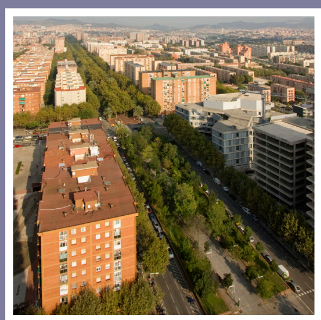
EEA Technical report | No 24/2015

# Urban sustainability issues — Resource-efficient cities: good practice

ISSN 1725-2237



European Environment Agency

EEA Technical report | No 24/2015

# Urban sustainability issues — Resource-efficient cities: good practice

European Environment Agency

Cover design: EEA
Cover photo: © Barcelona city Council
Layout: EEA/Rosendahls a/s



More information on the European Union is available on the Internet (http://europa.eu).

Luxembourg: Publications Office of the European Union, 2015

ISBN 978-92-9213-711-3
ISSN 1725-2237
doi:10.2800/69420

European Environment Agency
Kongens Nytorv 6
1050 Copenhagen K
Denmark

Tel.: +45 33 36 71 00
Web: eea.europa.eu
Enquiries: eea.europa.eu/enquiries

# Contents

# List of figures, tables and boxes

## List of figures



## List of tables



## List of boxes

# Acknowledgements

This report was written and coordinated by Marie Cugny-Seguin and reviewed by:

- European Environment Agency colleagues: Almut Reichel, Anca-Diana Barbu, Andrus Meiner, Bo Neergaard Jacobsen, Geertrui Louwagie, Jasmina Bogdanovic Milutinovic, Rastilav Stanik and Ronan Uhel;

- the European Topic Centre 'Urban, land and soil systems': Cristina Garzillo, Ece Aksoy, Jaume Fons, Mirko Gregor and Raquel Ubach,

- partners from the 'Integrated urban metabolism in Europe' network: David Ludlow (University of the West of England), Didier Vancutsem (International society of city and regional planners (ISOCARP)), Floriane Bernardot (Energy Cities), Lorenzo Bono (AmbienteItalia).

This report is based on different studies developed by ETC 'Urban, land and soil systems' for the EEA:

- 'Ensuring efficient cities in Europe: urbanisation, life styles and consumption': Jaume Fons-Esteve, Mirko Gregor, Alejandro Simon, Colina, Miquel Sainz and Emmanuel Mancosu;

- 'Resource efficient cities': Mirko Gregor, Jaume Fons, Raquel Ubach, Roger Milego, and the participation of Floriane Bernardot (Energy Cities).

The information on waste collection and the analysis of Urban Audit data on waste is broadly based on the study 'Waste in urban areas' prepared in 2013 by David McKinnon, Andrea Rispo, Leonidas Milios, Tamas Kallay, Peter Szuppinger, Christian Löwe from European Topic Centre 'Sustainable consumption and production'.

Floriane Bernardot (Energy Cities) has contributed to the different parts of the report with a focus on energy. Christine Marlet, Secretary General of Eurogypsum, has contributed to Box 3.22 on plasterboard waste.

# Executive summary

Our current pattern of resource use is leading to the depletion and, consequently, scarcity of natural resources ([1]), the degradation of ecosystems and volatile and increasing prices of natural resources. On a planet with finite resources, the challenge is to find a way of delivering greater value and more services with fewer inputs (EC, 2011a). Resources are defined as raw materials, such as fuels, minerals and metals, but also food, soil, water, air, biomass and ecosystems (EC, 2011b).

Resource efficiency is a priority objective of the Europe 2020 Strategy. The 'Roadmap to a resource efficient Europe' is one of its seven flagship initiatives (EC, 2011a). It sets out a framework to support the shift towards a resource-efficient and low-carbon economy in many policy areas: agendas for climate change, energy, transport, industry, raw materials, agriculture, fisheries, biodiversity and regional development. The Roadmap also gives guidance on the design and implementation of measures to transform the economy (EC, 2011c). According to the Roadmap, resource efficiency 'is a way to deliver more with less'. (EC, 2011a). The 7th Environment Action Programme (7th EAP), 'Living well, within the limits of our planet', which will guide European environment policy until 2020, identifies a resource-efficient, green and competitive low-carbon economy as a key objective (EU, 2013). Priority 8 of the 7th EAP focuses on urban sustainability.

Traditionally, resource efficiency policy has focused on production and consumption. However, urban areas have considerable potential for improving resource efficiency and helping to deliver the climate and energy package (the 20-20-20 targets) ([2]). Cities are home to 72,4% of the total EU28's population (Eurostat, 2015), are the engines of the economy, seats of learning and fertile ground for innovation, and, overall, municipalities supply and control public services to city residents and businesses that are responsible for the majority of resource and energy consumption and harmful emissions. However, owing to the density of the population and the proximity of the population to businesses, the urban system is a resource-efficient one.

Like living organisms, cities require considerable flows and stocks of physical, chemical and biological resources through the goods and services they import or export to supply the urban population and to maintain their functions (Barles, 2010). They need input flows (such as energy, fuel, metal, wood, water, food, materials for building and infrastructure, space) to maintain their vital functions (Decker et al., 2000). After transformation and use, these 'metabolic inputs' are discharged to the environment (atmosphere, water and soils) as 'metabolic outputs' in the form of air emissions, liquid and solid effluent and waste materials that have upstream and downstream environmental impacts.

These urban metabolic flows can be considerably reduced and recycled through better design, planning and management of the urban socio-technical system and by raising awareness in society. The main challenge for cities is to move from the current linear model, an open system depending on the hinterland ([3]) for both supply and disposal, to a circular model, thereby not only reducing metabolic flows but also recycling resources, harvesting (e.g. water harvesting) and producing energy (e.g. local production of renewables) and food (e.g. urban farming, including rooftop gardens). Owing to cities' critical mass, a slight change in the way they use resources can have a huge effect.

The density of cities makes them a resource-efficient model. The consumption per capita of resources (in particular biomass, metals and industrial minerals) is lower in densely populated areas than in relatively

([1]) Natural resources can be defined as all inputs into the economy (EC, 2011a) such as raw materials (fuels, minerals and metals) and food, soil, water, air, biomass and ecosystems (EC, 2011b).
([2]) The EU climate and energy package sets targets for the year 2020: a 20% reduction in greenhouse gas emissions (compared with 1990); 20% of energy from renewable sources; and a 20% improvement in energy efficiency.
([3]) The hinterland can be worldwide for the supply of certain resources (e.g. raw materials, food).

sparsely populated areas (Krausmann et al., 2008). Urban density reduces commuting distances, air pollution, energy demand, land take and soil destruction, and the fragmentation of habitats. It allows economies of scale in citizen-oriented services such as collective transport, power, water and sanitation services, waste management and district heating. Municipalities are key players in managing resources. They also have the capacity to raise urban players' (policymakers, city managers and stakeholders) awareness of urban flows and their impact and to encourage participation in decision-making.

Nevertheless, municipalities face diverse problems in managing resources, such as the temporal variations in quantity and quality that affect the supply of and the demand for resources or their dependency on trans-boundary engineered infrastructures (e.g. power grid, drinking water network). Their latest challenge is to move away from the current centralised system with one-site and end-of-pipe utilities driven by municipalities or utility suppliers to decentralised systems in which users are simultaneously owners and producers. Despite this complexity, some cities find a way of developing innovative place-based policies and strategies with local participants and of cooperating with neighbourhood municipalities instead of competing. Some cities have adopted ambitious agendas with targets, based on a long-term vision, and have successfully implemented transition management based on a co-creative and participatory process to bring about changes in society.

There is no 'one-size-fits-all' strategy. Each city needs to develop appropriate integrated place-based solutions, taking into account all the factors that influence resource efficiency. Technological solutions alone, such as the traditional end-of-pipe and one-site solutions, are no longer sufficient. Examples of good practice show that urban 'flows' and urban 'forms' need to be integrated, and spatial development (urban planning, land use, urban design, density) has to be coordinated with the planning of infrastructure systems (location, concentration, distribution, nature of demand, capacity thresholds, technology choices). Transition towards resource- and energy-efficient cities, and more generally sustainable cities, is a systemic challenge that will require radical transformation of every dimension of the urban system: technical (e.g. the interactions between policies, the long-term impacts, the integration of supply and demand), social (e.g. civil society's expectations, social practices) and institutional (Lorenzoni et al., 2007). Urban authorities need not only to develop better integration of sectoral policies but also to collaborate with different levels of government, cutting across jurisdictional boundaries, and to develop the art of working with participants with different interests.

This report is one of a series of three short reports, described below, based on an overview of recent literature and successful case studies focusing on resource efficiency issues in urban areas. The reports analyse the challenges faced by cities and some of the solutions developed to meet these challenges, including governance and finding ways of engaging society in the decision-making process. As there is no one-size-fits-all solution, each city has to find its own path to resource efficiency and, more generally, sustainability.

## What is a resource-efficient city?

This report focuses on the concept of urban metabolism and the circular model. Compactness is highlighted as a way of minimising input and output flows. It analyses in particular the need for land and the link between spatial development and the need for energy for transport. Causal loops are developed for water use and energy use related to transport.

***Key findings***

***Urban flows***
Urban flows depend on drivers (e.g. urban planning, infrastructure, demography, economic specialisation), spatial patterns (e.g. land use intensity, land cover change, urban density, urban form) and the lifestyle of the population (e.g. mobility, food, income). The spatial pattern is key to shaping flows, in particular those related to mobility. Apart from an efficient public transport system, sufficient street intersections and connectivity are required to achieve walkability and cyclability.

***Compactness***
A liveable, compact and dense urban area with an efficient public transport system, mixed land use at the local scale, and green spaces is considered to be a resource-efficient model making lower demands on resources per capita compared with a less dense city. In particular, compactness results in using less energy for mobility and less water and material for infrastructure and reduces the carbon dioxide emissions from housing. Good robust urban planning is crucial to densify the city and limit urban expansion at the same time as improving the quality of life for city residents. Strong urban planning that goes beyond the limits of an individual municipality is critical to achieving compactness.

***Research and methodology***
Researchers have developed different methodologies to analyse urban material flows. The major limitation of these methodologies (e.g. material flows analysis) is the lack of data on material flows at the city or metropolitan scale. However, studies have been carried on different cities in Europe that help us to understand the quantities in resource flows passing through cities and remaining as stocks (e.g. building, infrastructure) and therefore the opportunities for decoupling.

***Land as a finite resource***
Land is a finite resource providing space for people and supporting terrestrial ecosystems. Limiting land take is already an important land policy target at national (e.g. Germany) or sub-national level. Studies show that there is no correlation between growth in the urban area and population growth.

***Land recycling***
Land recycling, i.e. regeneration of previously developed land that is currently not in active use or available for redevelopment (so-called brownfield sites), is seen as a solution to limit land take. The reuse of brownfield land (e.g. former industrial areas, waterfront areas) has become important in developing housing, modernising cities and regenerating deprived areas. In many European cities, the reuse of former industrial and waterfront areas has become a key instrument in combatting urban sprawl and densifying urban areas.

## Resource-efficient cities: good practice

This report analyses innovative measures taken by local authorities to minimise the use of resources and to harvest resources (e.g. rainwater) in the city. It considers issues of both supply and demand, from upstream measures (e.g. avoidance, prevention, reduction) to downstream action (reusing, recycling, harvesting).

***Key findings***

Integration of the demand for and supply of resources
Oversized infrastructures that are not adapted to needs (e.g. the housing bubble in Spain and Ireland) result in a waste of resources and of funding for construction and maintenance. They may also limit the options in the future and lock the city in to an outdated vision of the urban environment. Empty buildings and apartments indicate a misuse of resources that is difficult to map owing to the dispersion of the information. Some cities have developed community mapping initiatives (e.g. Hamburg, Vienna, Budapest).

***The role of the hinterland***
Cities depend on their hinterland — a worldwide hinterland for globalised trade and regional and surrounding rural areas for ecosystem services (e.g. recreational areas, flood protection) — for the supply of resources (e.g. water, food, renewable energy), for the disposal of waste (e.g. waste management, wastewater management plan) and for space for an interconnected infrastructure (e.g. road network, power grid). This interdependence between urban areas and their rural surroundings, far from the limit of the city's jurisdiction, poses a major problem for resource management and governance. Some cities succeed in integrating their surroundings into the supply of resources (e.g. Copenhagen's offshore wind power development, Vienna's forest biomass power station, Amsterdam's food strategy).

***Integrated urban developments***
The complexity of the metabolism increases with the spatial scale, the mix of functions and sectors, and the complexity of the stakeholders and institutions. To optimise integration, all the initiatives need to be scaled up or down in order to be connected each other. There are many initiatives at the scale of the building unit where technology can be easily changed. The district scale offers more potential to significantly increase the benefits and savings. However, this requires acting on all components of the urban design, not only at the controlled scale of the district. Changes in dense urban areas need to take into account the existing urban fabric, the infrastructure networks and the social consequences (e.g. accessibility to green areas and services, exposure to noise and pollution, regulation of temperature). This requires an understanding of life cycles and flows within and beyond the site. Some cities have demonstrated that it is possible to develop an integrated approach at the urban scale (e.g. Amsterdam).

***Improvement of the urban technical system***
Improving resource efficiency requires renovation of the urban technical system — that related to energy and water supply, waste management, mobility and housing — that shapes the resource flows and affects the well-being of city residents. The renovation of existing buildings remains a major challenge, although there are technical solutions even for heritage buildings. The main obstacles are lack of motivation on the part of owners due to the cost, uncertainty over the

payback period and the lack of expertise. The existence of a reliable framework to promote energy saving and to provide information (e.g. Lyon, Grenoble, Bristol) seems a good way of motivating individual owners and community initiatives.

***Demand-side policies***
Lifestyle is matter of choice as well as habits that are shaped by the context. Everyday practices depend on normal standards (e.g. going on holiday, owning a computer), the existing infrastructure (e.g. a lack of public transport increases the use of cars) and the awareness of citizens. Municipalities have opportunities to develop demand-side policies to prevent waste (e.g. Brussels), including food waste (e.g. Halmstad, Brno), or to save water (e.g. Barcelona during its water crisis) or energy (e.g. Sønderborg, Gothenburg).

***Reusing and recycling resources***
The potential for reusing and recycling local resources depends on the scale, local conditions and urban patterns and activities. Some cities reuse energy losses through district heating (e.g. Copenhagen), energy stored in the water cycle (e.g. production of biogas from sewage sludge in Stockholm, energy from micro-turbines installed in the drinking water supply in Nice), promoting the reuse of greywater (e.g. some municipalities in the metropolitan area of Barcelona), and encouraging the reuse and swapping of goods, as well as markets for second-hand goods (e.g. a repair and reuse centre in the city of Graz). Some municipalities have also developed economic instruments to improve their recycling performance (e.g. 'pay as you throw' schemes in Flemish municipalities), targeted information aimed at reducing waste (e.g. the Trenndstadt Berlin initiative), and collection and treatment of organic waste (food waste, garden waste) to produce compost (e.g. Odense) or biogas (e.g. Malmö).

***Harvesting and producing***
The built environment and city surroundings can be self-producers and reservoirs of primary resources that can be harvested. Some cities have developed their own municipal energy company (e.g. Montdidier) or district heating incorporating a high proportion of renewable energy (e.g. Berlin, Copenhagen, Gothenburg, Helsinki, Stockholm, Vienna), some are promoting rainwater harvesting (e.g. some towns in the metropolitan area of Barcelona encourage the use of rainwater after recurrent droughts threatened their domestic supply), and some encourage local food production (e.g. Bristol, Berlin, Bologna). Even if most cities cannot be self-sufficient in food, energy and water, this sustainable approach changes perceptions regarding resources and therefore urban management and planning.

***Smart cities***
Information and communications technology is a key enabler in addressing urban challenges. It is a way of providing tools to manage utilities efficiently as well as providing intelligent organisation solutions (e.g. smart tickets and information on public transport such as in Vienna, a smart grid such as that in Sønderborg, car-sharing tools such as the Getaround app), and governance and participatory tools (e.g. smart cycling plans in Copenhagen).

## Enabling resource-efficient cities

The policy instruments for achieving resource and energy efficiency are inadequate to deal with the complexity of urban challenges owing to the variety of individuals and organisations contributing to resource efficiency through their daily decisions and practices. Some cities have adopted targeted policy agendas and developed a transition management approach based on dialogue between the participants.

***Key findings***

***Transition management***
Achieving the shift towards a resource-efficient society requires fundamental changes, not merely simple optimisation of urban flow management but a transformation in institutional frameworks, mindsets and practices. These changes cannot simply be planned by policymakers and city administrators. Cities and regions that have been successful in following ambitious agendas towards resource efficiency have engaged society in the decision-making process (e.g. the circular economy in Flanders, the sharing economy in Seoul, the transformation of the city of Bottrop). Engaging society ensures a solid knowledge base and co-ownership of the strategy, making it less vulnerable to short-term political changes.

As an entry point for mobilising people, the process can start with something practical and operational. Policymakers can also foster changes by empowering users and stakeholders (e.g. the Bicycle Account in Copenhagen), using grassroots initiatives that emerge at the local level and explore innovative solutions (e.g. 'organically grown' communities, collective gardening, sharing communities) (InContext, 2013).

***The arena***
Success stories show the importance of 'the arena' in the participatory process, a forum in which all stakeholders (users, firms, public research organisations and public authorities, non-governmental organisations) network to envisage a common future, identify pathways and start experimenting to put things into practice. It is a tool to facilitate societal change (e.g. Bottrop).

***Institutionalisation***
To ensure long-term commitment, institutionalisation goes hand in hand with sharing responsibility. The adoption of strategic frameworks or the establishment of new institutional actors (e.g. InnovationCity Management GmbH in Bottrop) act as a driving force for resource efficiency, as well as an insurance policy in the event of short-term changes in political commitment (e.g. Bologna's annual use of ecoBudget since 2001).

***Striving for excellence***
Choosing an ambitious goal, one that all stakeholders can get behind, has the power to set the entire city or region on a completely new path, setting off a transformative dynamic process and inspiring new, even more ambitious, goals (e.g. Güssing, Växjö).

***Scale and level***
There is no 'correct' level of governance at which to address the resource efficiency issue. Measures can be taken at all levels, ranging from the neighbourhood to the city, from the metropolitan area to the entire region or on another scale altogether. To a certain extent, the scale depends on the resources in question. For instance, vacant spaces can more easily be addressed at the neighbourhood level (e.g. cataloguing vacant spaces in Budapest, energy targets in Copenhagen's building code), whereas other issues are more appropriate at the regional level (e.g. developing a circular economy in Flanders) or the national level (e.g. legislation with national targets for daily land take in Germany), and some are best handled at the European level (e.g. the Covenant of Mayors).

***Taking stock***
Each city is unique and there are no one-size-fits-all solutions. Local specifics have to be taken into consideration in defining appropriate solutions. It is important to understand the assets of a territory and to make best use of them, and it is crucial to play to local strengths. Experience in different cities shows that it is important to learn from local participants and initiatives (Roorda and Wittmayer, 2014) and what already works (e.g. Güssing developed its project based on its rural setting, with an abundance of wood from its forests that could be used as biomass to produce energy).

***Monitoring***
A long-term vision and a strategic framework need to be combined with monitoring to analyse the effectiveness of policies. Pioneering monitoring initiatives show that one of the major difficulties is finding a reference point against which to judge efforts. Considering the diversity of European cities, any set of quantitative indicators will offer only limited information without the potential for comparison with other cities.

## Conclusion

To define strategies and long-term visions and to support dialogue with stakeholders during the decision-making process, policymakers need to understand the metabolism of cities to properly assess their current situation and to predict the potential consequences of their policy decisions. Existing information on European cities has been growing and improving in quality since 2006, thanks in particular to Urban Audit and Urban Atlas. However, there is no comprehensive database on urban metabolism, except for certain case studies developed as part of projects. The major limitations are different definitions of cities, different time series and sometimes different methodologies (measured versus estimated or modelled). There are considerable differences between European cities concerning the scope and quality of available information. Some Member States have very complete databases, while in other countries data are less systematic and more fragmented. Therefore, finding appropriate information to implement and interpret flows analyses remains a major challenge.

Priority 8 of the 7th EAP underpins the need for 'criteria to assess the environmental performance of cities, taking into account economic, social and territorial impacts'. Some initiatives are either under way or have already been developed to help local authorities to define sustainability criteria and to facilitate comparison between cities with similar characteristics. At the same time, cities are heterogeneous (e.g. in terms of climate, heritage, morphology, demography, geographical situation, trajectory, activities, local culture). The complexity of the urban system makes comparisons difficult but not impossible if they are done within a group of similar cities. In this way, the EEA has developed a typology of EU-28 cities (based on 383 cities) in order to analyse groups of cities with similar characteristics rather than an individual city.

Finally, these three reports show that the main limitation on developing resource-efficient policies in urban areas is not a lack of technical solutions but more a lack of vision in local participants. Some territories, even small towns, have demonstrated that it is possible to set and achieve ambitious goals by systematically implementing them in all domains (sectors and areas) over a long period of time and by mobilising stakeholders. They have experienced not only a new way of managing their city, more goal oriented, but also a new way of thinking about the complexity of the urban system and of cooperating with stakeholders and neighbourhood areas.

# 1 What is this report about?

Our current pattern of resource use is leading to the depletion and, consequently, scarcity of natural resources ([4]), the degradation of ecosystems, and volatile and increasing prices of natural resources. On a planet with finite resources, the challenge is to find a way of delivering greater value and more services with fewer inputs (EC, 2011a). The 7th EAP, 'Living well, within the limits of our planet', identifies a resource-efficient, green and competitive low-carbon economy as a key objective (EU, 2013).

Traditionally, resource efficiency policy has focused on production and consumption. However, urban areas (see Box 1.1) have considerable potential for improving resource efficiency and helping to deliver the climate and energy package ([5]). Cities require considerable flows, stocks and sinks of physical, chemical and biological resources through the goods and services they import or export to supply the urban population and to maintain their functions (Barles, 2010). These urban metabolic flows can be reduced and recycled through better design, planning and management of the urban socio-technical system and by raising society's awareness. Cities can undergo a radical transformation in different domains — energy, housing, transport systems, waste management, green areas, public spaces. Preparing for transformation towards resource-efficient urban areas in a controlled manner not only reduces the levels and impact of resource use but will also increase cities' prosperity, reduce the costs in the long term and improve the well-being of their citizens.

To ensure their long-term viability, some cities have developed an urban model using less material, less carbon and less nutrients. Some are already implementing innovative thematic programmes, such as those oriented towards zero carbon or zero waste, that cut across sectors, levels, institutions and scales. This report presents some examples of measures developed by innovative cities to manage resources flows more efficiently and closing the urban cycle. It analyses integrative solutions (e.g. ecodistricts) as well as sectoral solutions and optimisation on all scales — from the lowest possible (building) to larger scales.

## 1.1 Three reports on resource-efficient cities

This report is part of a series of three short reports, based on an overview of recent literature and successful case studies focusing on resource efficiency issues in urban areas (see Figure 1.1). The reports analyse the challenges faced by cities and some solutions to these challenges, including those related to governance and ways of engaging society in the decision-making process. As there is no one-size-fits-all solution, each city has to find its own path towards resource efficiency and, more generally, urban sustainability.

**Box 1.1 Urban areas, cities and the urban environment**

Urban areas are generally differentiated from other settlements by their population size and functional complexity. Most commonly, they are characterised by a particular human settlement pattern, a critical mass and density of people, a concentration of man-made structures and activities.

For ease of reading, the terms 'urban area', 'urban environment' and 'city' are used interchangeably throughout this report, and no specific distinction is made among the terms with regard to distinct morphologies or administrative boundaries.

([4]) Natural resources can be defined as all inputs into the economy (EC, 2011a), such as raw materials (fuels, minerals and metals) and food, soil, water, air, biomass and ecosystems (EC, 2011b).

([5]) The EU climate and energy package sets targets for the year 2020: a 20% reduction in greenhouse gas emissions (compared with 1990); 20% of energy from renewable sources; and a 20% improvement in energy efficiency.

- The objective of these reports is to support policy development and decision-making. They are targeted at policy-makers, decision-makers and stakeholders involved in urban management at the local and city level as well as at the regional level. They analyse the following:
- Why do resource-efficient urban areas matter?
- What are the main challenges and what can be done to meet these challenges?
- What solutions can be implemented on different scales and across sectors?
- What are the drivers of change?
- How can cities be governed to achieve the transition to resource-efficient urban areas?
- How can we involve society in the decision-making process?

This report is part of the following series of three short reports (see Figure 1.1), based on an overview of recent literature and successful case studies, that addresses resource efficiency issues in urban areas.

#### *1.1.1 What is a resource-efficient city?*

The report presents the concept of urban metabolism, the circular model and the role of compactness in urban resource efficiency. Cities requires natural resources and energy to sustain the daily life and activities of the urban population. Nevertheless, there are opportunities to minimise input and output flows. As the urban form shapes the way people live, work and move in urban areas, compactness offers the potential to reduce urban flows. The most well-documented effects of compactness are the reduced need for land and energy for transport. Urban planning, based on a vision of the future, developed with local stakeholders and crossing administrative borders, is a key factor in increasing the density of urban areas, developing mixed land use, avoiding the unnecessary uptake of land and soil sealing, reducing car dependency and encouraging the use of public transport, walking and cycling.

#### *1.1.2 Resource-efficient cities: good practice*

Cities are key players in minimising the use of resources and in developing the circular model. Generally, municipalities provide utilities and control public services for citizens and businesses that influence the majority of resource and energy use and the production of emissions and waste. Local authorities have the capacity to implement responses on multiple scales. The main challenge is to scale up actions from the most simple, one function, such as a building for housing, or one resource, such as water management, to integrated solutions in a large urban area (e.g. an ecodistrict) with many functions (e.g. housing, economic activities, green areas, renewable energy production, water harvesting). Another challenge is to move from the current centralised system, with mono-site and end-of-pipe utilities driven by municipalities or utility suppliers, to decentralised systems in which users are owners and producers. The report analyses both the supply and the demand issues. It is divided into two parts: the first is devoted to how to avoid, prevent and reduce the use of resources, and the second addresses reusing, cascading, recycling and harvesting.

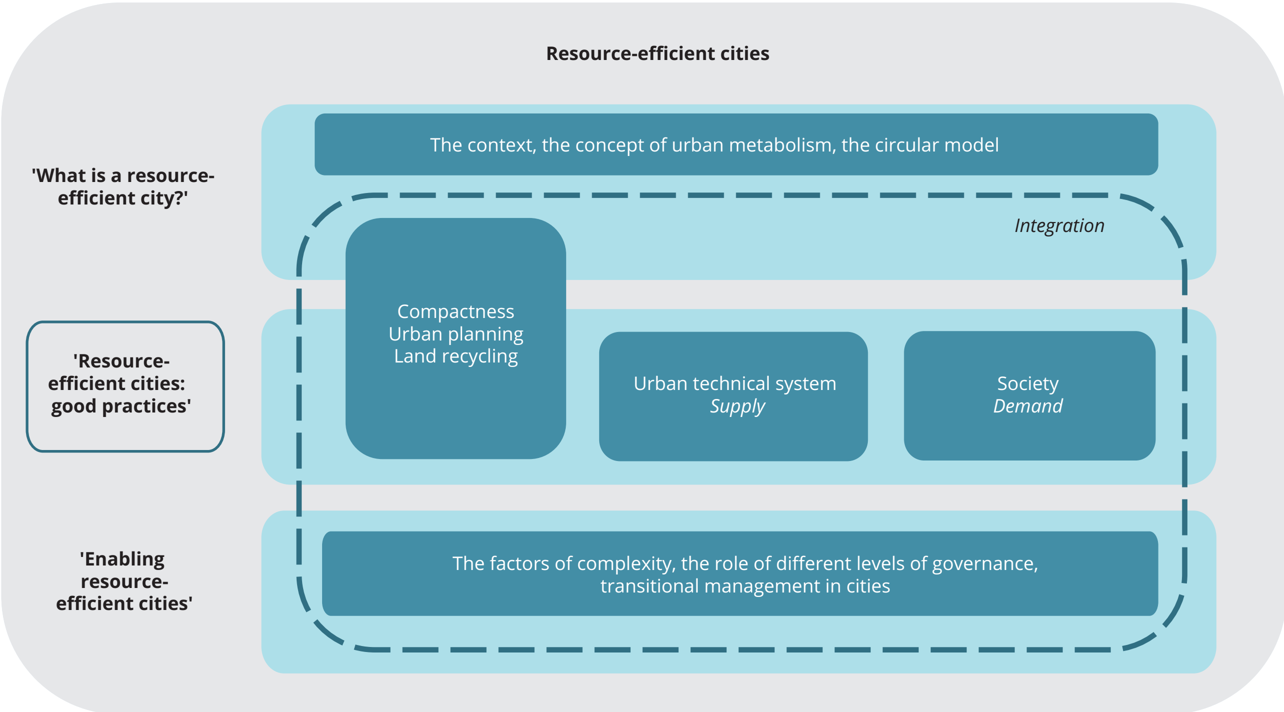
#### *1.1.3 Enabling resource-efficient cities*

To achieve resource- and energy-efficient cities, local authorities have to overcome the limitations of policy instruments that are insufficient to deal with the complexity of urban challenges. They face not only strategic, technical and financial challenges but also institutional barriers created by the fragmentation of responsibilities and decision-making, the number and variety of actors (public, private, civil society, individuals) contributing to resource efficiency through their daily decisions and practices and operating at different levels, the challenge of addressing the urban system as a whole, and the characteristics of the city (geography, economy, climate, history, natural capital, social capital, etc.). Despite this complexity, some cities have adopted ambitious policy agendas with targets, managing the city in a far-sighted goal-oriented way, cooperating with surrounding municipalities and other levels of governance, and developing a transition management approach. This is a form of governance that facilitates societal change. It is based on a dialogue between private and public actors (users, citizens, firms, universities, public authorities) that envisages a common future and identifies ways of achieving a resource-efficient society and, more generally, sustainability.

## 1.2 Scope of this report

The report presents a wide range of examples drawn from European cities to illustrate innovative approaches to resource efficiency. Even small cities with limited budgets have developed powerful solutions. The report is not exhaustive, and other solutions may exist. It emphasises the integrated

**Figure 1.1 The links between the three reports on resource-efficient cities**




approach and highlights the capacity of cities to change their way of thinking, decision-making and acting. Cities that are successful in this respect cooperate, collaborate, experiment, innovate and finally develop a new model. They succeed in finding solutions despite administrative, financial and technical constraints. In general, they define ambitious goals, targets and strategies for the long term and achieve them step by step.

The first part of the report is focused on 'avoiding, preventing, reducing' the use of resources. It analyses how a city can be planned and urban flows managed in order to use less resources. In general, it is relatively easy to take action at the small scale (e.g. a building) and in infrastructure having only one function (e.g. housing), but there is no significant effect on the urban metabolism. The impact of change increases with the degree of complexity, involving the spatial scale (building, block, neighbourhood, city, region, country), a mix of functions and sectors, and a number of different stakeholders and institutions.

The second part of the report analyses the potential for improvements in reusing and recycling local resources. It addresses not only the circular approach to the urban system but also ways of producing energy and harvesting food and water. Cities can be considered as a source of resources. In this perspective of 'productive' cities, the potential resource flows and self-production have to be identified so that they can be integrated into urban planning to allow efficient harvesting and self-production by reducing the distance between the source and the demand.

# 2 Avoiding, preventing and reducing

There are different options for improving resource efficiency, which can be ranked according to their feasibility and efficiency. The most desirable and feasible option is to avoid, prevent or minimise the use of resources and consequently to decrease the amount of waste. There is no unique path to resource efficiency, or more generally to urban sustainability, because there is no unique city model. Resource-efficient development depends on many parameters such as existing infrastructures and buildings, climate, natural capital, social capital, history, size, form and dynamics.

To develop relevant policies that encourage a culture of valuing resources and make preventing and reducing waste easier for people and businesses, local authorities need not only to network with all urban actors but also to cooperate with the surrounding rural neighbourhoods that are involved in supplying resources and waste disposal (Zaucha and Świątek, 2013).

This chapter explores ways of implementing projects to reduce resource use in cities — from the most complex and integrated solutions at the city level to the easier technical solutions at the building level.

## 2.1 Integration of demand and supply

Why develop a new infrastructure if demand is falling or if it is possible to make more efficient use of the existing infrastructure? Integration of demand and supply is a way of avoiding the use of raw materials and energy in the construction of infrastructure (e.g. the power grid, streets, housing, pipe networks) and its associated maintenance. It also helps to reduce the budget for investment and maintenance and the tariffs of utilities when they are based on the principle of cost recovery. An infrastructure that is not adapted to demand will be underused. Hence, the material used for its construction, the investment, the maintenance and the tariffs will be higher than is necessary (Didier and Prud'homme, 2007).

### *2.1.1 Oversized or underused infrastructure*

The infrastructure supplies 'infrastructure services' (UN-Habitat, 2012). It supplies city residents with natural resources, goods and services from outside the city. Without the necessary basic infrastructure (transport systems, electricity grids, water pipelines) the quality of life of city residents would be threatened and cities could not fulfil their full potential for growth. In slums, it is the lack of streets that results in the lack of a basic infrastructure.

Conversely an oversized infrastructure that is not adapted to needs results in cities wasting resources and money on construction and maintenance. It might limit options in the future and lock the city in to an outdated vision of the urban environment, as reconfiguring the building fabric and other infrastructure is a long, complex and expensive process. For example, in Paris, the existing roads along the riverside, built in the 1960s when the vision of urban planning was very car oriented, have made it difficult to reclaim the space for new uses (walking, recreation) (Les Echos, 2014).

The demand for infrastructure is driven by many factors: the need to replace existing assets built many years earlier; the need for increased productivity, safety, care for the environment; a growing population; and new needs. As a result of such complexity, errors in predicting demand are not rare, in particular for the transport infrastructure because of the systemic characteristics of transport. The most well-known case is Montréal–Mirabel International Airport, which opened in time for the 1976 Summer Olympic Games. When it opened, Mirabel was the world's largest airport. It was intended to replace Montréal's other airport (Dorval), which was predicted to be at full capacity within a decade. However, badly connected, oversized and obsolete, Mirabel airport is now due to be demolished (ArchDaily, 2014).

Estimates of numbers of passengers are often optimistic. A French report from the Conseil d'Analyse économique (Didier and Prud'homme, 2007) highlights some mistakes in estimating the demand for transport in some French high-speed railway projects, for example – 50% for the TGV Paris-Nord and – 39% for Interconnection TGV Ile-de-France (Chapulut and Taroux, 2006).

### *2.1.2 Housing bubbles and waste of resources*

A housing bubble is characterised by a 'period of fever' during which the market supplies more real estate than is necessary and then the housing market collapses. As a result large numbers of houses, either fully or partially built, remain empty. To avoid oversupply in the housing market, construction must meet the real needs of the population.

The consequences of the housing bubble are not only social and economic but also environmental. Housing bubbles generate a high demand for natural resources, in particular a high rate of land take. Energy and raw materials are used for manufacturing, transporting materials and building houses and infrastructure; waste and emissions are released. All this consumption of resources results in a significant increase in urban stocks that will generate costs for demolition, rehabilitation and maintenance.

Ireland experienced a phenomenal growth in property during the 'Celtic Tiger' boom from 1993 to 2007. Similarly, between 1997 and 2007, Spain experienced a long period of housing expansion. In 2007, Ireland and Spain alone created more than twice as many dwellings per capita as other European countries (Kitchin et al., 2010). In Ireland, more than 10% of the housing stock remains vacant and that figure reached around 15% in the 2011 census (CSO, 2011); it has been estimated than the housing bubble left behind more than 2 800 so-called 'ghost estates' — urban developments of 10 or more dwellings in which more than 50% of the houses are empty or incomplete (CSO, 2011). In Spain nearly seven million homes were built between 2001 and 2010, more than the population growth over the same period (López Moreno and González Blanco, 2014).

***A lack of urban planning***

Explanations of housing bubbles are focused almost exclusively on the role of the banks and tax incentives and failures on the part of the financial regulators. The role of urban planning has been given very little consideration. However, rapid growth in the housing market has led to increasing urban sprawl, with the development of scattered low-density settlements with detached or semi-detached housing and large commercial strips.

Even if Spanish cities have traditionally been compact compared with those in northern Europe, they have seen rapid expansion since the mid-1990s (Kasanko et al., 2006). The spatial structure of many Spanish cities is changing — e.g. Barcelona (Garcia-López, 2010), Madrid (EEA, 2006), Valencia (Membrado, 2012) — because of the process of suburbanisation, and they are notably becoming less dense (Schwarz, 2010). After the housing bubble burst, latent problems have emerged such as the lack of a territorial model, the unsustainability of urban projects and urban poverty. All these issues are addressed by, for example, the new Madrid Master Plan (Isocarp, 2014).

In a housing boom, planning should act as a counter-balance to the pressures of development to maintain a stable housing market and try to prevent the boom. A study on urban planning in Ireland revealed that a number of local authorities did not heed either good planning guidelines or regional and national objectives (Kitchin et al., 2010). They did not take account of the fact that much of the land zoned for housing lacked essential services (e.g. sewerage treatment plants, energy supply, public transport).

All these examples show the important role of diagnostics and long-term vision in setting relevant goals and developing strategies adapted to the needs of the place. In the case of housing bubbles, many decisions were based on insufficient evidence with respect to long-term demographics, market conditions and issues of sustainability, and cautious voices were marginalised and ignored. Beyond the well-known drivers of housing bubbles (such as speculation, easy access to credit, tax incentives form pro-growth authorities and a growing economy) social representation needs to be highlighted. The desire to own a higher standard of home (with a bigger floor area per capita, garden, etc.) has been a strong contributor to housing bubbles.

