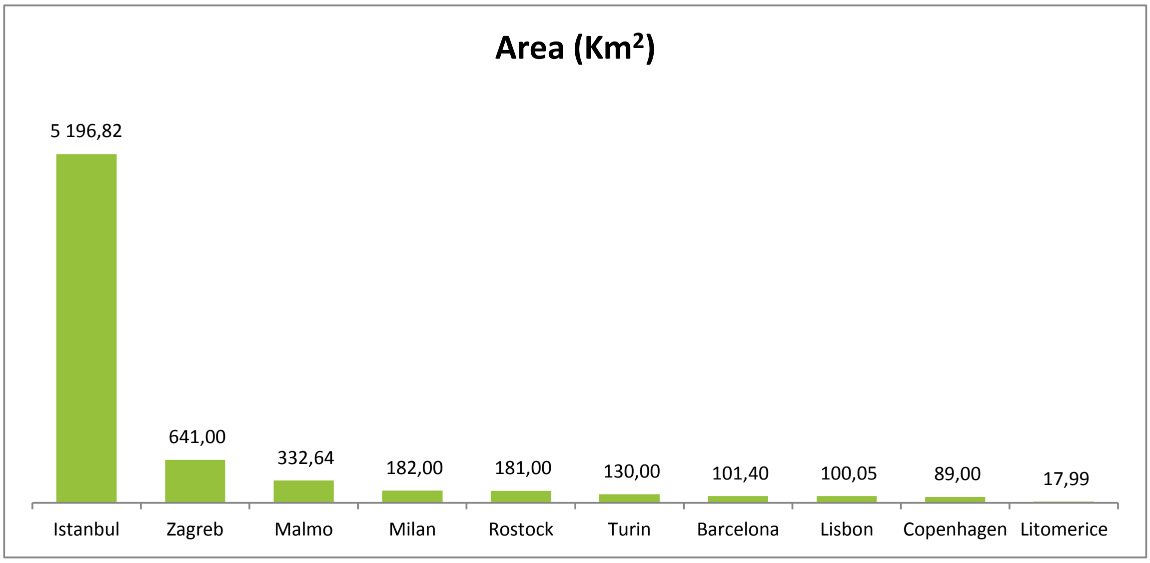


Figure 4: Area (km^2), Municipality, 2013

Note: Zagreb and Lisbon - 2011; Istanbul - 2012.

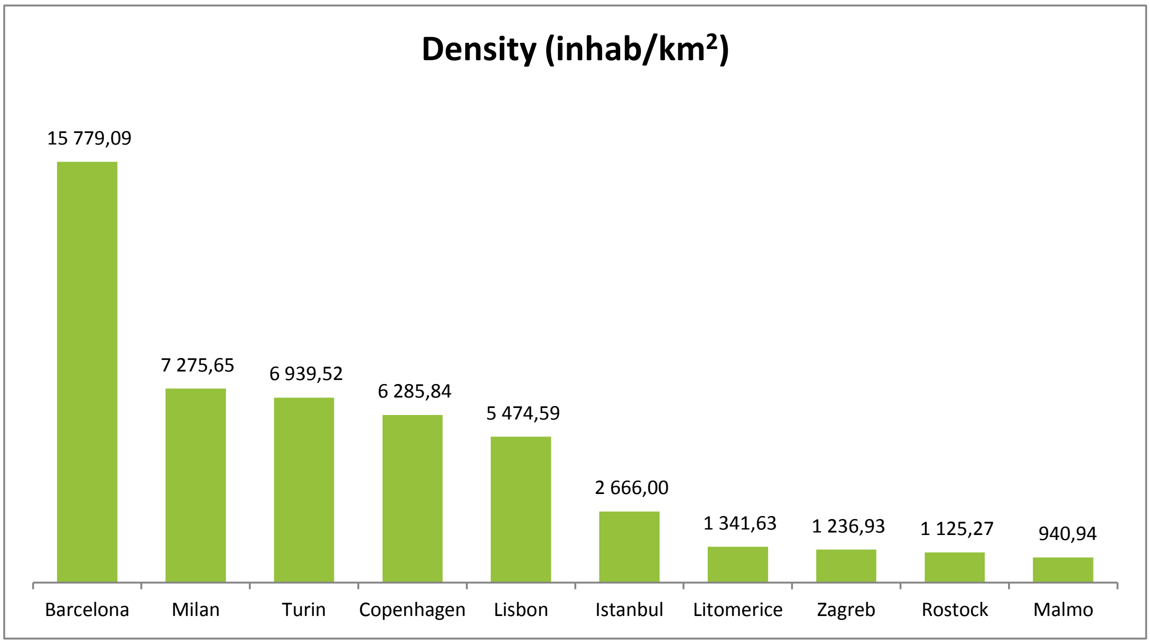


Figure 5: Density (inhabitants/km^2), Municipality, 2013

Note: Zagreb and Lisbon - 2011; Istanbul - 2012.

The number of inhabitants of the case study cities is very diverse: from around 14 million inhabitants of Istanbul to 24,000 of Litoměřice. It is worth of notice that Istanbul is a mega city, ranking 8 out of 78 OECD metropolitan regions in terms of population size and first for population growth since the mid-1990.

Foreign population is increasing in all cities, being Malmö (31%), Copenhagen (17.4%), Barcelona (15%), Milan (15%) and Turin (15%) the most cosmopolitan and diverse urban areas. Rostock and Litoměřice have only 4% of foreigners in their total population.

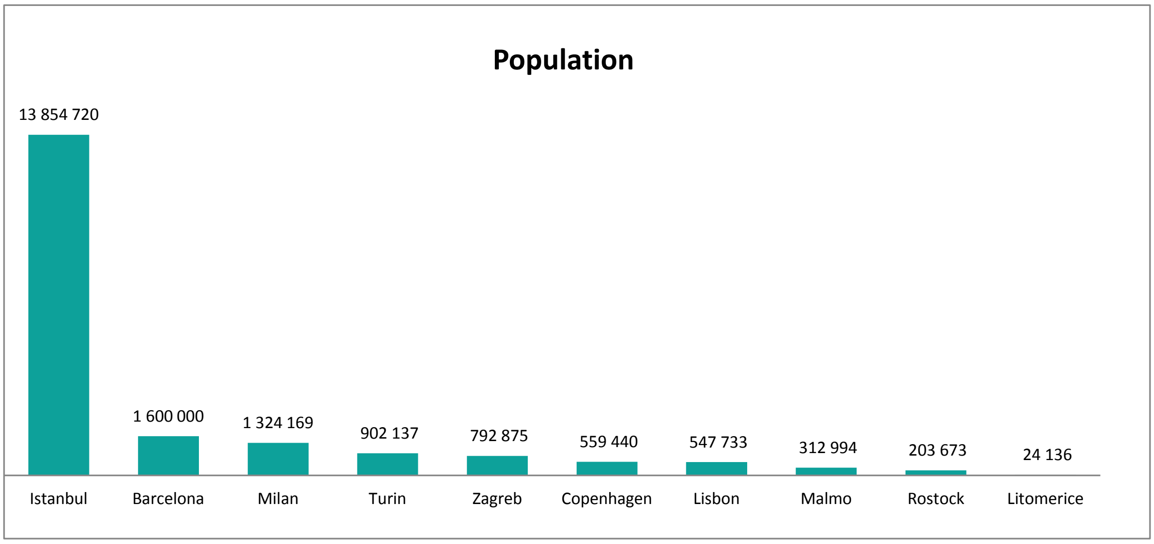


Figure 6: Population, Municipality, 2013

Note: Zagreb and Lisbon - 2011; Istanbul - 2012.

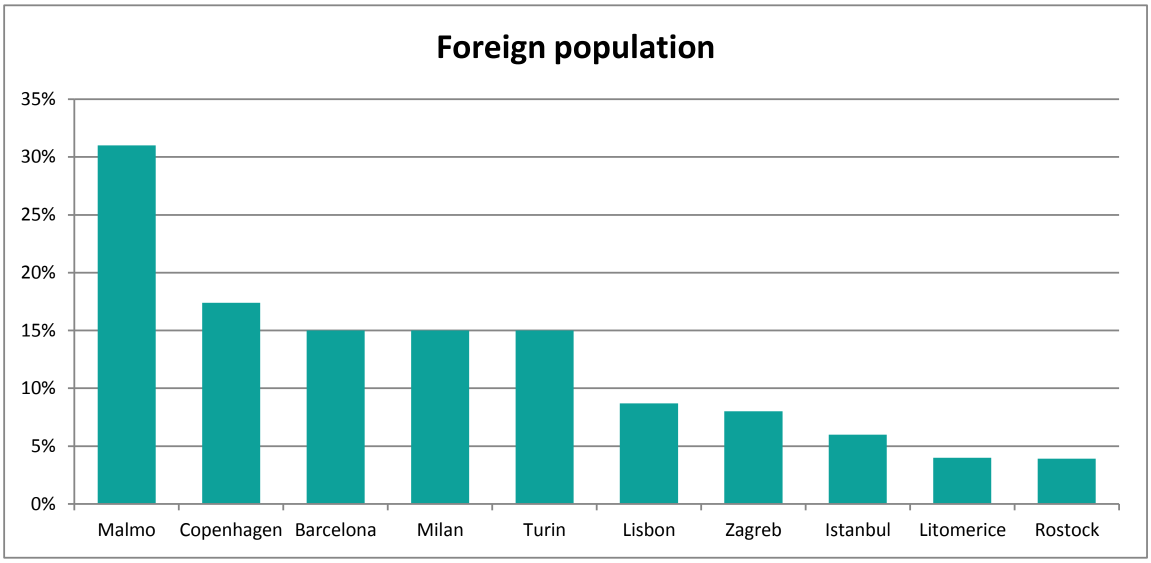


Figure 7: Foreign Population, Municipality, 2013

Note: Zagreb and Lisbon - 2011; Istanbul - 2012.

The age structure of the population of the case study cities is similar, being recognized a trend towards ageing population. This trend is not so visible in Istanbul, with the following distribution of the population: 23% (0-14), 71% (15-64) and 6% (over 65). Malmö and Copenhagen are exceptions. In Malmö almost half of the population is under 35 (49%) and 71% of the households consist of single parent or single person households (2013). Copenhagen has also a young population, with a markedly higher rate of residents between

20-49 years old than the national average. The majority of Copenhageners are less than 49 years old, and people moving into the city are young.