### *2.1.3 The empty buildings challenge*

Empty properties correspond to a misuse of resources (buildings stock and land). However, this is a problem that many municipalities across Europe face. Some national governments have introduced extra taxes on properties vacant for more than 6 months (e.g. the United Kingdom), while other states have offered tax breaks for owners who allow social or cultural activities in their empty properties (e.g. Czech Republic, Poland). Some municipalities have created online maps of available vacant properties (e.g. Amsterdam) or established legal and financial incentives to encourage the temporary use of unrented shops (e.g. Vienna).

Many local authorities have no means of cataloguing the vacant spaces in their territories and therefore they cannot estimate the potential for reuse. The main problem in cataloguing vacant spaces is how to share the information between the administration and individual citizens.  In many cases, the solution is community mapping initiatives (the crowdsourcing of real estate data). Many cities, with diverse development contexts, have now initiated the collective mapping of vacant properties ([6]) (e.g. New York, Paris, Hamburg, Vienna).

In addition, many public buildings are empty for part of the day (e. g. schools or offices in the evening) or the week or the year (in popular tourist areas). However, it is possible to integrate different uses for a common space over time (known as layering) (Suzuki et al., 2010). A school and its playgrounds might be used to educate children during the day; then it might host after-school programmes in the afternoon and classes for adults in the evening and, on weekends, serve as a coffee house, a theatre or a farmers' market. For example, in the case of the 'Sharing City Seoul' project, 779 public buildings have been open to the public during vacant times for events, meetings and more.

Similarly, the same place can be used for different purposes. The most common example is to put photovoltaic and solar water heating panels on rooftops (buildings, commercial buildings, parking) where they can take advantage of sunlight and provide useful shading for buildings.

## 2.2 The supply of resources from the hinterland

Cities depend on their hinterland and on a worldwide hinterland for globalised trade: food, goods and raw materials are shipped long distances by rail, ship and air. Regional and surrounding rural areas provide valuable ecosystems services for urban areas. The nearby surrounding areas play an important role in the supply of drinking water, local food, materials for construction, biomass, recreational areas, and places for developing renewable energy production (e.g. wind turbines, solar plants) and an interconnected infrastructure (e.g. roads, the power grid). This interdependence between urban areas and their rural surroundings, far from the city boundary, poses a major problem for resources management and governance.

**Box 2.1 Turning vacant spaces into community spaces in Budapest**

The problem of vacant buildings and spaces was particularly serious in Budapest. The recession, combined with many obsolete buildings and the mismanagement of real estate properties has left a significant proportion of the city's buildings empty. The vacancy rate of office stock in Budapest ([7]) was the highest among the central eastern European capitals, reaching 26% in 2012.

To address this situation, in 2012 the Hungarian Contemporary Architecture Centre (KÉK ([8])) launched a research and advocacy project called Vacant City (Lakatlan) ([9]). This has succeeded in drawing the attention of both citizens and the local administration to the problem of vacant spaces in the city. KÉK has launched an online mapping tool, inviting citizens to create a map of vacant properties and spaces around the city. This crowd-sourced database acts as a tool to support citizen's participation and stimulate discussion.

In 2013, KÉK has started the Vacant City_Reload (Lakatlan_Reload) ([10]) project ([11]), which aims to identify communal, social and cultural initiatives in need of space and pair them with the owners of vacant properties.

**Source:** ICLEI, 2014.

([6]) L. Polyak, 2013, The Recycled City: New uses in old settings, Contribution to Europan 13, (http://europan-europe.eu/media/default/0001/09/e13_themecontr_38_lpolyak_pdf.pdf) accessed 20 November 2015.
([7]) Cushman & Wakefield, 2014, MarketBeat Office Snapshot: Hungary (http://www.cushmanwakefield.com/~/media/marketbeat/2014/02/hungary_off_4q13.pdf) accessed 30 January 2015.
([8]) KÉK: Founded in 2005, KÉK is a cultural institute that promotes architectural education, awareness and innovation among professionals and the general public. KÉK's objectives are to initiate dialogue about architecture, the city and its culture and about the built environment
([9]) Based on http://lakatlan.kek.org.hu (accessed 3 July 2014).
([10]) http://toltsdujra.hu (accessed 3 July 2014).
([11]) In partnership with the Kreater Social Innovation Agency, Habitat for Humanity Hungary and the Oslo School of Architecture and Design. The project was funded by Norway Grants.

### 2.2.1 Conflict between water users

Cities are dependent on their surrounding areas for water supply and discharge. Water is a renewable and mobile resource that needs integrated resource management at the appropriate natural scale (e.g. the catchment area). The demand for water and pollution of it by cities puts pressure on ecosystems (e.g. stream degradation) that can affect ecosystem services. Generally, drinking water is extracted beyond the city limits from surface or ground water bodies, and sometimes this extends far beyond the city's nearest watershed (e.g. around 200 km in the case of Athens).

Water scarcity results from a combination of natural and human factors. The natural factors include specific geographic, hydrologic or climatic conditions. The human factors are the lack of governance (e.g. spatial planning, consultation, cooperation, price policy, regulation, investment), mismanagement and a poorly adapted infrastructure. The available water must be allocated between the urban and non-urban users, mainly agriculture, energy, large industrial consumers and navigation. Without appropriate governance, competition for water generates social conflicts between users and can lead to overexploitation.

Water scarcity does not concern only Mediterranean cities. England and Wales have periodic problems that can affect the urban water supply (Houses of Parliament, 2012). Owing to their high population density, the available water resources per person and per year are on average less than that of some Mediterranean countries. Water companies in charge of utilities regularly have to prepare 'drought plans' that set out measure to prevent water scarcity, including demand-side measures.

In many cases, to meet the growing demands of urban agglomerations, the main strategy has been the construction of large-scale, sophisticated, expensive and resource-consuming infrastructures such as dams or canal for transporting water by (e.g. Barcelona) (Saurí and del Moral, 2001). This technical approach is now being replaced by demand-side strategies. For example, in the metropolitan area of Barcelona, demand-side strategies using water from sources that differ from traditional surface or underground extraction (e.g. desalination, reusing greywater and rainwater, and controlling the demand for water) are growing in importance (Vidal et al., 2011).

Cities can be affected by water shortage whatever their size. For example, the medium-sized city of Niort in France and its surrounding areas, around 100 000 inhabitants, suffered a shortage in 2005 due to the characteristics of its underground resources (karst with limited reserves) and competition between agricultural needs for irrigation and urban uses. The solution has been based on a combination of scientific tools and indicators to allow better forecasting of supply and demand (in particular peaks in demand) and fostering better dialogue between stakeholders (Dörfliger and Perrin, 2011).

### 2.2.2 Surrounding areas as suppliers of renewable energy

The production of renewable energy, which is an important part of cities' low-carbon strategy, is developed inside or beyond the city limits. Although some cities succeed in installing wind power plants within the city limits (e.g. Copenhagen), the development of such an infrastructure in a dense urban fabric is more expensive and technically difficult than in the open spaces of the surrounding rural areas.

In larger cities, only a portion of the total energy demand is likely to be met by renewable energy production located within the city boundary (IEA, 2009) through mainly waste-to-energy combined heat and power plants, geothermal heat systems, solar thermal collectors on roofs, and buildings with integrated solar power systems. Other forms of renewable energy, such as wind power, hydro power, big solar power plants, solid biomass and liquid biofuels, are generally produced beyond the city limits in the nearby hinterland and brought to the city by power lines, pipes, road, rail or boat.

In densely populated urban areas, the production of renewable energy is complex owing to the orientation of buildings, available space, noise, visual effects, planning constraints and characteristics of old buildings. However, complex does not mean impossible. There are successful examples of micro-wind turbines or solar power, as well as heating production in schools, sports centres, business parks and residential buildings. It is usually easier for a small town, located in rural surroundings, to make a big contribution to renewable energy than it is for a mega-city. For example the small Austrian town of Güssing produces its entire energy requirements — electricity, heating/cooling, transport fuel — from renewable resources.

Cities near the coast benefit from offshore wind power and, in the future, will benefit from ocean energy technologies currently under development. In the case of the city of Copenhagen, which has an ambitious programme to develop wind power, a significant proportion of its wind turbines are installed offshore but close to the city.

In the case of combined heat and power plants fired totally or partly by wood (e.g. pellets), the location of the plant is dependent on the spatial distribution of resources, the size of the plant and the technology. Forest in the surrounding areas is considered to be an important factor for securing the supply, limiting the need for storage, and reducing the costs of transport and its associated emissions. To compete with fossil fuels, biomass must have a relatively low value. That means the wood has to be easily harvested and produced nearby.

Since 2006, Vienna has developed a forest biomass power station (in Simmering district) to replace two fossil fuel-fired power plants. It is fed by timber, waste wood fractions and garden waste. The plant uses an existing chimney and cladding plus additional infrastructure such as cooling systems using water from the Danube. The existing rail and road infrastructure simplify the delivery of biomass to the facility and minimise costs.

## 2.3 Integrated urban developments

As planners, providers of utilities and regulators, municipalities play a central role in developing strategies and plans including a mix of policies. In particular, they elaborate urban planning, target and prioritise investments in infrastructure, propose regulations and incentives and support innovative projects.

Many cities are developing integrated sustainable initiatives that are known by a variety of names (e.g. sustainable city, smart city, solar city, low-carbon city, carbon-neutral city, transition city, ecodistrict, etc.). Sustainable initiatives, and therefore resource-efficient cities, are much more than just adding some sustainable buildings or ecodistricts. To make sustainability citywide, all initiatives and projects have to be scaled up and down so that they are connected each other, to optimise effects, to avoid conflicts, to find synergies and to provide multi-function solutions.

### *2.3.1 Changes in the dense urban system*

The concept of the eco-city has become mainstream around the world. Some flagship projects ([12]) (e.g. Masdar ([13]) city in the United Arab Emirates) are at the forefront of eco-city development (Joss and Cowley, 2011). All these projects have been developed in newly urbanised areas where the urban fabric can be strongly integrated, the infrastructure network can achieve high levels of sustainability and innovations can be quickly and easily introduced. This model of the eco-city, a new city built on a greenfield site with the best current sustainable technologies, is not applicable to Europe, where the existing urban systems and infrastructures are very dense.

In Europe, urban sustainability is mainly based on the retrofitting of the existing urban infrastructure and building stocks (residential and non-residential), the conversion of underused or abandoned industrial zones into new dense mixed-use zones, the conversion of low-density suburban environments into high-density areas and the upgrading of unsustainable settlements. Changes in such a dense urban system generate systemic effects affecting different scales, resource flows and social behaviour.

### *2.3.2 The scale issue*

There are many initiatives at the scale of the building unit where the majority of resource consumption takes place and where technology can be easily and rapidly changed. As a building or a block has generally only one function (e.g. residential), it is not the optimal scale for water conservation, energy efficiency and renewable energy systems. The complexity of the metabolism increases with increasing spatial scale (building, block, neighbourhood, city, region, country), the mix of functions and sectors, the complexity of stakeholders and institutions (municipalities/metropolitan authorities/regional government/national government/Europe) (Agudelo-Vera et al., 2012; Ramaswami et al., 2012).

The district scale offers much more potential to significantly increase the benefits and savings through greater systems optimisation and integration because of the larger, yet manageable, scale of the district (Portland Sustainability Institute, 2012). It is small enough to innovate quickly and large enough to have a significant impact. Ecodistricts offer a format for testing the technical and financial viability of different applications and their acceptability to residents.

However, making urban areas sustainable is much more than just taking action at the relatively controlled

([12]) For example Tianjin Binhai in China; the four eco-cities (Changodar, Dahej, Manesar Bawal, Shendra) planned in the Delhi–Mumbai industrial corridor; Masdar in the United Arab Emirates; Hacienda Ecocities in Kenya (Joss and Cowley, 2011).
([13]) http://www.masdar.ae/en/#city/all (accessed 20 November 2015).

scale of the district. It is necessary to take action on all components of the urban design and sectors. This requires a holistic understanding of the existing life cycles associated with each development site, including the study of complex energy/water/materials flow patterns within and beyond the site (Carbon Disclosure Project, 2012)).

### *2.3.3 No unique strategy to become a 'green' city*

The concept of green urbanism has already been successfully adopted in many cities around the world (e.g. Europe, Australia, United States, Canada). Ecodistricts were constructed during the first decade of the 2000s, mainly in the Scandinavian countries and in the United Kingdom, as well as in France, Germany and the Netherlands. Some examples are well known such as the Vauban district in Freiburg (Germany), Västra hamnen in Malmö (Sweden), BedZED in London (United Kingdom), ZAC de Bonne in Grenoble (France), Hammarby Sjöstad in Stockholm (Sweden) (Joss et al., 2011), Pilestredet Park in Oslo (Norway), Greenwich Millennium Village in London, the city of Delft (Netherlands) and Tweewaters in Leuwen (Belgium. Generally, social housing programmes are integrated into residential projects (e.g. the districts of Bo01 in Malmö and Hammarby Sjöstad in Stockholm) (Locasso and D'Ambrosio, 2012).

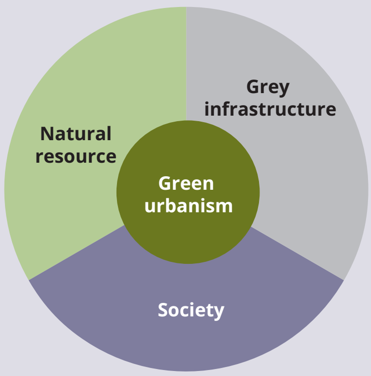
Whatever the size, the history, the location, the wealth, the human capital of a city, policymakers can develop a long-term vision tailored to its characteristics. The paths to urban sustainability are diverse and include

**Box 2.2 Green urbanism**

An Australian researcher, Steffen Lehman ([14]), has defined a conceptual framework, based on 15 holistic principles (see Figure 2.1), to achieve more sustainable cities (Lehmann, 2010; Lehmann, 2014). These principles can be effective in a wide variety of situations according to the specifics of the city such as size, form, climate, location, social capital, natural capital. The long-term goals of green urbanism concerning resources are zero emissions, zero waste and avoiding waste of energy/water/materials.

**Figure 2.1 The principles of green urbanism**

- **Green infrastructure**
  Landscaping
  Working with nature
  Biodiversity in parks and gardens
  Accessible green areas for recreational activities
  Green roofs, green walls, linear trees
- **Resource**
  Renewable or regional materials for construction
  Regional food supply, including from urban areas
  Zero-waste city and a circular approach
  Zero-land take
  Closing the water cycle through collection, filtration and rain gardens




- **Urban planning**
  Densification, land recycling, programmes for mixed land use
  Retrofitting buildings and infrastructure
  Affordable housing
  Eco-districts and eco-buildings
- **Urban design**
  High quality public spaces
  Architecture and place identity
  Eco-construction
- **Urban management**
  Smart management of resource flows
- **Mobility**
  Efficient public transport
  Cyclability and walkability
- **Energy**
  Production of renewable electricity
  Smart grids for efficient use of energy
- **Culture**
  Values, behaviour, lifestyle, identity
- **Governance and leadership**
  Long-term vision, planning, programmes
  Integrated place-based approach
  Liveability, health and well-being as main objectives
  Cooperation with surrounding areas
  Participation of citizens at the decision-making process
  Green procurement
- **Education, research, knowledge sharing**
  Information to raise awareness, training on sustainability issues
  Participation at networks to share experiences

**Note:** The 'grey' infrastructure system or the urban technico-system (roads, metro, railways, buildings, utilities) determines the spatial extent of the city and the urban pattern (urban form, density, design) (EEA, 2015).

**Source:** Adapted from Lehmann, 2014.

**([14]) Head of School, School of Built Environment, Curtin University, GPO Box U1987, Perth WA6845, Australia.**

carbon-neutral goals (e.g. Copenhagen, Växjö) and 'zero waste' in Capannori (Italy) ([15]). These different examples show that, even if local policy is focused on a specific topic, as a result of the necessary integration of policies, the objectives tend to become larger and finally to encompass many aspects of resource efficiency and more generally of urban sustainability.

***Leadership and a vision of the future***
Leadership is crucial to setting targets for the long term. In the city of Växjö in Sweden, political leadership was the important starting point for the 'Fossil fuel-free strategy' ([16]) elaborated in 1996. When the decision was taken, nobody really knew either if it was possible to achieve the goal by 2010 or what kind of measures would need to be taken (EnergyCities, 2009). The Växjö strategy is focussed on a combination of measures (Nordic Energy Municipality, 2011). Overall, Växjö has adopted ecoBUDGET, a sustainability-oriented method that provides information for political decision-making and city managers.

***Changes in the dense urban fabric***
All changes need to take into account the existing urban fabric, even if it is a difficult challenge. For example, in Rotterdam (Tillie et al., 2012), densifying and greening associated with low-carbon transport were identified as a pathway towards sustainability and a better quality of life. The challenge was not only to add many dwellings to the inner city but at the same time to increase the number of attractive houses and the citizens' quality of life, to improve the microclimate of the inner city and to expand and upgrade green areas. Densification of an already dense urban fabric is a matter of precision.

Regenerating and rebuilding some areas of the city is challenging because of the political and social consequences, the economic cost, and the necessary adaptation of the transport infrastructure (roads, public transport, cycle lanes, rapid transit lanes for buses) and utility networks (drinking water, wastewater, power, waste collection) to achieve better efficiency. Adding a building in dense urban fabric can have a positive effect if it is in the right place (Tillie et al., 2012). Bioclimatic design (see Figure 2.2) can help to develop a city with improved thermal comfort and therefore reduced energy consumption (Doepel, 2012).

Compared with development in dense existing urban fabric, it is easier, less expensive and more efficient to develop new urbanised areas in underutilised areas or brownfield sites. It is possible to provide innovative urban design, high-quality architecture, 'smart' buildings (with, in particular, high energy efficiency but also ventilation, optimised natural lighting, good indoor air quality), green areas (including green walls and green roofs), a closed water cycle (through collection, filtration, ponds and rain gardens), mixed uses and efficient and affordable public transport and to produce renewable energy. However, most of the current building stock will remain throughout the next

**Box 2.3 The Venlo-region: an approach to stop the decline**

The Venlo-region in the south-east of the Netherlands has embraced the cradle to cradle principles at regional scale. It was experiencing a decline in population, and this trend would have continued in the absence of any initiative to stop the decline. In 2009, at the beginning of the project, the cradle to cradle approach was regarded as a tool to achieve not only resource efficiency but also growth. The intention was to develop the highest possible levels of sustainability while at the same time boosting welfare across the region and creating a knowledge base that could be exported across Europe and the world.

Cradle to cradle principles have been applied in all domains, including manufacturing, construction, organisation and living and working areas. The city of Venlo's adoption of cradle to cradle® products (certificate and label) has been a driver for the economic development of the region, and it offers wider possibilities for systemic eco-innovations such as industrial symbiosis (EC, 2012). The city's procurement criteria have also been oriented towards innovative outcomes (e.g. building purifying water).

**Sources:** http://www.innovationseeds.eu/Policy-Library/Core-Articles/Cradle-To-Cradle-C2C--The-Dutch-Region-Of-Venlo-Towards-A-Circular-Economy.kl (accessed 29 June 2014).

http://www.c2c-centre.com.

http://www.c2cn.eu.

([15]) http://www.zerowasteeurope.eu/2013/09/the-story-of-capannori-a-zero-waste-champion/ (accessed 10 September 2014).
([16]) The real objective was to reduce carbon dioxide emissions from fossil fuels per inhabitant by at least 50% by the year 2010 and by at least 70% by the year 2025 compared with those in 1993 (Växjö Kommun, 2011).

**Box 2.4 The integrated approach of Copenhagen**

Copenhagen aims to achieve carbon neutrality by 2025. This means that heat and power production will be carbon neutral and that the city's renewable energy production will be sufficient to compensate for traffic emissions, wastewater management and industrial processes. Consequently, the production of renewable energy must be greater than the annual energy consumption (City of Copenhagen, 2012a). According its Climate Plan, more than 75% of the reduction has to be realised through changes in energy production and 10% has to come from energy savings.

To meet the goal of carbon neutrality, a long-term strategy for an energy supply based on a mix of renewables (biomass, wind, geothermal and solar) has been defined. The city has maintained and developed an extensive district heating network (98% of all homes are connected), switching progressively from non-renewable energy to biomass. Onshore and offshore wind turbines have been erected to produce electricity. Heat generated by the incineration of waste is used for heating houses within the municipality and the electricity generated goes into the grid.

The city has defined five main plans setting goals for transport planning to ensure a reduction in emissions and an increase in the percentage of people commuting by bike or public transport. The goal is to have 50% of people cycling to work or their place of education in 2015, compared with 35% in 2010 (City of Copenhagen, 2012b). The city of Copenhagen also has very strict energy standards to improve energy efficiency in new and existing buildings.

Carbon neutrality is only part of a larger sustainable urban policy focused on quality of life (City of Copenhagen, 2009). The urban environment offers parks and pocket parks for daily use in a dense city (City of Copenhagen, 2011). The city's green areas represent about 25% of the overall area ([17]), and 80% of Copenhageners live within 300 metres of a green area.

This sustainable approach is focused not only on the carbon-neutral goal. It also addresses most of the items of green urbanism. The success of the carbon-neutral policy is due to a combination of ambitious long-term targets and detailed short-term goals that have been rendered credible by immediate action (City of Copenhagen, 2012b). A political consensus has been forged around the carbon-neutral goals, and the project has won general support through the involvement and empowerment of a wide range of stakeholders. Local firms have seen business opportunities and citizens have seen the way to a better quality of life.

Copenhagen was awarded 'European Green Capital' for 2014 ([18]).

decades, and the morphology of European cities will be quite similar in the future. Most improvements need to focus on the existing city.

### *2.3.4 The ecodistrict as an integrated approach at the district level*

An ecodistrict is a small-scale area such as a neighbourhood or a district where integrated urban planning and design are oriented to sustainable development goals, in particular a drastic reduction in the consumption of energy and resources (PUCA, 2008). An ecodistrict is based on principles similar to those of green urbanism. Ecodistricts promote compact urban development using smart building techniques and sustainable land use strategies. The land area required for human settlement is decreased by intensifying land uses through mixed use that balances human needs and environmental constraints.

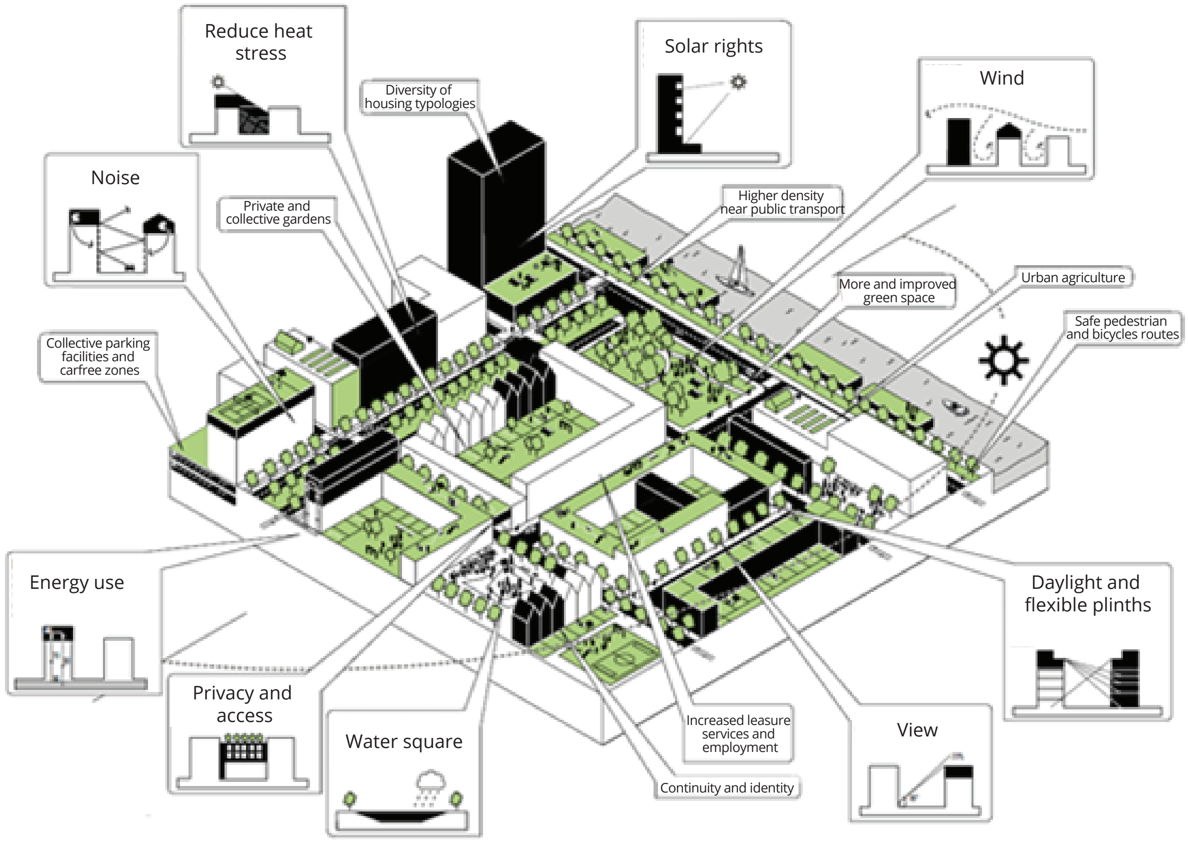
In an ecodistrict, net zero standards (zero fossil fuel energy use and zero carbon emissions, net zero waste, net zero water use) are achieved by residents closing the loop of production and consumption:

- energy standards address the production of local renewable energy, energy management and control, energy costs and energy emissions;
- water standards address water use, collection, storage and reuse;
- waste standards address the production, reuse and recycling of materials to decrease the consumption of raw materials.

***High quality of life standards***
Urban design and planning are people oriented. Districts have mixed-use planning that integrates daily amenities and services (supermarkets, shopping centres,

([17]) Around 42 m² of green area per inhabitant.
([18]) http://ec.europa.eu/environment/europeangreencapital (accessed 20 November 2015).

**Figure 2.2 Smart and bioclimatic densification**




**Sources:** Adapted from Doepel, 2012; Tillie et al., 2012.

schools, etc.) located within walking and cycling distance of residences. Mobility prioritises pedestrians, cyclists and public transport. In general, cars are relegated to the periphery. Greenery, including green roofs and green walls, is included in the built environment to improve the well-being of the inhabitants and provide services such as temperature regulation , clean air and noise reduction (Lehmann, 2014). Every resident has easy and open access, by walking or cycling, to green open areas. Community gardens can also be dispersed throughout residential areas to encourage urban agriculture and provide residents with space to grow their own food.

Ecodistricts offer attractive places not only for residents but also for businesses. The mix of land uses, with a balance of housing, employment and green areas facilitates place-based economic development. Residents, businesses and consumers are attracted to live, work and shop in an area by its physical features. In addition, the place provides food, waste with the potential for reusing and recycling, and the potential for energy generation that offers opportunities for local businesses and the community (Seltzer et al., 2010).

The ecodistrict is not only a resource-efficient place, it is also a community. Because of its neighbourhood scale, people are empowered to make it prosper. It is a framework for facilitating acceptance of new resource-efficient technologies and for developing the culture and values of sustainably, leading to changes in behaviour and consumption (Seltzer et al., 2010).

## 2.4 Renovating the building stock

Socio-technical transitions in response to major environmental challenges require renovation of the urban infrastructure — that related to energy and water supplies, waste management, mobility and housing — that sustains everyday life. As planners, providers of utilities and owners of social housing, municipalities have an important role to play in the retrofitting, refurbishing and re-engineering of the urban fabric (in particular buildings) that shapes resource flows and affects the well-being of the city's residents.

Renovating buildings is a key priority owing to their high energy consumption. It is a low-cost way of reducing emissions of greenhouse gases (GHGs) and saving energy (McKinsey & Company, 2010; Copenhagen Economics, 2012). It is also a way of reducing energy bills, improving the aesthetic of buildings, increasing asset values and providing a healthier and better quality of life for citizens.

The adoption of long-term strategies by national and local governments to frame the energy transition will require long-term investment in the renovation of buildings and in the production of renewable energy in cities (by means of solar, wind and geothermal energy, waste incineration, biomass production). Deep renovation of building stocks is expected to create around two million jobs in the EU and have a beneficial impact on the economy ([19]).The so called 'deep renovation' is a combination of adopting energy efficiency measures (improving insulation, draught excluders, windows, ventilation, heating/cooling system) and use of renewables (Lewis et al., 2013).

The study by Ecofys for Eurima (Bettgenhäusser et al., 2014) looks at different scenarios for the renovation of buildings. In the case of 'deep renovation', the total energy use for space heating, hot water and cooling will be reduced by 66%, gas consumption reduced by 95% and oil consumption reduced by 97%.

**Box 2.5 Well-designed buildings do not guarantee high energy efficiency: the case of ZAC de Bonne in Grenoble**

Launched in 2000, ZAC de Bonne in Grenoble (France) is an ecodistrict on a 8.5-hectare site, with 5 hectares of green areas. The project was developed taking a bioclimatic approach ([20]) to building design and a new approach promoting energy efficiency and innovative energy management.

The district was designed and built between 2000 and 2010 under the framework of the 'Sustainable Energy Systems in Advanced Cities' ([21]) (SESAC) project within the EU's Concerto initiative. In 2009, the project gained an award for its quality ([22]) from the French government.

The initial goal for new buildings was to halve energy consumption ([23]) compared with the French regulation in force at the time. To improve the understanding of energy use in such buildings and to suggest future strategies, a study was carried out to check the real energy performance of the buildings.

The study ([24]) showed that some of the assumptions used to calculate expected consumption did not reflect the intrinsic performance of buildings. The gap between observations and expectations could be explained by several factors:

- The choice of high-quality materials is not enough in itself to achieve high performance; the installation is almost as important and needs to be done carefully.
- The energy performance of a building can change after it has been used for a while. Servicing and maintenance of facilities, such as boilers and solar thermal systems, are crucial to avoid a decline in the building's energy performance.
- The building must be used in accordance with the way it has been designed. Its performance depends on the behaviour of the occupants: for example, regulation of the heating thermostat, opening windows, at home all day or for only parts of it, and number of showers or baths taken.

The ZAC de Bonne has taught us many lessons. Efficient technical solutions can be jeopardised by failure to involve all the different actors — such as the construction company, the owner of the building, the occupants — throughout the process, from construction to living in the building.

**Sources:** EnergyCities, 2010; Enertech, 2011; Fumagalli, 2013.

([19]) http://www.renovate-europe.eu/ (accessed 20 November 2015).
([20]) http://www.energy-cities.eu/IMG/pdf/De_Bonne_EN.pdf (accessed 22 November 2015).
([21]) http://concerto.eu/concerto/concerto-sites-a-projects/sites-con-projects/sites-con-projects-search-by-name/sesac.html
([22]) The award was presented by the French Ministry of Ecology and Sustainable Development: http://www.diplomatie.gouv.fr/fr/IMG/pdf/pfvt_18sept_cle471bd2.pdf
([23]) The goal in the ZAC de Bonne project for primary energy use was 50 kWh/m² of living area per year.
([24]) Between 400 and 700 sensors were placed on each of the eight buildings selected for the study, which recorded, at intervals of 10 minutes for a full year, temperature, instant power, air flow, etc. (Enertech, 2011).

**Box 2.6 Buildings are the largest energy-consuming component of infrastructure**

Residential and non-residential buildings together consumed around 40% of total energy requirements in the EU-28 in 2012. Residential energy consumption (for space and water heating and the use of electric appliances) accounted for 26% of total energy consumption in 2012 (Eurostat database) and non-residential buildings accounted for 14% (EU, 2014). Space heating accounts for 67% of total energy consumption in dwellings ([25]), lighting and electrical appliances for 15%, water heating for 14% and cooking for 4%.

Industry and households were the leading sectors in terms of energy efficiency during that time. In the case of households, efficiency increased by 27%, at an average rate of 1.6% per year ([26]). This was mainly due to improvements in space heating and large electrical appliances. Mandatory efficiency standards for new buildings have facilitated the use of condensing boilers and heat pumps; all this, combined with the retrofitting of existing dwellings, has improved the thermal performance of buildings. However, the greater number of electrical appliances and the need to heat larger homes offset the improvements made through technological innovation.

In the EU-28, residential buildings account for three-quarters of the total floor area. Single family houses account for 65% and flats for 35% of the total floor area. It is estimated that 67% of total household energy consumption (EEA, 2012a) is used for space heating.

**Figure 2.3 Drivers of the change in average annual energy consumption per household in the EU-27 between 1990 and 2010**


**Source:** EEA, 2013c (ENER-37 based on Odyssee database).

**Improvements in the efficiency of space heating**

The efficiency of space heating is continuously being improved. Mandatory efficiency standards for new buildings (insulation, condensing boilers, heat pumps, etc.), combined with the diffusion of more efficient heating appliances and the retrofitting of existing dwellings, have improved the thermal performance of buildings. Between 1990 and 2010, the energy efficiency of space heating per unit area increased in nearly all European countries (except Greece and Hungary).

It is estimated that new dwellings built in 2010 consume around 40% less energy than dwellings built in 1990 owing to new building regulation ([27]). By 2020 all new buildings in the EU should be 'nearly zero-energy buildings' according to the Energy Performance of Buildings Directive ([28]) (EPBD).

At the EU level, the annual energy consumption for buildings is around 220 kWh/m², with a large gap between residential (200 kWh/m²) and non-residential (295 kWh/m²) buildings. Despite the improvement, average energy consumption for space heating is still high, particularly compared with current state-of-the-art buildings such as low-energy houses (depending on the national classification, less than 70 kWh/m² or < 50 kWh/m²), passive houses (< 15 kWh/m²), zero-energy houses or plus-energy houses.

The reduction in consumption has been quite significant in the Netherlands, Ireland and France, as well as in Romania, Latvia, Estonia and Poland (Odyssee-Mure, 2013). The Netherlands is the EU country with the lowest levels of energy consumption per unit area and is at the same time among the countries that have made the greatest improvements in energy efficiency.

([25]) Odyssee indicators: http://www.buildup.eu.
([26]) EEA, 2013c (ENER-37 based on Odyssee database): http://www.eea.europa.eu/data-and-maps/indicators/progress-on-energy-efficiency-in-europe/assessment (accessed 28 July 2014).
([27]) EEA. 2013b. Progress on energy efficiency in Europe (ENER 37). http://www.eea.europa.eu/data-and-maps/indicators/progress-on-energy-efficiency-in-europe/ds_resolveuid/MNOAOE5FNC (accessed 20 November 2015).
([28]) Directive 2002/91/EC,EPBD.

**Box 2.6 Buildings are the largest energy-consuming component of infrastructure (cont)**

Floor spaces per capita increases over time in the EU, especially under favourable economic conditions. A larger floor space per capita increases the energy demand of buildings and therefore the energy efficiency of the current building stock needs to be greater. Improvements in energy efficiency are offset by increased floor space per capita and the proliferation of new electrical appliances. Larger dwellings and the fitting of central heating in the south of Europe have offset the equivalent of 25% of the energy efficiency gains (Odyssee-Mure, 2013).

**Great inertia in changing the building stock**

The low volume of construction limits the impact of energy efficiency standards on new dwellings. There is considerable inertia in the renovation of the building stock. Only around 1% of the existing floor area is renovated annually (Atanasiu and Kouloumpi, 2013). As changing the building stock is a slow process, the composition of the housing stock gives an idea of the required renovation techniques and technologies and the measures that will be needed to change it. Energy consumption in buildings is influenced by many factors, such as economic development, weather conditions, consumption pattern, age of buildings, size, etc. The period of construction is important because it determines construction techniques and building regulations that impose standards during the design phase (see Table 2.1). Without renovation to improve energy performance, the age of building is strongly linked to its level of energy use.

**Table 2.1 Age of housing stock in Europe**

| Geographical area | Built before 1960 (%) |
|---|---|
| South | 37 |
| North and west | 42 |
| Central and East | 35 |

**Note:** South: Cyprus, Greece, Italy, Malta, Portugal, Spain.

North and west: Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Luxembourg, Netherlands, Sweden, United Kingdom, Norway, Switzerland.

Central and East: Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, Slovenia.

**Source:** BPIE survey (Atanasiu et al., 2011).

**The composition of the housing stock**

The composition of the housing stock by type (detached house, semi-detached house and apartment) has significant implications for the kind of renovation techniques and technologies and the type of measures that can be employed. There is great variation between European countries in the composition of their housing stocks. Single homes represent more 50% of the building stocks in Austria, Finland, Romania, France, Belgium, Denmark, Portugal, Hungary, Croatia, the Netherlands, Portugal and Ireland (see Figure 2.4). Increasing energy efficiency results in a large number of small renovation sites. Other countries such as Italy and Germany have a majority of apartments.