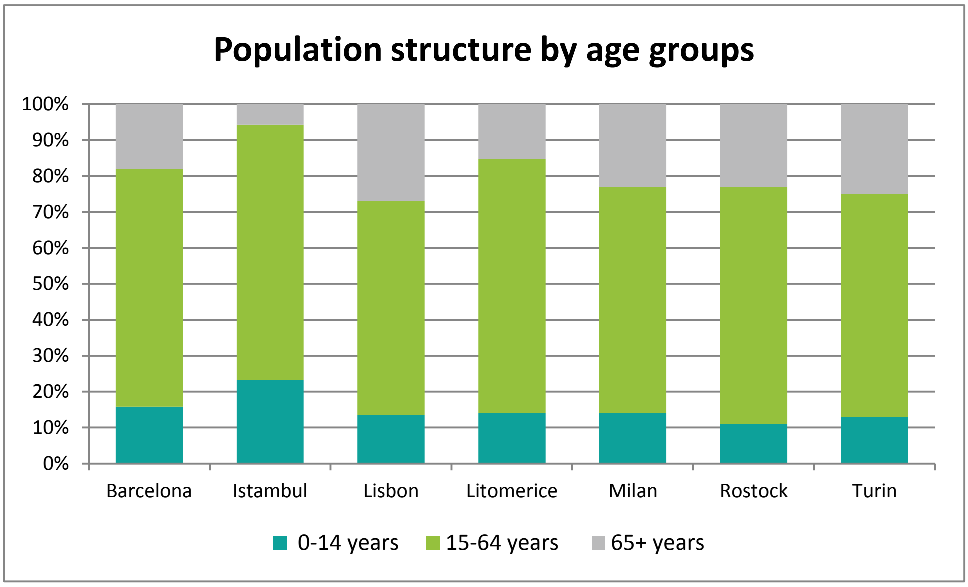


Figure 8: Population structure by age group, Municipality, 2013

Note: Barcelona – Barcelona Metropolitan Area; Lisbon - 2011; Istanbul - 2012; Non comparable data available for Zagreb, Malmö and Copenhagen (age groups are different).

V CASE STUDY CITIES PERFORMANCE

V.I ENVIRONMENTAL PERFORMANCE

Environmental performance of case study cities will be analysed based on selected KPI.

ECOSYSTEM PROTECTED AREAS

Litoměřice reports 92.1% of ecosystem protected areas as a percentage of total surface area, followed by Barcelona (28%).

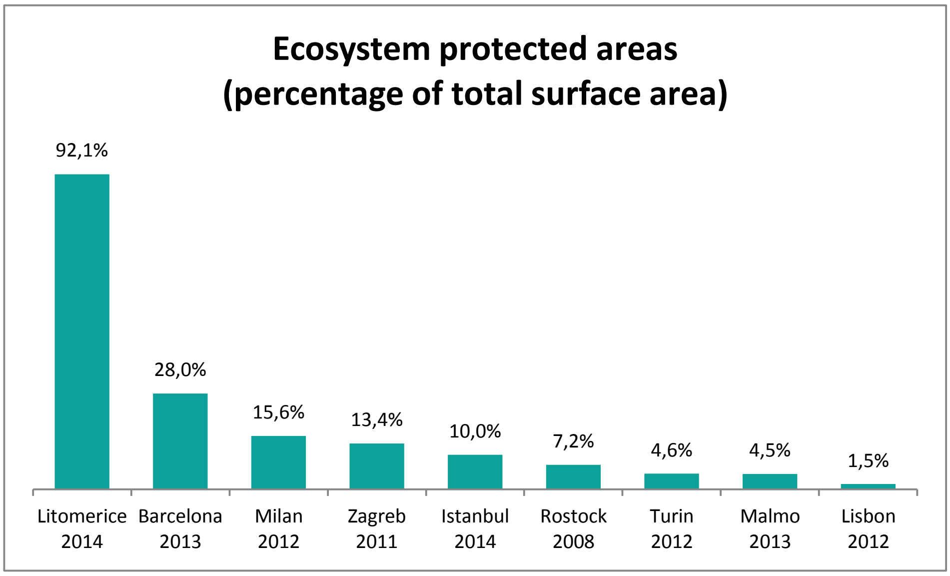


Figure 9: Ecosystem protected area (% total surface area), Municipality

Note: Milan – NUT II; Barcelona – Barcelona Metropolitan Area.

GREEN SPACE AVAILABILITY

Malmö and Rostock present a high percentage of green space over total urban area, compared with the other case study cities.

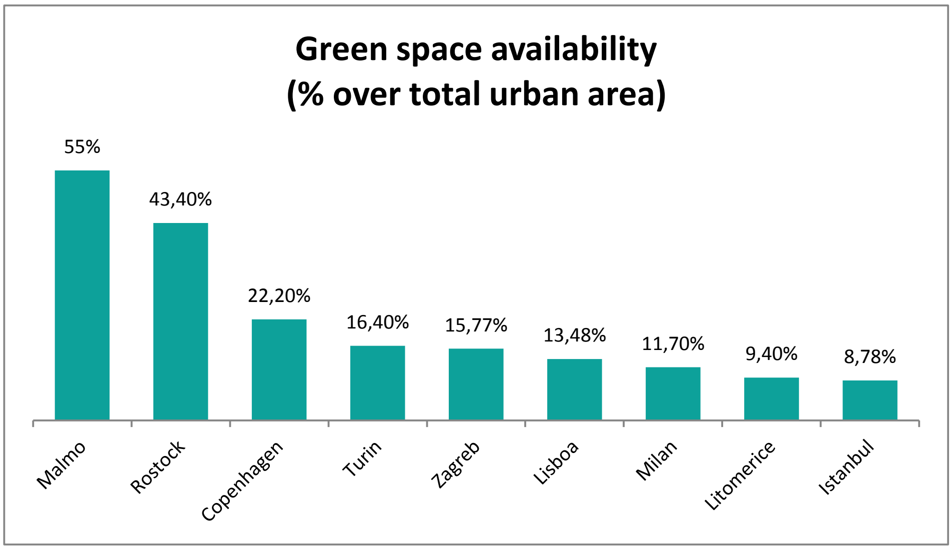


Figure 10: Percentage of green space over total urban area, Municipality, 2009

Note: Rostock – 2012; Litoměřice – 2013; Lisbon – 2014; Non comparable data for Barcelona.

ENERGY INTENSITY

Energy intensity is represented by the ratio of gross energy consumption by GDP. Cities with more energy intensity per GDP consume more energy to produce the same amount of goods. It is a proxy of energy efficiency.

Energy intensity is higher in Barcelona, followed by Zagreb and Turin. The general decrease in energy intensity is a trend in all case study cities.

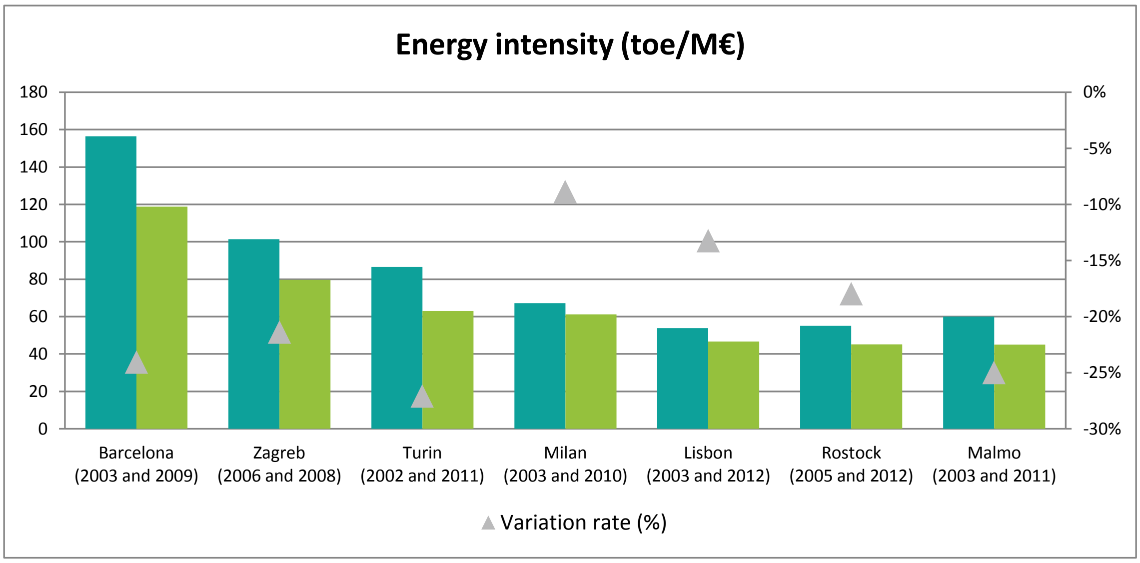


Figure 11: Energy intensity (toe/M€)

Note: Barcelona – NUT II; Lisbon, Milan, Turin – NUT III; Malmö, Rostock, Zagreb – Municipality; No information available for Copenhagen, Litoměřice and Istanbul.

ENERGY CONSUMPTION BY SECTOR

This indicator measures the sum of primary energy consumption in industry, agriculture, services, transports, residential and others, and allows us to identify the sectors that are more energy intensive and therefore need more action towards being more efficient.

Higher energy consumers are Barcelona, Zagreb and Turin. However, the profile of case study cities in terms of energy consumption by sectors is very diverse. In Milan, services present higher energy consumption in comparison with the other sectors. In Lisbon and Barcelona the higher energy consumer is the transport sector. In Turin, Copenhagen and Malmö the residential sector dominates. With a different sectors' classification, in Rostock industry, services and agriculture lead in terms of energy consumption, while in Zagreb are the residential and commercial sectors.

Some examples are given in the graphics below.

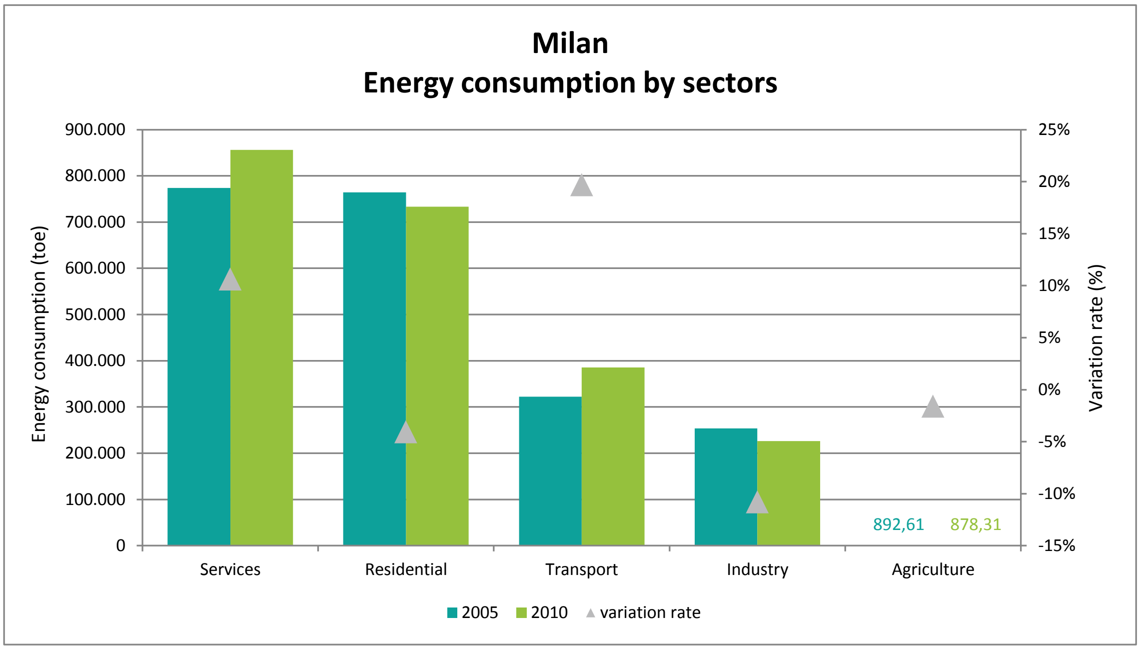


Figure 12: Milan - Energy consumption by sectors, Municipality, 2005 and 2010

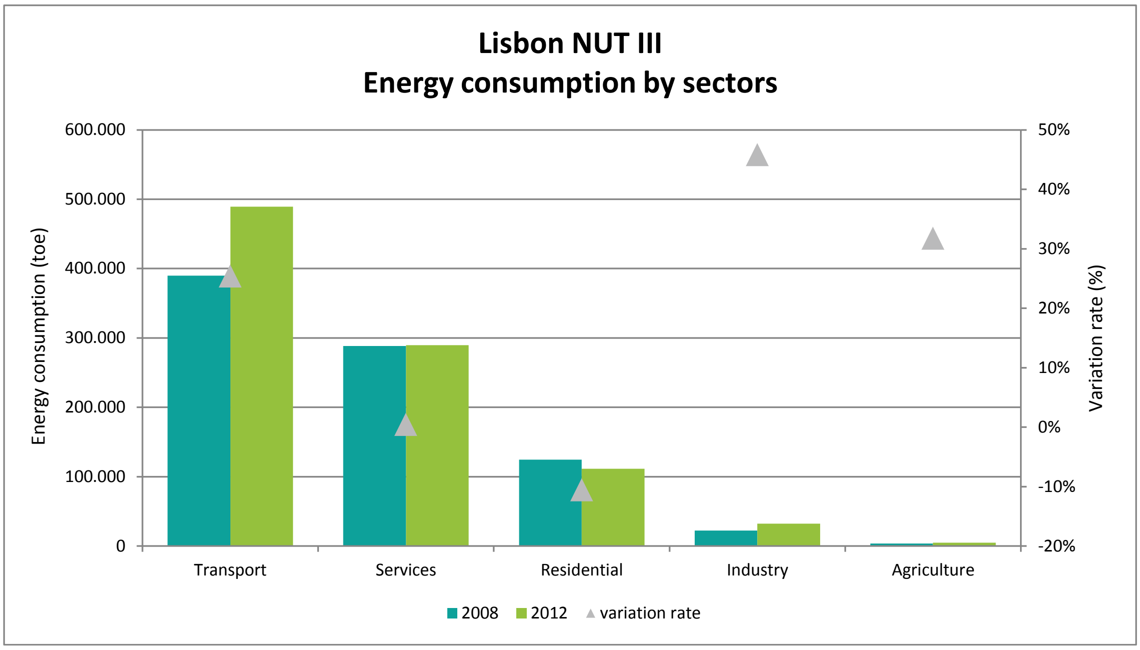


Figure 13: Lisbon - Energy consumption by sectors, NUT III, 2008 and 2012

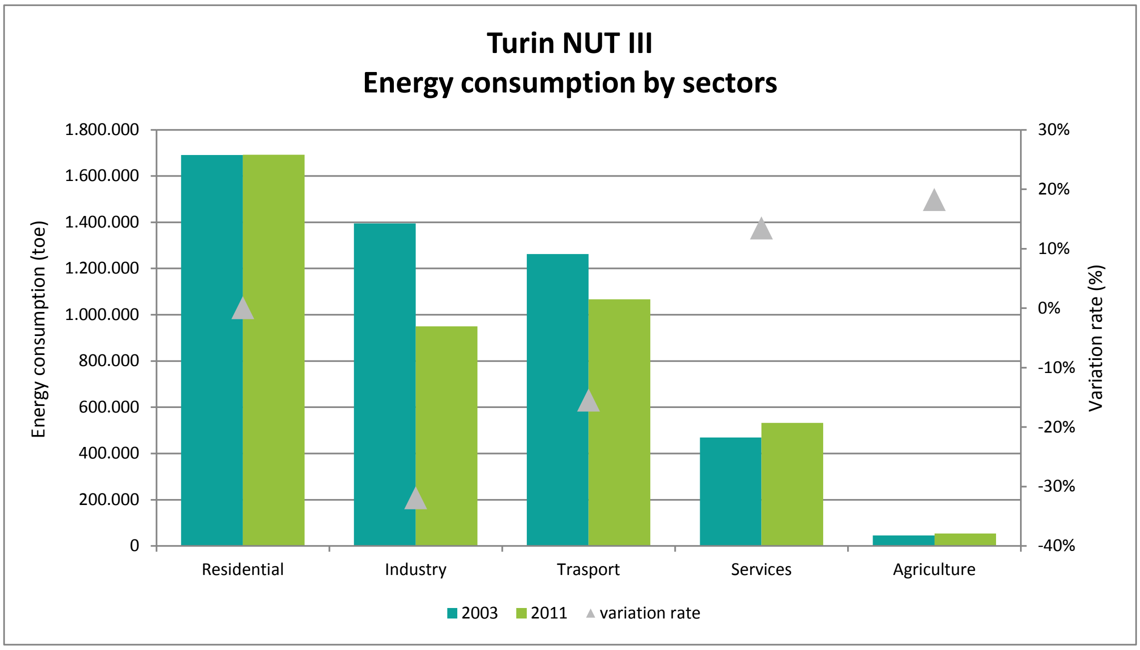


Figure 14: Turin - Energy consumption by sectors, NUT III, 2003 and 2011

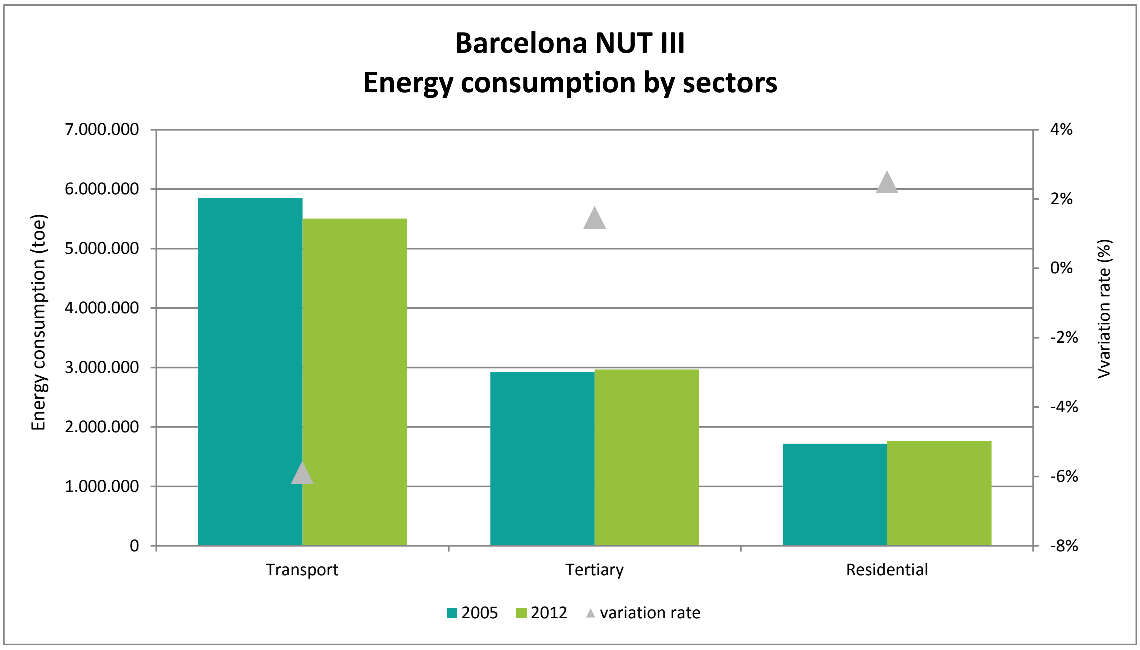


Figure 15: Barcelona - Energy consumption by sectors, NUT III, 2005 and 2012

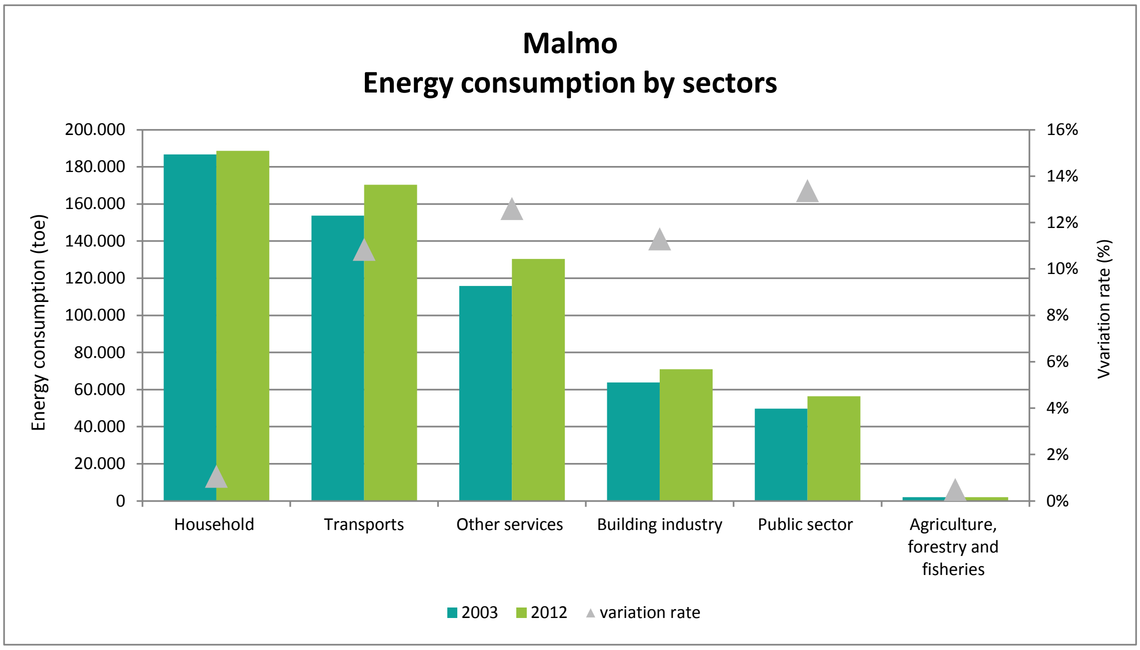


Figure 16: Malmö - Energy consumption by sectors, Municipality, 2003 and 2012

CARBON EMISSIONS INTENSITY

This indicator assesses the carbon emissions due to energy consumption. It is the ratio between CO_2 emissions and GDP. The carbon emissions intensity of the economy identifies the cities where more CO_2 are emitted to produce wealth. Carbon emissions intensity is higher in Barcelona and Istanbul, being Copenhagen the best performer. The general decrease in carbon emission intensity is a trend in all case study cities.