**Density and type of dwellings**

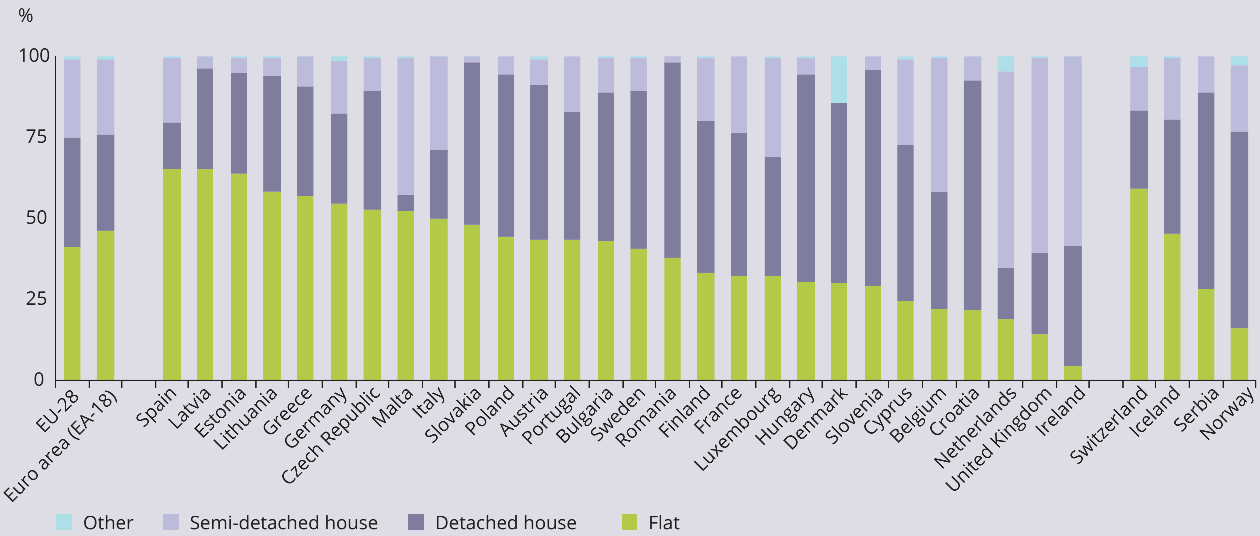
According Eurostat, in 2012, 41.3% of the EU-28 population lived in apartments, just over one-third (34.1%) in detached houses and 24.0% in semi-detached houses (Eurostat ([29])). Clearly, as urban density increases, the percentage of people dwelling in apartment blocks (multi-family dwellings) increase, while the percentage living in houses (single family and two families) decreases. Around 60% of the European population living in densely populated urban areas lives in apartments, while around 72% of Europeans live in dense or medium-density urban areas.

However, these averages hide significant differences between countries. The proportion of the population living in these urban areas varies significantly between countries: from close to 100% of the population in Malta and over 95% in Belgium, to just over 35% of the population in Sweden. Houses are by far the most common form of dwelling in dense or medium-density urban areas in Belgium, the United Kingdom, the Netherlands and Norway. Elsewhere (Spain, Greece, Estonia, Latvia and Lithuania, for example) the vast majority of the population living in dense or medium-density urban areas live in multi-family dwellings.

([29]) Eurostat database: ilc_lvho01.

**Box 2.6 Buildings are the largest energy-consuming component of infrastructure (cont)**

**Figure 2.4 Composition of housing stock, 2012**




**Note:** http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Housing_conditions (accessed 20 November 2015).

**Source:** Eurostat database.

### *2.4.1 Developing a holistic approach to renovation* (30)

***Technical solutions for renovation on the market***

The energy performance of buildings is influenced by many factors, such as ambient weather conditions, wind, exposure, area (e.g. green areas, shadows, the elevation of adjacent buildings), the urban pattern (e.g. dispersion, compactness, density), the use of the building (residential, commercial) the building structure (detached, semi-detached, multi-storey house), the number of occupants and their behaviour, and the building dimension and morphology (e.g. floor space, height, windows, façade and roof surfaces, lighting system, heating and ventilation systems, materials, insulation, function, age). There are technical solutions for renovating buildings already on the market, and many new solutions are being developed. There are also good instructive examples of successful building renovation ([31]).

Retrofitting can involve demand-side management, supply-side management and energy consumption patterns (Ma et al., 2012):

- *Heating and cooling:* reducing the need through insulation of the building's fabric (roof, walls), retrofitting windows, increasing air tightness, etc.
- *Energy-efficient equipment and low-energy technologies*: making use of natural ventilation, upgraded lighting, thermal storage, energy-efficient equipment and appliances, heat recovery, etc.
- *Renewable energy technologies and retrofitting the electric system:* solar thermal system, wind power system, biomass system, geothermal system, etc.
- *Human factors:* comfort requirements, occupancy regimes, management and maintenance, occupancy activities, access to controls, etc.

Resource-intensive materials and products can be replaced and insulation can be improved. New materials with better energy and environmental performance are being developed, such as cement using less energy (Global Cement Magazine, 2011), wood (which is a way of increasing the sustainability

([30]) More information and case studies are available on the following websites: Mangenergy: http://www.managenergy.net (accessed 20 November 2015).
([31]) Accessed 20 November 2015: http://www.managenergy.net/, http://www.energy-cities.eu, http://www.eu-smartcities.eu, http://www.eu-smartcities.eu/, http://www.buildup.eu/cases.

of buildings throughout their life cycle), even in multi-storey buildings ([32]), and straw ([33]), which is characterised by high insulation capacity creating a comfortable indoor climate.

***An urban sustainability issue***

Renovation of existing buildings can have a substantial impact in terms of energy saving and reducing GHG emissions. Refurbishments account for roughly 2% of the housing stock per year. It is estimated that around one million dwellings are refurbished every year (R2Cities, 2014).

The technical measures required for the refurbishment of only one building are different from those for the refurbishment of a whole residential area. Although it is reasonable to start with small-scale pilot projects to

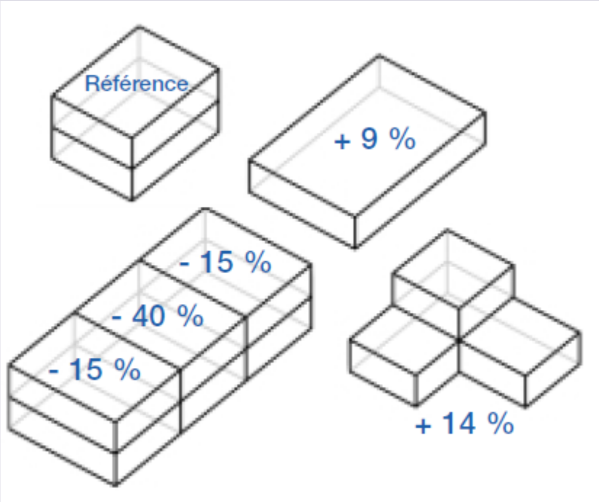
**Box 2.7 Building shape influences energy performance**

The energy performance and the comfort of buildings depends on different factors: compactness, size, site, orientation related to the sun, solar shading, insulation, interaction with surrounding buildings, orientation of wind, buffer spaces, windows, thermal mass, air tightness and moisture, ventilation, and hours of daylight. For optimum performance, it is necessary to reduce or even eliminate the need for active mechanical systems.

Building shape and the geometry and orientation of the building have great potential to reduce the building's intensity of energy, use, but they are often influenced by other planning considerations, the type of building and its use, the feasibility and initial cost, liveability, etc. Buildings with a smaller exterior envelope area (for a similar floor surface area) will achieve better energy efficiency (see Figure 2.5). The more compact a building, the easier it is to achieve high energy performance, and less insulation is needed to achieve a given level of performance. As a result detached houses require more energy than similar-sized attached houses because they have more outer walls (CSTB, 2012). Bigger houses require more energy than smaller ones because there is more space to heat and cool.

The ideal form is a sphere or a cube. For the same shape, the compactness factor decreases with size ([34]). The outer walls have a high cost economically and ecologically. Reducing the surface area of the outer walls reduces heat loss and the cost and impact of buildings on the environment. For example, the heat loss of an attached house (96 m²) with one floor is 40% less than that of a detached house of the same size with one floor (Effinergie, 2008).

**Figure 2.5 Energy loss for buildings with a floor area of 96 m² and different envelope areas**




**Source:** Effinergie, 2008.

A life cycle energy analysis of a recent residential development in the Greater Dublin Area (Duffy, 2009) showed that operating emissions from dwellings in the commuter and extra-urban zones were almost twice those in the city centre, due to both the larger dwelling sizes and the predominance of detached and semi-detached houses, which consume large amounts of energy because of their completely exposed external envelopes. Conversely, apartments have the lowest per dwelling consumption owing to both their smaller size and their smaller external envelope area.

Compact low-rise buildings are more energy efficient than high-rise buildings (City of Vancouver, 2009), which are subject to the effects of too much sun and wind. All-glass skin high-rise buildings are inefficient because glass provides minimal insulation; however, the production of steel and concrete generates a lot of GHG emissions (Wong and Hallsworth, 2012).

([32]) The 'life cycle tower' in Austria demonstrates that is possible to build energy-efficient buildings with up to 20 storeys in wood: www.rhombergbau.at (accessed 10 July 2014).

([33]) It can be produced regionally at a low cost. A two-storey house has been built in Austria (the so-called S-House) that uses only 10% of the resources and energy of conventional construction. Around 400 multi-storey buildings were built in Europe in 2011.

([34]) The form coefficient is the ratio of the surface of the building (only the outer walls and the roof) to the heated volume of the building. In an attached house, the party walls are not taken into account in the calculation.

test feasibility, the project will have to be embedded in an integrated urban development plan for the entire city area (HELCOM, 2010; URB Energy, 2011a).

For the renovation and refurbishment of buildings on a large scale, a systemic approach and innovative solutions need to be developed for the whole construction process using tools and procedures that already exist, such as Leadership in Energy and Environmental Design (LEED) ([35]), the Building Research Establishment Environmental Assessment Method (BREEAM) ([36]), integrated project delivery ([37]), building information modelling ([38]), life cycle assessment, life cycle cost and simulation software.

It is possible to meet ambitious targets for refurbishment with technologies already on the market. For example, in the R2Cities project ([39]), the objective is to achieve an energy consumption of 70 kWh/m² per year, representing around a 60% reduction compared with the current situation (R2Cities, 2014). The project is based on holistic approaches combining technologies already on the market such as insulation, information and communications technologies (ICTs) and renewable energy systems.

A city is made up of a multitude of diverse buildings. Some are very old, even historic, while others are more recent, and their thermal quality may vary from 1 to 10 (EnergyCities, 2014a). The spectrum of potential management and decision-making systems is very large and the solvency of owners is variable. It is useful to develop specific recommendations for neighbourhoods with similar characteristics in relation to the provision of utilities, socio-spatial organisation and urban development, rather than examining each building individually (URB Energy, 2011b).

Energy-efficient refurbishment cannot be seen only as an improvement in the energy performance of buildings but must be seen also as an issue of urban sustainability embedding many other fields (e.g. the upgrading of the neighbourhood, mobility, the development of district heating and combined heat and power, green infrastructure) (URB Energy, 2011b). Urban planning needs to be energy efficiency oriented through increasing compactness and mixed uses, reducing traffic, and developing public transport. Attention also needs to be paid to adapting the urban structure to manage the consequences of climate change (e.g. avoiding the heat island effect, creating ventilation corridors, protecting against flooding) (EEA, 2012b).

Energy efficiency projects can be an opportunity to create a vision for the future of a city or a district. For example, the refurbishment of the centre of Jelvaga in Latvia has used an urban energy project to build an integrated urban development plan. In terms of the energy-efficient upgrading of infrastructure and multi-storey buildings, the objective is the enhancement of the environment and the improvement of the whole area (URB Energy, 2011b).

Older, pre-First World War property is the least energy efficient but is also often the easiest to renovate to make it more energy-efficient. Social housing estates and concrete blocks of flats can also be renovated to high environmental standards, as a German programme has shown. In Ireland, the Empty Homes Agency (2005) has also demonstrated the feasibility of cost-effective and energy-efficient renovation.

### *2.4.2 Renovation of the built heritage*

The challenge in historic buildings is to maintain the existing quality of the built heritage while improving the quality of housing in accordance with modern energy standards. Ancient buildings are often not only very inefficient buildings but also damaged buildings. Historic city centres have to offer comfortable and energy-saving housing in order to offer a credible alternative to peripheral housing estates. It is necessary to find a balance between the needs of the inhabitants and the economic development of the centre.

One major issue is how to renovate older and damaged areas without moving out the most vulnerable populations. It is necessary to find a balance between the residential functions, often the most fragile ones, of a city centre and its urban centrality and attractiveness (Lewis et al., 2013). The plan for the regeneration of Delft since the year 2000 is a good example of the

([35]) LEED is a green building certification programme that recognises best-in-class building strategies and practices: http://www.leed.net (accessed 30 October 2014).
([36]) BREEAM sets the standard for best practice in sustainable building design, construction and operational performance: http://www.breeam.org (accessed 20 November 2015).
([37]) The *Integrated Project Delivery Guide* is a tool to assist owners, designers and builders to move towards integrated models and improved design, construction and operational processes (American Institute of Architects, 2007).
([38]) Building information modelling (BIM) is a set of interacting policies, processes and technologies generating a 'methodology to manage the essential building design and project data in digital format throughout the building's life-cycle' (Penttilä, 2006).
([39]) Three demonstration sites: Kartal in the municipality of Istanbul, Valladolid in Spain and Genoa in Italy: http://r2cities.eu/Demos/The_Case_Studies.kl (accessed 20 November 2015).

reuse of historic buildings in the city centre (Urbact, 2013) and of how the transformation and reuse of buildings has stimulated eco-restoration.

In some cities where a major part of the city centre is listed, it is crucial to find a way of refurbishing buildings without incurring high costs. For example the city of Westminster, London, accounts for over 11 000 listed buildings (in 56 conservation areas covering 76% of the city). The main problems were fuel poverty and new obligations for landlords making it impossible to rent the most inefficient properties after 2018. The guide to retrofitting historic buildings, published by the municipality (City of Westminster, 2013), proposes an energy hierarchy from the lowest cost and simplest solutions (e.g. insulating hot water tanks and pipes, draught proofing doors and windows, repairing and using original internal shutters) to the most complex and expensive solutions (e.g. insulating roofs and floors, installing condensing boilers, installing heat pumps or micro-combined heat and power plants).

In Austria, around one-fifth of the total number of buildings were built between 1848 and 1918 (known as the 'Gründerzeit'). The flagship 'Building of Tomorrow' project (a Federal Ministry of Transport, Innovation and Technology research and technology programme) is focused on the modernisation of these buildings. The aim is to raise the thermal efficiency of these buildings to a modern standard. The annual energy demand for space heating ought to be cut from around 120–160 kWh/m² to less than 30 kWh/m² (Federal Ministry for Transport, Innovation and Technology, 2014). To achieve this result a combination of measures has been established (e.g. thermally efficient building envelope, efficient heating and ventilation strategy). Apart from technical issues, a comprehensive strategy (taking into account economic, social and legal aspects) has been developed (Bettgenhäusser et al., 2014). In Vienna, the first-ever renovation of a 'Gründerzeit' building to passive house standard ([40]) has been completed. The renovation was carried out in close cooperation with the tenants living in the building.

In Berlin, the refurbishment of the 'Bremer Höhe' (a historic building) presented a challenge owing to the strict conservation requirements. However, a photovoltaic plant was installed on the roofs. Electricity is produced by photovoltaic areas of 341 m² that feed the local network (URB Energy, 2011a).

**Box 2.8 Demolition or refurbishment?**

As regeneration and restructuring sometimes are difficult and costly, the idea of demolishing the oldest homes and those in the poorest condition has gained in importance. However, throwing away material is harmful to the environment and wasteful of energy and materials. Demolishing houses, which are bulky and valuable material objects, should be a last resort (Power, 2010).

To planners and policymakers, it may seem easier and cheaper to demolish extremely rundown areas than to renovate them. However, demolition is not a socially acceptable or resource-efficient way of solving the shortage of housing. Demolition is slow, and often unpopular. It may provoke opposition in the community that is supposed to benefit from it. It often leads to a loss of social capital that takes decades to rebuild (Power, 2007).

New building developments are resource and energy consuming. Energy, materials and environmental impacts (land take, habitat fragmentation, water consumption, emissions, pollution, waste) are embodied in the new material produced, processed and transported for construction; the development of new builds increases land take and urban sprawl if there is no land recycling; the demolition and the construction processes generate waste. In addition, new building areas need new and adapted infrastructure, in particular for public transport. Essential infrastructure that has been demolished will take decades to rebuild.

A new home uses up to eight times more resources than an equivalent refurbishment (Empty Home Agency, London, 2008). This is because most of the building mass and structural elements are already there and rarely need to be replaced (Power, 2010). Even given the extremely high energy performance of new buildings, and including the necessary maintenance and permanent renewal of the building stock, only extreme physical dereliction justifies such social and environmental costs (Power, 2010). There are good solutions for retrofitting and they are becoming more and more energy efficient.

([40]) The renovation was based on the installation of a composite thermal insulation system outside the façades, top-grade windows and doors, a passive house standard, central ventilation system with ultra-efficient heat recovery, a groundwater heat pump and photovoltaic equipment. The entire electrics, heating and ventilation were replaced by an energy-efficient system that saves even more primary energy. After renovation, the building qualified as a zero-energy building.

### 2.4.3 Scaling up renovation

A city cannot be considered only as an aggregation of buildings. The major issue is not increasing the energy performance of individual buildings but extending the improvement to a larger scale (at district or city level) and integrating the change into the urban planning process. When scaling up, there can be complex interactions with the urban fabric, and measures that were successful at the building scale can have quite different results on a larger scale (Bourdic and Salat, 2012).

Building efficiency is just part of urban energy efficiency, which also depends on urban morphology, the system's efficiency (e.g. transport, energy grid) and social behaviour. Systemic, multi-scale and transverse approaches take into account the intrinsic complexity of the urban fabric. A strong planning framework is required to secure reductions in the use of energy and resources.

Plans for driving energy (and, more generally, resource) reductions have to consider the relationship of the city with its rural hinterland and avoid too narrow a focus on the building, site and district. Renewable resources need to be harnessed if they would be the easiest and most cost effective (TCPA and CHPA, 2008). There are opportunities for the cost-effective deployment of medium- to large-scale wind power generation (and, for some cities, offshore power generation), the development of biomass supply chains and solar photovoltaic plants. Planning implies exploring which combination of technologies makes best sense on the different scales for developing local energy solutions.

For example, Barnsley Metropolitan Borough Council, in a former coal-mining region of the United Kingdom has reduced GHG emissions through a comprehensive programme to improve the energy efficiency of its buildings and to switch from coal to biomass for heating (schools, public buildings, council blocks of flats). The wood comes from locally managed woodland and wood waste that would otherwise be sent to landfill. Neglected woodlands have been brought into active management, enhancing woodland biodiversity, and jobs have been created (Forestry Commission England, 2010).

A long-term vision to 2020 and 2050 is generally the starting point for developing a city's strategy (e.g. Copenhagen, Delft). A strategy tailored to the characteristics of the city influences all the components of the planning policy and city management. Targets and specific requirements (e.g. 'fossil fuel-free city' for Växjö) are defined and included in planning.

### 2.4.4 Enabling changes

As efficient building solutions are often technically demanding, cities can stimulate innovation and the development of new skills by public procurement (Liimatainen et al., 2014). For example, the city of Cologne has launched the Climate Round Table Cologne (KlimaKreis Köln) to promote projects addressing climate change issues. It comprises a group of experts in the field of climate and energy issues, representing academic institutions and others actors (associations, administrators, economists) (Celsius-Smart Cities).

The resource and energy efficiency policies of local governments have to confront individual motivations and beliefs around the environment (Dixon, 2011). They can set ambitious sustainability targets, but without regulation to enforce the renovation, effective retrofitting depends on voluntary decision on the part of building owners. If they do not feel that national, regional or city sustainability goals are their concern, buildings owners have no motivation for retrofitting buildings, leading to a locked-in situation. Relying on voluntary action creates considerable uncertainties that hamper the practical realisation of the strategy defined by local government (Lepoutre et al., 2007). Cities can create reliable frameworks of stakeholders dedicated to providing information on refurbishment that include planners, tenants and landlords, the municipality administration, and chambers of professional associations (URB Energy, 2011b). Individual ownership structures are a real challenge.

A lack of technical and financial expertise is often an obstacle to refurbishment. Local governments can create interface capacities between public authorities and civil society to accelerate the transition by supporting stakeholders and giving advice and information. For example, Bristol City Council in the United Kingdom has created Bristol Tenants' Energy Advice to provide advice on energy. In the main French cities ([41]), a local energy agency provides technical and financial information to promote energy saving (e.g. Lyon, Grenoble, Toulouse).

The lack of resources and uncertainty about the payback period for retrofitting measures (Lewis et al., 2013) is a major difficulty. The selection of retrofitting measures is a trade-off between capital investment and benefits that can be achieved by implementing the retrofitting

([41]) Thirty-two local energy agencies funded nationally.

measures. The heterogeneity and dispersion of owners is a major barrier to financing retrofitting. It is difficult to stimulate collective action and adopt the best technical solutions when individual property owners tend to operate in isolation, in particular when this is combined with owners on low incomes (URB Energy, 2011b).

Scaling up urban retrofitting activities implies dialogue and cooperation between multiple stakeholders that do not necessarily have the same social interests (e.g. policymakers, owners, occupiers, developers, financiers, utility providers). For example, in the city of Rakvere (Estonia), residents, who were satisfied with their living situation, had little interest in energy-efficient refurbishment and the municipality has had to convince them (URB Energy, 2011b). Modelling and decision support tools can help to elaborate long-term planning for urban retrofitting, taking into account the complexity of the built environment. For municipalities, it is not easy to estimate the scale of retrofitting; a municipal or regional analysis of the situation is the first step in developing targets and a strategy and estimating the financial requirements.

**Box 2.9 Cities tackle energy poverty**

There is no European definition of energy poverty, but European Council Directive 2009/72/EC ([42]) acknowledges that energy poverty not only exists but is also a growing problem. Energy poverty is a situation in which a household is unable to access a socially — and materially — necessary level of energy services in the home ([43]) (Walker et al., 2013; Bouzarovski, 2014). This reduces quality of life, influences attainment and poses health problems. The link between excess winter deaths and cold temperatures is well established, as is the role of inadequate housing (WHO, 2007; McMunn et al., 2009). The elderly, young children and people with a disability suffer more from cold.

Energy poverty cannot be described only as the inability to access affordable warmth. It is a combination of low incomes, homes with poor thermal properties and, in some cases, high energy prices. Other factors can increase energy poverty, such as the nature of heating systems and socio-demographic characteristics such as household size, age, gender and level of education.

In 2012, 10.8% of the total EU-28 population were unable to keep their homes adequately warm, increasing to 24.4% when people on low incomes were considered (Eurostat, 2014). (This figure includes urban and rural energy poverty.) The highest proportions of the population with inadequate domestic warmth are concentrated in the EU-10, especially Bulgaria and Lithuania. On the contrary, in colder northern countries (Sweden, Finland, the Netherlands and Denmark), only a small percentage of the population is unable to afford an adequately heated home (Bouzarovski, 2014).

Energy price regulation, direct financial support to low-income households and social tariffs offer only a temporary solution to the energy poverty problem (BPIE, 2014). They address the effect rather than the cause of the problem. A long-term sustainable solution will require the renovation of poor energy-performance buildings and enhanced local energy planning. However, homeowners in energy poverty cannot afford significant investments (Power, 2010), and landlords expect incentives. Therefore, energy efficiency measures for fuel-poor people largely depend on the availability of public finance schemes and regulatory measures.

Urban planning policies at the city scale are also crucial to tackling energy poverty. For example, household electricity use is disproportionately high in the United Kingdom's cities and in municipal housing (Bouzarovski, 2014). Energy-related forms of deprivation and inequality are inextricably tied to planning practices and spatial morphologies. Some national programmes involving municipalities are entirely or partly dedicated to energy poverty (e.g. 'Kirklees Warm Zone' ([44]) in the United Kingdom ([45]), 'Warmer Homes Scheme' ([46]) in Ireland and 'Habiter mieux' in France ([47])).

([42]) Directive 2009/72/EC of the European Parliament and of the Council of 13 July 2009 concerning common rules for the internal market in electricity and repealing Directive 2003/54/EC.
([43]) In the United Kingdom, fuel poverty is defined as the circumstance in which a household spends more than 10% of its income on energy bills (Bouzarovski, 2014).
([44]) A programme of cooperation between local authorities, energy companies and other entities interested in fighting energy poverty in the United Kingdom: http://kirkleeswarmzone.wordpress.com/social-issues/ (accessed 20 November 2015).
([45]) In the United Kingdom the 'Fuel Poverty Strategy' was launched in 2001.
([46]) A programme that provides advice and funds for the adoption of energy efficiency measures in vulnerable and energy-poor homes: http://www.seai.ie/Grants/Warmer_Homes_Scheme/ (accessed 20 November 2015).
([47]) http://www.anah.fr/proprietaires/proprietaires-occupants/etre-mieux-chauffe/ (accessed 20 November 2015).

## 2.5 The urban transport system

The urban transport system, carrying both passengers and freight, is crucial for economic prosperity and competitiveness of cities and the everyday life of the people living and working within and around cities. As transport systems become more complex, a successful urban mobility policy needs to combine both individual and societal points of view to find a balance between competing interests.

The Green Paper on urban mobility (EC, 2007) identified five challenges faced by cities:

1. congestion that has negative economic, environmental and health impacts;
2. dependency on fossil fuels and the resulting GHG emissions, air pollution and noise;
3. increases in freight and passenger flows;
4. a public transport system that meets people's needs (accessible, affordable, frequent, fast, flexible, safe, reliable and connected to a variety of sustainable modes of transport);
5. ensuring the safety of the infrastructure, rolling stock and citizens.

The annex of the *Roadmap to a resource efficient Europe* (EC, 2011c) analyses the interlinkages between sectors and resources and outlines possible improvements to achieve resource efficiency in urban transport:

- reducing dependency on fossil fuels by using more efficient vehicles, renewable energy and better transport networks;
- reducing air pollution and GHG emissions from urban transport;
- increasing the resource efficiency of infrastructures;
- minimising the impacts of soil sealing and land fragmentation and pollution;
- optimising the logistics of transporting materials;
- ensuring the efficient recycling of end-of-life vehicles.

The standard response to improving urban mobility typically has been to increase the infrastructure, mostly for cars. Unfortunately, such developments engender a vicious circle: more infrastructure stimulates urban sprawl because access to peripheral urban areas is easier and commuting times are reduced. Finally, that results in an increasing use of cars which, in turn, calls for further infrastructure development, and so on. To break this cycle and reduce congestion and fuel use, and therefore air pollution and GHG emissions, urban policies can act in different ways (see also Table 2.2):

- *Urban planning and a sustainable urban mobility plan:* The integration of transport and land use planning, encouraging density and mixed land use, with easy access to public transport and walking and cycling facilities to reduce the use of private cars, congestion, air pollution, GHG emissions and land take (EEA, 2015).
- *Efficient public transport:* The transport infrastructure and equipment and the amount of traffic cannot be changed quickly. However, efficient public transport helps address the increase in the demand for transport. The attractiveness of public transport can be increased by providing reliable, frequent, affordable, comfortable, safe, fast and accessible public transport in most of the urban area, in particular in the most deprived districts. Interconnectivity and interoperability of the different networks will increase the number of users and the area covered.
- *Tariff scheme:* Taking measures to simply and unify the tariff scheme for different forms of public transport in the urban area. Some cities have integrated into one ticket the fares for buses, trams, subway, cycles or car sharing (e.g. in La Rochelle in France the entire transport system is accessible with a single electronic ticket). Other cities (e.g. Winchester in the United Kingdom) have developed a push-and-pull strategy through the pricing scheme: the most environmentally friendly vehicles are encouraged into the centre of the city and high-emission vehicles are encouraged to use parking on the outskirts of the city.
- *Regulation and charging:* Some cities have restricted the access of private vehicles to certain zones (e.g. the Central London congestion charge, Stockholm, Milan).
- *New technology:* Besides the reduction in the number of vehicles, the use of more energy-efficient technologies for both private and public transport can be promoted and the necessary infrastructure (e.g. vehicle charging stations, compressed natural gas stations) installed.
- *Smart mobility:* Using ICT, mobility and transport systems can be optimised and better oriented to societal needs and environmental challenges.

ICT applications allow optimisation of transport logistics, improvements in the energy efficiency of vehicles, cost-effective management, travel dematerialisation (telepresence), traffic monitoring and control, simulation of planning changes, and crowd-sourcing, a tool to encourage citizens' participation (European Parliament, 2014).

- *Freight transport:* Some cities have worked with the private sector to take measures to improve the efficiency of the delivery of goods to urban areas (in particular to the centre of the city and pedestrianised areas) and to reduce air pollution. The use of smaller and cleaner vehicles for city deliveries in dense urban areas is encouraged.

- *Changes in behaviour and lifestyle:* Cities can launch campaigns to raise the awareness of citizens and to promote more sustainable transport through a range of options such as changes in fares, frequency, accessibility and comfort of public transport. They can also promote smart organisational approaches, such as teleworking and telepresence, in order to reduce the number of daily commutes (Akyelken et al., 2013).

This report does not present a detailed review of opportunities or examples of good practice. To support the exchange of information and highlight the best practices, the European Commission has developed several initiatives:

- CIVITAS Initiative ([48]): Several cities are working together on urban sustainability. They have developed a body of evidence on the impacts of single and integrated measures and on the implementation of these measures.

- ELTIS PLUS programme ([49]): This offers practical support to cities for the development of sustainable urban mobility plans through workshops and guidelines.

**Table 2.2 Framework of policy instruments to promote sustainable mobility**

| Strategies and instruments | Avoid (Reduction) | Shift (Alteration) | Improve (Efficiency) |
|---|---|---|---|
| Direct regulatory instruments | Car-free events<br>Spatial planning<br>Urban planning | Restricted zones (e.g. environmental zones, car-free districts, pedestrian areas)<br>Separate lanes for public transport<br>Lanes for high-occupancy vehicles<br>Spatial planning | Environmental zones<br>Speed limits<br>Emission standards<br>End-of-life treatment |
| Market-based financial instruments | | Fuel tax<br>Congestion charge<br>Registration tax<br>Fares on public transport | Scrapping schemes<br>Tax incentives<br>Annual circulation tax<br>Registration tax<br>Road pricing<br>Green public procurement<br>Research subsidies |
| Information-based instruments | Mass awareness campaigns<br>Endorsement labels | Comparative labels<br>Endorsement labels<br>Rankings<br>Mass awareness campaigns<br>Carbon footprint calculators | Comparative labels<br>Endorsement labels Rankings<br>Mass awareness campaigns<br>Carbon footprint calculators |
| Support for behavioural change | Flexible working models<br>Car-sharing schemes<br>Car-free residential areas | Social marketing campaigns<br>Job tickets<br>Car-sharing schemes | Carbon compensation schemes<br>Eco-driving programmes |
| Provision of infrastructure | Integrated city planning | Public transport infrastructure<br>Cycling infrastructure (e.g. cycling lanes, bicycle parking facilities)<br>Park and ride facilities<br>Bicycle-sharing schemes<br>Integrated city planning | |

**Source:** Rubik et al., 2011; Filcak et al., 2013.

([48]) http://civitas.eu (accessed 20 November 2015).
([49]) http://www.eltis.org (accessed 20 November 2015).

## 2.6 The urban water system

In cities, the demand for water is concentrated into a small area. This concentration of the population increases the pressure on fresh- or groundwater. However, as cities also represent a concentration of economic and political power, they have the financial and human resources to develop resource-efficient integrated urban water management and smart infrastructure. However, leakages in water supply networks and energy consumption for water treatment remain an ongoing issue. For European cities, the maintenance and upgrading of ageing and deteriorating water infrastructure is a technical and financial challenge (WssTP, 2010).

### *2.6.1 The role of the urban pattern*

The form of urban areas affects their water use. Low-density development means a more extensive water supply network than that required in a compact development. Therefore, it means more leakages, greater demand and higher cost.

Urban sprawl and rapid growth bring problems related to financing the water infrastructure. The housing bubbles in Spain and Ireland showed that new housing developments lead not only to an increase in water demand but also a need for more water infrastructure. The consumption of water per capita is bigger in single houses with gardens than in multi-storey houses (see Chapter 4), because the surface area per capita is bigger and watering gardens ([50]) (and filling swimming pools in southern countries) increases the consumption of water.

Smart compact urban planning, with high-density and mixed land use is the way to reduce the demand for water per resident, to reduce the length of the pipe network, therefore making it more efficient and less susceptible to water loss through leakage, and to reduce the need for maintenance and therefore the cost of water. There is a good relation between the cost of water and the distance from the water service centre. The demand for water for gardens is directly related to the size of the lot for both residential and non-residential buildings (EPA, 2006).

### *2.6.2 Water losses*

Water losses are an inevitable part of the public water supply infrastructure. For economic and technical reasons, water losses cannot be entirely eliminated. The urban water infrastructure is vulnerable owing to deterioration with age, damage from excavations or overloading. Currently, water leakage rates are not subject to any regulation other than management decisions taken by utility suppliers.

Leakage in sewerage systems will result in infiltration or exfiltration depending on the local groundwater tables. Exfiltration of wastewater may result in the contamination of groundwater. Infiltration dilutes wastewater and increases the pollution load on the environment (EEA, 2012c).

Leakage in public water supply systems results not only in the loss of purified drinking water but also in a waste of the energy and material resources used for abstraction, transport and treatment. It increases the risk of bacterial contamination of water for human consumption and the pollution load on the environment. Distribution losses (between 5% and 50%) are much larger than production losses (between 2% and 10%) (EEA, 2014a).

A benchmarking study on water distribution losses in three federal states in Germany (Hesse, Rhineland-Palatinate and Schleswig-Holstein) shows a range of mean values between 0.9 and 3.1 $m^3$/km per

**Box 2.10 The urban water cycle**

The urban water cycle relies on water supply, wastewater and storm water systems. These include water abstraction, storage, supply, distribution, wastewater treatment, and storm water collection disposal and control systems. Resource efficiency in the urban water cycle includes the use and reuse of treated effluents in water-scarce environments but also the use of material resources and the output of emissions in water utility operations. Water can be provided by public utilities or commercial organisations. Some municipalities are directly in charge of the water supply.

([50]) EPA (United States Environmental Protection Agency) — Growing Toward More Efficient Water Use: linking development, infrastructure and drinking water policies http://www2.epa.gov/sites/production/files/2014-01/documents/growing_water_use_efficiency.pdf (accessed 20 November 2015).

day. Aggregated benchmark data for 32 water utilities in Germany (representing around 75 million persons served) for 3 years show a mean value of 8.3–8.4 $m^3$/km per day. Other data for Denmark, France and Sweden put losses at between 1 and 10 $m^3$/km per day. The lowest losses are in Germany, Denmark and France and the highest in Sweden (EEA, 2014a).

32% of cities of the 46 European cities analysed by Informed Cities, have leakages below 10%, and 15% below 5% (see Figure 2.6). With the exception of Barcelona, no southern cities have less than 10% leakage.

However, stopping water leakages is not always easy and might have also negative economic and social costs, especially in low-density cities where the water pipe network is long and the number of people to pay for servicing and maintenance is relatively low. The first difficulty is detecting and measuring water leakages. In some countries such as Sweden, active leakage control is not cost-effective; owing to deep pipes and frozen ground digging is too expensive. Only major leakages are repaired and 10–15% 'background leakage' is accepted (WssTP, 2011).

Different technologies can be used to detect leakages (e.g. monitoring leakages in district metering areas, night flow analysis, acoustic and gas tracer technologies).

Some cities use the district metering technique in combination with other methods such as the leak noise cross-correlation technique and surveys using acoustic loggers (e.g. city of Bresca in Italy).

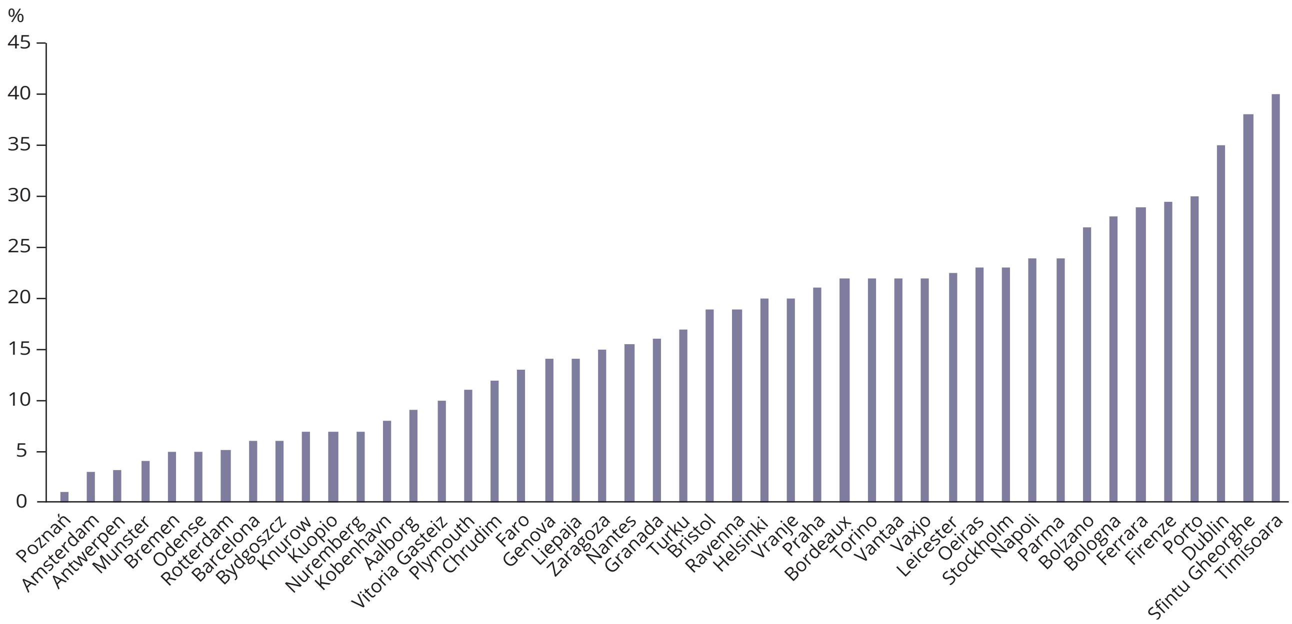
Water leakages are expected to increase because of climate change (Markopoulos et al., 2012). In hot climates, the dehydration will cause pipe breakages. In cold climates, pipe breakages will increase during a thaw. This has already been observed in European and North American cities. The higher number of freeze/thaw periods increases the strain on pipes and the corrosiveness of the ground.