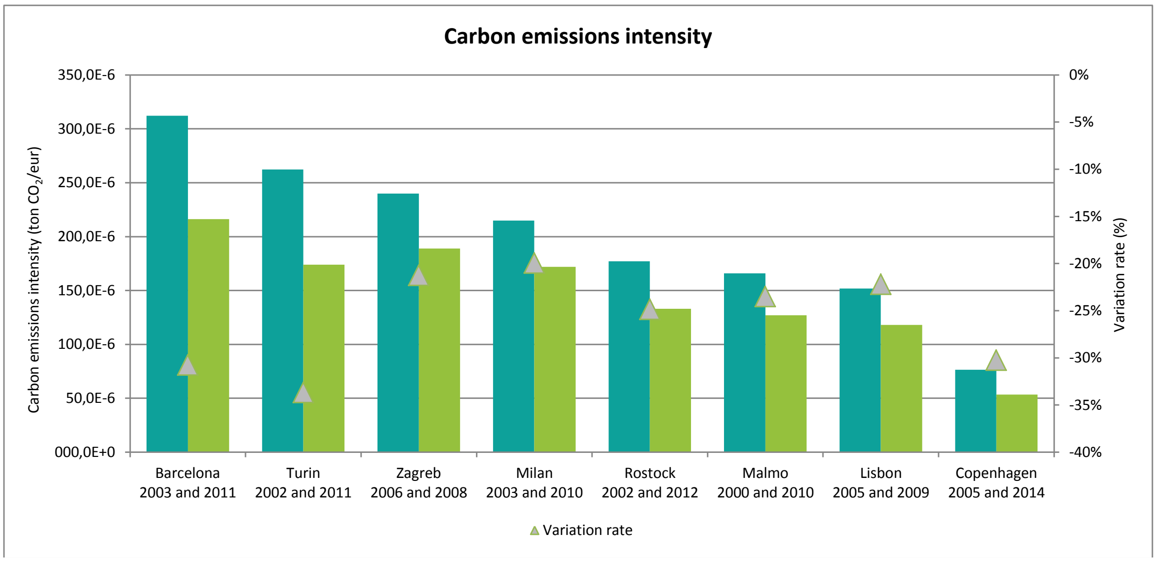


Figure 17: Carbon emissions intensity

Note: Lisbon, Milan, Turin – NUT III; Barcelona – NUT II; Malmö, Rostock, Zagreb – Municipality; No comparable data available for Istanbul and Litoměřice.

CARBON EMISSIONS BY SECTOR

This indicator assesses the measurement of CO_2 emissions per sector: industry, agriculture, services, transports, residential and others.

Emissions are higher in Turin and Istanbul. However, the profile of case study cities in terms of carbon emissions by sectors is very diverse. In Milan and Turin, services and residential sectors present higher carbon emissions in comparison with the other sectors. In Malmö road transport dominates. With a different classification, in Barcelona energy production lead in terms of carbon emissions, while in Litoměřice and Istanbul is the residential sector. In Zagreb industry sector is the higher producer of carbon emissions. Finally, in Copenhagen industry and energy sectors are leading in terms of carbon emissions.

Some examples are given in the graphics below.