### *2.6.3 Water–energy nexus*

Water utility suppliers take significant measures to reduce their energy consumption, in particular electricity use, and increase their energy recovery.

Global targets for energy efficiency in water utilities were one of the outcomes of the Sixth World Water Forum (12–17 March 2012 in Marseille). Following the forum, some public authorities and water utility suppliers are implementing measures to improve energy efficiency in water and wastewater systems; the target ([51]) is to reduce energy use by 20% by 2020, compared with 1990 levels (EEA, 2014a).

**Figure 2.6 Water losses in some European cities**




**Source:** Informed Cities, 2009–2010.

([51]) This target has been endorsed by the International Water Association, the worldwide network for water professionals and companies on behalf of the sector.

There is considerable variation in energy consumption in drinking water production and distribution, which depends to a large degree on the source water quality, the distance it has to be transported and the elevation for pumping (Table 2.3). Energy consumption for wastewater treatment depends on several factors, including the type of treatment and size of plant. Energy consumption for wastewater transport (pumping) in sewerage systems depends to a very high degree on the topography of the service area but also on the technology installed (pumping yield efficiency and automated control).

By comparison, the EU-27 average household electricity consumption in is about 70 million tonnes of oil equivalent (toe) ([52]) or 814 TWh, which, with a population of about 500 million people ([53]), corresponds to an average of about 1 600 kWh/year per person. The net annual electricity consumption for urban water management represents about 5.5% for the household sector, and corresponds to each person constantly burning a 10 W light bulb (EEA, 2014a). This does not include the management of industrial wastewater or storm water run-off.

The chemical composition of wastewater and its available heat enable energy recovery and therefore reduce or eliminate the plant's dependence on conventional electricity (WERF, 2011; Markopoulos et al., 2012). Energy savings can be obtained by optimising the process, in particular the most energy-intensive steps such as pumping, the aeration process or aerobic digestion. Automated control is a way of quickly adjusting the process to variable conditions and saving energy (EPA, 2010).

**Table 2.3 Estimation of energy consumed in water management for the household sector**

| | |
|---|---|
| Drinking water production and supply | +34 kWh/year per person |
| Wastewater transport | +20 kWh/year per person |
| Wastewater treatment (total consumption) | +43 kWh/year per person |
| Cogeneration of electricity | – 9 kWh/year per person |
| Total, net consumption | +88 kWh/year per person |

**Source:** EEA, 2014a, p. 52.

**Box 2.11 Reducing energy consumed in water collection in Grobbendonk, Belgium**

The Provincial and Interurban Drinking Water Company provides water to 65 municipalities. The water is produced from 30 wells that collect groundwater. The water collection system was susceptible to blockages. The groundwater level can vary by between 2 and 5 metres. Therefore, the wells were equipped with oversized pumps.

Variable frequency drives were installed to vary the speed of the pump to match the flow conditions. The result was a close match between the electrical power input to the pump and the hydraulic power needed to pump the water. This technology, often used where the flow rate is highly variable, saves power.

Around 15–20% was saved, representing a payback time of 2.5 years.

**Source:** Markopoulos et al., 2012.

**Box 2.12 Carbon-neutral wastewater treatment plant**

Hamburg Wasser Central wastewater treatment plant 'Köhlbrandhöft' (2.7 million inhabitant equivalents) is carbon neutral. It has taken many projects to reach this target. Waste heat from the sludge incineration process supplies district heating. Two wind turbines provide the wastewater management plant with electric power. Surplus digester gas is purified and converted into biomethane and then fed into the grid of the local gas supplier.

**Source:** TRUST, 2014.

([52]) http://epp.eurostat.ec.europa.eu/tgm/table.do?tab=table&init=1&language=en&pcode=tsdpc310&plugin=1 (accessed 20 October 2014).
([53]) Eurostat database: http://epp.eurostat.ec.europa.eu/statistics_explained/index.php?title=File:Demographic_balance,_2011_(1)_(1_000).png&filetimestamp=20130129110805.

**Box 2.13 Hamburg water cycle**

The city of Hamburg has developed a new approach to wastewater management, HAMBURG WATER Cycle®, which is different from conventional sewerage systems. It takes into account the entire water cycle, with the aim of upgrading local drainage systems through decentralised storm water management.

The HAMBURG WATER Cycle® takes a holistic approach to the energy supply and sanitation needs of urban areas. The objective is to close the material cycles within the residential environment. The water and energy infrastructures are interdependent, simultaneously protecting water resources and utilising wastewater to produce energy.

The most critical component of the HAMBURG WATER Cycle® is the separate treatment of the different wastewater streams, the so-called partial flow treatment. Storm water, wastewater from the toilet, and wastewater from the kitchen and bathroom (from handwashing or using the washing machine, for example) are collected separately and then treated separately.

The 'Jenfelder Au' will be the first neighbourhood project in Hamburg incorporating the HAMBURG WATER Cycle® into newly constructed buildings.

**Source:** TRUST, 2014 — http://www.hamburgwatercycle.de/ (accessed 20 November 2015).

## 2.7 Demand-side policies

The transition towards a sustainable society cannot be achieved only by policies focused on the supply side and technological interventions. Policies acting on the demand side are opportunities for overall long-term improvement in resource and energy efficiency and sufficiency. Transition is a dynamic societal process of radical and structural changes that need to be accompanied by public policies. It is a society-wide transformation that aims to change the everyday behaviour of citizens, as consumers, users and residents. To a certain extent the transition phase can be seen as a period of destabilisation. It is why there is a clear need for transition management to facilitate and accelerate societal change.

Local governments can play an important role in enabling change by supporting socio-technical transition, planning compact cities with a high quality of life, developing decentralised supply systems, encouraging eco-industrial development, stimulating innovation and promoting smart measures. They can develop forms of governance that encourage dialogue and the participation of stakeholders, support individual and collective initiatives (led by market or non-market initiatives) and promote a city-wide vision that goes beyond each project and the limits of the city (e.g. city-region) (Dixon, 2011).

### *2.7.1 Infrastructure shapes our everyday practice*

Human behaviour is influenced by different types of factors (DEFRA, 2011):

- *geographical factors* such as culture, geography, social network, institutional framework, information, infrastructure;
- *behaviour factors* such as beliefs, norms, attitudes, habits, values, knowledge, perceptions;
- *environmental changes* such climate change, loss of biodiversity, change in natural hazards, water scarcity.

Lifestyle refers to our ways of doing, having, using, consuming, moving, working and displaying — in effect, our behaviour (Backhaus et al., 2012). It is a matter of choice, as well as habits that are shaped by the context (social, cultural, technical, economic, political, institutional and geographical surroundings). Our everyday practices are routine behaviour that depends on 'normal standards' (such as taking a daily shower, travelling by car, owning a computer, going on holiday, etc.), existing infrastructure (e.g. the use of public transport is dependent on affordable, efficient and accessible means of public transport), pricing policies, regulation and technological innovations.

Practices change over time. Technical change leads to the emergence of new practices (e.g. the new role of ICT and mobile phones in our daily lives). Technical development and rising living standards are drivers for consumption. At the same time, technology provides smart tools to support better sustainable lifestyles (e.g. energy-efficient products and communication and information services that support public transport information services).

Even if people undertake symbolic actions to demonstrate their 'green credentials' (e.g. sorting waste), most everyday practices are undertaken with little consideration for the environment and often they conflict with other concerns (e.g. price, time taken, ease of use) (Røpke, 2009). Shortage of time is an important factor that determines the strategies that people adopt (e.g. in urban areas, the choice between driving or using public transport is often more a question of time rather than price or thinking sustainably).

Existing infrastructures for transport or energy supply can 'lock' people into unsustainable behaviour. therefore municipalities have to facilitate a change in behaviour by a significant group of people by the following measures (Backhaus et al., 2012):

- making sustainable lifestyles easier, cheaper and more enjoyable by developing appropriate infrastructure and solutions adapted to the context;
- providing solutions and a range of options, taking into account the diversity of the population and its needs (age, gender, socio-economic group, level of education);
- developing systemic and holistic approaches focused on end users and tailored to the city through strong multi-stakeholder participation;
- supporting local innovation and small-scale sustainable initiatives.

### *2.7.2 Preventing resource consumption*

Consumption has increased dramatically, generating waste causing damage to the environment. Today, consumers have more choice, and products are designed to have shorter lifespans (e.g. single-use and disposable products). Owing to rapid technological progress, people own and use more personal devices and replace them more often. High levels of material consumption are accepted as the norm and are associated with well-being and success.

In consumption-driven society, successful sustainability initiatives need to go beyond the 'one-size-fits-all' approach. It is crucial to understand how to motivate and facilitate a change in behaviour across ages, socio-economic groups and groups with different levels of knowledge, awareness and interest. Solutions and combinations of solutions have to fit specific contexts and target groups (Backhaus et al., 2012). Beyond an awareness-raising campaign, municipalities can help people to make decisions and take action by providing advice and support.

Not all spending generates the same level of waste. For example, we assume that buying more expensive organic food would lead to the same amount of household food waste per unit food but result in less household food waste per euro spent. We also assume that spending on material goods should generate more waste than spending on non-material services. This is particularly the case in urban areas, where access to culture and other opportunities for non-material expenditure is considerably greater than it is in a rural setting. Some initiatives that seek to shift spending from material goods to non-material services include the way in which some supermarkets design their loyalty schemes to favour payback in terms of cultural services rather than material products. Another example is the growth in 'experience giving', whereby one can give a cultural experience in place of a physical present.

***Waste prevention***

Waste prevention is the first step in the waste hierarchy. By avoiding waste generation, one avoids all of the other steps in waste management. Preventing waste also minimises the material input to the economy. All EU member states have to develop national waste prevention programmes in accordance with the Waste Framework Directive (EU, 2008), and the EEA reviews these programmes on a regular basis (EEA, 2014b). Multiple waste policies and targets set at European level include minimum requirements for managing certain waste types. The most relevant targets for municipal waste are the Landfill Directive's landfill-diversion targets for biodegradable municipal waste (EU, 1999); the Packaging and Packaging Waste Directive's recycling targets (EU, 1994); and the Waste Framework Directive's recycling target for household and similar wastes.

Waste prevention has both quantitative and qualitative aspects:

- *Quantitative waste prevention* can be achieved by reducing the quantity of material used in the manufacture of products and increasing the efficiency with which products, once manufactured, are used. Waste can be avoided by limiting unnecessary consumption and by designing and consuming products that generate less waste. Quantitative waste prevention also encompasses actions that can be undertaken before a product reaches the end of its life; rather than discarding the product as waste, the end user should be able to consider reuse, repair or refurbishment. Extending a product's life or considering options such as reuse before it enters the waste management system are forms of prevention that can be realised through the diversion of waste flows (EC, 2012).

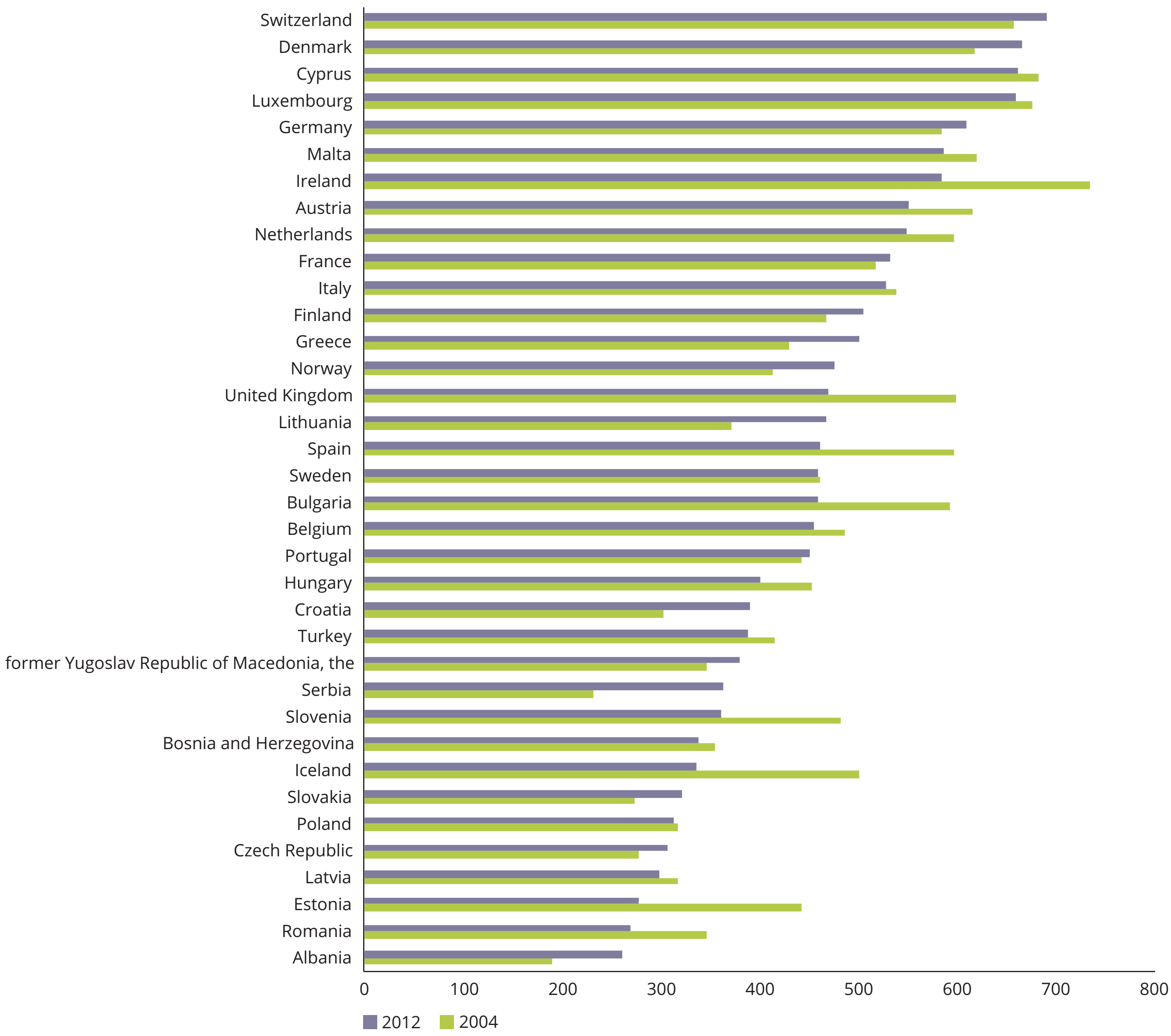
- *Qualitative waste prevention* is defined as reducing its hazardous content (Article 3 (12) of the Waste Framework Directive). This helps reduce human and environmental exposure to hazardous materials (EC, 2012).

Waste can be prevented at different steps of the production–consumption system:

- *in the production phase* by improving material efficiency, using processes that generate less waste and product and service innovations;
- *in the distribution phase* by, inter alia, good planning of supply and stocks and choosing less waste-intensive packaging options;
- *in the consumption phase* by choosing products that are less waste intensive over their life cycle, keeping products in use for a longer period; repairing, sharing or hiring products; or through reducing consumption levels.

Urban areas are generally well suited to waste prevention activities as many of these activities require

**Figure 2.7 Municipal waste generated per capita in 36 European countries (2004 and 2012)**




**Note:** The recycling rate is calculated as the percentage of municipal waste generated that is recycled and composted. Changes in the reporting methodology means that 2012 data are not fully comparable with 2004 data for Austria, Cyprus, Malta, Slovakia and Spain. 2005 data have been used instead of 2004 data for Poland because of changes in methodology. Owing to data availability, instead of 2004 data, 2003 data were used for Iceland; 2007 data were used for Croatia; and 2006 data were used for Serbia. For the former Yugoslav Republic of Macedonia, 2008 data were used for 2004, and 2011 data used for 2012.

**Source:** Eurostat. Municipality waste statistics.

a large potential market and/or the higher level of participation that high-density urban areas provide. High-density housing, with its limited storage space, may also act as a disincentive to hoard old or unused items and encourage their return to the marketplace.

Waste prevention includes a wide range of activities throughout the whole life cycle of a product, from the initial design phase, through the production process to packaging, retail and use and reuse. In households, waste prevention can, for example, be promoted by reusing and preparing for reuse (fixing, swapping, reselling, and borrowing), minimising packaging (refillable packaging, reduced packaging), reducing ownership without reducing use (e.g. product service systems, leasing, short-term rental), and improving consumption (e.g. buying low-material-content and high-value items). Such approaches can be supported by new networks and neighbourhood initiatives. Retailers (particularly food retailers), cafes and restaurants can also contribute to preventing municipal waste.

Waste prevention in commercial enterprises has a different set of drivers and therefore requires quite different types of initiatives.

481 kg of municipal waste per capita (EU-28) was generated in 2013 ([54]); municipal waste generation totals varied considerably, ranging from 747 kg per capita in Denmark to 272 kg/capita in Romania. The variations reflect differences in consumption patterns and economic wealth, but they also depend considerably on how municipal waste is reported, collected and managed. Households generate between 60% and 90% of municipal waste, while the remainder can be attributed to commercial sources and administration ([55]).

Working with individual retailers could be a way of reducing the amount of packaging used for bulk products. Similarly, there are also initiatives from individual take-away restaurants to reduce the packaging associated with their food. These include, for example, (slightly) discounted food when customers bring their own packaging.

Eco-design is a way of preventing waste by improving manufacturing methods. Eco-friendly products, for example, avoid the use of hazardous substances, use recycled secondary raw materials, or use less energy and packaging. Even if city authorities cannot control the manufacturing process, they can launch awareness-raising campaigns and encourage consumers to demand goods that produce less waste and drive the creation of a more resource-efficient market (Promoting ZeroWaste, 2014).

**Box 2.14 Waste generation in European cities**

Data on the generation and management of waste in urban areas is considerably scarcer than data at the national level. However, Eurostat's 2011 update of the Urban Audit ([56]) statistics database provides some incomplete data on the generation of household and commercial waste in European cities. The data on municipal waste includes household and commercial waste. There is no guarantee that the same waste types are covered in all cities in the database, as waste collection is managed differently by different Member States and regional authorities. Nevertheless, by covering both household and commercial waste, the data set reflects the quantities of waste that authorities must regularly manage. Commercial waste, in particular, is often more concentrated in urban areas.

Based on data from Urban Audit — for the 294 cities for which both waste and population data are available — the generation of household and commercial waste in 2011 ranged between 166 kg/capita in Tomaszów Mazowiecki in Poland and 748 kg/capita in's-Hertogenbosch in the Netherlands.

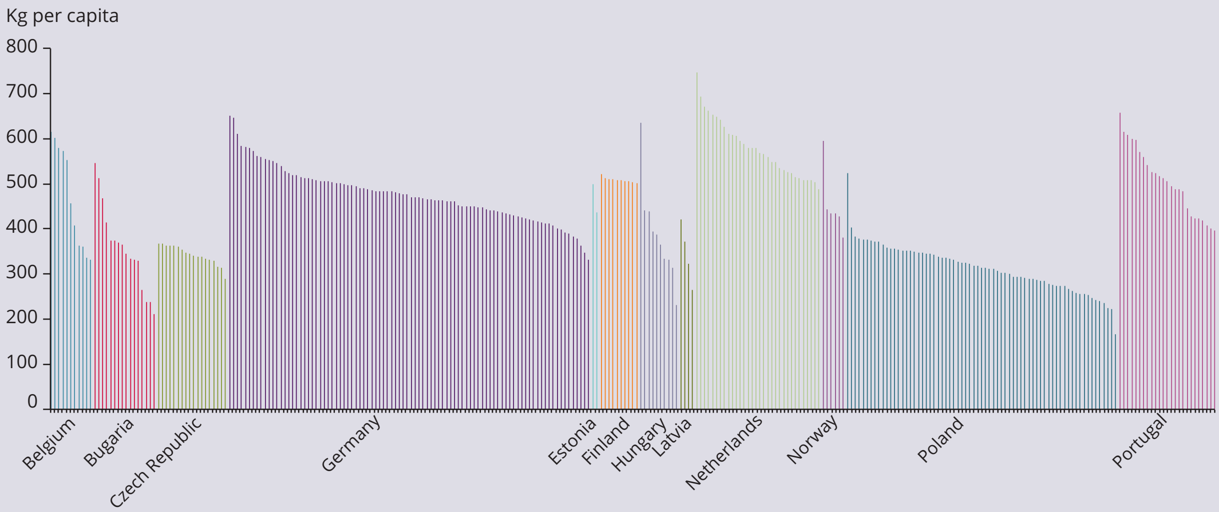
**Waste and affluence**

Affluence — measured by gross domestic product (GDP)/capita — is a significant factor determining the generation of municipal and commercial waste, although the relationship is not linear. Waste generation is generally lower in less affluent countries. However, Germany and Portugal, countries with very different economic conditions, infrastructure and cultural practices, cover a similar range of waste generation – from around 650 kg/capita to about 350–400 kg/capita (see Figure 2.8). Finland and the Czech Republic provide interesting examples of countries in which waste generation in cities tends to be near uniform throughout the country.

([54]) http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Municipal_waste_statistics.
([55]) http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Municipal_waste_statistics.
([56]) Urban Audit data are submitted voluntarily — there is no European obligation to provide Eurostat with Urban Audit data. There are data for some or all cities in: Belgium, Bulgaria, the Czech Republic, Estonia, Finland, Germany, Hungary, Latvia, the Netherlands, Poland, Portugal, Slovenia and Norway. There *are no* data for any cities in: Austria, Croatia, Denmark, France, Greece, Ireland, Italy, Lithuania, Luxembourg, Romania, Slovakia, Spain, Sweden, the United Kingdom, Switzerland and Turkey. There are *only* larger urban zone (LUZ) waste data available for some German and Portuguese LUZs.

**Box 2.14 Waste generation in European cities (cont.)**

**Figure 2.8 Waste generation per capita by city and country**

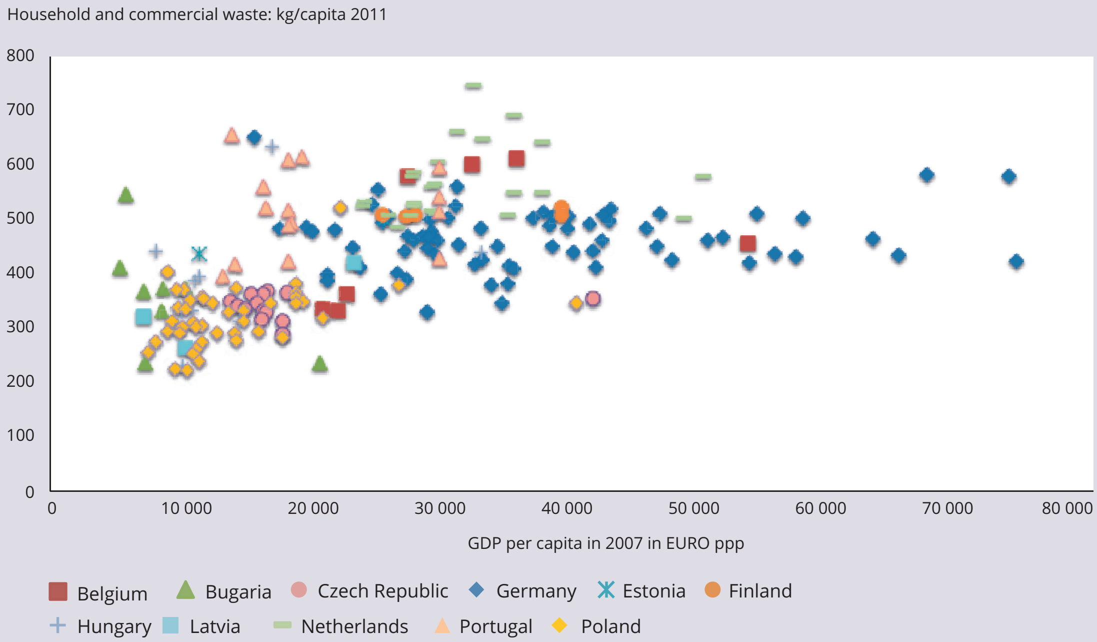



**Note:** Includes only cities for which data were available; waste data are from 2011; some city population data has been synthesised from the preceding or following year where necessary.

**Source:** Eurostat Urban Audit.

Factors other than affluence play a role in determining the quantity of waste generated. For example, Vidin in Belgium and Frankfurt in Germany both generate around 410 kg/capita per year of household and commercial waste (see Figure 2.9). However, Vidin has the lowest GDP per capita (the point furthest to the left) and Frankfurt the highest GDP per capita (the point furthest to the right).

**Figure 2.9 Waste generation and GDP per capita in European cities by country**




**Note:** Includes only cities for which data were available; GDP data are from 2007; waste data are from 2011; some city population data have been synthesised from the preceding or following year where necessary.

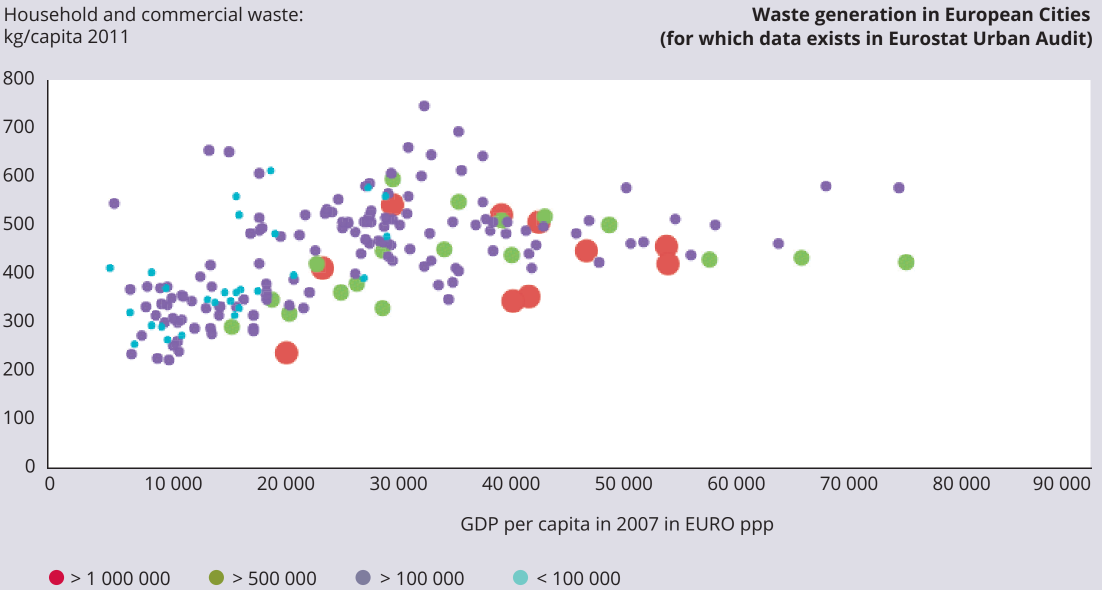
**Source:** Eurostat Urban Audit.

**Box 2.14 Waste generation in European cities (cont.)**

**Waste and the size of cities**

It seems that large cities generate less waste for an increase in GDP than smaller cities, but the relationship is difficult to interpret because big cities are also the ones with the highest GDP (see Figure 2.10).

**Figure 2.10 Waste generation and GDP per capita by size of European city**




**Note:** Includes only cities for which data were available; GDP data are from 2007; waste data are from 2011; some city population data have been synthesised from the preceding or following year where necessary.

**Source:** Eurostat Urban Audit.

**Comparison between cities and countries**

There is also a distinct clustering of cities from the same country. For example, although German cities span a large range of GDP per capita, in terms of waste generation, they tend to be clustered in a relatively narrow band from about 400 kg/capita to 500 kg/capita (with some outliers). Cities in the Netherlands and Portugal cover far narrower bands of GDP per capita but wider bands of waste generation per capita (the spread of cities extends vertically rather than horizontally in Figure 2.10. The clustering of Czech cities, with the exception of Prague, also indicates a relatively uniform waste generation and affluence in urban areas outside the capital.

The average amount of waste generated per capita in urban areas and at the national level generally seems quite similar ([57]), probably due to the convergence of standards of living and habits between rural and urban areas. The urbanisation process is associated with the diffusion of new lifestyles, new social perceptions and new habits that relate to waste generation.

**Source:** ETC-SCP study for EEA: 'Waste in Urban Areas' ([58]).

([57]) Except for German urban areas that produce almost 25% less waste per capita than the national average — probably related to the way in which garden waste is managed in urban and non-urban areas, but without considerably more research it is not possible to be more precise.

([58]) ETC/SCP study *'Waste in urban areas'* for EEA, prepared and compiled by David McKinnon, Andrea Rispo, Leonidas Milios, Tamas Kallay, Peter Szuppinger, Christian Löwe.

**Box 2.15 Waste prevention measures in accordance with the life cycle approach**

Annex IV of the Waste Framework Directive categorises examples of waste prevention measures into 16 classes that are addressed under three areas:

Framework conditions related to the generation of waste:

1. supporting efficient use of resources;
2. promotion of research and development;
3. development of indicators;

**Design, production and distribution phase:**

4. promotion of eco-design;
5. provision of information on waste prevention techniques;
6. organising training to include waste prevention in permits;
7. prevention of waste production at installations;
8. use of awareness campaigns and other ways of supporting businesses;
9. helping businesses to establish their own waste prevention plans;
10. promotion of environmental management systems;

**Consumption and use phase:**

11. introducing economic instruments (subsidies, charges) to prevent waste;
12. provision of information for consumers;
13. promotion of eco-labels;
14. agreements with industry;
15. integration of environmental and waste prevention criteria into calls for tenders and contracts;
16. promotion of reuse and repair.

**Box 2.16 Labels for ecodynamic companies in Brussels**

As part of the waste prevention programme in Brussels, an 'ecodynamic company' label has been developed to give official recognition of good environmental management practices of public and private companies. It rewards their environmental dynamism and progress in waste management, reducing energy consumption and the rational use of raw materials. It also encourages the introduction of an environmental management system — the EMAS or ISO 14001. The label has a three-star rating, depending on the level of environmental performance within the organisation.

**Source:** EEA, 2014c.

**Box 2.17 Eco-labelling for packaging in Poland**

The Polish waste prevention programme supports the development and implementation of an eco-labelling scheme for packaging that allows consumers to identify products that meet ecological criteria, including performance criteria and restrictions on the use of hazardous substances in packaging. The underlying rationale is to provide consumers with information on waste prevention when making a purchase.

**Source:** EEA, 2014c.

**Box 2.18 Waste avoidance: from information to action**

A campaign in Brussels encouraged people to 'Buy wisely and throw less away'.

In the Piedmont region in Italy, the 'Self-service detergents' project plans to reduce the packaging used in the purchase and use of detergents, through the sale of on-tap detergents in retail chains, making use of reusable bottles. The result of collaboration between the region, the retail sector and the detergent producers, the project will address the bulk sale of detergents such as dish-washing liquids, fabric conditioners, laundry liquids and all-purpose cleaners.

In the Umbria region in Italy, citizens can collect purified drinking water from water fountains, which can also be refrigerated. The fountains are usually installed in strategic places in town and cities, easily accessible by the public. The public fountains offset the common practice of buying water exclusively in plastic bottles and therefore contribute to decreasing waste.

These examples show that measures can be taken at both local and regional level.

**Source:** Promoting ZeroWaste, 2014.

***Food waste***

Reducing food waste would decrease the environmental impact associated with resource use and waste generation along the food value chain:

- *land usage and soil degradation* related to crop cultivation and livestock farming;
- *water consumption* due to irrigation but also to the increasing consumption of meat; for example, bovine meat production requires roughly 8–10 times more water than cereal production (Schaffnit-Chatterjee, 2011);
- *GHG emissions* caused by the use of mineral fertilisers, synthetic pesticides, livestock farming, transport, and energy used in the packaging and processing of food, cooling and cooking;
- *eutrophication* caused by the use of fertilisers and emissions of ammonia and nitrogen oxide from livestock farming;
- *biodiversity* damaged by intensive farming.

Food waste is a major issue in developed countries. Around 100 million tonnes of food is wasted annually in

**Box 2.19 Municipalities acting to prevent food waste**

Municipalities can raise the awareness of city residents of the environmental problems related to food waste. Many innovative solutions are being developed. For example, in the United Kingdom, WRAP (Waste and Resources Action Programme) ([59]) launched its 'Love Food Hate Waste ([60])' campaign, which is designed to support local authorities. The objective was to reduce the amount of food wasted in households by making inhabitants more aware of it. Kent County Council has involved local independent grocers in the campaign; grocers now work directly with their own customers to reduce food waste.

In Halmstad in Sweden, the municipality organises competition among schools to decrease food wastage in school canteens.

To decrease organic waste, the city of Brno ([61]) in the Czech Republic has developed a comprehensive strategy based on composting and reduction of waste food (e.g. the cooking of leftovers). Individual and collective composting bins have been installed in private and public organisations (e.g. schools, social centres) and composting demonstration sites developed. Promotion of and training on composting at home (individual and collective housing) and on site (schools, cafeterias and restaurants, catering services, etc.) has been also undertaken.

([59]) WRAP was set up in 2000 and works throughout England, Scotland, Wales and Northern Ireland to help businesses and individuals to reduce waste, develop sustainable products and use resources in an efficient way: http://www.wrap.org.uk/ (accessed 23 November 2015).

([60]) http://www.lovefoodhatewaste.com/ (accessed 23 November 2015).

([61]) http://www.miniwaste.eu/en/the-partners/brno.html and http://www.miniwaste.eu/index.php?lang=EN (accessed 1 March 2014).

**Table 2.4 Causes of food waste in households and the food service sector**

| | Household | Food service sector | Wholesale/retail sector |
|---|---|---|---|
| **Lack of awareness** | Little perception of the amount of food waste and the resulting environmental problems | | |
| **Lack of knowledge** | Little knowledge on how to use food efficiently in order to reduce waste (e.g. cooking leftovers) | | |
| **Attitudes** | Underestimate the value of food | Taking leftovers from restaurants is not common practice | |
| **Preferences** | Some food is wasted due to personal preference (e.g. apple skins) | Food offered may not meet customer expectation | |
| **Planning issues** | Buying more than is needed | Difficulties in anticipating the number of clients leading to overstocking | Difficulties in anticipating demand resulting in overstocking |
| **Date issues** | Stringent adherence to expiry dates | | |
| **Storage** | Inadequate storage conditions | | Meat and dairy products reliable on very strict temperatures for storage |
| **Portion sizes** | Portions often too large | Portions often too large | Encourage customers to purchase more than is needed |
| **Marketing** | | | Products are rejected for aesthetic issues or packaging defects |
| **Supply chain** | | | Need for better coordination along the supply chain |

**Source:** Adapted from Bio Intelligence Service et al., 2010.

Europe (estimation 2014 — European Commission) ([62]). One-third of the food for human consumption is wasted globally (Esnouf et al., 2011). The recent Communication from the European Commission, Towards a circular economy: A zero waste programme for Europe (EC, 2014) proposes a non-binding target to reduce food waste by at least 30% by 2025, in addition to the development, inter alia, of national food waste prevention strategies.

Food waste is generated throughout the food chain, from farmers to consumers. The causes are multiple and include lack of awareness, oversupply, planning shopping, standard portion sizes, difficulty in anticipating the number of clients, unsuitable storage and packaging, inadequate storage and inadequate packaging (Table 2.5). Food waste can be avoided upstream during cultivation, processing and distribution. Downstream, it is highly dependent on individual behaviour and habits, and it can be avoided by private households and the food service sector.

***Water saving in buildings***

Residential water consumption was estimated at 125 litres/capita per day in a benchmarking study in Germany, 135 declining to 129 litres/capita per day (2010–2012) for 31 large utility suppliers in geographical Europe and 151 litres/capita per day for 3 700 utility suppliers serving 32 million people (EEA, 2014a).

Many things can be done at the final consumer level to reduce the quantity of water used. Up to 30% of the water consumed in buildings in some regions could be saved. A study commissioned by the EU executive claims that a number of specific technological and technical changes to taps, toilets, showers and water-using equipment such as dishwashers could reduce water demand and result in water savings of up to 80% ([63]). A study in Spain found that indoor water use could be reduced by as much as 30% by regulating the water flow in taps and installing low-flush toilets (Sauri, 2013). A water-saving campaign in Frankfurt in the 1990s, which promoted

([62]) EUROPA — Food safety — Sustainability of the food chain (http://ec.europa.eu/food/food/sustainability/index_en.htm) accessed 20 October 2014.

([63]) Euractiv, sustainable development news, EU to table directive on water savings in buildings (http://www.euractiv.com/sustainability/commission-table-directive-water-efficiency-buildings-news-399420) accessed 22 November 2015.

water-saving devices, achieved its goal of a 20% reduction in water use in 1998 ([64]).

Toilet flushing accounts for up to 25–30% of total domestic water use and, as such, considerable overall water savings can be achieved by reducing flush volumes. The amount of water used by a single toilet flush has dropped considerably in some countries in recent decades, particularly as dual-flush and low-flush (less than 6 litres per flush) toilets have come onto European markets. In some cases, regulation has driven changes. For example, under United Kingdom building standards,, the maximum cistern volume allowed has fallen from over 12 litres in the 1950s to just over 4 litres today (EEA, 2009). Both waterless and vacuum toilets are relatively recent technologies, but they are currently neither practical nor cost-effective for domestic use, as they are too expensive. Water use by showers can be reduced considerably by aerating the water flow, which helps to simulate the feel of a power shower without the need for high volumes of water. Such aeration can also be applied to tap water and can reduce water consumption up to 50%. Thermostatic mixing valves in both showers and taps maintain selected temperatures and have been shown to result in considerable savings of both water and energy. Taps with infra-red sensors provide water only when an object is detected beneath them, resulting in water savings of 70% or more (EEA, 2009).

However, water-saving technologies may also have undesired effects. One such effect is the so-called off-setting behaviour, meaning that consumers may inadvertently adopt a behaviour that cancels the potential savings associated with presumably more efficient devices. For example, some experience with ultralow-flush toilets in the United Kingdom and the United States have shown that consumers may not believe that cleaning is sufficient with one flush and may tend to flush two or even three times, resulting in increased water use compared with the older less-efficient toilet (Saurí, 2013).

To sum up, the adoption of water-efficient appliances and devices, which is related to economic and behavioural factors, is an expanding component of urban water conservation (Millock and Nauges, 2010). It should be stressed, as well, that the proactive use of domestic water-saving devices is very much linked to public awareness of water scarcity and the need to save water.

**Box 2.20 The role of demand-side policies in Barcelona's water crisis**

The main measures put in place to resolve the drought were adopted under a law passed by the Regional Government of Catalonia ([65]). The aim of this law was to promote exceptional and emergency measures to rationalise and make economies in the use of water throughout the territory of Catalonia, in order to secure the water supply for human consumption. The law included both supply- and demand-side measures. The area was almost at the point of making domestic cuts. Water was being shipped by tanker from various places along the Mediterranean coast.

During the drought, restrictions were placed on outdoor water uses such as watering gardens or filling swimming pools. Managing the demand for water was crucial. Awareness campaigns were launched asking citizens to reduce water consumption. Technology devices such as aerators for taps were distributed to reduce water consumption. The average savings in the period from March 2007 to January 2009 were around 14.5%. The Catalan Water Agency states that on average the region retained an approximately 5% water saving after the drought.

The drought opened up a debate on the demand for water in Barcelona and this was extended to the question: how can we provide the extra flow needed when dams and transporting water have been severely criticised? To face this challenge, unconventional water sources were considered. A big seawater desalinisation plant was installed. A few municipalities experimented with projects on the reuse of greywater and rooftop rainwater harvesting (e.g. Sant Cugat del Vallès) and distributing the reclaimed water for irrigating public and private parks (e.g. Viladecans).

A centralised water infrastructure (water transport, desalination plants) is considered by some authors to create a techno-institutional lock-in (Domènech et al., 2013). Decentralised water supply systems, such as rainwater harvesting and reuse of greywater, are seen as the best options for new developments of eco-neighbourhoods, municipalities or suburban areas. Some municipalities in Barcelona area are promoting these unconventional systems as part of water conservation and efficiency programmes that are integrated into urban planning. These systems are rarely used in more traditionally built environments. Despite their apparent simplicity, they need to be designed specifically for the building and adapting them to existing buildings requires a lot of work.

**Source:** Martin-Ortega and Markandya, 2009; Domènech et al., 2013.

([64]) http://www.frankfurt-greencity.de/fileadmin/Redakteur_Dateien/05_gca_umweltindikatoren_english/08_water_consumption_frankfurt.pdf (accessed 20 November 2015).

([65]) Decree 84/2007, 3 April, on the adoption of exceptional and emergency measures regarding the use of water resources.

**Box 2.21 Thames Water's water efficiency programme ([66])**

Save Water Swindon' is a project aimed at challenging domestic and non-household customers to reduce their daily water use. In 2013, a media campaign was launched. This was combined with direct mailings to over 50 000 homes in Swindon offering water-saving devices and free home water makeovers. Water audits and leak detection checks were also undertaken for a number of schools and non-household properties in the town.

A range of free water-saving products are on offer to customers. The calculator 'Waterwisely' ([67]) gives tailored advice on water use and how customers can save water, as well as identifying the most suitable products for their homes. As a result, around 5.19 million litres per day have been saved compared with the target figure of 4.42 million litres per day.

The programme includes both household and non-household customers via a progressive metering programme. It also includes partnership projects with third parties to help deliver engagement, water audits and water efficiency retrofits and installations. Water efficiency has been promoted to a number of secondary schools in order to encourage the use of water-saving devices, leak detection equipment and 'smart' water meters, as well as engaging pupils with the importance of saving water.

**Source:** http://www.thameswater.co.uk (accessed 10 July 2014).

***Learning by doing***

Smart metering gives consumers near-real-time information on their energy or water consumption to help them reduce it. It also helps consumers to estimate their bills. For suppliers, it gives access to accurate data for billing and to improve customer service. It also provides additional data that gives them a better understanding of customer behaviour and peak demand.

To achieve a change in behaviour, the EU Directive on Energy End-use Efficiency and Energy Services (EU, 2006) encourages the introduction of smart metering where feasible and cost-effective. It is considered to be a way of leading consumers to adopt long-term energy-saving attitudes. The directive also requires energy billing to be based on real consumption and to provide complementary information on historical energy consumption. Since 2009 a number of directives and regulations ([68]) require transparency in energy billing information and encourage the introduction of smart meters.

Consumers and users need appropriate frames of reference in order to determine whether their energy or water consumption is excessive. Feedback from suppliers is the most successful strategy to change consumer behaviour and achieve resource savings. Direct feedback includes information received via smart meters combined with in-home displays or internet portals. Indirect feedback could include more informative and frequent bills containing historical and/or comparative information on energy consumption (EEA, 2013a).

The in-building display is critical to bringing about a change in behaviour. Smart meters need to provide information that is easy to understand and information on time of day when it is cheaper to run certain equipment, in order to reduce peak consumption and thus cost. Generally, projects on smart metering are developed by the energy or water suppliers. For example, the Danish utility Nord Energi — NRGi — installed 210 000 smart meters between 2009 and 2012 (EEA, 2013a). Some countries have defined a national programme, for example in the United Kingdom, the roll-out of smart metering ([69])will see the installation of 53 million meters (electricity and gas meters) in households and smaller non-domestic premises by 2020 (DECC, 2013).

([66]) 'Thames water' provides tap water for 9 million customers and sewerage services for 15 million customers across London and the Thames Valley.
([67]) http://secure.thameswater.co.uk/waterwisely/index.htm#!/calculate.htm (accessed 20 November 2015).
([68]) For details, see the European Commission website: http://www.europarl.europa.eu/sides/getDoc.do?pubRef=-//EP//TEXT+IM-PRESS+20080616FCS31737+0+DOC+XML+V0//EN (accessed 20 November 2015).
([69]) https://www.gov.uk/government/collections/smart-meters-statistics (accessed 20 November 2015).

**Box 2.22 Smart City Cologne**

'A Smart City is a city seeking to address public issues via ICT-based solutions on the basis of a multi-stakeholder, municipally based partnership' (European Parliament, 2014). The city of Cologne, in cooperation with RheinEnergie, other urban partners and local industry, launched the Smart City Cologne concept in 2013.

Around 30 000 smart meters have been installed in 350 larger apartment buildings in Cologne. The devices record electricity, gas and water data. This advanced metering infrastructure allows customers to keep an eye on their current and previous energy consumption at all times, to control their consumption and to use energy more efficiently to protect the environment and save money.

**Source:** European Parliament, 2014: http://www.smartcity-cologne.de/smartmeter/ (accessed 20 November 2015).

**Box 2.23 Learning to save energy**

Building Denmark's first ZERO+ home in Sønderborg has had a major impact on changing citizens' perceptions of a home to one of a net producer of energy instead of merely a consumer of energy. Strong citizen participation proved to be crucial to the success of the project. Initiatives have been developed for different sectors of the population to strengthen their participation and the impact of the initiatives.

Among the most successful have been the ZEROfamily and the ZEROhome programmes, focused on learning how to save energy in everyday life through awareness. The average energy saving was 25% and the average water saving was 45%, indicating that there is a lot to be saved simply by paying more (family) attention.

**Source:** Ministry of Housing, Urban and Rural Affairs and Danish Energy Agency, 2014.

**Box 2.24 Learning to lead a green lifestyle**

Based on the Swedish waste prevention programme, a feasibility study will investigate the possibilities scaling the Leva Livet (Living Life) project. In 2010, the Leva Livet project in Gothenburg challenged eight families to try out a new, more pleasurable green lifestyle for one year, helped by coaching from municipal experts. As far as wastes were concerned, the families reduced their food waste by a quarter, newspaper waste by a tenth and regular waste by approximately 40%. A central objective was to learn how to introduce sustainable living to ordinary people (p. 26).

**Source:** EEA, 2014c.

### *2.7.3 Sharing or borrowing rather than owning*

The potential offered by ICT has made sharing practices and service provision easier for consumers and businesses alike. Buying products is more and more being replaced by buying services (car sharing, bike sharing). In this 'functional economy', customer satisfaction is achieved by acquiring the function of the product rather than the product itself and/or by increasing the service component of the offer (Stahel, 2008; Akyelken et al., 2013). This approach includes a range of formal and informal, free and paid, services allowing the temporary use of products. This minimises waste generation, and reduces the number of items required for a given population. It also encourages the use of better, longer lasting products. The high population density of urban areas provides an excellent basis for these types of initiatives.

Local governments can boost innovative partnerships and networks, encourage the emergence of new participants, facilitate the development of the supporting infrastructure and regulatory frameworks, and promote smart ICT software solutions to optimise systems, communicate with citizens and change society's perception of these services.

***Borrowing and lending***

Borrowing and lending can be more or less formal. It includes peer-to-peer borrowing from people in the immediate vicinity, semi-formal borrowing networks

**Box 2.25 Sharing clothes instead of owning them**

Fashion has always been characterised by seasonal and swift changes that lead to increased consumption. Lånegarderoben is a grassroots initiative that started up in response and as a counter-measure to the high consumption of clothing, and with a desire to promote the reuse of clothing.

The Lånegarderoben initiative introduces the renting and reusing of clothes by consumers, who thereby avoid buying new clothes and other fashion items. The objectives of the initiative are to instigate the idea of collaborative consumption and drive waste prevention in the fashion sector.

The project was started in 2010 by four young people who put their creativity to good use to modify and repair used clothes and offer them as second-hand and vintage clothing as an alternative to the current buying culture in Stockholm. Lånegarderoben works just like a library where people can borrow clothes instead of books.

**Source:** http://www.lanegarderoben.se (accessed 20 October 2014).

**Box 2.26 Lending tools instead of owning them**

The Instrument Hake Association, which acts in accordance with the principles of a 'resource-based economy', seeks to put into practice the concept of accessing use without possession. Consumers often have to purchase expensive tools that it makes no sense to own because they are used only a few times a year. The association has sets up a kind of 'library' that lends household tools free of charge. The association also offers workshops based on the interests and needs of its members.

Lending tools free of charge contributes to fighting poverty, preventing wastage of raw materials and overconsumption, encouraging efficient use of resources, and strengthening social cohesion and interaction (in particular through workshops).

**Sources:** http://www.instrumentheek.be (accessed 20 November 2015).

http://www.oaklandlibrary.org/locations/tool-lending-library (accessed 20 January 2015).

http://www.today.com/video/today/52839801#52839801 (accessed 20 January 2015).

(in which communally owned goods can be used by all members) and open lending libraries.

Libraries are the most visible form of formal lending and were traditionally for the lending of books. However, an increasing number of initiatives are adding other lending services to libraries, such as power tools, consumer electronics and digital media, musical instruments and other equipment for hobbies and pastimes. There are also examples of housing associations and cooperatives that hold communally owned tools and equipment that can be borrowed by members. City authorities can support and promote these kinds of initiatives.

***Leasing product service systems***

Product service systems provide the use of a good without the necessity of owning it. The primary example of product service system is leasing, whereby one has the use of a product on a fixed or rolling contract. Any problems that arise with the functioning of the product are the responsibility of the leasing company rather than the customer. As the leasing company maintains ownership of the item, it is in its interest to keep the product in active service as long as possible. It is a driver for better and regular maintenance and the development of reliable and robust products. This business model is well established and is becoming relevant to a growing number of sectors.

Leasing contracts are usually framed in terms of months or years. However, other appliances can be rented for shorter periods (e.g. a camera ([70])). This is particularly useful for items that are seldom used. Hardware shops renting out do-it-yourself equipment, for example, provide consumers with access to a wide range of tools without the need to own them. Again, these tools tend to be more robust than those actually on sale, as their active lifetime needs to be longer. In theory, this leads to a lower throughput of materials.

([70]) http://www.hireacamera.com/ (accessed 20 November 2015).

***Car sharing***

Owing to the increasing negative impacts of car ownership and rising personal transport costs, the concept of sharing cars has emerged worldwide. It is a radical socio-cultural change with regard to ownership and consumption and in terms of business model.

Car-sharing systems can be based on fixed stations, and users have to bring the car back to their pick-up point or designated parking space (e.g. the services provided by Zipcar ([71])). Free-floating car-sharing systems concern one-way trips of any length without a booking requirement; users take and leave vehicles at any point within the city limits (e.g. car2go ([72])). Car pooling refers to a system in which people are encouraged to pick up others while driving to certain destinations including work and school (e.g. BlaBlaCar ([73])); it can be organised by companies for their employees or it can be arranged by local governments. Car renting is operated by agencies and companies that rent cars for short periods of time; car owners and customers can find each other through a smartphone app or a website (e.g. Getaround ([74])).

Some example are famous, such as Bremen's car-sharing scheme, with 42 sites scattered around the city and 160 rental cars estimated to have replaced more than 1 000 private cars in 2010 (Akyelken et al., 2013). Autolib' is the e-car-sharing programme in Paris that has around 110 000 subscribers (as at end of 2014) ([75]).In London, the involvement of Transport for London in the development of the London Car Club Consortium is a good example of the role of government in encouraging the establishment of car clubs (e.g. City Car Club ([76])). In contrast, the Finnish City Car Club is a small-scale system that follows the traditional car-sharing concept with additional technology innovations to facilitate use by the customer.

The environmental impacts of car sharing arise from the reduction in car ownership and kilometres driven. Studies of several car-sharing schemes show a reduction in the average number of vehicles per household using car-sharing programme (Martin et al., 2010). After becoming car share members, some of them cancelled a car purchase (Akyelken et al., 2013) or at least sold one car (Loose, 2010). In the United Kingdom, the Carplus 2012 survey shows that car-sharing schemes attract those who already use cars less (Akyelken et al., 2013) and travel short distances; this observation was also made in Switzerland and Berlin. In Milan, five operators (including one using only electric cars) have more than 190 000 subscribers, about 15% of the whole population ([77]).

Car sharing brings environmental benefits and seems to be an efficient way of changing people's attitude. It reduces car ownership rates and distance travelled and therefore road congestion. It has good potential to reduce emissions because of the choice of car (e.g. Autolib' uses electric vehicles using green energy). Car-share vehicles have lower carbon dioxide emissions than private cars (Agence parisienne du climat, 2013; Carplus, 2013). It is also a way of promoting electric and other low-emission vehicles. However, one criticism of car-sharing schemes is that they provide affordable and easy access to a car for those who do not currently own a car, and therefore could encourage increased motoring (EEA, 2013b). Furthermore, walking, cycling, using public transport (buses, metro) and in certain cases increasing vehicle occupancy rates have a better potential environmental benefit than car sharing.

***Bike sharing***

Bike-sharing schemes are systems in which bicycles are provided for short-term rental between docking stations, enabling point-to-point trips to be made by bicycle without having to own one. The concept of bike sharing is almost five decades old. Most of the innovations concerning bike sharing are mainly interoperability with other modes of transport and the introduction of ICT solutions to better inform the cyclist. For example, ReKola ([78]) in Prague uses a smartphone app that enables users to find a bicycle and receive a code to unlock the bicycle (the investment is relatively low cost).

The motivation for the majority of cities is to make urban areas more sustainable. The benefits of bike-sharing programmes are flexible mobility, reduction in emissions, individual financial savings, reductions in congestion and fuel use, health benefits and support for multimodal transport connections (Shaheen et al., 2010). The involvement of local governments is important in terms of safety and

([71]) http://www.zipcar.com/ (accessed 20 November 2015).
([72]) https://www.car2go.com/ (accessed 20 November 2015).
([73]) http://www.blablacar.com/ (accessed 20 November 2015).
([74]) https://www.getaround.com/ (accessed 20 November 2015).
([75]) http://www.avere-france.org/Site/Article/?article_id=6213 (accessed 20 November 2015).
([76]) http://www.citycarclub.co.uk/ (20 November 2015).
([77]) Communication from Lorenzo Bono AmbianteItalia (http://www.ambienteitalia.it/).
([78]) http://www.rekola.cz/en/ (accessed 20 November 2015).

connectivity with other transport modes, incentives and pricing, and regulation. The provider and the local government are jointly responsible for the density of stations, the comfort and availability of the bikes, and smart systems (e.g. integrated global positioning systems, smartphone apps).

The majority of the users combine bike sharing with the use of the metro and bus systems. In London, in 2010, Transport for London found that around one-third of scheme members use public transport rather than bikes during peak hours (Transport for London, 2010).

Bike sharing modifies people's behaviour. In London, 17% of people decided to buy their own bicycles following their experience with London Cycle Hire, and 48% of people were not cycling at all before the London scheme was introduced (Akyelken et al., 2013).

## 2.8 In a nutshell

Table 2.5 presents the opportunities for the local authorities to prevent and reduce the consumption of resources.

**Table 2.5 The role of local authorities in preventing and reducing the consumption of resources**

| | Local authorities | |
|---|---|---|
| | **Supply side** | **Demand side** |
| Avoiding urban sprawl | Elaborating better integrated spatial and urban planning to encourage dense and compact cities<br>Cooperating with surrounding areas<br>Emphasising urban design and green infrastructure supporting quality of life | Developing a sense of community |
| Moving sustainably | Developing a long-term sustainable strategy (definition of targets)<br>Elaborating better integrated urban planning to encourage dense and compact cities with mixed use in order to reduce commuting distances<br>Developing affordable, accessible, frequent, reliable and low-carbon public transport<br>Developing tax policies to support sustainability<br>Developing non-incentive car-parking policies<br>Developing safe, interconnected and continuous walkways and cycle lanes to encourage zero-carbon transport<br>Encouraging low-carbon interconnections between cities (e.g. train, boat for freight)<br>Regulating and organising freight traffic in the city centre and giving priority to low-emission modes of transport<br>Promoting travel alternatives (e.g. videoconferences, teleworking)<br>Leading by example: using a fleet of low-carbon municipality vehicles | Developing car and bike sharing to change behaviour<br>Promoting to citizens and businesses eco-driving techniques and combining trips to reduce distance travelled<br>Improving the participation of end users in the decision-making process (e.g. involving cyclists in decisions related to the cycling infrastructure) |
| Saving energy | Developing a long-term sustainable strategy (definition of targets, elaboration of the vision)<br>Promoting collective action for retrofitting of energy efficiency measures (insulation, upgrading heating and hot water systems, etc.) oriented towards households and businesses<br>Developing low-carbon district heating<br>Leading by example: regulating the temperature of public buildings, retrofitting of public buildings and social housing, developing flagship energy-saving projects, making public information on the energy consumption of public buildings, using local food in canteens, reducing energy for the supply of drinking water, etc. | Promoting retrofitting of residential and non-residential buildings for all types of owners<br>Supporting the dissemination of information (to household and businesses) on energy saving (campaigns, information services, participative processes, etc.)<br>Encouraging the installation of smart metering in public buildings and social housing (and more if possible) |

**Table 2.5 The role of local authorities in preventing and reducing the consumption of resources (cont.)**

| | Local authorities | |
|---|---|---|
| | **Supply side** | **Demand side** |
| Saving water | Elaborating better integrated urban planning to encourage dense and compact cities with mixed use (e.g. reducing the size of the lots, developing land recycling), the aim being to reduce the length of the pipe network<br><br>Reducing leakages<br><br>In public gardens, using plants adapted to the local climate that do not need watering<br><br>Adapting the quality of water required to the type of use (reusing water when it is possible)<br><br>Developing a decentralised water treatment plan and a wastewater plan where possible<br><br>Promoting low-tech solutions based on natural systems where possible<br><br>Managing storm water as a resource | Developing dialogue with all stakeholders,<br><br>Developing dialogue with users beyond the city limits (agriculture, industry, tourist areas)<br><br>Promoting information on water-saving measures and stimulating change (e.g. water-saving washing machines, low-flush toilets, drought-tolerant gardens)<br><br>Encouraging the installation of smart metering in public buildings and social housing (and more if possible) |
| Reducing waste | Facilitating cooperation between retailers to allow bulk sales and reusable containers<br><br>Encouraging the inclusion of the end-of-life phase in the design of buildings<br><br>Developing farmers' food markets | Raising the awareness of citizens of the consequences of hyperconsumption<br><br>Promoting local and seasonal food without packaging<br><br>Coaching families to investigate the potential for waste reduction and disseminating good practice<br><br>Distributing guidance on how to prevent household waste |
| Using the benefits of green areas | Developing green areas (horizontally and vertically) in order to reduce the heat island effect and the need for air conditioning, to reduce the need to travel at the weekend and to improve air quality<br><br>Using local vegetation in public spaces to avoid the need for watering | Encouraging the use of locally adapted plants in gardens and the development of green roofs<br><br>Improving participation of citizens in the decision-making process regarding green areas |
| Organisation and governance | Developing training on resource efficiency for city managers<br><br>Engaging in a participation process with stakeholders (homeowners and home occupiers, all groups of citizens, businesses, non-governmental organisations) | Encouraging the participation and the involvement of stakeholders (including researchers, children, people working but not living in the city)<br><br>Organising the dissemination of information |

# 3 Reusing, recycling, harvesting and producing

Most cities ignore the potential offered by their own territory for providing resources. Some urban outflows and stocks are still considered to be waste, despite their remaining quality. However, city authorities can improve the way in which resources are supplied and reduce the demand for them through a wide range of measures. There is also a huge potential to improve the reuse, recycling and harvesting of local resources and the self-production of resources and energy. The efficiency of these different options depends on the scale, local conditions, urban pattern, city characteristics (e.g. activities) and technology.

The use of local renewable resources is one option to become less dependent on the external supply of water, energy, nutrients and other materials. The built environment and city surroundings can be seen as areas for self-production and reservoirs of secondary resources. Outflows can be reused or recycled; useful substances can be recovered from stocks, waste or emissions; energy can be recovered from waste or produced by solar roofs or windmills; and food can be locally produced in urban gardens and farms.

Major obstacles to developing this 'productive' approach in the urban system are the temporal variations in quantity and quality that affect the supply and the demand of resources and the need for scaling up from block to city scale and beyond (each scale is associated with boundaries, activities and flows). Urban planning is crucial to allow efficient harvesting and self-production by reducing the distance between the source and the demand and by identifying all potential resource flows in the urban tissue (including those from industry: the high density of enterprises in urban environments creates opportunities for industrial symbiosis programmes ([79])). Another major challenge is moving from a centralised system — with one-site and end-of-pipe utilities driven by municipalities or the private sector (e.g. energy companies) — to decentralised systems in which users are owners and producers — 'prosumers' — in particular for renewable energy and water harvesting. However, the improvement of utility infrastructures and their management, in particular ICT-enabled infrastructures (e.g. smart power systems with intelligent management of energy mixes, smart grids, smart metering, heat storage), is also a major challenge.

This chapter explores how a city can become more self-sufficient in terms of resources and energy.

## 3.1 Reusing and recycling

Reusing, recycling and cascading mean finding value in a resource or a product that that has already been used. It means converting costs into revenues by finding alternative uses for losses and waste. In this context, all the decisions taken by municipalities (e.g. urban planning and design, innovation in utility management) are different from those in traditional urban management. All the flows entering and leaving the urban system have to be considered.

Because of the complexity of the system and the diversity of stakeholders, actors and sectors, recycling and reusing need to be analysed and implemented at a sufficiently large scale to take into account all the opportunities of the territory (industry, municipalities in the neighbourhood, potential users, etc.) and to cover a sufficiently large catchment area of potential providers and users. Projects for recycling and reusing resources are overall territorial projects in which each participant has a different role. Municipalities define resource efficiency targets, lead discussions with stakeholders, raise awareness of participants and support the implementation of the projects. Industrial companies reinforce their competitiveness by producing in a sustainable manner — they are mainly interesting in measures that reduce costs, emissions and losses. Researchers propose innovative solutions. Civil society participates in the debate and takes initiatives (e.g. grassroots associations). Cities have opportunities to develop and implement projects in many domains: water, energy, materials, waste management and buildings.

([79]) For examples, s ee the European Industrial Symbiosis Association: http://eur-isa.org/ (accessed 22 November 2015).

**Box 3.1 What does it mean?**

**Harvesting**

This refers to an efficient resource management approach that considers cities as reservoirs of resources and producers of secondary resources. Local resources are harvested to meet local demand (e.g. using renewable sources of energy, food from urban farming, rainwater harvesting). The main challenge is to scale up urban harvesting from the building to the city scale or beyond (see Figure 3.1).

**Reusing**

This is the use of products or components in their original form (e.g. the use of glass bottles after being sterilised and refilled for resale).

**Cascading**

This refers to the direct use of outputs but generally with reduced quality. The resource is reintroduced into the system at a lower quality and the remaining quality of the resource is used (e.g. using waste heat from industry for households, using grey water for non-potable requirements).

**Recycling**

This refers to reusing a resource after upgrading its quality, which generally requires energy. The high-quality resource can then be reintroduced to the system upstream (e.g. plasterboard recycling).

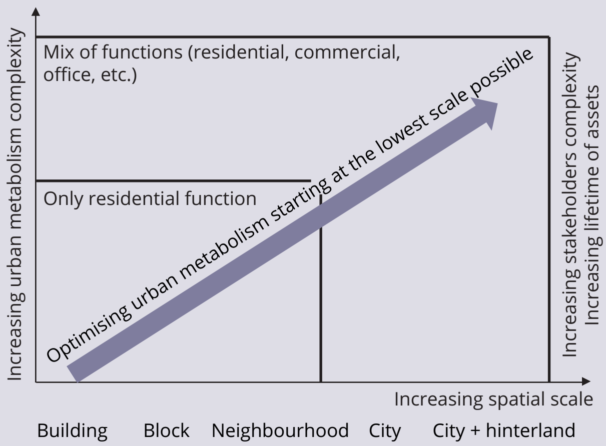
**Recovery**

This refers to the extraction of useful substances or energy from waste flows that can be reintroduced into the system at their remaining quality (e.g. nutrients and heat from wastewater, recovery from a biodigester used for biogas production).

**Multi-sourcing**

This refers to the harvesting of primary and secondary sources — with different levels of quality — that are locally available and renewable.

**Figure 3.1 Scaling up urban harvesting from block to city scale**




**Source:** Adapted from Agudelo-Vera et al., 2012.

### *3.1.1 Energy losses*

Energy losses represent an opportunity for more advanced and increasingly efficient energy systems. They are mainly linked to three activities: energy production processes, energy supply and self-consumption, and distribution. In 2009, in the EU-27 only 71.6% of the total energy consumption reached the end users ([80]): 22% was lost in transformation, 5% in the energy supply sector and 1.4% in distribution.

Energy losses are associated *upstream* with energy generation, distribution and conversion and *downstream* with waste heat, flared gases and wastewater. Distribution losses include losses in gas and heat distribution, electricity transmission and distribution, and transport of coal. They depend on factors such as network design, operation, maintenance and population density. Minimising the transformation steps and optimising the length of power lines are key to reducing network losses. Distribution losses are in general small at the European level but there is a significant variation across countries.

The first issue to address is energy production. Significant effort is being made to tackle energy losses such as the closure of old inefficient plants and improvements in existing technologies, often combined with a switch from coal-powered plants to more efficient combined cycle gas turbines. In production activities, major losses are derived from energy conversion during the transformation of energy into electricity, being up to 58% of fuel input

([80]) Indicator ENER 36: http://www.eea.europa.eu/data-and-maps/indicators/energy-efficiency-in-transformation/energy-efficiency-in-transformation-assessment-3#toc-1 (accessed 20 January 2015).

**Box 3.2 CitInES (City and Industry Energy Strategy)**

The objective of the 7th Framework Programme project CitInES is to design and develop a multi-scale, multi-energy decision-making tool to optimise the energy strategy of cities and large industrial complexes by enabling them to define sustainable, reliable and cost-effective long-term energy plans. Demonstrations of tools are being developed for different cities and organisations: Cesena and Bologna in Italy and Turkey's only oil refiner, Tüpraş.

Innovative energy system modelling and optimisation algorithms are designed to allow end users to optimise their energy strategy through detailed simulations of local energy generation, storage, transport, distribution and demand, including demand-side management and functionalities enabled by smart grid technologies. All energy vectors (electricity, gas, heat), uses (heating, air conditioning, lighting, transport) and sectors (residential, industrial, tertiary, urban infrastructure) are considered in drawing up a holistic map of the city's/industry's energy behaviour.

As economic and technical situations are constantly evolving, a relevant energy strategy has to be robust under different prospective scenarios.

**Source:** www.citines.com (accessed 23 November 2015).

lost (EEA, 2013c). However, this type of energy loss is declining with the increasing efficiency of power plants and the popularity of renewables ([81]).

Waste energy losses, currently unused, might be reused. The recovery of heat losses from electricity and industrial production processes can solve thermal energy needs for heating and cooling in residential, commercial or industrial buildings. An increase in the use of cogeneration, in particular from municipal waste treatment plants, and district heating and cooling can significantly contribute to energy efficiency, as stated in the Energy Efficiency Plan 2011 (EC, 2011d). Combined heat and power and district heating should be combined with electricity generation wherever possible.

***Energy stored in water***

There is also a large amount of energy stored in the water cycle, especially thermal energy. In some cities, a large part of the electrical energy for treatment plants is self-generated, and heating requirements for wastewater treatment are largely covered through the conversion of biogas.

**Box 3.3 Stockholm biogas for vehicle transport**

Two sewage treatment plants in Stockholm — Bromma (184 000 p.e. (population equivalent)) and Henriksdal (750 000 p.e.) — upgrade the biogas they produce to vehicle fuel quality. A pilot-scale upgrading plant started operating in Bromma as early as 1996. Large-scale upgrading started in 2000, and an upgrading plant began operating at Henriksdal in 2003. A number of biogas filling stations have opened and more and more biogas cars are being bought. Currently, 130 biogas buses are refuelled at a filling station connected via a direct supply line from nearby Henriksdal wastewater treatment plant.

**Source:** EEA, 2014a.

**Box 3.4 Micro-turbines in a drinking water treatment plant in Nice**

Some parts of the Nice (France) water supply network are higher than the customers leading to an excess pressure at domestic network inlets. Micro-turbines installed in the drinking water supply network convert the hydraulic potential energy loss into electric energy. The installation of four micro-turbines in the drinking water supply network generates 4.5 million kWh/year. The payback period is 6 years.

**Source:** Markopoulos et al., 2012.

([81]) Renewables are more efficient, as the primary energy form of wind, hydro and solar photovoltaic power is electricity, so there are no transformation losses associated with conversion.

**Box 3.5 New technologies for heat recovery from wastewater**

The goals of the project INNERS — Innovative Energy Recovery Strategies in the Urban Water Cycle, funded by Interrreg IVB and started in 2011 — are to investigate both how to reduce energy consumption and how to increase energy production in the urban water cycle.

The pilot project developed by the municipality of Leuwen ([82]) in 2014 is focused on the realisation of a heat exchanger to recover heat from municipal sewage water for heating 100 nearby houses (Vlario ([83])). If the project proves to be cost-effective, the city of Leuven will use this technology for other buildings as well.

**Source:** http://inners.eu/ (accessed 20 August 2014).

The full energy balance for water utilities goes beyond electricity consumption; heat recovery, for instance, may contribute significantly to energy savings if connected to district heating systems. The full energy balances may be taken into account by calculating 'carbon footprints' in the context of life cycle analysis.

There is also a great potential for heat recovery in wastewater:

- *Organic matter from sewage sludge* can be converted into a methane-rich 'biogas' by anaerobic digestion. The biogas can be captured and used to generate electricity and heat. It can be used directly by vehicles, engines and combined heat and power plants.
- *Micro-turbines can be installed in the drinking water supply network* to convert the hydraulic potential into electrical energy. A micro-turbine installed at the lowest point of the water or sanitation distribution network will rotate in response to water pressure.

The thermal heat contained in wastewater may be captured by heat pumps for low-energy uses such as the heating of buildings.

### *3.1.2 Water cascading*

Greywater is water from bathroom sinks, showers, tubs and washing machines. It is not water that has come into contact with faeces, either from the toilet or

**Box 3.6 Learning to use greywater in the metropolitan area of Barcelona**

In mid-2011, about 50 Catalan municipalities ([84]) — totalling some 1.2 million people — had approved local ordinances on water conservation. About half of these municipalities included specifications on greywater use in buildings, which were considered to be interesting for use in high-density urban areas.

Greywater — essentially water from showers — may be treated and reused on site for a series of uses not requiring drinking water quality. It is generated on a daily basis following a regular production pattern that makes this resource very suitable for everyday uses such as toilet flushing. Replacing potable water used in toilets with greywater results in a saving of between 13% and 21% of domestic water consumption. These figures can be increased by using greywater for other secondary uses such as watering gardens and laundry.

Adequate treatment of water and ongoing maintenance of the system are needed to avoid health problems. The use of membranes is an easy solution to improve the quality of water and avoid health issues.

These experiences show that the role of the large public and private water supply companies decreases (the end-of-pipe model) and in contrast the role of individuals increases. New institutional arrangements for water management emerge. Residents — often organised in small associations gathering together owners/tenants of flats in a building — become the owners of the greywater reuse system and they become responsible for its correct operation and maintenance.

**Source:** Domènech and Saurí, 2011.

([82]) http://inners.eu/news/leuven-first-municipality-belgium-recovers-heat-sewage-water (accessed 20 November 2015).
([83]) http://inners.eu/project/vlario (accessed 20 November 2015).
([84]) Most of them located in the metropolitan region of Barcelona.

from washing diapers. Greywater may contain traces of dirt, food, grease, hair and certain household cleaning products.

Aside from the obvious benefits of saving water and of reducing people's water bills, reusing greywater keeps it out of the sewer or septic system, thereby reducing the chance that it will pollute local water bodies. In addition, reusing greywater for irrigation reconnects urban residents and their backyard gardens to the natural water cycle ([85]). The use of greywater for watering gardens and flushing toilets was successfully implemented in Cyprus, reducing per capita water use by up to 40% (EEA, 2009)

While greywater may look 'dirty,' it is a safe and even beneficial source of irrigation water in parks and gardens. If released into rivers, lakes or estuaries, the nutrients in greywater become pollutants but, to plants, they are valuable fertiliser. However, the problem with greywater is that without proper treatment it may retain increased levels of elements that are harmful to the soil and the crops or trees that grow in it. One particular concern is sodium, which in higher concentrations can damage soil permeability and structure, ultimately reducing crop yields ([86]). Furthermore, it is not suitable for watering salad crops and vegetables, for instance, if they are not going to be cooked before eating. A study carried out in Germany (Nolde, 2005) suggested that investments in greywater treatment plants within buildings can be amortised over a 5- to 7-year period and concluded that biological treatment is indispensable to avoid technical problems and health risks, as well as to promote public acceptance. Those treatments are typically carried out through underground recycling tanks.

### *3.1.3 Recovery of nutrients from wastewater*

Nowadays wastewater is being viewed not only as waste and a problem but also as a potential resource based on recoverable components, in addition to water and energy, such as nutrients, carbon and inorganic materials. Given the progress made in the recovery of nutrients, wastewater will be more and more recognised as a 'renewable' resource. It will be also a way of improving environmental quality at least cost to the community and contributing to the local economy. However, more research is needed to identify the full range of nutrient-extracting processes and how this resource can be commodified (Pramanik and Burn, 2014).

Recently, a new category of processes has emerged that extracts specific chemical compounds, with a market value, from wastewater treatment streams. One of the challenges is not only identifying resources but also assessing the practicality of recovering resources from wastewater. This is still basically a research topic, apart from some pilot studies, but it shows a promising future.

### *3.1.4 Waste challenges*

Waste generation (quantity and composition) is a complex process depending on various factors such as demography and characteristics of the population (income, age, consumption, lifestyle), land use (type of buildings, density), productive activities and policy measures (e.g. rate of home composting).

Solid waste management is one of the most challenging issues for cities as places where people and activities are concentrated. Yet, city authorities have demonstrated considerable resilience in finding solutions that reduce overall waste and increase recycling and in pioneering new forms of environmentally friendly waste treatment. The main objective is to follow the waste hierarchy, which prioritises waste prevention, followed by reuse, recycling, other recovery and finally disposal or landfilling as the least desirable option.