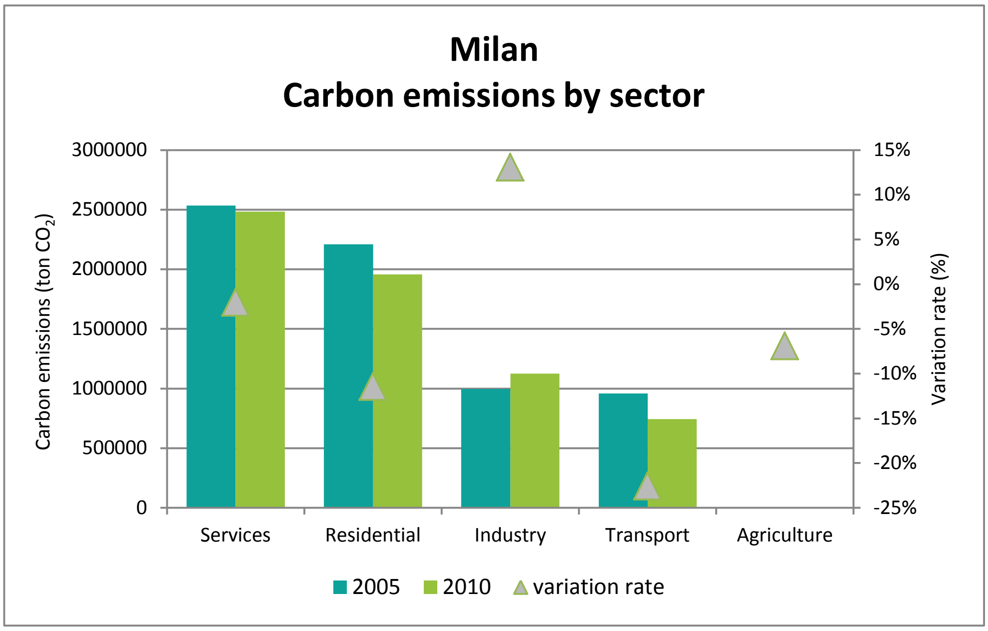


Figure 18: Milan - Carbon emissions by sector, Municipality, 2005 and 2010

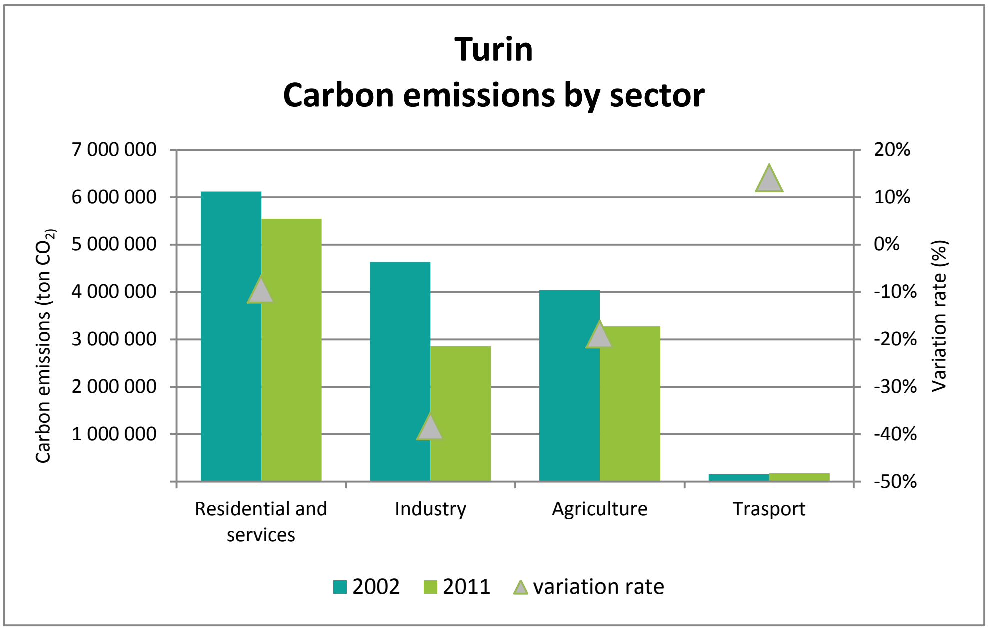


Figure 19: Turin - Carbon emissions by sector, NUT III, 2002 and 2011

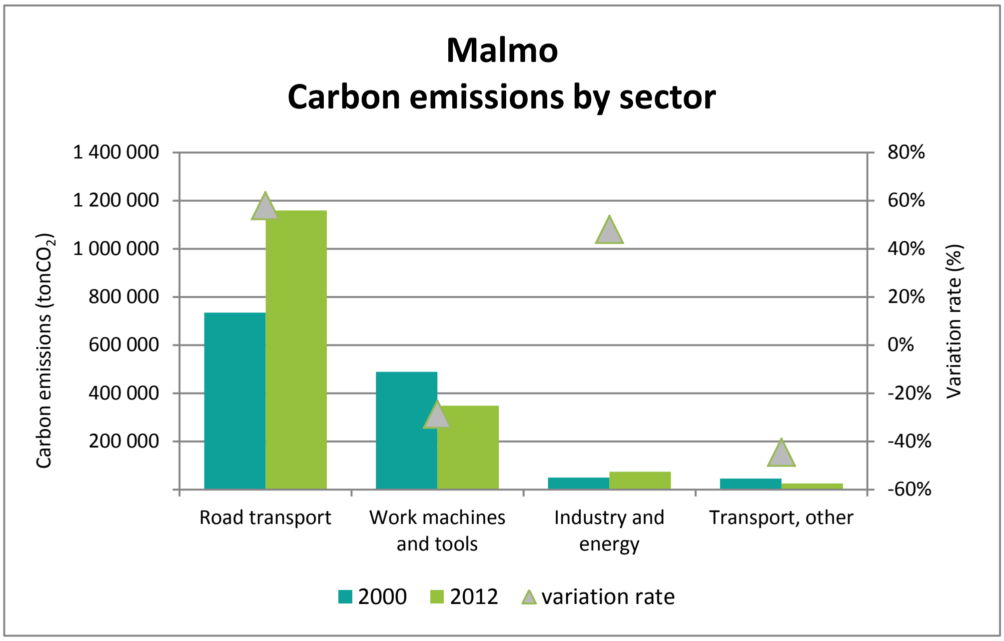


Figure 20: Malmö - Carbon emissions by sector, Municipality, 2000 and 2012

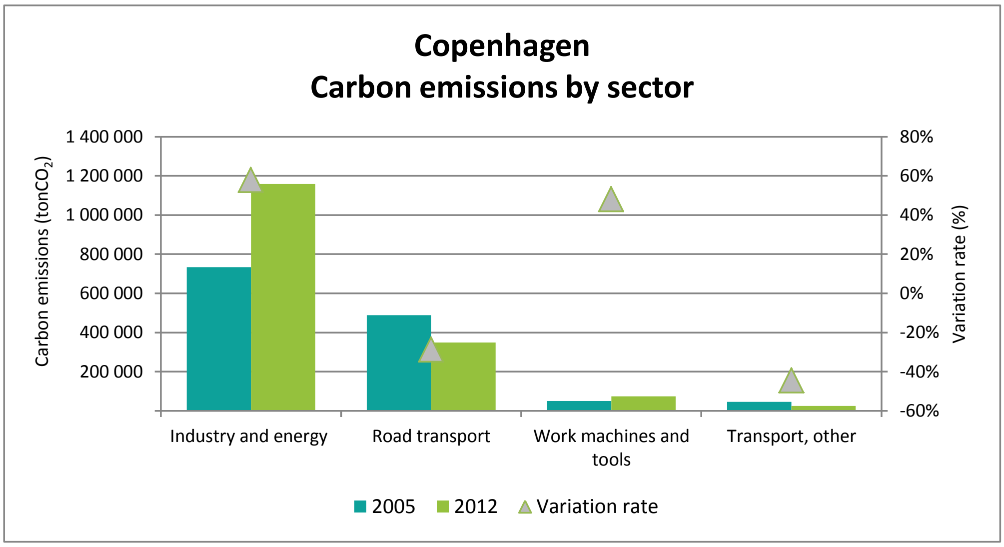


Figure 21: Copenhagen - Carbon emissions by sector, Municipality, 2005 and 2012

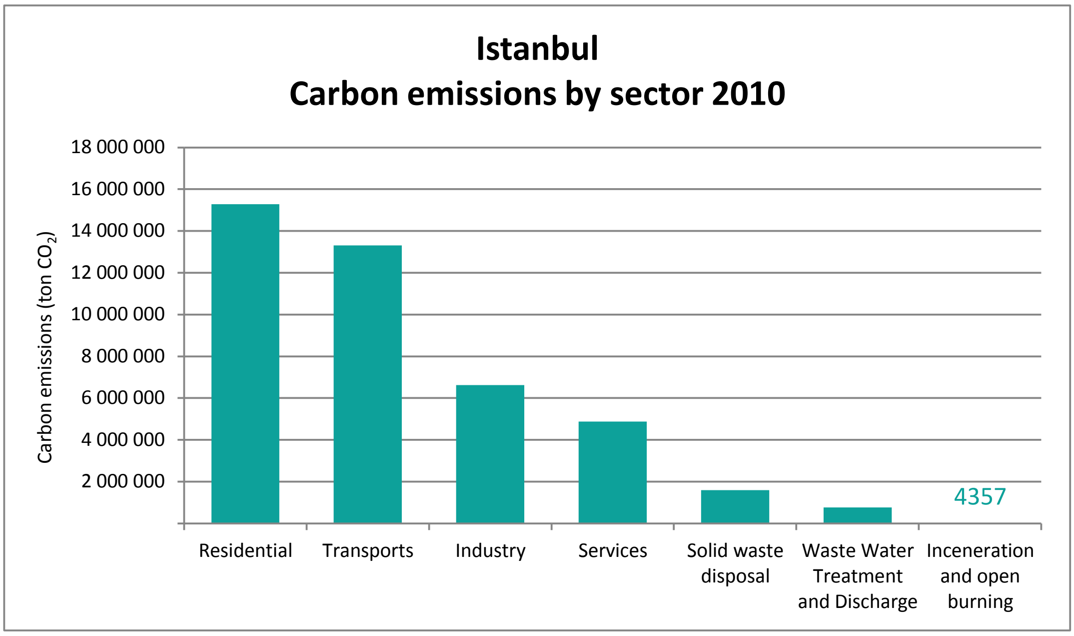


Figure 22: Istanbul - Carbon emissions by sector, Municipality, 2010

TRANSPORTS AND MOBILITY

The share of sustainable transportation (public transports, walk, and bike) in total modal share is higher in Istanbul, followed by Litoměřice and Copenhagen. Copenhagen, Malmö and Rostock residents use intensively bicycle as an alternative transportation mode. It is worth of notice that Copenhagen wants to become the best cycling city in the world.

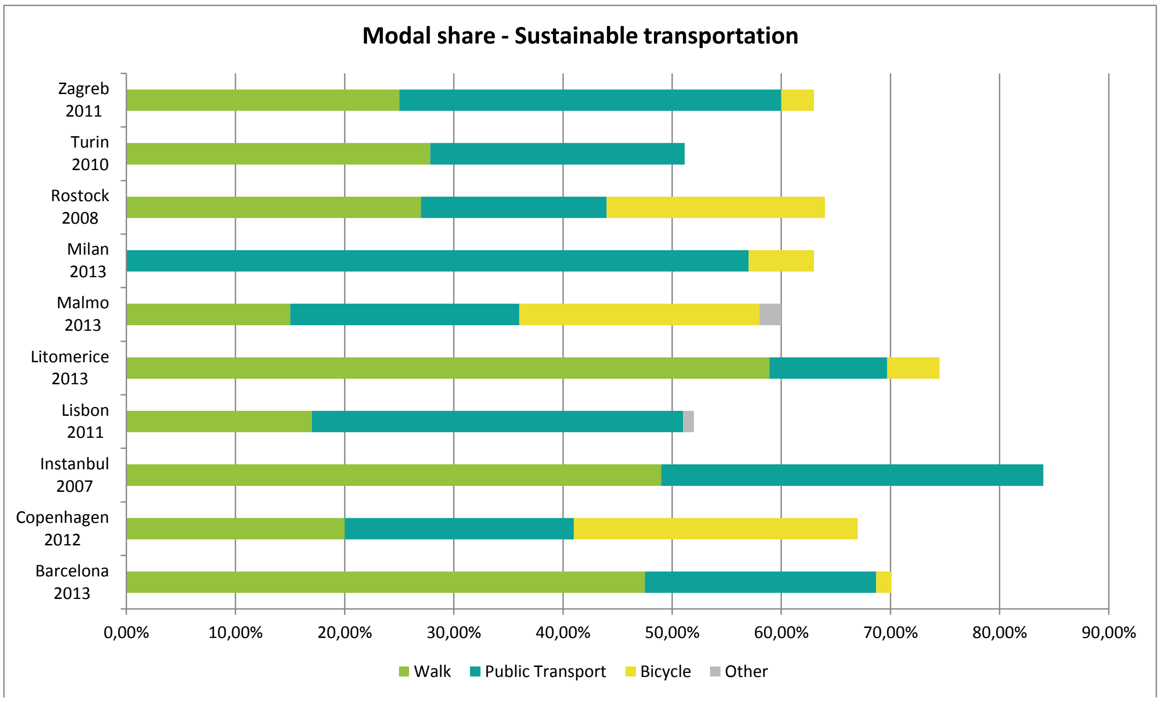


Figure 23: Sustainable transportation

URBAN WASTE

Urban waste production is calculated by the total amount of city urban solid waste generated per capita in kilogram.

Urban waste production was higher in Copenhagen, Turin and Milan in 2007. In 2011, Copenhagen and Lisbon reported the highest urban waste generation. However, the decrease in the amount of this indicator is the general trend, with exception of Lisbon and Istanbul.

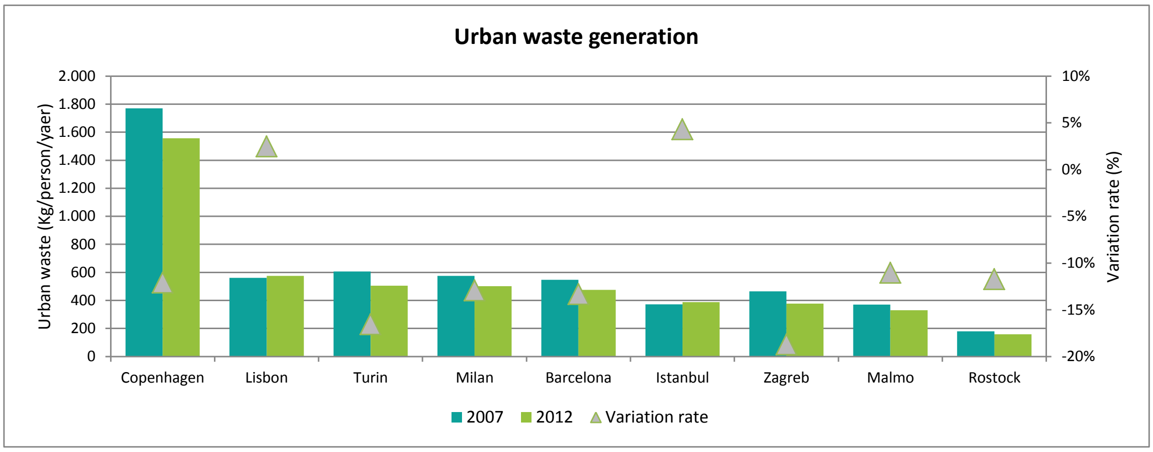


Figure 24: Urban waste generation, 2007 and 2012

Note: Zagreb – 2008-2011; Rostock – 2006-2012.

Urban waste recovery corresponds to the percentage of recovered/treated waste. The information on waste recovering/treatment system is broken down into five categories of final destination: material recycling; total incineration, including energy recovery; deposit onto or into land; and composting; and digestion.

This indicator is higher in Copenhagen, Rostock, Turin, Milan and Barcelona, being Lisbon, Zagreb and Istanbul the worst performers. The trend is towards the increase of urban waste recovery, with the exception of Lisbon.

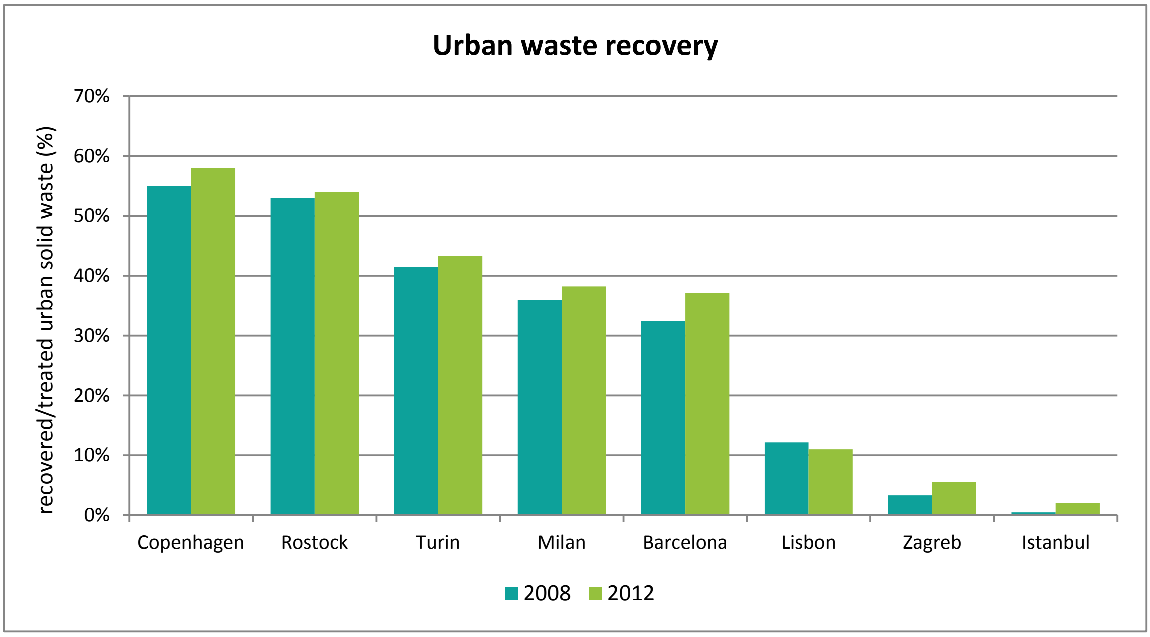


Figure 25: Urban waste recovery, 2008 and 2012

Note: Zagreb – 2009-2011; Rostock – 2009-2013; Copenhagen – 2006 and 2012.