Waste management has strong links with urban planning and economic development. Developing efficient waste management requires integrating it into mainstream sustainable urban planning. In particular, new city developments should have waste generation and the impacts of its disposal integrated into their planning.

Municipalities can act at different points in the waste management process:

- They can separate waste into fractions from one homogeneous collection (e.g. paper and cardboard, metal, glass, plastic, multilayer packaging, biowaste, wood, textiles, tyres, used cooking oils, waste electrical and electronic equipment (WEEE), batteries, medicine, hazardous waste).
- They can collect separated waste (e.g. door-to-door collections, bring banks, civic amenity sites, collections by request, collections from shops).

([85]) Only a few countries (Denmark, Germany, Sweden) seem to have regulations in this respect. In general, it is a topic not yet regulated.
([86]) 'Is greywater safe for irrigation?', Science for Environment Policy, Environment Directorate-General News Alert Service, 17 June 2010: http://ec.europa.eu/environment/integration/research/newsalert/pdf/200na6_en.pdf (accessed 25 March 2015).

A waste collection service is one of the most visible responsibilities of local authorities; it largely depends on the characteristics of the buildings and their density. The separate collection of recyclable wastes is the first step of recycling, and cities play a very important role in organising effective separate collection systems and in setting incentives for citizens to participate in such systems.

- They can provide sorting facilities to segregate recyclables *from bulky waste or residual waste*.
- Finally, they can provide treatment facilities such as mechanical–biological treatment, composting for biodegradable waste, anaerobic digestion, and recycling facilities whereby specific waste fractions are recycled or reprocessed for reuse).

**Box 3.7 Research on the zero waste index**

The concept of the 'zero waste index' has been proposed by some researchers to forecast the amount of virgin materials, energy, water and GHG emissions offset by the resources that are recovered from waste streams. They argue that the zero waste concept should go beyond zero landfill and aim for 'zero depletion of natural resources'.

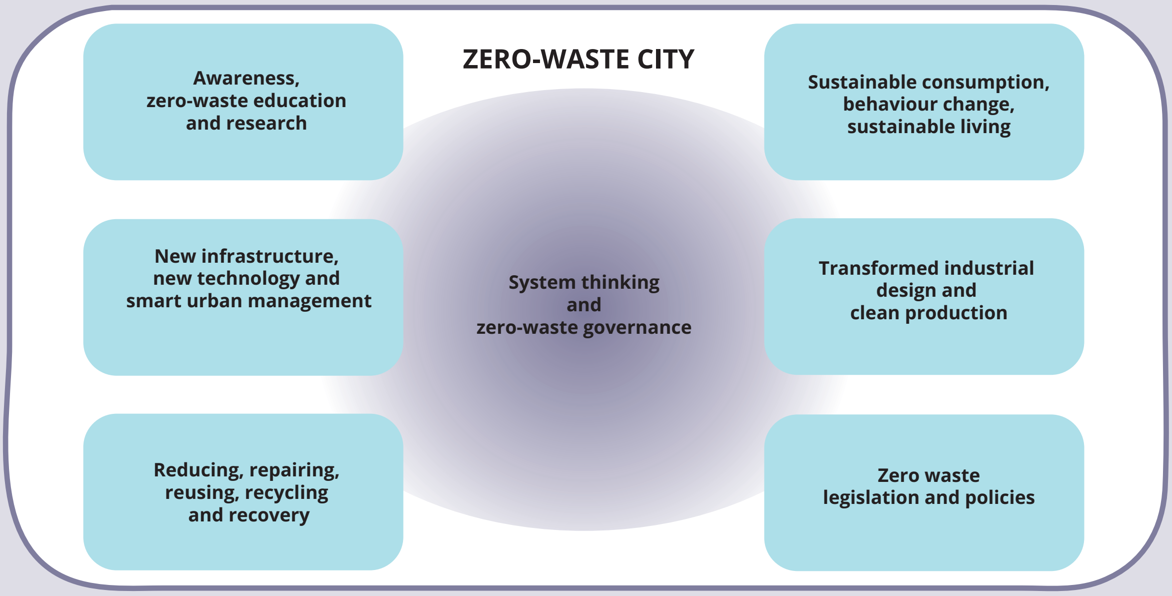
The zero waste index they propose quantifies solid waste flows and measures the extent to which materials may be reused as substitutes for virgin materials. In addition to the overall percentage of material recovery and substitution, the approach calculates other 'savings' made, including energy saved, GHG emissions avoided and water saved (regarding the use of water within material supply chains).

The researchers first calculated the generation of domestic waste materials, specifically paper, glass, metal, plastic, organic and mixed solid municipal waste for three cities, all of which are working towards becoming the world's first zero-waste city (see Figure 3.2).

According the zero waste index, a city generating less waste per capita but making a lot of use of incineration (therefore losing large amounts of raw materials) will not perform well. The index is based on the value of material that can potentially replace virgin material inputs. The offsetting of energy, water and GHG emissions is also taken into account as material substitution. The result is based only on the recovered resources and not on the resources used in and emissions arising from the production of goods that then become waste. This example demonstrates the limits of the index.

**Source:** EC, DG Environment, News Alert Service, 2013; Zaman and Lehmann, 2013.

**Figure 3.2 Drivers for transforming cities into zero waste cities**




**Source:** Adapted from Zaman and Lehmann, 2013.

**Box 3.8 'Pay as you throw' in Flemish municipalities**

Owing to the increasing cost of collecting and treating municipal solid waste, municipalities have had to find new ways of financing those costs. The Flemish government introduced for the whole region the principle of sorting municipal solid waste from households at source.

The initial question was: how to motivate households to sort their waste at source? The response was the creation of financial incentives or different tariffs for the separate collection of those waste streams that can be recycled, reused or composted, instead of ending in landfill or in an incinerator. The 'pay as you throw' principle makes the producer of the waste financially responsible for the collection and treatment of the waste he or she produced. Households are charged for the collection and treatment of municipal solid waste, based on the amount they throw away. This principle is combined with differential tariffs to make residual and bulky waste more expensive than selective collected waste streams.

The enabling factors were a clear legal framework (mandatory separate collection schemes for the municipal solid waste), financial support for local governments from the regional government for the initial costs and installation of the infrastructure for separate waste collection, measures to make recycling financially more compelling, permanent awareness raising and information campaigns directed at citizens to familiarise them with the principles of 'pay as you throw', and continuous and active dialogue with the municipalities, associations of municipalities and the key players in the chain of waste management (citizens, private waste service providers (collectors), waste treatment companies).

Monitoring has shown an increase in the separate collection of municipal solid waste and a marked reduction in residual waste.

**Source:** R4R, 2014.

**Box 3.9 Pay-per-weight charging system**

Under the pay-per-weight charging system, householders pay for the amount of waste they produce. An electronic micro-chip is fixed to each wheelie bin, which identifies the customer and allows the bins to be weighed on collection. The primary aim of this charging system is to prevent waste generation and thereby reduce the quantity of waste going to landfill and/or energy recovery. This system encourages householders to dispose of items (especially WEEE, which can be heavy) through the proper channels without charge. An Environmental Protection Agency (EPA, Ireland) study published ([87]) in 2011 concluded that this system is highly effective.

**Source:** R4R, 2014.

**Box 3.10 Eco Shop in the Greater Oporto Area**

The Eco Shop is a free loyalty card delivered to citizens that rewards their cooperation with the recycling process. The reward comes in the form of points that are accumulated on the card and can later be exchanged for goods and services. The project aims to increase citizens' participation in the recycling process and reward citizens for good practice. The allocation of points is based on the number of deliveries made to drop-off sites. Each kind of waste has a specific number of points based on its value and importance to the recycling process.

**Source:** R4R, 2014.

([87]) EPA, 2011, Study of pay-by-use systems for maximising waste reduction behaviour in Ireland, Environmental Protection Agency, Dublin, Ireland.

***Economic instruments***
Economic instruments help municipalities in implementing policy to improve their recycling performance, for example a waste tax (for waste collections) will increase the cost putting waste to landfill or incineration and therefore provide an incentive to prevent, recycle or reuse. Users can also be charged depending on their use of the service. Municipalities can also use specific instruments, for example giving citizens money (or a coupon for a shop or a discount) when they bring back recyclable goods, consumers buying a product are charged on extra fee (for the packaging material) that is refunded when they return the empty packaging, and changing engine oil free of charge in car service centres.

***Targeted communication***
Municipalities have an important role to play in communicating with households and small companies through advertising campaigns in the different media (TV, radio, newspaper, website, smartphone apps, leaflets) to promote and provide guidance on recycling. To be effective, the communication needs to be addressed to targeted recipients and the message personalised, for example from a local ambassador in charge of direct communication with the population (e.g. during special events, training sessions, door-to-door visits), or through an interactive help line (internet or phone) providing guidance for citizens on sorting and waste collection. Awards can also highlight good practice on the part of individuals or organisations.

***Legal instruments***
Local, and more often national and regional, authorities can ban the use of incineration or the use of landfill for several waste fractions, making it impossible for waste collectors. They can make mandatory to sort out waste by households (clear sorting instruction need to be established). They can also make the producer responsible for the collection, recycling and final treatment of his product, the packaging and the associated cost when the product becomes a waste material; by this obligation, the producer is stimulated to think about the life cycle of his product.

***Collection in multi-family dwellings***
Householders in multi-family dwellings recycle less than householders in single-family dwellings, because drop-off stations involving storage, time and transport costs for individuals can stifle recycling (Miafodzyeva and Brandt, 2012). The waste collection system in a multi-family dwelling is mainly limited by the storage capacity in the building. One of the difficulties with kerbside collection is that there is less sense of ownership of the system, as the elements of waste management are not part of the household. Generally, a household's tendency to recycle decreases with increasing physical constraints and with the perceived value of the added effort associated with choosing to sort recyclable materials (Ando and Gosselin, 2005).

However, the recycling infrastructure can be improved in flats. For example, to achieve the targets in London's Municipal Waste Strategy ([88]) ([89]), a range of measures were taken to increase recycling, such as the installation of small internal recycling containers, better infographics on the materials accepted, better provision of recycling banks, delivery of bags to encourage internal storage and facilitate transport to bins, community events, and a campaign run through various media channels.

***Collection in single-family dwellings***
Single-family dwellings generate different (and often more) waste than multi-family dwellings. The primary additional waste type is garden waste. Home

**Box 3.11 Door-to-door information campaign in Elefsina (Greece)**

In order to enhance its recycling rate, the municipality implemented a door-to-door information campaign. A number of young citizens visited households after attending a training seminar and receiving leaflets and questionnaires. They provided information on the recycling facilities available and they also recorded citizens' opinions of how waste was being managed. The objective of the campaign was to engage the population at a personal level and create a sense of commitment towards the community. The key success factor was the number of households that were visited. This successful campaign was financed by the municipality, which has benefited in terms of reduced waste and thereby reduced costs.

**Source :** R4R — Region for recycling, 2014.

([88]) London's Municipal Waste Strategy intends to achieve zero municipal waste going directly to landfill by 2025, to reduce household waste by 20% by 2031 compared with 2009/10 levels, to recycle or compost at least 45% of municipal waste by 2015 and 60% by 2031, and to reduce the city's GHG emissions.
([89]) www.minutes.haringey.gov.uk (accessed 20 November 2015); www.london.gov.uk (accessed 20 November 2015).

composting can largely avoid this waste type entering the waste management system.

Participation and capture of materials are usually higher in residential areas with detached, semi-detached and terraced houses rather than in centralised or communal residences (Williams, 2013). Generally collection costs are higher in these schemes, but this may be compensated by the increased quantity and quality of recovered materials returned to the market (Williams, 2013).

It has been demonstrated that changing the residual waste collection frequency from weekly to fortnightly and introducing separate kerbside collection of organic waste increases the probability of reaching waste minimisation goals (Gellynck et al., 2011). The introduction of fortnightly ([90]) collection schemes leads to an increase in the amount of recyclable materials collected from households (Williams and Cole, 2013). This collection frequency scheme improves recycling rates, helps to achieve landfill diversion targets, and reduces the environmental impacts of the service and its operational costs (Williams and Cole, 2013). As an example, Newcastle City Council in the United Kingdom in 2013 introduced such a scheme, estimating increased levels of recycling and savings by 2016 of GBP 100 million ([91]) as a consequence of increased sales of recyclable materials and reducing landfill tax payments.

***Public collection points***

Collection systems vary with the urban context. In the main, there are two groups of recycling schemes for source-separated materials, one requiring residents to bring the materials to a certain point and the other providing a kerbside door-to-door collection (Williams, 2013). Generally, collection systems in Europe are a combination of both types, with large variations between municipalities and even within countries.

Some European cities in Denmark, Portugal, Spain and Sweden have implemented complementary underground vacuum collection systems (Williams, 2013), generally in areas of cities where there is a shortage of public space available for waste facilities, either due to physical limitations (such as narrow streets) or for development reasons (regeneration of urban centres). In this case, residents and commercial premises are expected to deposit waste at drop-off points (inlets) from where it is transported through a system of compressed air pipes to a central point. This system allows for the separate collection of different materials. Some of the drawbacks of this technology are related to the energy costs incurred by its operation and also the high investment costs in the early stages of implementation. From a life cycle analysis perspective, this system has the greatest environmental impact compared with door-to-door and street multi-container collection schemes (Iriarte et al., 2009).

**Box 3.12 The Treynntstadt Berlin initiative to increase participation in waste separation**

BSR (Berliner Stadtreinigungsbetriebe — Anstalt nach Berliner Betriebsgesetz) is the publicly owned waste management company of the city of Berlin. The company's objective is to make waste and resource management a fundamental part of sustainable urban development. For this work, BSR has received many national, European and international awards in the areas of innovation, sustainable development, corporate social responsibility, design and public communication.

In 2010 BSR initiated the Trenntstadt Berlin initiative to further increase public awareness and household participation in waste separation and recycling activities. The key objective was to mobilise public institutions, companies and private households to become participate in increasing the separation levels in the various waste streams. This initiative is based on innovative communication and participative approaches. Waste management and recycling are promoted as part of the trend-setting image of Berlin.

The initiative uses a new, modern narrative of waste separation, recycling and prevention to motivate private households to become more intensely involved in the city's strategy for resource management and achieving a circular economy. Innovative communication techniques are complemented by infrastructure measures and increased management capacity.

As a result, the quantities of waste in Berlin are continuously decreasing while the population continues to grow.

**Source:** http://www.trenntstadt-berlin.de; http://www.bsr.de (accessed 20 November 2015).

([90]) In southern European countries, the collection frequency for residual waste cannot be fortnightly because of the warmer weather conditions, which can lead to odour and vermin. To avoid this, residual waste collection tends to be on a daily basis (e.g. Palermo, Italy) (Williams, 2013).

([91]) Newcastle City Council, 2013. Changes to bin collections: http://www.newcastle.gov.uk/environment-and-waste/rubbish-waste-and-recycling (accessed 15 December 2014).

For some other materials that are not collected in street containers or in kerbside collections, local authorities have established civic amenity sites, also known as household recycling centres. These facilities usually allow residents to dispose of all types of waste, such as residual waste, paper, cardboard, glass, construction and demolition waste, plastics, garden waste, textiles, combustible materials, electronic scrap, bulky waste and hazardous waste. The location of these centres represents a challenge for local authorities, as these facilities take up considerable space in the densely populated areas of cities where land values are high.

### *3.1.5 Organic waste*

Organic wastes are food waste and garden waste produced by households and by others sources in cities (e.g. canteens, restaurants, retail sector, factories). There are several technical options for the treatment of organic wastes, which are at the same time cost saving and resource efficient (Al Seadi et al., 2013):

- *Anaerobic digestion:* This industrial process takes place in a digester tank. The output of the process is biogas (a methane-rich gas that can be used as renewable fuel for direct combustion or cogeneration or upgraded to biomethane and injected into the gas grid) and the digestate (the residues left after the decomposition of the organic waste, which can be used as fertiliser).

- *Composting:* This is the decomposition process that occurs naturally in the environment, in the presence of atmospheric oxygen. Compost is used as a fertiliser and soil improver. Composting can be done on a small scale (home composting) or on an industrial scale.

- *Mechanical–biological treatment:* This is a combination of mechanical and biological processes to separate and transform the residual waste into several outputs. It is not a final disposal solution and can be considered as a mechanical-biological pre-treatment (frequent in Austria and Germany). The main aim is to reduce the biodegradable content of the waste, to extract further value from the waste and to recover the energy it contains. The mechanical process separates out some dry recyclables (e.g. glass, metals). The biological process reduces the water content and handles the organic-rich fraction, which can be further composted or treated by anaerobic digestion. The outputs of this process are of considerably lower quality than that of separately collected recyclables.

***Food waste***

Over 100 million tonnes ([92]) of food are wasted annually in the EU (2014 estimate). If nothing is done, food waste is expected to rise to about 126 million tonnes by 2020. At the same time, the Food and Agriculture Organization estimates that about 805 million people ([93]) were chronically undernourished in 2012–2014. Even in Europe, a number of households suffer from poverty. In 2013, 10% of the EU-28 population was severely materially ([94]) deprived (Eurostat, 2014). In addition, in developed countries, obesity is one of the main public health challenges and the number of obese people continues to rise.

Food waste occurs at every stage of the food chain: manufacturing, wholesale/retail, food service sectors, household. Wasting food is not only an ethical and economic issue but it also depletes our limited natural resources.

**Box 3.13 Two types of compost in Odense**

At Odense Environmental Centre (Denmark), two types of compost are produced: one is for gardens and contains only garden and park waste; and the other is for agricultural purposes and contains a mixture of garden waste, sewage sludge and straw. A plant for composting from the three wastewater treatment plants in the municipality has been established. The annual production is about 35 000 tonnes of final biocompost, most of which is used as fertiliser for crops, such as cereals.

**Source:** http://www.environmental-expert.com/services/composting-services-361314 (accessed 25 June 2015).

([92]) http://ec.europa.eu/food/safety/food_waste/index_en.htm (accessed 15 March 2015).
([93]) FAO, 2014, *In brief: State of food insecurity in the world:* http://www.fao.org/3/a-i4037e.pdf (accessed 15 March 2015).
([94]) Severely materially deprived persons have their living conditions constrained by a lack of resources and experience at least four out of the nine following deprivation conditions: cannot afford (1) to pay rent/mortgage or utility bills on time, (2) to keep their home adequately warm, (3) to face unexpected expenses, (4) to eat meat, fish or a protein equivalent every second day, (5) a 1-week holiday away from home, (6) a car, (7) a washing machine, (8) a colour TV, or (9) a telephone (including a mobile phone).

The design and organisation of food waste collection systems are particularly important depending on how biodegradable waste will be treated. The main issue is how to accommodate the infrastructure required to collect food waste and to enhance participation. Municipalities have an important role to play, not only in the collection of food waste but also in raising awareness of the issue of food waste.

The waste can be collected directly from properties (residential, institutional, commercial) or from municipal collection points. It is necessary to collect high-quality material (free of contamination) to produce high-quality fertiliser. Residents need additional bins and liners or multi-compartment bins for collecting food waste. In Sweden, the oldest and most common system for food waste collection uses separate bins (Al Seadi et al., 2013); the size and the design vary depending on the collection source (multi-apartment building, apartment, single house).

Communication with households and others potential users is vital to ensure that the collection service is used properly in order to minimise contamination

**Box 3.14 Waste food collection, the United Kingdom's experience**

Two case studies of door-to-door food waste collection in multi-occupancy dwellings in the United Kingdom (Newtownabbey and Kingston-upon-Thames) showed that when residents were required to keep their food waste within their properties for a week, either with or without the provision of kitchen caddies and compostable liners, the system achieved average food waste yields of around 0.5 kg per household served per week (WRAP, 2009a,b).

On the other hand, in Hackney, where residents were required to take food waste to communal bins next to the recycling bins, lower values were achieved ranging from 0.24 to 0.34 kg per household per week (WRAP, 2009a). In comparison, it is estimated that kerbside food waste collection from single-family dwellings ranges from 1 to 1.7 kg per household per week. This illustrates the limitations on achieving high separation values in this kind of dwelling, considering the barriers faced by residents in participating in a complex collection system.

Results from these experiences indicate that access to properties requires coordination between collection crews and management agents. In communal bin schemes, the design of the bin and its location will influence residents' participation.

**Source:** WRAP, 2009a,b.

**Box 3.15 Collection and treatment of food waste in Malmö**

Since 2003 the Swedish government has recognised food waste as a very important waste stream with considerable potential for recovery of nutrients and energy. In 2003, the parliament decreed, as a national environmental objective, that 35% of food waste should be recycled or biologically treated (including home composting) by 2010. In the new Swedish Waste Management Plan, the target for food waste has been extended to 50% being recycled by 2018.

In order to achieve the national targets at city level, the authorities of Malmö and Burlöv decided in 2012 to make compulsory separate food waste collection from all households and businesses in their municipalities. They adopted the target of 40% of food waste collected and treated biologically by 2015. In addition, the regional council of Scania has adopted the target that all city buses will use only biogas by 2015; this also applies in Malmö.

The collected food waste is redirected to peri-urban bio-processing plants for biogas production. The biogas can be used for either electricity or heat production, as well as fuel for local public transport (buses, garbage trucks, taxis and cars). The entire Malmö bus fleet has been engineered to run on gaseous energy sources: approximately 200 city buses run on a mixture of biogas and compressed natural gas.

The system is financed through municipal fees for waste management. The fee for maintaining a separate food waste bin is more than three times lower than that for a residual waste bin, therefore making it a more attractive option for citizens, because by sorting out food waste it is possible to replace one residual bin with one food waste bin and save a lot of money annually.

**Source:** http://malmo.se/English/Sustainable-City-Development/Recycling.html (accessed 24 February 2015).

**Box 3.16 Milan: door-to-door food waste collection**

The door-to-door household organic waste collection plan was extend to the whole city in 2014. Brown bins and compostable bags are used for collection and small kitchen bins in apartments.

The information campaign used multiple communication channels: direct marketing sent to families, letters and posters sent to public administrations, a free smartphone app for exchanging information, and a website. In three-quarters of the city the recycling rate has risen from 34.5% in 2011 to 48.3% in 2014 ([95]). Food waste recycled per capita is estimated at 90 kg/year.

**Source :** R4R, 2014)

in the collected material. How to do the separation needs to be clearly explained. Verbal instructions on recycling food waste can be given by door-stepping in high-density residential areas. In Sweden, this approach has proved to be effective to reduce the amount of residual waste, although over time the source-separated ratio has decreased, suggesting that the effect of these campaigns is not long lived (Bernstad et al., 2013). In Norway, it was found that awareness and communication campaigns for food waste collection required long-term objectives and repetition in order to retain support over the long term (Refsgaard and Magnussen, 2009).

***Garden waste***

People living in towns and cities produce large amounts of garden waste such as grass cuttings, hedge clippings, weeds, dead plants. The municipality itself also produces organic waste from the maintenance of urban areas. Composting is the best environmental option and a low-cost solution (e.g. reduced collection, reduced transport, production of compost) to manage household organic waste at source. Urban garden waste can be composted locally or at source in the garden.

The compost must have certain physical, chemical and biological properties to be fit for purpose, in particular it must be safe for humans and the environment. Compost brings a number of benefits; it improves the soil biodiversity and the structure of the soil and is a source of nutrients. More and more cities offer free home composters to households and advice on composting and gardening.

Some innovative cities have proposed keeping chickens in the backyard (e.g. Mouscron in Belgium, Châtillon in France). The objective is to feed chickens with kitchen scraps. In addition, chickens eat insects and can serve as an organic pest control agent; they also eat many weeds, making the gardener's work easier, and provide eggs every day.

### *3.1.6 Reusing products and preparing for reuse*

Waste is a symbol of inefficiency and represents misallocated resources. Disposable products (e.g. food cans foods, safety razors, packaging), designed to be thrown away after a brief use, were introduced in the last century with the rise of consumerism. Usable products and components (e.g. devices, electric and electronic products, textiles, shoes, furniture, tyres, toys, books, bikes) are scrapped. Repair costs are often higher than the cost of a new product that offers technical improvements or is more fashionable. Products need to be replaced early because of their short lifespan ([96]).

To address this challenge, many smart initiatives from local authorities, non-profit organisations or individual citizens are emerging. They encourage and organise reusing, sharing, borrowing, exchanges, lending goods and tools, etc. Social media and the internet generally have largely contributed to the success of this creative initiative.

***Selling***

Peer-to-peer selling of used items is not a new phenomenon, but it has exploded with the advent of the internet and often area-specific internet services. eBay is one international example, but there are many local examples. These are often online versions of existing classified newspapers, such as Loot ([97]) in London and den blå avis ([98]) in Copenhagen. These

([95]) The first 3 months of 2014.

([96]) The obsolescence of products is planned and built in at their conception (the so-called 'planned obsolescence'). Therefore, the consumer feels the need to purchase new products and services that manufacturers bring out as replacement.

([97]) http://loot.com (accessed 20 November 2015).

([98]) http://www.dba.dk (accessed 20 November 2015).

**Box 3.17 Developing a local market for reusing and recycling materials in Ferrara**

The LIFE+ project LOWaste in Ferrara is developing a circular economy based on prevention, reuse and recycling of waste through public–private partnerships. Starting from some pilot tests it is creating the foundations for a green circular economy.

The main objective is to reduce urban waste by developing a local market for recycled or reused materials. Measures are focused on:

- *The supply side:* The objective is to create a market by collecting and adding value to recyclable waste. Technical protocols have been established on waste management procedures, on the characteristics of products for reuse and on eco-design innovations.
- *The demand side:* The objective is to create demand through green public procurement policies in public bodies and green buying procedures in companies. The demand side is strengthened through the development of LOWaste technical protocols that include quality criteria for second-life products in green public procurement and green buying quality criteria for second-life products.

The project aims to persuade at least 10 companies to commit to purchasing products to be reused and will involve at least three social cooperatives, giving disadvantaged people the opportunity to learn technical skills.

**Source:** http://www.lowaste.it/ (accessed 20 November 2015).

**Box 3.18 The swap market — Byttemarked**

The swap market stops used products such as toys, films, electronics and clothes ending up as waste. It prolongs products' lifespan and gives them new value. It is a grassroots innovation initiated by and for local citizens.

The non-profit organisation Byttemarked works as a facilitator for swap markets in Denmark. The swap markets are mainly arranged by volunteers. At the start, the idea was to set up a user collaboration without involving money, but to make it economically sustainable the organisers have applied to committees and communities for funding.

The platform Byttemarked facilitates the arrangement of a swap market by providing advice, experience and help to find location. On the web page there is contact information and guidelines on how to arrange a swap market. It also provides a calendar for upcoming swap market events.

**Source:** http://www.byttemarked.nu/ (accessed 25 July 2014).

types of initiative tend to be entirely self-generating and self-financing.

Flea markets and car boot sales also provide people with the opportunity to pass on their unwanted but undamaged items rather than allowing them to become waste. Local authorities can help facilitate this type of selling by including such events in facility schedule planning and making them available.

Second-hand shops also provide an excellent outlet for certain types of goods. Clothes and books, for example, are both ideal for the second-hand market, as they tend to be discarded long before their functional lifetime has expired.

***Swapping***

More or less formal swapping networks and events also provide an excellent way of satisfying the need for different products without needing to buy new and having to bin the old. These tend to be self-generating and self-funded (although little finance is really required — often only a venue if an event is being held). Some examples (e.g. Danish Swap Thing) shows that a significant amount of waste can be prevented through this type of activity.

Less formal examples of swapping networks include the establishment of a swap room in the waste facility of apartment buildings, where items can be left for others to take if they so wish. Online versions have also had limited success, but are in direct competition with direct peer-to-peer selling.

**Box 3.19 Vienna Repair Network**

The Vienna Repair Network was established to strengthen repair services and offer an alternative to disposal by developing sustainable consumption and repair services for different kinds of electrical and electronic equipment. The network comprises about 60 small enterprises that, under the umbrella of the network, drive an economically sustainable business.

The initiative has both social and environmental objectives, such as to help the community to repair rather than buying new goods, to help long-term unemployed and older people to reintegrate into the job market, and to give low-income households access to good-quality second-hand household electronic items.

The repair network offers good-quality repair services for a variety of electronic appliances and other household equipment, such as furniture and bicycles. By offering good-quality services and guarantees for the life of the repaired products, the network has been successful in attracting many customers and the attention of large percentage of the population in Vienna and beyond. A major strength of the initiative is its flexibility, which allows it to meet consumers' changing demands.

The repair network is becoming increasingly popular and serves more than 14 000 customers every year. A representative brand recognition survey resulted in 24% name recognition in Vienna. Since 1998, more than 10 000 tonnes of WEEE have been prevented from going to landfill. It is estimated that the lifetime of electric equipment is extended by 25% and the average household saves about EUR 75 per appliance. The network has also created a repair 'industry' in Vienna, which promotes the local economy and creates added value. It has also launched its own eco-design label for household appliances.

**Sources:** http://www.reparaturnetzwerk.at and http://www.prewaste.eu/index.php?option=com_k2&view=item&id=272&Itemid=101 (accessed 20 December 2013).

**Box 3.20 Repair and reuse centre in the city of Graz**

A repair and reuse centre in Graz brings together all reuse activities, namely the acquisition, treatment (repair) and sales of items, in the same place. The centre deals with reusable electrical and electronic items and other non-hazardous reusable products such as furniture, textiles and accessories. Items come through direct delivery by citizens, direct collection from households and companies and a house-clearing out service. The items are first stored then sorted by reuse experts and checked and repaired. Materials that are not suitable for reuse are reserved for the upcycling laboratory. As the functioning of the repair and reuse centre depends on the general public as customers, a professional promotion campaign, including the development of a brand and a marketing plan, has been undertaken. The broad awareness-raising and promotion campaign was launched via regular events, the website, posters, flyers and newspaper announcements and a press conference.

**Source:** R4R, 2014.

***Fixing***

Improving the reliability and quality of second-hand goods is key to developing a sustainable formal market for them. This is particularly true for items such as furniture and electric and electronic appliances, and it allows a potentially larger range and number of second-[hand items to re-enter the marketplace. While this used to be, and still is in many locations, achieved by the informal sector, some initiatives have been launched in recent years to provide a more coordinated and formal approach to repairing used items for resale. These often provide certification or a guarantee for a product for a fixed period and a recognisable brand to reassure customers. They also often work as both repair workshops for broken goods (where one can take a broken item for repair) and as a resale point for items that have already entered, or would otherwise enter, the waste management system.

While these initiatives do generate revenue, they also tend to require some form of financial support from municipalities or regional government. This is often justified by the inclusion of other social goods in the initiative concept, for example, the employment of long-term unemployed or those with a minor disability or impairment.

As with many waste prevention initiatives, repair workshops and repairing for resale require a high population density to function effectively, and so are ideally suited to urban areas.

***Repurposing and upcycling***
It is also possible to create new products from discarded products, both within the product group and in other product groups. This can include, for example, the use of potential waste items as inputs for art and cultural activities in schools or other institutions or interest groups. Another example is the use of clothing to create new clothing rather than breaking down the clothes into textiles and using that as input material, which would be more akin to recycling. This type of initiative creates new designs from old clothes (e.g. the Upcycling Academy in London explores textile waste, upcycling and introduces people to better fashion industry practices ([99])). Clothes are not a minor challenge. According to a WRAP report, 30% of the clothing hanging in the closet of an average United Kingdom household has not been worn in a year and 80% of people own clothing that has never been worn. It is estimated that the average global footprint of a United Kingdom household's clothing exceeds 200 000 litres per year (WRAP, 2011). Over 90% of the water footprint of the clothes bought in the United Kingdom is overseas, often in countries where there is water stress and scarcity.

### *3.1.7 Recycling waste from construction and demolition*

Housing represents a significant amount of the total material flows. Around 22% of the total European material flows are directly related to housing and, when furnishing and household appliances are included, the share rises to 38% of the European resource use (EEA, 2012a). About 857 million tonnes of construction and demolition waste was generated in 2010 in the EU-27 (1 708 kg per capita) with large variations between the EU countries ([100]). The composition of construction and demolition wastes varies greatly. The European Concrete Platform ([101]) estimates the amount of concrete waste to be around 320–380 million tonnes ([102]).

**Box 3.21 Examples of good practice in national waste prevention programmes**

**Austria: 'Building material passes'**
The Austrian waste prevention programme contains a bundle of measures related to 'building material passes' as a planning instrument to support repair, reuse and high-quality recycling in the construction sector. The plan is to develop standards for these building passes and to incorporate core information into the central building register run by Statistics Austria. In future, the details of the material composition and the contents of potentially hazardous substances will also be recorded.

**Hungary: Coordinating body for prevention of construction and demolition waste**
Following a significant increase in construction and demolition waste over the last 10 years in combination with a rather low recycling rate, the Hungarian waste prevention programme will create a coordinating body for the prevention of construction and demolition waste. The main purpose of this new institution will be to support research and development activities in the field and to exploit synergies between different ongoing research projects more efficiently.

**Finland: Environmental classification system for buildings**
In Finland, the waste prevention programme promotes aspects of waste prevention and material efficiency in the construction phase of new buildings by applying an environmental classification system. The aim is to put an increased emphasis on building convertibility, durability of structures, prevention of water and module damage, and the updatability of building automation when designing, constructing and supervising buildings.

**Wales: Agreement on the use of recycled materials in buildings**
The Welsh Government will encourage designers and architects to design for the end of life of buildings. This will ensure that materials used in the construction contain a high percentage of recycled materials and that, throughout the life of the building, the materials can be either reused or recycled. This agreement aims to raise awareness of the importance of the end of life of buildings and to create a market for material-efficient construction and recycled materials and products (p. 52).

**Source:** EEA, 2014c.

([99]) http://fabrications-hackney.blogspot.dk/2012/10/the-upcycling-academy.html (accessed January 2014).
([100]) ETC/SCP, 2013, *Housing assessment*, Final report, ETC/SCP Working Paper No 4/2013: http://scp.eionet.europa.eu/publications/wp2013_4/wp/wp2013_4 (accessed 1 March 2015).
([101]) http://www.europeanconcrete.eu/ (accessed 20 November 2015).
([102]) BIOIS, ARCADIS, IEEP, 2011, Service contract on management of construction and demolition waste — SR1, Final report: http://www.eusmr.eu/cdw/docs/BIO_Construction%20and%20Demolition%20Waste_Final%20report_09022011.pdf (accessed 5 December 2012).

Concrete, aggregates, bricks, tiles and asphalt are the main recycled materials from all construction and demolition waste, while soil recycling plays a large role in some countries. Materials used for building houses (concrete, bricks and tiles), are specifically targeted by the recyclers, creating a market for these materials. Road construction, recycled concrete aggregates and civil engineering applications, all of which use mainly aggregates, are the main users of all construction and demolition waste. In the Netherlands, 93% of recycled construction and demolition is used in road base construction (ETC/SCP, 2013).

The recycling of concrete aggregates, whereby the waste is crushed and used as inert aggregate material in new concrete, is the most relevant application of recycled construction and demolition waste for housing. Gypsum products such as plasterboards and blocks can also be counted among the very few construction materials for which 'closed-loop' recycling is possible.

**Box 3.22 The recycling of plasterboard waste**

Plasterboards and blocks are made of gypsum, an abundant mineral rock commonly found in the earth's crust. Gypsum powder ([103]), is a natural substance that can be restored to its original rock-like state by the addition of water, formed into shape and hardened. Gypsum products can be counted among the very few construction materials for which 'closed-loop' recycling is possible, that is, where the waste is used to make the same product again. Gypsum can be reused because the chemical composition of the raw material always remains the same in the application and in the raw material.

The largest market for recycled gypsum is incorporation into new plasterboard. Recycled gypsum, as with virgin gypsum, can also be used for cement manufacture and road construction, as a soil improver and stabiliser or as a replacement for clay block manufacture.

The gypsum industry, gypsum recyclers, demolition companies and universities are engaged in the GtoG project ([104]), which aims to develop more recycling of gypsum.

The recycling route involves demolishers, recyclers and manufacturers. With non-regulatory government incentives, recycling can be organised on a private basis (e.g. Belgium, the Netherlands and the United Kingdom). It can also be pushed by manufacturers (e.g. France) who see recycling as the gypsum source of the future. Cities and regions have a key role in implementing recycling, as collection and sorting centres for household plasterboard waste should be carried out at municipal level (e.g. Denmark is a good example of organising this type of collection).

Deconstruction is a key step in the feasibility of waste recycling. To properly manage construction and demolition waste during construction works, separation and selection of recyclable wastes must be done on the construction and demolition sites. In the countries usually practising deconstruction (Belgium, France, the Netherlands, the United Kingdom), plasterboard is stripped out on site by hand and undesirable materials are removed on site (e.g. screws, nails, cables, various plastics). A cost–benefit analysis of deconstruction in Paris (a refurbishment operation in 2000 ([105]) shows that dismantling is cost-effective.

In Europe the recycling route is mature only in Belgium, France, the Netherlands, Scandinavia and the United Kingdom. The average reincorporation rate in plasterboard for the four countries/regions is 19%. The gypsum waste re-incorporated includes production waste and construction and demolition waste. In the other countries considered in the project (Germany, Greece, Poland and Spain ), only around 5% of the gypsum waste produced is re-incorporated.

For successful re-incorporation in the manufacturing process and to avoid impacts on human health (e.g. traces of heavy metal), manufacturers will only accept a certain quality of recycled gypsum that can be re-incorporated during the manufacturing process. The cost of recycling is more or less equal to the cost of landfilling, depending on the landfill costs of each country ([106]).

**Source:** http://gypsumtogypsum.org/ (accessed 20 July 2014).

([103]) Hydrated calcium sulphate.
([104]) The GtoG is a Life+ project involving 17 partners and co-financed by the EC, Environment Directorate-General. It spanned 3 years, starting in January 2013 and ending in December 2015. Website: http://gypsumtogypsum.org/ (accessed 20 July 2014).
([105]) Life11 ENV/BE/001039: Deliverable 1 of the GtoG project — report-inventory of current practices for dismantling, recycling and re-incorporating recycled gypsum in the manufacturing process.
([106]) Life11 ENV/BE/001039: Deliverable 1 of the GtoG project — report-inventory of current practices for dismantling, recycling and re-incorporating recycled gypsum in the manufacturing process.

## 3.2 Harvesting and producing

Cities rely on imported energy, water, food and materials. However, urban areas could sites of production instead of consumption of resources. Primary resources, such as rain, sunlight and water, can be captured and harvested. Secondary resources, such as organic waste or wastewater, can be captured and reused. As cities grow and urban delineations blur, the potential for them to be productive places is increasing. Some researchers are studying the feasibility of self-reliant cities, reaching net productivity by combining reduction of consumption, reusing, recycling, harvesting and production possibilities mainly for energy, water, and food.

Decentralised renewable energy production at city and regional levels can be provided by wind power, biomass production, solar rooftop installations and biogas production. Besides the more commonly used renewable energy sources such as solar energy or geothermal energy, there are many other sources of energy at the local scale that should be explored. For example, the city of Paris launched a call for contribution that was open to all citizens to identify the energy potential of its territory: heat generated by data centres, the coolness of quarries, rainwater, pedestrians' kinetic energy and heat from bakery ovens or underground stations, and as many others as can be imagined (EnergyCities, 2013). All this information will be the foundation for local energy action plans. In addition, cities can play a key role in developing appropriate measures to require property developers to adopt best practice and to encourage their tenants to save on energy bills and to reduce GHG emissions.

Cities need a large amount of food provided from outside the city limits and increasingly from the global hinterland. For example, London has a surface of around 159 000 ha, but it requires over 50 times ([107]) its own surface area to feed it. Some cities have developed food strategies, such as Amsterdam — the 'Proeftuin Amsterdam' — that aims to create a more environmentally friendly food chain that will benefit urban and rural dwellers alike ([108]). Many examples demonstrate that is possible to develop urban agriculture within and around cities and towns and to market the products. Urban and peri-urban agriculture is seen by some authors as an efficient way of feeding cities and an important component of urban living (Girardet, 2010).

Most cities depend on water imported from their hinterland and sometimes from afar. However, water can be harvested in cities. The harvesting begins at the building unit, because that is where the major consumption occurs; then the harvesting needs to be organised at the block level and neighbourhood to city level (Agudelo-Vera et al., 2012).

### *3.2.1 Local energy production*

Cities have to create agreed long-term strategies to frame their energy transition and ensure its viability and execution, independently of the elected party. In this way, long-term investments will ensure the promotion of renewable production in cities (whatever the means: solar, wind, geothermal energy, waste incineration, biomass).

A mix of sources of energy makes it independent of availability and provides stability to the system and security for the energy supply. There are many potential combinations of photovoltaic solar panels, wind farms, biogas plants, wood-fired boilers, district heating systems, cogeneration or combined heat and power plants, and geothermal heat pumps. Local electricity production with renewable energy sources and with distributed energy generation is a step on the way to self-sufficient cities that are strongly dependent on the local energy sources. Combined heat and power

**Box 3.23 A cooperative for producing renewable energy**

A REScoop (Renewable Energy Sources Cooperative) is a group of citizens who cooperate in the field of renewable energy, developing new production, selling renewable energy or providing services to new initiatives, with the aim of speeding up local renewable energy projects in order to achieve the European 20-20-20 energy targets through the direct involvement of citizens. More than 400 local and regional groups and cooperatives of citizens have already developed projects.

**Source:** http://www.rescoop.eu (accessed 20 November 2015).

([107]) http://www.worldfuturecouncil.org/fileadmin/user_upload/PDF/Towards_Regenerative_Cities_web_01.pdf (accessed 20 January 2015).
([108]) The Amsterdam Food Strategy: http://ec.europa.eu/regional_policy/archive/conferences/urban_rural/2008/doc/pdf/6a_iclei_amsterdam.pdf (accessed 20 February 2015).

and district heating and cooling have been proven to be cost-effective because of their enhanced energy supply efficiency and use of waste heat and low-carbon renewable energy resources (IEA, 2009). District heating takes advantage of local energy production and economies of scale.

Producing energy closer to consumers is a way of minimising the effects of distribution losses by reducing the length of power lines. Moreover, investing in local energy production also keeps the money spent on energy consumption in the territory that is served.

In Europe, depending on the country, local authorities may or may not be directly responsible for the energy supply in their territories. In Scandinavian and federal countries, municipalities are responsible for their territories' energy supply and set up local energy utilities to do this. This contributes to developing a sense of responsibility among local authorities, while providing them with a source of income ([109]). In other western, eastern and southern European countries, local authorities do not have such power or responsibility Some cities own their energy networks and are allowed to build heating networks, even using combined heat and power. However, large energy companies always have the upper hand and get all the added value.

Some cities and towns have their own municipal energy company, like the town of Montdidier (around 6 500 inhabitants), in France. In other cases, citizens' cooperatives take the role of distributing renewable energy, such as the earliest Schönau cooperative founded in 1999 in Germany, or more recently SomEnergia ([110]) in Spain. However, this is not the usual situation, especially in southern countries, where local authorities do not have the power to decide what type of energy is supplied in their territories. In some of these countries, a state monopoly has evolved into private oligopolies or monopolies (EnergyCities, 2014b). Moreover, in this context, when these powerful companies' and local authorities' interests are not heading in the same direction, such an organisation becomes an obstacle to defining local energy efficiency strategies. On the contrary, in countries where local authorities have control of the energy supply, innovation, mobilisation of local resources and combined heat and power development are clearly forging ahead, as is the case in Scandinavian countries (EnergyCities, 2014b) and seen at its best in Växjö (Sweden), with a project that aims to make it a '100% fossil fuel-free' city.

**Box 3.24 Ambitious goals are achievable, even for a medium-sized city**

The 'ProjectZero' vision of the city of Sønderborg is to achieve carbon dioxide neutrality by 2029, including the emissions attributable to citizens. The project is mainly based on a combination of energy efficiency improvements, conversion of energy sources to renewables and creating a dynamic energy system with flexible pricing. 22% of the carbon reduction had been achieved by 2012 (baseline 2007 comparison), and the next milestone is focused on achieving a 50% carbon reduction by 2020 (Ministry of Housing, Urban and Rural Affairs and Danish Energy Agency, 2014).

A public–private partnership, the ProjectZero Company, was created from industry ([111]), the national energy company ([112]), regional utility companies ([113]), banks ([114]) and the municipality. The objective was to assist stakeholders in planning activities, drive stakeholder participation, implement solutions, and monitor the impact on climate and society. Strong stakeholder participation has been developed in the process of transition, including citizens, corporations, utility companies, schools and universities.

Cross-sector planning for energy and climate has been developed. The potential for utilising local resources has been analysed and an energy policy strategy was elaborated in 2008. Today energy and climate considerations are an integral part of municipal long-term planning.

The planning crosses municipal borders. Strong regional cooperation among clusters of adjacent municipalities has been developed to coordinate their energy and climate actions in order to optimise solutions.

**Source:** Ministry of Housing, Urban and Rural Affairs and Danish Energy Agency, 2014.

([109]) http://www.energy-cities.eu/wiki/index.php/Proposal_1.1 (accessed 1 March 2015).
([110]) http://www.somenergia.coop/welcome-to-som-energia (accessed 1 March 2015).
([111]) The Danfoss Group.
([112]) DONG Energy, formerly Dansk Olie og Naturgas.
([113]) Sønderborg Heat Company.
([114]) The Nordea Bank Foundation.

External factors should be incorporated into the costs of producing and distributing energy, following the 'polluter–payer' principle. In this way consumers become more aware and take responsibility for their choices and the consequences. It is also important to include investment decisions made by local authorities, especially those related to new infrastructure, likewise accounting for the operating and maintenance costs. Both producing energy locally and applying resource efficiency measures will increase local savings. This is a good opportunity for investing in sustainable projects within the urban context that can improve resource efficiency of the city in a positive loop.

Energy efficiency investments are most often cost-effective, but the execution of those projects can be impeded by financial and regulatory barriers (EC, 2011d). Solid financial structures must be consolidated by local authorities, together with innovative solutions to facilitate investment in cost-effective measures.

### *3.2.2 Producing heating and power*

District heating is not a new technology; for example, the first combined heat and power plant in Denmark was built back in 1903 (Danish Energy Agency, 2013). In some countries, district heating is a very important part of the heating supply. In Finland, in 2011, approximately half of the population was served by district heating (IEA, 2013). The European Energy Efficiency Directive calls for an assessment of the potential for increasing deployment of this technology (EU, 2012).

A district heating system comprises a network of insulated pipes used to deliver heat, in the form of hot water or steam, from the point of generation to a large number of individual buildings or houses. This system can be adapted to a large variety of energy central sources such as gas, biomass and waste. The extent of a network can be readily extended by simply adding more providers of heat, or 'heat sources', along the way. District heating is often combined with a cooling system that distributes cold water to buildings in need of cooling in summer. The coolant is supplied through a coherent system of pipes, similar to the existing system for the distribution of heating.

A district heating plant is also often a combined heat and power plant that is also commonly referred as cogeneration. By co-producing heat and power in the same process, the heat that would otherwise be wasted in electricity production is utilised. Thermal power plants achieve a conversion efficiency of 36% compared with 58% for cogeneration (IEA, 2014). State-of-the-art cogeneration units can reach conversion efficiencies of as much 90% (IEA, 2014). In 2011, in Finland, combined heat and power accounted for about 36% of the country's overall electricity generation (IEA, 2013).

**Box 3.25 The London Energy Master Plan**

Currently, electrical power in the United Kingdom is generally supplied from a relatively small number of very large power stations, most of which are in remote locations away from population centres. This approach creates a variety of inefficiencies in the overall energy system, of which the greatest is the inability to use the waste heat from power stations for beneficial purposes. By locating a generating station close to where the energy is used, decentralised energy offers the potential for the waste heat to be captured and distributed to buildings or industrial processes that need it.

The objectives of the current mayor's Climate Change Mitigation and Energy Strategy are to achieve a reduction of 60% in London's carbon dioxide emissions by 2025 and to ensure that 25% of London's energy is delivered through a more efficient decentralised energy system by 2025. The decentralised energy — the generation and distribution of energy closer to the locations where energy is consumed – is seen as 'low and zero carbon power and/or heat generated and delivered within London.'

In the Decentralised Energy Master Planning (DEMaP) programme, opportunities for new networks in an area are identified in order to set out a long-term vision for district heating developments (Mayor of London, 2013). This definition covers a wide range of technology and scales, from single building schemes using microgeneration technologies to wide-area schemes connected to local power stations and large energy centres serving thousands of customers.

The programme is focused on delivering decentralised energy at a scale that is sufficient to maximise market competitiveness. Even small projects have to be designed from the start to enable their growth and connection into larger systems in order to operate efficiently.

**Sources:** London Borough of Haringey, 2012: https://www.london.gov.uk/priorities/environment/tackling-climate-change (accessed 1 March 2015).

***Managing the off-peak period***
Heat accumulators can be used to store heat during off-peak periods and supply heat at times of peak heat demand, reducing the total installed capacity of plant required. By storing the heat generated, they can be used with combined heat and power plants to allow electricity generation when the demand for heat is not high.

For example, to optimise the district heating of Copenhagen, two accumulator tanks (with a total capacity of 44 000 $m^3$) collect any surplus hot water and keep it in reserve for times of the day when demand is the highest (Metropolitan Copenhagen Heating Transmission Company, 2012). Without heat storage, heat production is governed by the present heat demand. However with heat storage, the cogenerated heat can be stored and the plant can operate when there is a low demand for heat. In the case of Copenhagen, there is also a balancing measure to integrate a high proportion of renewable wind energy into the supply, as the velocity of the wind is always fluctuating (Sievers et al., 2006). With the introduction of renewable energy there is a need for a more flexible energy system — a smart grid — that provides the optimum balance between energy generation and energy consumption.

***Controlling emissions***
District heating and cooling networks provide environmental benefits. They replace small uncontrolled sources of air pollution with a fully controlled central source. They use energy more efficiently (IEA, 2014), in particular they allow waste heat to be used. They can use a variety of fuels and benefit from local carbon-free energy sources such as solar thermal heat or waste heat recovered from industrial processes that can be injected into a district heating network or converted into cooling capacity using absorption chillers. Natural cooling sources, such as water from lakes, seas and rivers, can also be used ([115]) — for example, Copenhagen uses seawater (Copenhagen Cleantech Cluster, 2012). Owing to their energy efficiency, they provide opportunities for the deployment of renewable technologies that otherwise would not be viable. They can also operate as energy-balancing tools by incorporating other technologies such as heat pumps and thermal storage capacity. District heating is a basis for cooperation among city governments (e.g. the Metropolitan Copenhagen Heating Transmission Company is a partnership of the municipalities of Frederiksberg, Gentofte, Gladsaxe, Copenhagen and Tårnby), utility companies, industry, building owners and residents. District heating and cooling networks also stimulate developments in the field of energy planning and management. Generally, they have lower costs of energy generation and reduced maintenance costs compared with individual systems. To facilitate investment to improve existing district networks and to develop new networks, it is important to ensure the long-term stability of policies and market regulation to secure investments (IEA, 2014).

***The social dimension***
However, district heating may have social consequences if it is not properly managed. Energy poverty can be associated with district heating due to disproportionately high heating costs (Tirado Herrero and Ürge-Vorsatz, 2012). Consumers are trapped in the system and obliged to pay elevated heating costs. First, consumers cannot change their supplier or fuel type because of technical and institutional constraints. Second, they cannot significantly reduce their heating costs through individual efficiency improvements. Many cities are threatened with bankruptcy as a result of district heating debts (IEA-OECD, 2004). In many cases, rehabilitating ageing district heating systems is economically viable because district heating has comparative advantages in urban areas with cold winters. However, careful city-specific economic analysis is needed before new investments are made.

***The specificity of Nordic cities***
Districts heating plays an important role in the energy supply strategy of cities with cold climates in eastern Europe and the Nordic regions. Most cities focused on ambitious low-carbon objectives have developed district heating and incorporated a high proportion of renewable energy in the system. They vary in size depending on the scale of the city served and the local climatic conditions. In 2011, more than three-quarters of Swedish district heating systems were small-scale systems with an annual district heat production of less than 100 GWh heat per year (Truong and Gustavsson, 2014). In contrast, some district heating systems serve a large number of buildings (e.g. the main networks: Warsaw, Bucharest, Berlin, Copenhagen, Stockholm, Helsinki, Paris, Vienna, Hamburg, Prague, Sofia, Gothenburg).

***Smart thermal grids***
A smart thermal grid is a way of developing a heating system that is more flexible, reliable and efficient. Smart thermal grids can be distinguished from conventional district heating by their greater energy

([115]) The use of natural cooling sources will need to comply with local environmental regulation and required impact assessments.

**Box 3.26 From consumer to 'prosumer'**

In June 2012, a project to transform Kalundborg into a smart city was launched. Behind the project is the municipality of Kalundborg, the Danish Energy Association and a private smart grid company.

The project aims to turn energy distribution in Kalundborg into an open platform. This means that the city's energy system will be able to incorporate solar energy, wind, biogas and many other sources, and that citizens will be able to choose from a range of different energy solutions.

This approach will make the citizens of Kalundborg 'prosumers'. They will be involved as consumers of energy, but also as suppliers of electricity back into the energy grid. Citizens will be able to control the time at which their electrical devices are recharged (e.g. electric cars can be recharged at times when there is surplus energy or at times when there is low pressure on the electricity network).

In order to ensure optimum exploitation of the various energy sources without any negative impact on the stability of supply, suppliers are collaborating on intelligent consumption management. If the energy from wind power is unstable because of a lack of wind, the missing power in the electricity grid will be counterbalanced by decentralised energy installations and through intelligent consumption management. Furthermore, the consumption management system will also exploit surplus heat in the heating network to achieve a balance without overloading the transmission system (Copenhagen Cleantech Cluster, 2014).

**Sources:** www.kalundborg.dk (accessed 20 November 2015); www.spirae.dk (accessed 20 August 2014).

efficiency through making wider use of all types of energy sources (combined heat and power systems, all types of renewable energy — including small-scale installations and those utilising industrial waste heat, waste incineration and geothermal, biomass and solar thermal resources), including decentralised electricity generated from renewable sources that can result in an unpredictable supply of electricity (Smart Cities — Stakeholders Platform, 2013). Smart thermal grids can adapt to changes in supply and demand and facilitate the participation of end users, for instance by supplying heating or cooling back to the network. They also allow maximum exploitation of available local energy resources through cascade usage and therefore contribute to improving the efficiency of urban heating and cooling.

The smart thermal grid can range from neighbourhood to city level. The grid needs to be spatially integrated into the whole urban energy system and interact with other urban infrastructure such as networks for electricity, sewage, water and ICT. State-of-the-art solutions have already been developed in some cities (e.g. Heerlen and Delft in the Netherlands, Sunstore 4 in Marstal, Denmark, the geothermal district heating in the Paris basin, Gothenburg in Sweden).

### *3.2.3 Urban water harvesting*

Rainwater harvesting systems provide water close to where it is used. Systems can be owned by the consumer or operated and managed by utilities. Rainwater can be collected on existing infrastructures (e.g. rooftops, parking lots, playgrounds, parks, ponds, flood plains, etc.). There is no negative environmental impact compared with other technologies such as water recycling and reusing. Rainwater is relatively clean and the quality is usually acceptable for many purposes with little or even no treatment (UNEP, 2004).

There are multiple benefits in rainwater harvesting. Besides avoiding drinking water being used for, for example, flushing toilets, the diversion of rainwater for use becomes an increasingly important advantage of rainwater harvesting. This means a reduction in the rainwater finding its way into the sewerage system during rainfall, cutting the peak load and avoiding overloading the system, which might result in flooding in city streets and serious health problems. Rainwater harvesting can co-exist with other water sources and utility systems and can provide supplementary water in the event of water crisis (e.g. the water crisis in Barcelona). Moreover, rainwater harvesting technologies are flexible and their construction and maintenance are not labour intensive.

Even if urban areas consume far more water than is available within their own city limits, they can still provide part of their water requirement. For example, the suburb Stenløse Syd, in the municipality of Egedal in Denmark, consists of 750 dwellings. Around one-quarter of the water needed is provided by rooftop collection of rainwater while the remainder is imported from the public water supply (Rygaard et al., 2011). To meet future needs, the reliability of urban water supplies rests more and more on improvements in resource efficiency, focused on the management of demand, the multi-sourcing of resources (including urban harvesting) and reallocation of water among users.

Collecting rainwater is relatively easy and cost-efficient, although rainwater systems may not provide as much mains water saving as greywater systems, as they are dependent on local rainfall patterns, catchment size and size of rainwater collection tanks. The main uses are toilet flushing and watering of gardens, taking into account that plants prefer rainwater to tap water.

The users of rainwater are usually the owners who operate and manage the catchment system; therefore, they are more likely to conserve water because they know how much water is in storage, and they will try to prevent the storage tank from drying up.

In Europe, Germany is the leading country in terms of rainwater harvesting, and developments can also be found in Austria, Belgium, Denmark and Switzerland, whereas in the southern European countries, such as Greece, Italy, Portugal and Spain , there are few initiatives in that regard.

**Box 3.27 Water harvesting in Berlin**

The well-known flagship example of the Daimler Chrysler Potsdamer Platz Project demonstrates the importance of integrating all aspects of urban sustainability from the very start of the planning process, such as energy-efficient buildings and a water management system. Since 1998, rainwater utilisation systems have been used in Berlin as part of large-scale urban redevelopments to control urban flooding, save water and create a better microclimate.

Rainwater falling on the rooftops (32 000 $m^2$) of 19 buildings has been collected and stored in a 3 500 $m^3$ rainwater basement tank. It is then used for toilet flushing, watering of green areas (including roofs with vegetative cover) and the replenishment of an artificial pond.

In another project at the Belss-Luedecke-Strasse estate in Berlin, rainwater from all roof areas (with an approximate area of 7 000 $m^2$) is discharged into a separate public rainwater sewer and transferred into a cistern, together with the runoff from streets, parking spaces and pathways. The water is treated in several stages and used for toilet flushing as well as for garden watering. The design of the system ensures that the majority of the pollutants in the initial flow are flushed out of the rainwater sewer into the sanitary sewer for proper treatment in a sewage plant.

It is estimated that 58% of the rainwater can be retained locally through the use of this system. Based on a 10-year simulation, the savings of potable water through the utilisation of rainwater are estimated to be about 2 430 $m^3$ per year, thus preserving the groundwater reservoirs of Berlin by a similar amount.

These systems not only conserve the city's water but also reduce the potential for pollutant discharges from sewerage systems into surface waters that might result from storm-water overflows.

**Source:** UNEP, 2004; Schmidt, 2008.

**Box 3.28 Rainwater harvesting in the metropolitan area of Barcelona**

After suffering recurrent droughts threatening the domestic water supply between 1999 and 2008, around 40 municipalities of the metropolitan area of Barcelona area approved water-saving regulations to promote the use of local sources such as rainwater, greywater and groundwater. Their building codes mandate the installation of rainwater harvesting systems in new buildings and offer subsidies to households installing rainwater harvesting systems on their own initiative.

A study in the municipality of Sant Cugat del Vallès shows that, despite low precipitation and a high variability in precipitation in the area, the water demand for toilet flushing of a single family house can be practically met with a relatively small tank. Rooftop rainwater can also meet more than 60% of the demand for landscape irrigation in both single- and multi-family buildings.

The main drawback is the long payback period of rainwater harvesting systems.

**Source:** Domènech and Saurí, 2011.

### 3.2.4 *Urban food production*

The daily basic need for food is met almost exclusively from importation. Every day, large amounts of food are brought into urban areas from the hinterland, often from a considerable distance. Production and consumption are more and more separated by physical distance. The production and supply chains become more and more specialised and separate. The place of production loses its influence on the quality and nature of products (except for some products for which quality is very important).

The issue of food is generally regarded as both an agricultural and rural issue and a regional-national-international issue. The urban food system is less visible than other urban systems (e.g. transport, housing). However, despite its low visibility, the urban food system contributes significantly to community health and welfare, to the metropolitan economy and to the impact of urban areas (e.g. land use, retailing and food distribution systems rely on motorised transport and, increasingly, on airfreight).

Most cities cannot be self-sufficient in food and a local food supply can be one of the sources but not the only one. Many cities are considering reviving agricultural production in urban areas or on the urban fringe to reduce their urban footprint, in particular the demand for land for their sustenance on the global scale. Urban and peri-urban agriculture is considered to be one additional source of food and become an important driver for many other urban policies such as health, nutrition, education, planning, social cohesion, economic development, transport, environment, and waste and water management.

Urban agriculture can be defined as the production, processing and distribution of edible agricultural products through intensive crop cultivation and animal husbandry in urban and peri-urban areas, in response to the daily demand from consumers in the city or metropolis. Food production inside and around cities can take many forms: farms, market gardens, orchards, backyard poultry production, home gardens, community gardens, market gardens, school gardens, rooftop hydroponic gardens, windowsill gardens, and aquaculture.

Currently, most city residents *buy* food and do not *grow* it themselves and they have only rare contact with food producers. Not all city dwellers want to grow food themselves but at least they want a supply of fresh and healthy food and to know where it comes from (Deelstra and Girardet, 2000). This generates new ways of marketing such as farmers' markets, vegetable box schemes, community gardens.

A close relationship between the producer and consumers encourages the production of food in a sustainable manner. The benefits of urban or local agriculture are mainly (Grewal and Grewal, 2012):

- a reduction in human impact on the environment (e.g. less freight transport, promotion of organic agriculture, use of storm water if rainwater is redirected to gardens, development of green areas reducing the urban heat island effect, development of composting);
- a change in people's perception of food (e.g. better perception of the seasonal cycle leading to the consumption of seasonal vegetables and fruits, less food waste and improved food literacy ([116]));
- a sense of community (e.g. community gardens cut across social barriers, food-friendly neighbourhoods, alternative food networks reconnecting producers and consumers);
- improved resilience and liveability of the city (e.g. food security, improvement of a poor-quality environment, recreational activities);
- improved access to healthy, fresh and nutritious food (in terms of quality and diversity) and dietary changes (more vegetables are eaten) (Blaine et al., 2010);
- an increase in the amount of physical exercise taken (important in fighting obesity);
- economic benefits (e.g. creation of local jobs through the food sector for producing, marketing, and processing, abandoned lots acquiring new value);
- social justice (e.g. fighting food poverty, provision of affordable healthy food, fairness in the food chain);
- territorial benefits (e.g. connecting the city with the surrounding countryside, preservation of the surrounding agricultural landscapes, maintaining vegetation in cities, city as part of the regional food system).

([116]) Food literacy is the ability to organise one's everyday nutrition in a self-determined, responsible and enjoyable way: http://www.foodliteracycenter.org/ (accessed 24 November 2015).

Until recently, little attention has been paid to the urban food system in urban planning and there has been little provision of space in recent decades. However, it is connected to other urban systems, in particular housing and transport. The food system is often perceived by planners as a rural policy because farms are generally located outside cities and they have not recognised other parts of the food chain, for example, food processing, wholesaling, retailing, consumption and waste disposal (Pothukuchi and Kaufman, 2000). In addition, planners have considered the food system to be dominated by the private sector, thereby limiting their role.

The lack of space available for growing food in cities is seen to be a major obstacle. Access to land for self-provisioning, small-scale growing and commercial activities is a problem that is not simply satisfied by the state owning and controlling land (Reed et al., 2013). However, many cities have experienced industrial decline and vacant lots in derelict areas are opportunities for urban agriculture projects (except if the land is contaminated). In addition, many places can be cultivated, such as roofs, balconies, small areas between buildings, containers on patios, areas waiting for new development and playgrounds in schools. It is mainly a planning and regulation problem at the local level.

However, municipalities play a key role in promoting urban farming and gardening. There is a need to shift the scale from isolated projects to larger scale programmes (e.g. metropolis and city-region scale) including urban and rural areas around cities and many stakeholders ([117]). The food system needs to be integrated into land use planning and city development planning ([118]). To facilitate local implementation, municipalities can support citizens' initiatives by providing places for farming, places for direct marketing, providing training on how to cultivate vegetables, buying the produce for its canteens, providing financial incentives and forming strategic partnerships. They can also work with farmers and retailers commercialise of local produce.

Urban agriculture produces many benefits; in particular, it helps by reducing and recycling waste and wastewater. Food produced locally does not need packaging to protect it for long-distance transport. Organic waste from households can produce compost to fertilise gardens. The use of recovered wastewater for food production can improve water efficiency, in particular in countries with limited water resources. In addition, collective food-growing sites develop a sense of community and social interaction; they can also be the repositories of reusable household waste and places for the promotion of sustainable behaviour. Urban farming and gardening can be associated with environmental training and campaigns or educational programmes on sustainability.

***The urban food strategy***

The urban food strategy is how a city envisages changing its food system and how it strives to achieve this change (Moragues et al., 2013). Urban food strategies embrace various policy domains, including land use planning, health and well-being, environment (water, waste, biodiversity), economy and community development, transport and energy systems, social and cultural development, and education. They consider all the aspects of the food system: production, processing, storage, transport, retail, consumption, and waste. Overall, they are based on holistic approach that strengthen the connection between rural suppliers and urban consumers.

Municipalities can use different instruments to influence the food system:

- *spatial and urban planning* to support short supply chains and diversity of food retailers (e.g. zoning to protect land for urban agriculture and gardening, opening up land around housing for gardening);
- *public procurement* (e.g. more healthy, organic, vegetarian, local, culturally appropriate food);
- *communal infrastructure:* creating facilities that support short food supply chains (e.g. slaughterhouses, storage facilities, food hubs);
- *demand-side policies* (e.g. developing maps indicating where to buy and eat healthy local food, supporting grassroots food initiatives and local networks, delivering advice on gardening, teaching people how to cook vegetarian or seasonally, promoting food growing in schools ([119])).

Integrated urban planning is vital for developing urban farming and gardening, in particular for finding spaces in urban areas. The development of urban farming and gardening can be part of a regeneration process (e.g. Malmö's Policy for Sustainable Development and Food ([120])). Most municipal policies are included; for example, the municipal responsibility for school meal procurement can be a way of reducing GHG emissions (e.g. Malmö).

([117]) http://beras.eu (accessed 20 November 2015).
([118]) http://www.iclei.org/index.php?id=1348 (accessed 25 March 2015).
([119]) http://skolehave.dk/kbhskolehaver/School%20gardens%20Copenhagen.pdf (accessed 25 March 2015).
([120]) http://malmo.se/download/18.d8bc6b31373089f7d9800018573/Foodpolicy_Malmo.pdf (accessed 25 March 2015).

More and more local governments have already developed or are developing a food strategy or specific policies regarding food (often associated with action to reduce food waste) adapted to the local context, for example Amsterdam, Rotterdam, Bristol, London, Brussels Capital Region.

**Box 3.29 Bristol's Food Policy Council**

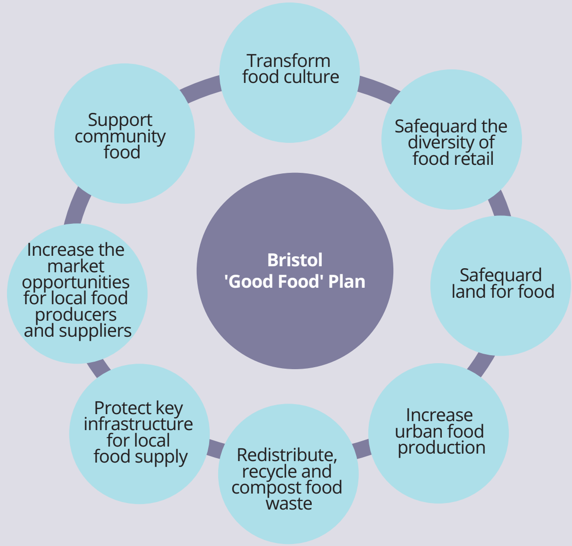
The strong food culture in Bristol is at the same time the cause and consequence of its flourishing 'green' urban civil society.

A Food Policy Council, inspired by Canadian and American examples, has been set up (Moragues et al., 2013). This is a network of stakeholders who investigate food issues at the city level, make recommendations on how to improve it (in particular its connection with existing programmes). It is an independent body including representatives from the local government and a board of local key players. Its role can be summarised as 'validating, influencing, connecting, communicating and creating visibility' of all aspects of the sustainable food agenda (Jegou and Carey, 2015).

The work of the Food Policy Council is based on three principles:

- Good for people: Everyone should have access to information, training and resources that enable them to grow, buy, cook and enjoy good food.
- Good for places: The public and policymakers should support and value food enterprises that promote local jobs, prosperity and diversity and that treat workers well.
- Good for the planet: Food should be produced, processed, distributed and disposed of in ways that benefit nature.

**Figure 3.3 Bristol has designed a Good Food Plan to coordinate its food system**




**Source:** Adapted from Food Policy Council, 2011.

Bristol Food Policy Council, 2011; Moragues et al., 2013.

The Food Policy Council (see Figure 3.4) acts as a hub for information and plays an important role in fostering coordination, building up an important body of knowledge and providing a platform for discussion (Reed et al., 2013).

**Box 3.30 The potential for production in rooftop gardens in Bologna**

In Bologna there are 29 ha of vegetable gardens, about 2.5% of the total public green area of the city: 16 ha are communal gardens, assigned to 2 600 people, while 13 ha represent different types (vegetable gardens in schools, spontaneous gardens, etc.). In 2010, Bologna became the first Italian city to test rooftop vegetable gardens on public buildings as part of a project led by the local authority, the university and a non-profit organisation.

Researchers followed the trial over 3 years between 2012 and 2014, carrying out a study to quantify the potential for rooftop vegetable production in the city. Besides its contribution to the food security of the city, the potential benefits to urban biodiversity and ecosystem service provision were also estimated. They found that rooftop gardens could provide more than 12 000 tonnes of vegetables annually, satisfying 77% of the inhabitants' requirements. The study also advances a hypothesis to implement biodiversity roofs, connecting biodiversity-rich areas across and around the city: these would form a network of green corridors over 94 km in length with a density of about 0.67 km/km$^2$.

**Source:** Orsini et al., 2014.

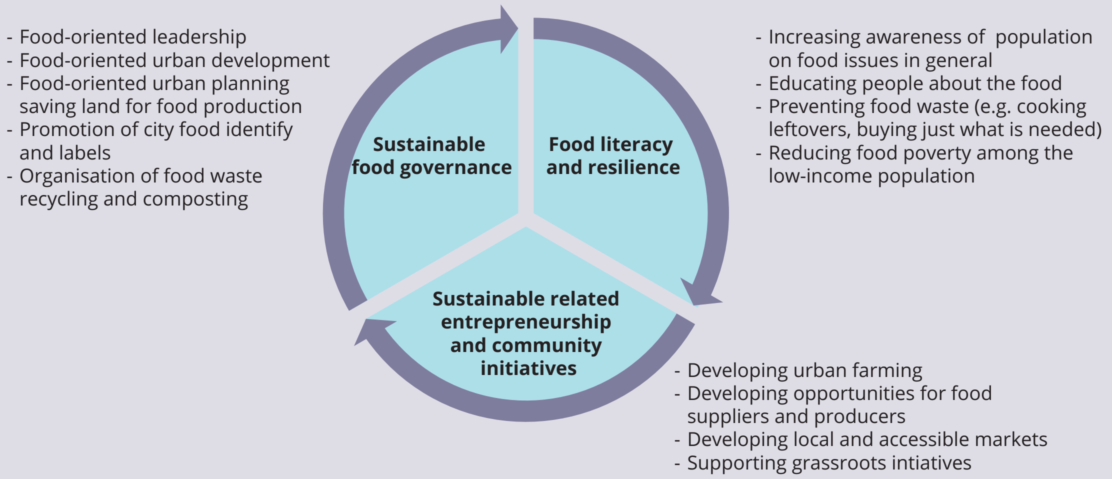
**Box 3.31 Creating space for sustainable food systems in urban communities**

An Urbact thematic network, 'Sustainable Food in Urban Communities', has been created to develop low-carbon and resource-efficient urban food systems. Ten European cities have worked together and exchanged ides for 3 years ([121]). From their experience, a handbook has been prepared that gives examples of promising local practices shared by the partners. It highlights the most powerful policies that cities have at their disposal as:

- procurement policy (the power of purchase);
- urban planning (e.g. increasing the food retail outlets that are accessible by foot, bicycle or public transport, facilitating access to allotments and to agriculture in and around cities, offering community growing spaces and underutilised public and private spaces, recycling food waste);
- collaborative partnership with local business, social enterprises and civil society.

Creating space for food in the city is a governance issue, and therefore a planning issue. To achieve their goals, local authorities have to raise awareness among decision-makers of the strategic dimensions of food in the urban context in order to foster food-oriented leadership and to explore synergies between food and other sectors (see Figure 3.4).

**Figure 3.4 Some opportunities for action at city level**




**Source:** Adapted from Jegou and Carey, 2015.

This project shows that each city has to find its own pathway to improve its food system:

- *Valdemone Messina* promotes 'slow food': a good, fresh and flavoursome seasonal diet based on a system of production that does not harm the environment. Traditional specialities that were no longer produced have been revived and taste ateliers providing an educational sensory experience have been set up.
- *In Amersfoort*, food is grown on temporarily unused land in the city (around 8 ha). The produce find its way to consumers in the city thanks to direct sales and sales to farm shops and a food-purchasing group.
- *In Ourense*, the 'gardens bank' project relies on cooperation between landowners and potential producers (in particular the unemployed). In order to boost suburban food production, the municipality is focusing on the rehabilitation of two traditional markets as 'food hubs'.
- *In Brussels*, a programme encourages residents to grow their own vegetables. Many citizens have a small space in which they can grow herbs, fruits or vegetables at home (balcony, terrace, small garden, pots) but they do not know how to. Tools to help have been developed such as training courses, a network of gardening experts and a grow-your-own kit ([122]).
- *In Athens*, organic farmers' markets have been established to provide access to local and organic food at affordable prices.

**Source:** Jegou and Carey, 2015.

([121]) The 10 cities were Amersfoort (Netherlands), Athens (Greece), Brussels Capital Region (Belgium), Bristol (United Kingdom), Gothenburg (Sweden), Lyon (France), Messina (Italy), Ourense (Spain), Vaslui (Romania), Oslo (Norway).

([122]) A cardboard box containing seeds and guidance.

**Box 3.32 Sustainable urban gardening in Berlin**

In the last decade, urban gardening has become a popular activity in Berlin that has seen an increase in both the number of people participating and the area of land devoted to gardening. The emergence of urban gardening in Berlin started in 2003 with a project on community and intercultural gardens ([123]) that became a pilot project in its Local Agenda 21. Ten years later in 2013, there were around 100 non-commercial garden initiatives ([124]).