WATER LOSSES

This indicator determines the percentage of water losses registered in public supply networks. Water losses are bigger in Istanbul and Turin, being Lisbon and Rostock the best performers.

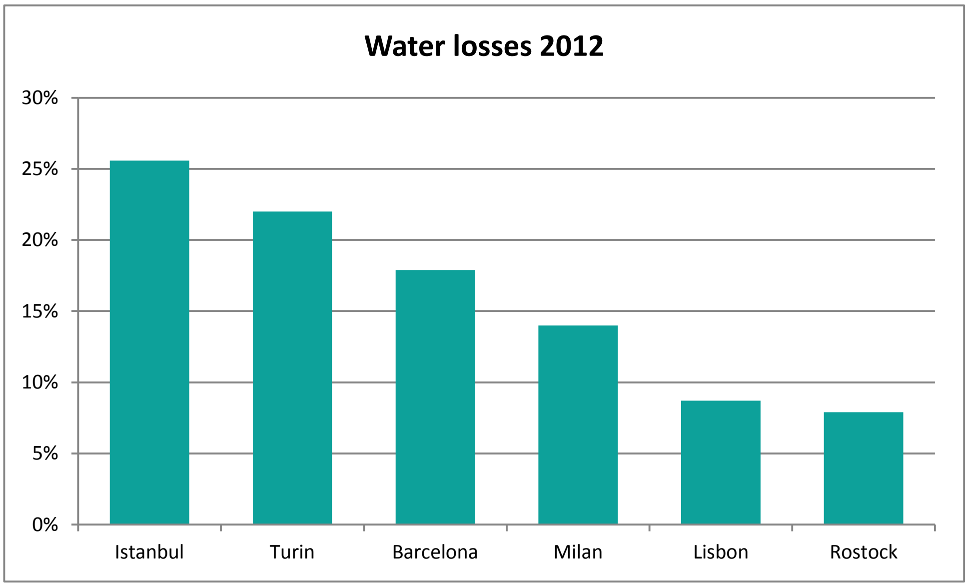


Figure 26: Water losses, 2012

Note: Barcelona – 2013; No information available for Copenhagen, Litoměřice, Malmö, Zagreb.

V.II SOCIAL PERFORMANCE

Social performance of case study cities will be analysed based on selected KPI.

UNEMPLOYMENT LEVEL

In general, from 2006 to 2012 unemployment rate has increased mostly because of the adverse effects of the economic and financial crisis. Higher rates are reported in Barcelona. In this period, in Barcelona the variation of male's unemployment rate was +239% and the variation of women unemployment rate was +158%. Exceptions are Istanbul, Rostock and Zagreb.

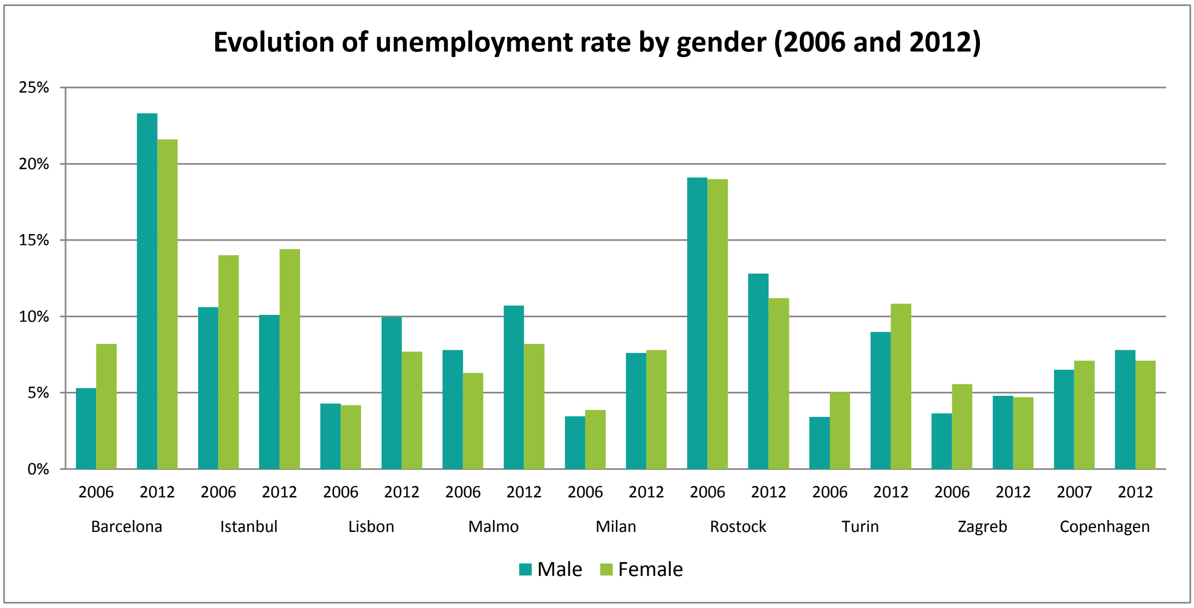


Figure 27: Evolution of unemployment rate by gender, 2006 and 2012

Note: Barcelona, Milan, Turin - NUT III; Istanbul, Lisbon, Rostock - NUT II; Malmö, Zagreb - Municipality; Information for Litoměřice not available.

TERCIARY EDUCATION LEVEL

Tertiary education rate is higher in Zagreb and Copenhagen, followed by Malmö, Lisbon and Barcelona. Istanbul reports the lowest tertiary education level. It is interesting to note that female have generally higher education rates than men.

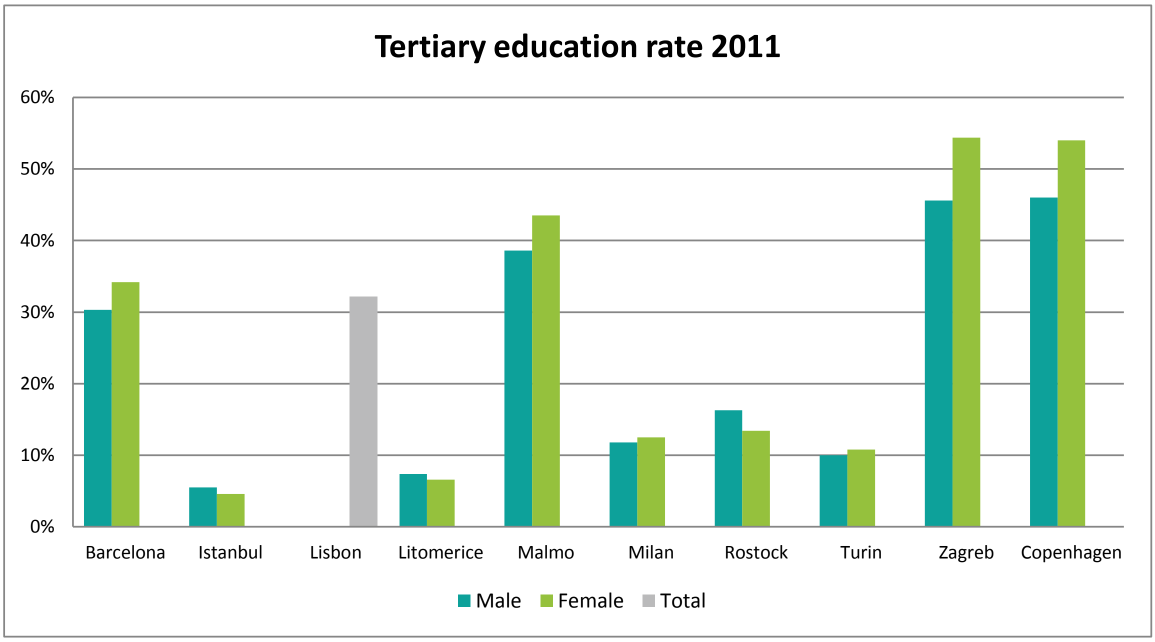


Figure 28: Tertiary education rate by gender, NUT II, 2011

Note: Malmö – Municipality; Copenhagen – 2012.

POVERTY LEVEL

In 2009, Litoměřice and Zagreb (Croatia) presented the highest poverty rates, followed by Rostock and Barcelona. Istanbul reported a poverty rate of 14.9%.

A sharp increase in the poverty rate happened between 2008 and 2011 while a reversion of this trend can be appreciated from 2011 onwards, being Milan the exception. It is worth of notice that Copenhagen reported a decrease in poverty levels since 2008.

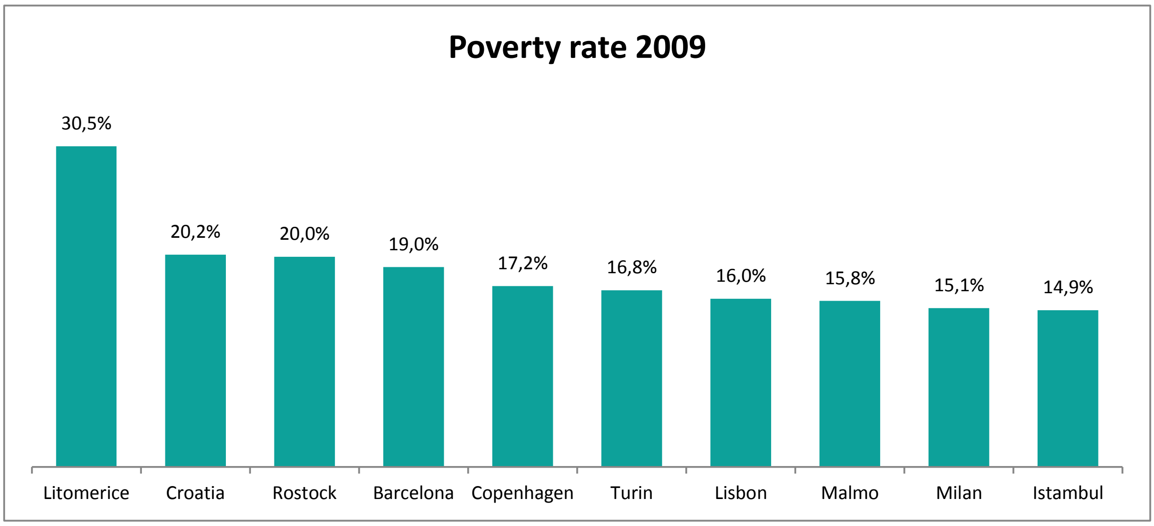


Figure 29: Poverty rate, NUT II, 2009

Note: Litoměřice - 2010; Zagreb – Croatia – NUT I.

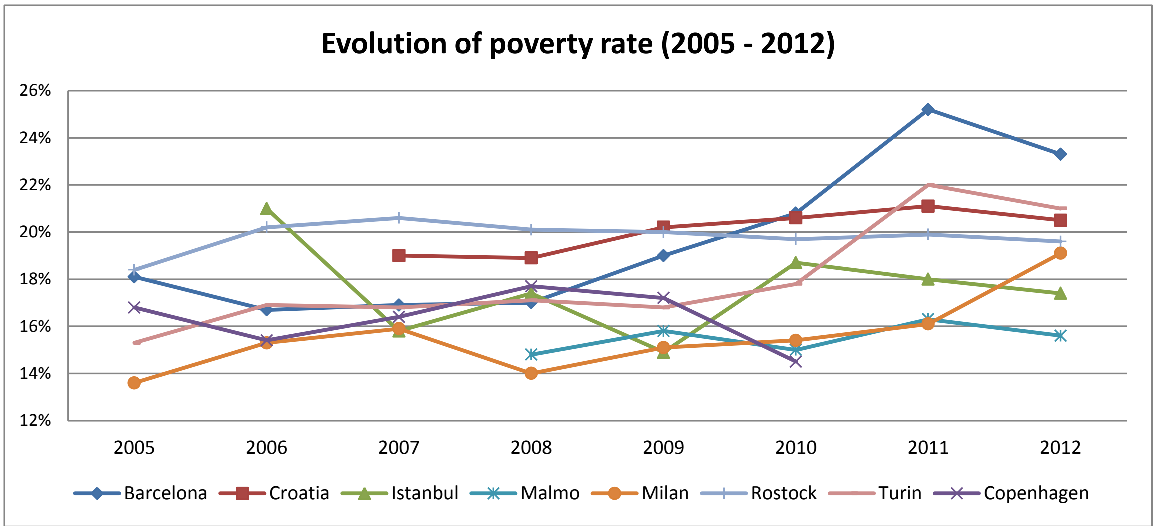


Figure 30: Evolution of poverty rate, NUT II, 2005-2012

Note: Litoměřice - 2010; Zagreb – Croatia: NUT I; Non comparable data for Lisbon and Zagreb.

V.III ECONOMIC PERFORMANCE

Economic performance of case study cities will be analysed based on selected KPI.

WEALTH

Copenhagen, Milan and Malmö have the highest level of GDP per capita among the case study cities. This position is followed by Rostock, Turin and Barcelona. Turin and Barcelona presents a decrease in the level of wealth between 2007 and 2010.

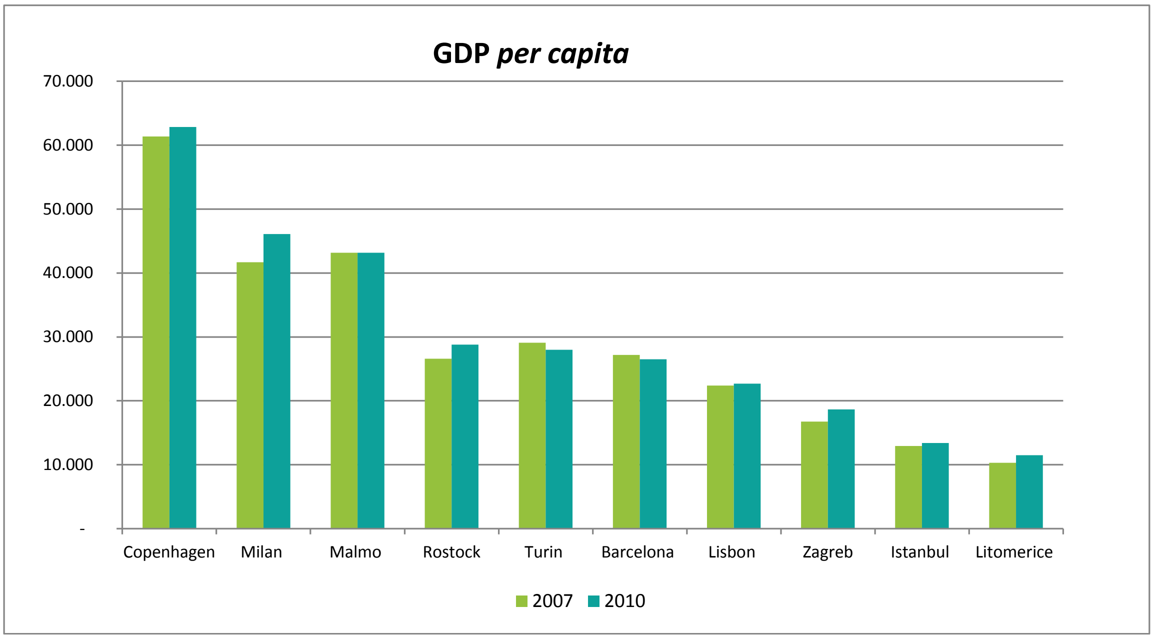


Figure 31: Evolution of GDP per capita, NUT III, 2007 and 2010

Note: Istanbul, Lisbon – NUT II; Rostock, Zagreb – Municipality; Copenhagen – 2005 and 2012.

R&D INTENSITY

Malmö (3.2%) and Lisbon (2.48%) are the best performers in term of R&D expenditure as a percentage of GDP, followed by Rostock and Turin. The worst performer is Litoměřice (0.28%).

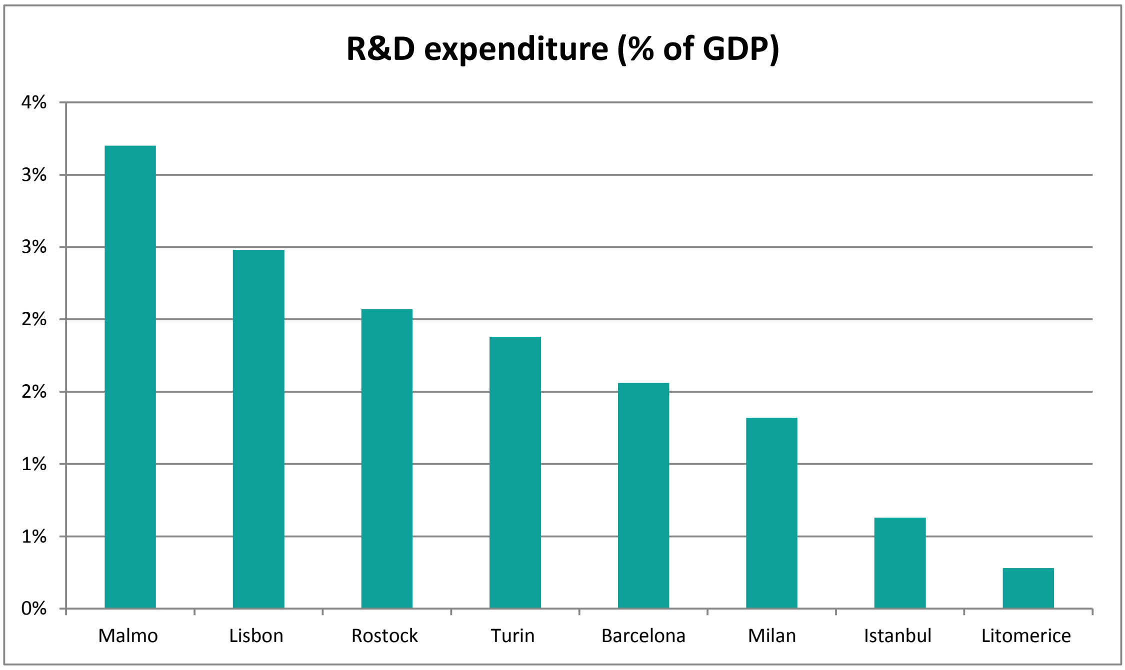


Figure 32: R&D expenditure as % of GDP, NUT II, 2011

Note: Malmö, Lisbon – NUT III; Lisbon – 2010; No available data for Copenhagen.

VI KEY FINDINGS AND CHALLENGES

The evaluation of the pre-defined Key Performance Indicators in the case study cities suggests that there is a global trend towards a post-carbon paradigm. However, cities were generally affected by the economic and financial crisis, with negative consequences on unemployment and poverty. Case study cities present different development stages towards sustainability:

Barcelona is at the forefront of the smart cities movement, with an intensive use of smart technologies. Several strategies towards a post-carbon city are being implemented by the Metropolitan Area; but energy and carbon emissions intensity are still high. Unemployment and poverty are weaknesses that have been enhanced by the economic and financial crisis. One of the bigger challenges of the city is to find a balance between the need to maintain it as a tourist centre, while keeping its local character.

Copenhagen is a leading city in terms of urban sustainability, being climate change one of the prominent urban policy issues. The ambition for Copenhagen is to become the first CO_2 neutral capital in the world by 2025. Several strategies and plans are being implemented in the areas of climate change, green buildings and mobility. Moreover, the city developed an integrated monitoring system of a large quantity of environmental indicators. It is a young, qualified and diverse city with good economic performance. High level of low-income citizens and widening income gap are the main challenges faced by the city.

Istanbul is in an initial stage of development towards a post-carbon city. Environmental performance is the weakest dimension and most underestimated by the city. However, some investments were made in the area of transportation. The main problems are population increase and growing urbanisation, urban sprawl towards peripheries, air and environmental pollution, and stress on natural protection areas and forests. However, Istanbul is improving in economic and social terms, being a dynamic and vibrant city.

Lisbon is in an intermediate stage of development in the transition towards a post-carbon city. Several strategies and projects have been launched in the areas of energy, mobility, and biodiversity but with limited impacts. The car is still the privileged transport mode, being mobility one of the main urban challenges. However, the reduction of water losses was expressive. Due to economic and financial crisis, unemployment and risk of poverty are increasing. Reduced population and aging people in the city centre are also a problem. There is a need to invest in buildings renovation.

Litoměřice is in an initial stage of development in the transition towards a post-carbon city. It is a small city that is influenced by the development of higher territorial units. However, it is one of pioneer cities in Czech Republic aiming at energy efficiency and renewable energy production. To become an energy self-sufficient city is the ambition, mostly based on the geothermal power plant future project. A dependence on the availability of external financial sources is a reality.

Malmö is also a frontrunner in the transition towards a post-carbon city. An ambitious energy strategy is being implemented with positive impacts in carbon emissions and energy consumption. Several improvements were made in the area of sustainable transportation. It is a young, qualified and multicultural city with reasonable economic and social performance. Economic inequity and social segregation (due to high immigration numbers) are the main urban challenges.

Milan is in an intermediate stage of development in the transition towards a post-carbon city. It is a leading city in economic terms but the investment in environmental policy issues is comparatively lower. However, it has an advantage compared to other Italian cities in terms of environmental standards, but behind European average standards. There is a need to invest in the shift towards a zero-carbon paradigm and to increase civil awareness. Major urban problems are pollution, poor air quality and aged building stock.

Rostock is in an advanced-intermediate stage of development in the transition towards a post-carbon paradigm. Important measures were adopted to reduce the environmental footprint of the city, namely in the areas of air quality, waste and water management and sustainable mobility with positive impacts. The main urban challenges are linked to poverty, unemployment and weak infrastructures.

Turin is in an intermediate stage of development in the transition towards a post-carbon city. It is an innovative city, but it is being affected by unemployment and poverty due to strong specialisation. Major urban problems are pollution and poor air quality.

Zagreb is in an initial stage of development in the transition towards a post-carbon city. Some grassroots movements are in place, but strategic planning is weak. Critical success factors are unemployment and poverty (social), public transportation and municipal waste management (environment), and GDP per capita, business survival and social entrepreneurship (economic). It is worth of notice the high qualification of the population, in comparison with other case study cities.

Based on the previous analysis (see Annex I) and through the cross analysis of GDP per capita and carbon emissions intensity, we can identify tentatively clusters of cities with different stages of development in the transition towards a post-carbon city.

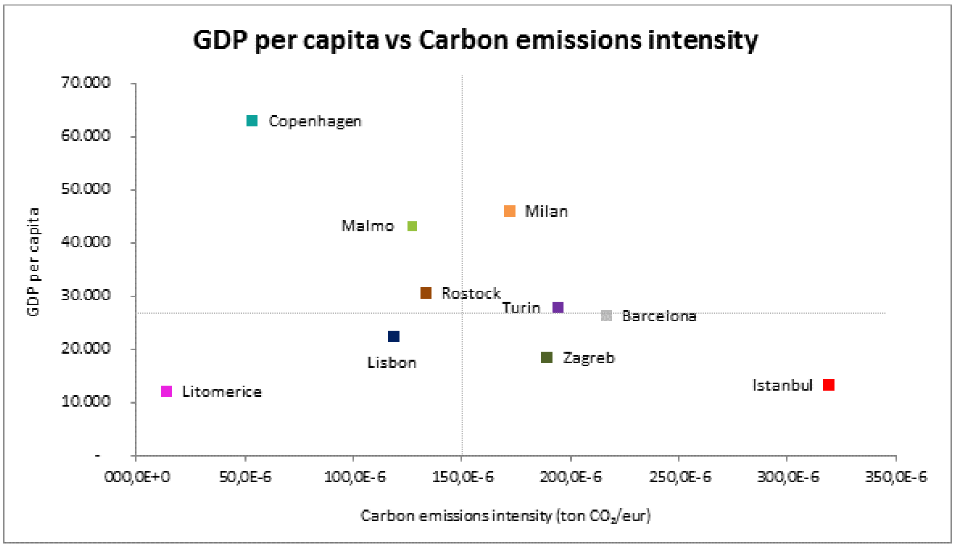


Figure 33: GDP per capita vs. Carbon emissions intensity

In conclusion, **Copenhagen** and **Malmö** are at the forefront of the transition towards a post-carbon city. They are young, qualified and multicultural cities and present a good economic performance in terms of GDP per capita. These cities have clear strategic visions in the area of urban sustainability, and are implementing several projects on mobility, energy and climate with positive impacts.

VII CONCLUSIONS

The analysis of case study cities suggests that there is a global trend towards a post-carbon paradigm. However, cities were generally affected by the economic and financial crisis, with negative consequences on unemployment and poverty.

Copenhagen and Malmö are at the forefront of the transition towards a post-carbon city. They are young, qualified and multicultural cities and present a good economic performance in terms of GDP per capita. These cities have clear strategic visions in the area of urban sustainability, and are implementing several projects on mobility, energy and climate with positive impacts.

However, case study cities are very different in terms of population size and economic, social and cultural dynamics, which makes the comparison difficult. Moreover, the majority of cities had problems on data collection; thus, the development of urban information systems is a recommendation for all case study cities.

VIII REFERENCES

Adger, W. Neil. 2006. "Vulnerability." *Global Environmental Change* 16 (3): 268–81.

Berkes, Fikret, Carl Folke, and Johan Colding. 2000. *Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience*. Cambridge University Press. http://books.google.de/books?hl=en&lr=&id=XixuNvX2zLwC&oi=fnd&pg=PR9&dq=Berkes,+F.,+and+C.+Folke,+editors.+1998.+Linking+social+and+ecological+systems:+management+practices+and+social+mechanisms+for+building+resilience&ots=klWDgtySeQ&sig=aoznAkLvYMO38Bb7K8losAGZAgg.

Duren, Riley M., and Charles E. Miller. 2012. "Measuring the Carbon Emissions of Megacities." Nature Climate Change 2 (8): 560–62.

Economist Intelligence Unit. 2012. "The Green City Index - A Summary of the Green City Index Research Series." Siemens AG Corporate Communication and Government Affairs.

Evans, G. 2008. "Transformation from'Carbon Valley'to a'Post-Carbon Society'in a Climate Change Hot Spot: The Coalfields of the Hunter Valley, New South Wales, Australia." *Ecology and Society* 13 (1): 39.

Folke, Carl, Steve Carpenter, Brian Walker, Marten Scheffer, Thomas Elmqvist, Lance Gunderson, and C. S. Holling. 2004. "Regime Shifts, Resilience, and Biodiversity in Ecosystem Management." *Annual Review of Ecology, Evolution, and Systematics*, 557–81.

Gallopín, Gilberto C. 2006. "Linkages between Vulnerability, Resilience, and Adaptive Capacity." *Global Environmental Change* 16 (3): 293–303. doi:10.1016/j.gloenvcha.2006.02.004.

Geels, Frank W. 2011. "The Multi-Level Perspective on Sustainability Transitions: Responses to Seven Criticisms." Environmental Innovation and Societal Transitions 1 (1): 24–40.

Gunderson, Lance H., and C.S. Holling. 2001. *Panarchy: Understanding Transformations in Human and Natural Systems*. Island Press. http://books.google.de/books?hl=en&lr=&id=o4u89akUhJMC&oi=fnd&pg=PR7&dq=Gunderson,+L.+H.,+and+C.+S.+Holling,+editors.+2002.+Panarchy:+understanding+transformations+in+human+and+natural+systems&ots=ec8AarlOXI&sig=M2yXwOisrMQmbBU-H1k53yWQWgU.

Keivani, Ramin. 2010. "A Review of the Main Challenges to Urban Sustainability." *International Journal of Urban Sustainable Development* 1 (1-2): 5–16.

Lebel, Louis, John M. Anderies, Bruce Campbell, Carl Folke, Steve Hatfield-Dodds, Terry P. Hughes, and James Wilson. 2006. "Governance and the Capacity to Manage Resilience in Regional Social-Ecological Systems." http://digitalcommons.library.umaine.edu/sms_facpub/52/?utm_source=digitalcommons

.library.umaine.edu%2Fsms_facpub%2F52&utm_medium=PDF&utm_campaign=PDFCoverPages.

Levin, Simon A., and Jeffrey A. Harvey. 1999. *Fragile Dominion: Complexity and the Commons*. Perseus Reading, MA. http://osyka.pixub.com/data/fragile-dominion-complexity-and-the-commons-by-simon-levin.pdf.

Marcelino, M. et al. Environmental Portuguese Agency, New University of Lisbon - Faculty of Science and Technology. 2007. "Indicators System of Sustainable Development - SIDS Portugal". Environmental Portuguese Agency.

National Research Council. 2004. "Adaptive Management for Water Resources Planning". The National Academies Press, Washington, DC.

Neil Adger, W., Nigel W. Arnell, and Emma L. Tompkins. 2005. "Successful Adaptation to Climate Change across Scales." *Global Environmental Change* 15 (2): 77–86.

Norberg, Jon, and Graeme Cumming. 2008. *Complexity Theory for a Sustainable Future*. Columbia University Press.

OECD/LEED. 2013. "Green Growth in the Benelux: Indicators of Local Transition to a Low-Carbon Economy in Cross-Border Regions." Secretary-General of the OECD.

Olsson, Per, Lance H. Gunderson, Steve R. Carpenter, Paul Ryan, Louis Lebel, Carl Folke, and Crawford S. Holling. 2006. "Shooting the Rapids: Navigating Transitions to Adaptive Governance of Social-Ecological Systems." *Ecology and Society* 11 (1): 18.

Pisano, Umberto, Katrin Lepuschitz, and Gerald Berger. 2014. "Framing Urban Sustainable Development." http://www.sd-network.eu/quarterly%20reports/report%20files/pdf/2014-January-Framing_Urban_Sustainable_Development.pdf.

Rotmans, Jan, René Kemp, and Marjolein Van Asselt. 2001. "More Evolution than Revolution: Transition Management in Public Policy." Foresight 3 (1): 15–31.

Satterthwaite, David. 2008. "Cities' Contribution to Global Warming: Notes on the Allocation of Greenhouse Gas Emissions." Environment and Urbanization 20 (2): 539–49.

UN-DESA. 2013. "An Integrated Strategy for Sustainable Cities." http://www.un.org/en/development/desa/policy/publications/policy_briefs/policybrief40.pdf.

UNEP. 2011. "Towards a Green Economy: Pathways to Sustainable Development and Poverty Eradication - A Synthesis for Policy Makers", www.unep.org/greeneconomy.

Vivid Economics. 2013. "G20 Low Carbon Competitiveness Index: 2013 Update". Climate Institute.

Yale University, Columbia University, Joint Research Centre European Commission, World Economic Forum. 2012. "Environmental Performance Index and Pilot Trend Environmental Performance Index." Yale University, Columbia University.

IX ANNEX I

KPI in Case Study Cities – Weak and Strong Points (comparison perspective)

CASE STUDY CITIES	WEAK POINTS (KPI)	STRONG POINTS (KPI)
Barcelona	Population structure by age group Unemployment level Energy intensity Energy consumption Carbon emissions intensity Water losses	Share of sustainable transportation Tertiary education level
Copenhagen	Urban waste generation	Population structure by age group Unemployment level Tertiary education level GDP per capita Share of sustainable transportation Carbon emissions intensity Urban waste recovery Green areas
Istanbul	Urban waste generation Carbon emissions intensity Carbon emissions R&D expenditure Water losses Tertiary education level GDP per capita	Urban waste recovery
Lisbon	Population structure by age group Share of sustainable transportation Urban waste generation Urban waste recovery	Water losses R&D expenditure
Litoměřice	Population structure by age group Tertiary education level R&D expenditure Poverty level GDP per capita	Share of sustainable transportation Ecosystem protected areas

CASE STUDY CITIES	WEAK POINTS (KPI)	STRONG POINTS (KPI)
Malmö		Population structure by age group Tertiary education level GDP per capita R&D expenditure Share of sustainable transportation Energy intensity Green areas
Milan	Population structure by age group Poverty level Energy intensity Carbon emissions intensity	GDP per capita Urban waste recovery
Turin	Population structure by age group Energy intensity Energy consumption Carbon emissions Carbon emissions intensity Share of sustainable transportation Water losses	Urban waste recovery
Rostock	Population structure by age group Unemployment level	Share of sustainable transportation Energy intensity Urban waste recovery Green areas Water losses
Zagreb	Population structure by age group Energy intensity Energy consumption Carbon emissions intensity Urban waste recovery	Unemployment level Tertiary education level