Most people involved in urban gardening have an interest in connecting to nature — 'getting their hands dirty' — and sharing knowledge on how food is grown and what to eat. Beyond their individual motivations, many people also have community-centred motivations. They share a desire to influence the quality of life in their neighbourhood, to be involved and to make a contribution through a 'do-it-yourself' approach. Some community gardens are important for social groups such as refugees, ethnic minorities or unemployed persons; the production of food through a shared labour is a way of building friendships and to developing inter-generational relationships.

Based on Berlin's experience, the 7th Framework Programme Solinsa research project identified the key factors in the success of such programmes, such as the availability of land and the supply of temporary land in the future, the relationships forged, and the importance of cooperation between the administration and urban gardening activists.

**Source:** Wunder, 2013; http://www.solinsa.net/ (accessed 20 November 2015).

## 3.3 In a nutshell

Table 3.1 presents the role of citizens, businesses and local authorities in reusing, recycling, harvesting and producing resources in urban areas

([123]) Stiftung Interkultur.
([124]) This category excludes traditional allotment gardens, children farms and school gardens. Urban gardening is also different from urban agriculture, which relates to conventional farms close to the city that are more sales oriented.

**Table 3.1 The role of citizens, businesses and local authorities in reusing, recycling, harvesting and producing resources in urban areas**

| | **Local authorities** | |
|---|---|---|
| | **Supply side** | **Demand side** |
| Land recycling | Elaborating strong integrated spatial and urban planning to create dense and compact cities<br><br>Recycling land for new development (densification) or green areas | Using abandoned land for community gardens |
| Energy recycling and producing | Developing a long-term sustainable strategy (definition of targets, elaboration of the vision)<br><br>Developing cross-sector planning, including the production of decentralised renewable energy<br><br>Recycling thermal losses from electricity and industrial processes (e.g. energy stored in wastewater) through district heating and cooling<br><br>Producing biogas from organic matter (e.g. sewage sludge, food waste, garden waste, industrial waste)<br><br>Developing cogeneration<br><br>Developing decentralised local production of renewable energy (e.g. windmills, biomass)<br><br>Developing a structure to enable the production of renewable energy (e.g. public–private partnership) | Supporting the dissemination of information (household and businesses) on the production of decentralised renewable energy<br><br>Removing legal barriers in order to enable decentralised local production of renewable energy<br><br>Developing dialogue with all stakeholders (e.g. utility suppliers) and end users (households, businesses)<br><br>Organising collection of organic waste for biogas production |
| Water reusing and harvesting | Changing the building code so that rainwater harvesting becomes compulsory in new buildings and in renovations if possible<br><br>Promoting the reuse of greywater in new buildings<br><br>Encouraging the recovery of nutrients from wastewater | Providing guidance for owners and constructors on how to develop rainwater harvesting and greywater reuse systems; developing demonstration pilot projects<br><br>Removing legal barriers |
| Waste: collection, reusing, recycling | Organising efficient separate waste collection in both high- and low-density parts of the city, including waste food<br><br>Developing good conditions for a local market for reusing and recycling materials (e.g. plasterboard waste)<br><br>Collecting garden waste or developing individual composting at source | Supporting grassroots initiatives regarding peer-to-peer selling, swapping and reuse of second-hand goods (e.g. repair services) to make things last longer<br><br>Developing demonstration pilot projects<br><br>Providing information on local initiatives to create demand<br><br>Raising the awareness of citizens of the consequences of hyperconsumption |
| Food system | Facilitating cooperation between retailers to allow bulk sales and reusable containers<br><br>Providing guidance for restaurants and canteens on portion size to reduce food waste<br><br>Integrating the food system into urban planning<br><br>Facilitating access to land for food production (urban farming and urban gardens), including temporary vacant land | Running a communications campaign targeting households (e.g. avoiding food waste, information on seasonal products, promotion of local food production, label information), organising a taste day<br><br>Supporting grassroots initiatives (e.g. teaching people how to use leftovers,, how to grow vegetables)<br><br>Facilitating the distribution of locally produced food by opening a market |
| Organisation and governance | Developing training on resource efficiency for city managers<br><br>Engaging in a participation process with stakeholders (homeowners and home occupiers, all groups of citizens, businesses, non-governmental organisations) | Encouraging the participation and involvement of stakeholders (including researchers, children, people working but not living in the city) |

# 4 The key lessons learnt

Each city is different and the potential for action depends on the characteristics of the city and the context — size, function (national or regional capital), presence of high-tech firms and universities, wealth and funding potential, and territorial capital.

***There is no optimal size of city or scale***
All sizes of cities can find a way of becoming more resource efficient. Even small towns can develop consistent policies and achieve ambitious goals. Local specifics, not only the available natural resources but also the dynamics and initiatives of local participants, are taken into consideration to define appropriate solutions and strategies. For example, concerning the production of renewable energy, it is usually easier for a small town in rural surroundings to achieve a high proportion of its energy from renewables than it is for a large city. The small rural town of Güssing in Austria produces its entire energy requirement — electricity, heating/cooling, transport fuels — from renewable resources using the abundant biomass from the surrounding forests.

***Urban planning beyond the limit of the core city***
The city has been transformed by increasing mobility. Generally, the delineation of the core city no longer matches the 'real' city. People live, work and move in a wider functional area, the 'real' city, extending far beyond the limits of the core city. Urban planning, which is crucial to addressing resource efficiency challenges, is generally developed at the relevant scale in successful cities. For example, 'The Metropolis of Greater Paris', a new global plan for the Paris metropolitan region, has a new transport master plan for the Paris region and includes plans to develop several areas around Paris.

***Cross-sector planning and management***
To be more resource efficient and minimise costs, urban authorities need to improve efficiency in all aspects of urban planning, development and management. They must develop an integrated way of thinking at the appropriate scale, find synergies between policies and develop innovative approaches, not only technological but also organisational, financial and knowledge management. For example, many cities, such as Copenhagen, have developed cross-sector planning (energy, climate, transport, housing, green areas).

***Goal-oriented policy and leadership***
Successful resource-efficient cities have generally chosen an ambitious goal, one that all stakeholders can get behind, and then found a way of achieving it, even when, at the start, nobody knew how to do so. It seems crucial to set long-term targets as a starting point. For example, in the case of the 'fossil fuel-free strategy' of the city of Växjö, elaborated in 1996, the measures that needed to be taken were determined step by step. And, overall, the adoption of *eco*BUDGET, a sustainability-oriented environmental management system, provided valuable information for political decision-making and city managers. If we reflect on this example, the main challenge was not related to technical problems (most solutions were already on the market) but more related to organisation — thinking differently and in an integrated way — and governance — keeping the same objective ([125]) and motivating stakeholders.

([125]) The real objective was to reduce carbon dioxide emissions from fossil fuels per inhabitant by at least 50% by the year 2010 and by at least 70% by the year 2025 compared with 1993 (Växjö Kommun, 2011) .

# Bibliography

Agudelo-Vera, C. M., Mels, A., Keesman, K., Rijnaarts, H. and Marcella, C., 2012, 'The urban harvest approach as an aid for sustainable urban resource planning', *Journal of Industrial Ecology*, 16(6) 839–850.

Akyelken, N., Anderton, K., Plepys, A., Mont, O. and Kaufman, D., 2013, *Mobility sector report — FP7 project: SPREE (Servicizing Policy for Resource Efficient Economy)*, Report of research project delivrable 5.1, FP7 SPREE. http://www.spreeproject.com/wp-content/uploads/2013/04/D5.1-Mobility-sector-report_website.pdf (accessed 20 November 2015).

Al Seadi, T., Owen, N., Hellström, H. and Kang, H., 2013, *Source separation of MSW*, IEA Bioenergy, Paris.

American Institute of Architects, 2007, *Integrated project delivery: A guide*, American Institute of Architects, Washington, DC.

Ando, A. W. and Gosselin, A. Y., 2005, 'Recycling in multifamily dwellings: Does convenience matter?', *Economic Inquiry*, 43(2) 426–438.

ArchDaily, 2014, 'Montreal's Mirabel Airport Terminal to be demolished' (http://www.archdaily.com/502638/montreal-s-mirabel-airport-terminal-to-be-demolished/) accessed 20 November 2015.

Atanasiu, B., Despret, C., Ecnomidou, M., Malo, J., Nolte, I. and Rapf, O., 2011, *Europe's building under the microscope*, Buildings Performance Institute Europe (BPIE), Brussels.

Atanasiu, B. and Kouloumpi, I., 2013, *Boosting building renovation. An overview of good practices*, Buildings Performance Institute Europe (BPIE), Brussels.

Backhaus, J., Breukers, S., Mont, O., Paukovic, M. and Mourik, R., 2012, *Sustainable lifestyles: Today's facts & tomorrow's trends*, Sustainable lifestyles baseline report, FP7 research project (http://www.sustainable-lifestyles.eu/fileadmin/images/content/D1.1_Baseline_Report.pdf) accessed 24 November 2015.

Barles, S., 2010, 'Society, energy and materials: the contribution of urban metabolism studies to sustainable urban development issues', *Journal of Environmental Planning and Management*, 53(4) 439–455.

Bernstad, A., La Cour Jansen, J. and Aspegren, A., 2013, 'Door-stepping as a strategy for improved food waste recycling behaviour: Evaluation of a full-scale experiment', *Resources, Conservation and Recycling*, 73, 94–103.

Bettgenhäusser, K., de Vos, R., Grözinger, J. and Boermans, T., 2014, Deep renovation of buildings. *An effective way to decrease Europe's energy import dependency*, Ecofys, Cologne.

Bio Intelligence Service, Umweltbundesamt and AEA Energy & Environment, 2010, *Preparatory study on food waste across EU 27*, Technical report 2010-054, European Commission, Brussels.

BIOIS, ARCADIS and IEEP, 2011, 'Service contract on management of construction and demolition waste — SR1', Final report (http://www.eusmr.eu/cdw/docs/BIO_Construction%20and%20Demolition%20Waste_Final%20report_09022011.pdf) accessed 5 December 2012.

Blaine, T. W., Grewal, P. S., Dawes, A. and Snider, D., 2010, 'Profiling community gardeners' (http://www.joe.org/joe/2010december/a6.php) accessed 16 March 2015.

Bourdic, L. and Salat, S., 2012, 'Building energy models and assessment systems at the district and city scales: a review', *Building Research & Information*, 40(4) 518–526.

Bouzarovski, S., 2014, 'Energy poverty in the European Union: landscapes of vulnerability', *Wiley Interdisciplinary Reviews: Energy and Environment*, 3(3) 276–289.

BPIE, 2014, *Alleviating fuel poverty in the EU*. Buildings Performance Institute Europe, Brussels.

Bristol Food Policy Council, 2011, A good food plan for Bristol (http://bristolfoodpolicycouncil.org/wp-content/uploads/2013/03/Bristol-Good-Food-Plan_lowres.pdf) accessed 17 November 2015.

Carbon Disclosure Project, 2012, *Seven climate change lessons from the cities of Europe*. Carbon Disclosure Project, London.

Carplus, 2013, 'Carplus — Rethinking car use' (http://www.carplus.org.uk/) accessed 3 October 2014.

Chapulut, J. N. and Taroux, J. P., 2006, *Rapport sur les bilans LOTI des LGV Nord Europe et Interconnexion Ile de France* (http://www.ladocumentationfrancaise.fr/rapports-publics/064000666/index.shtml) accessed 25 August 2014.

City of Copenhagen, 2009, *A metropolis for people — Visions and goals for urban life in Copenhagen 2015* (http://kk.sites.itera.dk/apps/kk_pub2/pdf/646_mIr0dQ6Wdu.pdf) accessed 20 November 2015.

City of Copenhagen, 2011, *Copenhagen climate adaptation plan* (http://en.klimatilpasning.dk/media/568851/copenhagen_adaption_plan.pdf) accessed 20 November 2015.

City of Copenhagen, 2012a, *Copenhagen climate plan 2025* (http://www.energycommunity.org/documents/copenhagen.pdf) accessed 22 November 2015.

City of Copenhagen, 2012b, *European Green Capital Award — Copenhagen's application* (http://ec.europa.eu/environment/europeangreencapital/winning-cities/2014-copenhagen/index.html) accessed 22 November 2015.

City of Hamburg, 2011, *European Green Capital Award — application of Hamburg* (http://ec.europa.eu/environment/europeangreencapital/winning-cities/2011-hamburg/index.html) accessed 22 November 2015.

City of Vancouver, 2009, *Passive design toolkit* (http://vancouver.ca/files/cov/passive-home-design.pdf) accessed 20 November 2015.

City of Westminster, 2013, *Retrofitting historic buildings for sustainability* (http://transact.westminster.gov.uk/docstores/publications_store/Retrofitting_Historic_Buildings_for_Sustainability_January_2013.pdf) accessed 22 November 2015.

Copenhagen Cleantech cluster, 2012, *District cooling — Keeping the city cool during summer periods* (http://dbdh.dk/download/member_contries/district_cooling/District%20cooling_HOFOR_experience.pdf) accessed 22 November 2015.

Copenhagen Cleantech Cluster, 2014, *Danish smart cities: Sustainable living in an urban world* (http://www.dac.dk/media/37489/Danish%20smart%20cities_report.pdf) accessed 22 November 2015.

Copenhagen Economics, 2012, *Multiple benefits of investing in energy efficient renovation of buildings impact*, Copenhagen Economics, Copenhagen.

CSO, 2011, *Census 2011 report*. Central Statistical Office of Ireland, Dublin.

CSTB, 2012, *Guide-Concilier efficacité énergétique et acoustique dans le bâtiment*, Centre Scientifique et Technique de Bâtiments, Champs-sur-Marne.

Cushman and Wakefield (2014). *MarketBeat office snapshot: Hungary* (http://www.cushmanwakefield.com/~/media/marketbeat/2014/02/hungary_off_4q13.pdf) accessed 30 January 2015.

Danish Energy Agency, 2013, *District heating — Danish and Chinese experience*. Danish Energy Agency, Copenhagen.

DECC, 2013, *Smart metering implementation programme*, Department of Energy & Climate Change, London (https://www.gov.uk/government/publications/smart-metering-implementation-programme-information-leaflet) accessed 22 November.

Decker, E., Scott, E., Smith, F. A., Blake, D. and Rowland, S., 2000, 'Energy and material flow through the urban ecosystem', *Annual Review of Energy and the Environment*, 25, 685–740.

Deelstra, T. and Girardet, H., 2000, *Growing cities, growing food urban agriculture on the policy agenda — Thematic paper 2: Urban agriculture and sustainable cities*, Deutsche Stiftung für internationale Entwicklung, Bonn.

DEFRA, 2011, *The sustainable lifestyle framework* (http://archive.defra.gov.uk/environment/economy/documents/sustainable-life-framework.pdf) accessed 8 April 2014.

Didier, M. and Prud'homme, R., 2007, *Infrastructures de transport, mobilité et croissance*, La Documentation Française, Les rapports du conseil d'analyse économique, Paris.

Dixon, T., 2011. *Sustainable urban development to 2050: Complex transitions in the built environment*. WP2011/5, Oxford Institute for Sustainable Development, Oxford (http://www.retrofit2050.org.uk/sites/default/files/resources/WP20115.pdf) accessed 11 November 2015.

Doepel, D., 2012, *Creating comfortable climatic cities*, Rotterdam University Press, Rotterdam.

Domènech, L. and Saurí, D., 2011, 'A comparative appraisal of the use of rainwater harvesting in single and multi-family buildings of the Metropolitan Area of Barcelona (Spain): social experience, drinking water savings and economic costs', *Journal of Cleaner Production*, 19(6–7) 598–608.

Domènech, L., March, H. and Saurí, D., 2013, 'Degrowth initiatives in the urban water sector? A social multi-criteria evaluation of non-conventional water alternatives in Metropolitan Barcelona', *Journal of Cleaner Production*, 38 44–55.

Dörfliger, N. and Perrin, J., 2011, 'Ressources en eau: Une gestion nécessairement locale dans une approche globale', *Géosciences*, 13, 94–101.

Duffy, A., 2009, 'Land use planning in Ireland — a life cycle energy analysis of recent residential development in the Greater Dublin Area', *The International Journal of Life Cycle Assessment*, 14(3), 268–277.

EC, 2007, 'Green Paper — Towards a new culture for urban mobility' ({SEC(2007) 1209} /* COM/2007/0551 final).

EC, 2009, Directive 2009/72/EC of the European Parliament and of the Council of 13 July 2009 concerning common rules for the internal market in electricity and repealing Directive 2003/54/EC (OJ L 211, 14.8.2009, p. 55–93).

EC, 2011a, Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions 'Analysis associated with the Roadmap to a Resource Efficient Europe' (COM(2011) 571 final of 20.9.2011) (http://ec.europa.eu/environment/resource_efficiency/pdf/working_paper_part1.pdf) accessed 13 March 2014.

EC, 2011b, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions 'A resource-efficient Europe — Flagship initiative under the Europe 2020 Strategy' (COM(2011) 21 of 26.1.2011).

EC, 2011c, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions 'Roadmap to a resource efficient Europe' (COM(2011) 571 final).

EC, 2011d, Communication from the Commission to the European Parliament, the Council, the Economic and Social Committee and the Committee of the Regions 'Energy efficiency plan 2011' (COM(2011) 109 final of 8.3.2011).

EC, 2012, *Connecting smart and sustainable growth through smart specialisation*, Publications Office of the European Union, Luxembourg.

EC, 2014, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions 'Towards a circular economy: A zero waste programme for Europe' (COM(2014) 398 final).

EC, Environment Directorate-General, 2010, Science for Environment Policy News Alert Service, 'Is greywater safe for irrigation?', 17 June 2010 (http://ec.europa.eu/environment/integration/research/newsalert/pdf/200na6_en.pdf) accessed 25 March 2015.

EC, Environment Directorate-General, 2013, Science for Environment Policy News Alert Service, 'Zero waste index proposed for improving city waste management' (http://ec.europa.eu/environment/integration/research/newsalert/pdf/324na3_en.pdf) accessed 20 November 2015.

EEA, 2006, *Urban sprawl in Europe:* The ignored challenge, EEA Report No 10/2006, European Environment Agency.

EEA, 2009, *Water resources across Europe — Confronting water scarcity and drought*, EEA Report No 2/2009, European Environment Agency.

EEA, 2012a, *Consumption and the environment — 2012 update: The European environment state and outlook 2010*, European Environment Agency.

EEA, 2012b, *Urban adaptation to climate change in Europe*, EEA Report No 2/2012, European Environment Agency.

EEA, 2012c, *Towards efficient use of water resources in Europe*, EEA Report No 1/2012, European Environment Agency.

EEA, 2013a, *Achieving energy efficiency through behaviour change what does it take?*, EEA Report No 5/2013, European Environment Agency.

EEA, 2013b, *A closer look at urban transport — TERM 2013: Transport indicators tracking progress towards environmental targets in Europe*, EEA Report No 11/2013, European Environment Agency.

EEA, 2013c, 'Progress on energy efficiency in Europe (ENER 037) — Assessment published March 2013, European Environment Agency (http://www.eea.europa.eu/data-and-maps/indicators/progress-on-energy-efficiency-in-europe/assessment) accessed 26 September 2014.

EEA, 2014a, *Performance of water utilities beyond compliance*, EEA Report No 5/2014, European Environment Agency.

EEA, 2014c, *Waste prevention in Europe — The status in 2013*, EEA Report No 9/2014, European Environment Agency (http://www.eea.europa.eu/publications/waste-prevention-in-europe-2014) accessed 20 November 2015.

EEA, 2015, *Urban sustainability issues — What is a resource-efficient city?*, EEA Technical report No 23/2015 (http://www.eea.europa.eu/publications/resource-efficient-cities).

Effinergie, 2008, *Low-consumption building: the achievement of a project*, Effinergie, Paris.

Empty Home Agency, 2008, *New tricks with old bricks — How reusing old buildings can cut carbon emissions*, Empty Home Agency, London.

EnergyCities, 2009, 'Fossil fuel free Växjö — the story' (http://www.energy-cities.eu/IMG/pdf/Fossil_Fuel_Free_Vaxjo_-_the_story.pdf) accessed 17 November 2015.

Energy-cities, 2010, 'Energy Cities — Eco-district in Grenoble, France: Top-down or bottom-up eco-district development' (http://www.energy-cities.eu/Eco-District-in-Grenoble-France,2149) accessed 16 September 2014.

Energy Cities, 2013, 'Identify local energy potential in order to live within our means' (http://energy-cities.eu/wiki/index.php/Proposal_2.2) accessed 5 May 2014.

Energy Cities, 2014a, 'Prepare an energy retrofitting plan for the whole building stock — Energy Cities Wiki' (http://www.energy-cities.eu/wiki/index.php/Prepare_an_energy_retrofitting_plan_for_the_whole_building_stock) accessed 25 September 2014.

EnergyCities, 2014b, *30 EnergyCities' proposals for the energy transition of cities and towns* (http://www.energy-cities.eu/IMG/pdf/cahier_short_jan2014_en.pdf) accessed 17 November 2015.

Enertech, 2011, *Evaluation par mesure des performances énergétiques des 8 bâtiments construits dans le cadre du programme européen Concerto* (http://www.enertech.fr/modules/catalogue/pdf/66/zdb_b2_pallium-jardins-db_rapport_final-120603.pdf) accessed 22 November 2015.

EPA, 2006, *Growing toward more efficient water use: Linking development, infrastructure, and drinking water policies*, United States Environmental Protection Agency, Washington, DC.

EPA, 2010, *Evaluation of energy conservation measures for wastewater treatment facilities*, United States Environmental Protection Agency, Washington, DC.

EPA, 2011, *Study of pay-by-use systems for maximising waste reduction behaviour in Ireland*, Environmental Protection Agency, Ireland, Dublin.

Esnouf, C., Russel, M. and Bricas, N., 2011, *Dualine — Durabilité de l'alimentation face à de nouveaux enjeux* (http://www.cirad.fr/en/publications-resources/publishing/studies-and-documents/dualine) accessed 22 November 2015.

ETC/SCP, 2013, *Housing assessment*, Final report, ETC/SCP Working Paper No 4/2013 (http://scp.eionet.europa.eu/publications/wp2013_4/wp/wp2013_4) accessed 1 March 2015.

EU, 1994, European Parliament and Council Directive 94/62/EC of 20 December 1994 on packaging and packaging waste (OJ L 365, 31.12.1994, p. 10–23).

EU, 1999, Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste (OJ L 182, 16.7.1999, p. 1–19).

EU, 2006, Directive 2006/32/EC of the European Parliament and of the Council of 5 April 2006 on energy end-use efficiency and energy services and repealing Council Directive 93/76/EEC (OJ L 114, 27.4.2006, p. 64–85).

EU, 2008, Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives (OJ L 312, 22.11.2008, p. 3–30).

EU, 2012, Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC (OJ L 315/1, 14.11.2012, p. 1–56).

EU, 2013, Decision No 1386/2013/EU of the European Parliament and of the Council of 20 November 2013 on a General Union Environment Action Programme to 2020 'Living well, within the limits of our planet' (OJ L 354, 20.12.2013, p. 171–200).

EU, 2014, *EU Energy in figures — Statistical pocketbook 2014*, Publications Office of the European Union, Luxembourg.

European Parliament, 2014, *Mapping Smart Cities in the EU*, European Parliament, Luxembourg.

Eurostat, 2013, *Eurostat regional yearbook 2013*, Publications Office of the European Union, Luxembourg (http://ec.europa.eu/eurostat/documents/3217494/5784301/KS-HA-13-001-EN.PDF/ec68c62e-0ca9-40af-83c2-949e152f9269) accessed 20 November 2015.

Eurostat, 2014, 'At risk of poverty or social exclusion in the EU28', *Newsrelease* 168/2014, 4 November.

Eurostat, 2015, *Eurostat regional yearbook 2015*, Publications Office of the European Union, Luxembourg (http://ec.europa.eu/eurostat/en/web/products-statistical-books/-/KS-HA-15-001) accessed 20 November 2015.

FAO, 2014, *In brief: State of food insecurity in the world* (http://www.fao.org/3/a-i4037e.pdf) accessed 15 March 2015.

Federal Ministry for Transport, Innovation and Technology, 2014, Energy Innovation Austria (http://www.bmvit.gv.at/en/service/publications/downloads/downloads_ftb/ftb_2014_en.pdf) accessed 20 November 2015.

Filcak, R., Rubik, F., Kuhn, J., Sabo, S., Gossen, M. and Sedlacko, M., 2013, *Towards sustainable mobility in European cities: Insights and issues for policy makers and researchers — RESPONDER FP7 research project*, Background paper, Bratislava (http://www.scp-responder.eu/pdf/knowledge/papers/RESPONDER_2013%20Background%20Paper%20on%20urban%20mobility.pdf) accessed 22 November 2015.

Forestry Commission England, 2010, *Barnsley biomass — Working towards carbon emissions reduction in Yorkshire* (http://www.forestry.gov.uk/pdf/yh-casestudies-barnselybiomass.pdf/$FILE/yh-casestudies-barnselybiomass.pdf) accessed 12 October 2014.

Fumagalli, B., 2013, *Energy performance assessment of collective housing buildings*, Master of Science Thesis, KTH School of Industrial Engineering and Management, Stockholm.

Garcia-López, M.-À., 2010, 'Population suburbanization in Barcelona, 1991–2005: Is its spatial structure changing?', *Journal of Housing Economics*, 19(2) 119–132.

Gellynck, X., Jacobsen, R. and Verhelst, P., 2011, 'Identifying the key factors in increasing recycling and reducing residual household waste: A case study of the Flemish region of Belgium', *Journal of Environmental Management*, 92(10) 2 683–2 690.

Girardet, H., 2010, *Regenerative cities*, World Future Council, Hamburg.

Global Cement, 2011, 'Future Cement — Looking beyond OPC' (http://www.globalcement.com/magazine/articles/315-future-cement-looking-beyond-opc) accessed 16 September 2014.

Grewal, S. S. and Grewal, P. S., 2012, 'Can cities become self-reliant in food?', Cities, 29(1) 1–11.

HELCOM, 2010, *Ecosystem health of the Baltic Sea 2003–2007: HELCOM initial holistic assessment*, Baltic Sea Environment Proceedings 122, Helsinki (http://helcom.fi/Lists/Publications/BSEP122.pdf) accessed 18 November 2015.

Houses of Parliament, 2012, 'Water resource resilience', Houses of Parliament PostNote No 419, Houses of Parliament, London.

ICLEI, 2014, 'Study for EEA on urban governance and resource efficiency', unpublished.

IEA, 2009, *Cities, towns & renewable energy*, International Energy Agency, Paris (http://www.iea.org/publications/freepublications/publication/Cities2009.pdf) accessed 20 November 2015.

IEA, 2013, *The IEA CHP and DHC collaborative — Countryscorecard: Finland*, Insights Series 2013, International Energy Agency, Paris.

IEA, 2014, *Linking heat and electricity systems*, International Energy Agency, Paris.

IEA-OECD, 2004, *Improving district heating policy in transition economies*, International Energy Agency and Organisation for Economic Co-operation and Development, Paris.

InContext, 2013, *How to create space for change? Key insights for policymakers and grassroots activists*, InContext Research Project (FP7), InContext, Berlin (http://www.incontext-fp7.eu/sites/default/files/InContext-KeyMessages-eng-screen-final.pdf) accessed 20 November 2015.

Iriarte, A., Gabarrell, X. and Rieradevall, J., 2009, 'LCA of selective waste collection systems in dense urban areas', *Waste Management*, 29(2) 903–914.

Isocarp, 2014, 'International summer school “Planning for the post-speculative city” ' (http://www.isocarp.org/index.php?id=planningthepost-speculativeci) accessed 27 August 2014.

Jegou, F. and Carey, J., 2015, Handbook: *Creating space for sustainable food systems in urban communities — Practical approach and examples for cities*, Urbact, Saint-Denis.

Joss, S. and Cowley, T. and R., 2011, *Eco-Cities — A global survey 2011*, University of Westminster, London.

Kasanko, M., Barredo, J. I., Lavalle, C., McCormick, N., Demicheli, L., Sagris, V. and Brezger, A., 2006, 'Are European cities becoming dispersed?: A comparative analysis of 15 European urban areas', *Landscape and Urban Planning*, 77(1–2) 111–130.

Kitchin, R., Gleeson, J., Keaveney, K. and O'Callaghan, C., 2010, 'A haunted landscape: Housing and ghost estates in post-Celtic Tiger Ireland', NIRSA Working Paper Series No 59 (http://eprints.nuim.ie/2236/) accessed 28 August 2014.

Krausmann, F., Fischer-Kowalski, M., Schandl, H. and Eisenmenger, N., 2008, 'The global socio-metabolic transition: past and present metabolic profiles and their future trajectories', *Journal of Industrial Ecology*, 12(5–6) 637–656.

Lehmann, S., 2010, 'Green urbanism: Formulating a series of holistic principles', *SAPIENS. Surveys and Perspectives Integrating Environment and Society*, 3(2).

Lehmann, S., 2014, 'Low carbon districts: Mitigating the urban heat island with green roof infrastructure', *City, Culture and Society*, 5(1), 1–8.

Lepoutre, J., Dentchev, N. A. and Heene, A., 2007, 'Dealing with uncertainties — When governing CSR policies', *Journal of Business Ethics*, 73, 391–408.

Les Echos, L., 2014, 'Voies sur berges: Paris rêve désormais de piétonniser la rive droite' (http://www.lesechos.fr/politique-societe/regions/0203563198394-voies-sur-berges-paris-reve-desormais-de-pietonniser-la-rive-droite-1012566.php#Xtor=AD-6000) accessed 22 August 2014.

Lewis, J. O., Hogain, S. N. and Borghi, A., 2013, Building energy efficiency in European cities, Urbact II, Saint-Denis.

Liimatainen, H., Nykänen, L., Arvidsson, N., Hovi, I. B., Jensen, T. C. and Østli, V., 2014, 'Energy efficiency of road freight hauliers — A Nordic comparison', *Energy Policy*, 67, 378–387.

Locasso, M. and D'Ambrosio, V., 2012, 'Eco-districts and social housing in northern Europe', TECHNE — *Journal of Technology for Architecture and Environment*, 44–52, October 2012.

London Borough of Haringey, 2012, *Decentralised energy masterplanning — A manual for local authorities* (http://www.londonheatmap.org.uk/Content/uploaded/documents/EMP_Manual_lo.pdf) accessed 18 November 2015.

Loose, W., 2010, 'The state of European car-sharing', Final report D2.4 (http://www.motiva.fi/files/4138/WP2_Final_Report.pdf) accessed 2 October 2014.

López Moreno, E. and González Blanco, Z., 2014, 'Ghost cities and empty houses: Wasted prosperity', *American International Journal of Social Science*, 3(2), 207–216.

Lorenzoni, I., Nicholson-Cole, S. and Whitmarsh, L., 2007, 'Barriers perceived to engaging with climate change among the UK public and their policy implications', *Global Environmental Change*, 17, 445–459.

Ma, Z., Cooper, P., Daly, D. and Ledo, L., 2012, 'Existing building retrofits: Methodology and state-of-the-art', *Faculty of Engineering — Papers (Archive)*, 889–902 (DOI: 10.1016/j.enbuild.2012.08.018).

McKinsey & Company, 2010, *Impact of the financial crisis on carbon economics*, McKinsey & Company, New York.

McMunn, A., Nazroo, J. and Breeze, E., 2009, 'Inequalities in health at older ages: A longitudinal investigation of the onset of illness and survival effects in England', *Age and Ageing,* 38(2), 181–187 (DOI: 10.1093/ageing/afn236).

Markopoulos, C., Rozos, E., Bruaset, S., Fruns, J. and Van der Zouwen, M., 2012, *Best practices for sustainable urban water cycle systems*, Trust D 11.1 (http://www.trust-i.net/downloads/index.php?iddesc=67) accessed 22 November 2015.

Martin, E., Shaheen S. and Lidicker, J., 2010, 'Impact of carsharing on household vehicle holdings. Results from North American shared-use vehicle survey', *Transportation Research Record*, 2143, 150–158.

Martin-Ortega, J. and Markandya, A., 2009, *The costs of drought: The exceptional 2007–2008 case of Barcelona*, Working paper BC3 2009–09, Basque Centre for Climate Change, Bilbao.

Mayor of London, 2013, *District heating manual for London* (http://www.londonheatmap.org.uk/Content/uploaded/documents/DH_Manual_for_London_February_2013_v1.0.pdf) accessed 18 November 2015

Membrado, J. C., 2012, 'Urban sprawl and housing bubble (1997–2007) in València (Spain) according to Corine and Siose data', *Bolletino AIC*, (http://www.academia.edu/5093295/Urban_Sprawl_and_Housing_Bubble_1997-2007_in_Val%C3%A8ncia_Spain_according_to_CORINE_and_SIOSE_Data) accessed 23 November 2015.

Miafodzyeva, S. and Brandt, N., 2012, 'Recycling behaviour among householders: Synthesizing determinants via a meta-analysis', *Waste and Biomass Valorization*, 4(2) 221–235.

Millock, K., Nauges, C., 2010, Household adoption of water-efficient equipement: the role of socio-economic factors, environmental attitudes and policy, European Association of Environmental and Resource Economistsy 46 (4), 539-565.

Ministry of Housing, Urban and Rural Affairs and Danish Energy Agency, 2014, *Low carbon and new energy — Cities in Denmark*, , Copenhagen (http://www.cnrec.org.cn/english/publication/2014-09-26-447.html) accessed 20 November 2015.

Moragues, A., Morgan, K., Moschitz, H., Neimane, I., Nilsson, H., Pinto, M., Rohracher, H., Ruiz, R., Thuswald, M., Tisenkopfs, T. and Halliday, J., 2013, 'Urban food strategies: The rough guide to sustainable food systems', Document developed in the framework of the FP7 project FOODLINKS ( http://www.foodlinkscommunity.net/fileadmin/documents_organicresearch/foodlinks/publications/Urban_food_strategies.pdf) accessed 22 November 2015.

Newcastle City Council, 2013. 'Changes to bin collections' (http://www.newcastle.gov.uk/environment-and-waste/rubbish-waste-and-recycling/household-waste-collection/changes-to-bin-collections) accessed December 2013.

Nolde, E., 2005, 'Greywater recycling systems in Germany — results, experiences and guidelines', *Water Science and Technology*, 51(10) 203–210.

Nordic Energy Municipality, 2011, Nominated to Nordic Energy Municipality 2011 (http://www.norden.org/sv/nordiska-ministerraadet/ministerraad/nordiska-ministerraadet-foer-naeringsliv-energi-och-regionalpolitik-mr-ner/nordiske-energikommuner/nominerade-kommuner/vaexjoe-kommune-factsheet) accessed 20 November 2015.

Odyssee-Mure, 2013, Energy efficiency: *Trends in the EU — Lessons from the ODYSSEE MURE project* (http://www.odyssee-mure.eu/publications/br/synthesis-energy-efficiency-trends-policies.pdf) accessed 20 November 2015.

Orsini, F., Gasperi, D., Marchetti, L., Plovene, C., Draghetti, S., Ramazzotti, S., Bazzochi, G. and Gianquinto, G., 2014, 'Exploring the production capacity of rooftop gardens (RTGs) in urban agriculture: The potential impact on food and nutrition security, biodiversity and other ecosystem services in the city of Bologna', *Food Security Journal*, 6(6) 781–793.

Penttilä, H., 2006, 'Describing the changes in architectural information technology to understand design complexity and free-form architectural expression' (http://www.itcon.org/cgi-bin/works/Show?2006_29) accessed 6 October 2014.

Polyak, L., 2013, *The recycled city: New uses in old settings*, European 13 (http://europan-europe.eu/media/default/0001/09/e13_themecontr_38_lpolyak_pdf.pdf) accessed 22 November 2015.

Portland Sustainability Institute, 2012, *The building blocks of sustainable cities*, Portland Sustainability Institute, Portland, OR.

Pothukuchi, K. and Kaufman, J., 2000, 'Food system: Stranger to the planning field' (http://www.cityfarmer.org/foodplan.html) accessed 16 March 2015.

Power, A., 2007, *City survivors: Bringing up children in disadvantaged neighbourhoods*, Policy Press, Bristol.

Power, A., 2010, 'Housing and sustainability: Demolition or refurbishment?', *Urban Design and Planning, 163*(DP4) 205–2016.

Pramanik, A. and Burn, S., 2014, *Resource recovery from wastewater: A research agenda*, Water Environment Research Foundation, Alexandria, VA.

Promoting ZeroWaste, 2014, *Guide on green solutions for waste for and from public administrations*, Promoting ZeroWaste, Attiki

PUCA, 2008, 'Concevoir un éco-quartier', *Le journal d'information du PUCA*, 16.

R2Cities, 2014, 'The project' (http://r2cities.eu/Project/The_Project.kl) accessed 6 October 2014.

R4R, 2014, *Good practice Flanders: PAYT*, Regions for Recycling (http://www.regions4recycling.eu/upload/

public/Good-Practices/GP_OVAM_PAYT.pdf) accessed 18 November 2015.

Ramaswami, A., Weible, C., Main, D., Heikkila, T., Siddiki, S., Duvall, A., Pattison, A. and Bernard, M., 2012, 'A social-ecological-infrastructural systems framework for interdisciplinary study of sustainable city systems', *Journal of Industrial Ecology*, 16(6) 801–813.

Reed, M., Curry, N., Keech, D., Kirwan, J. and Maye, D., 2013, *City-region report synthesis. Research Project: SUPURBFOOD*, Work package 2/Deliverable 2.3 (http://www.ruaf.org/sites/default/files/Synthesis%20report%20Innovative%20experiences%20with%20%28peri-%29%20urban%20agriculture%20and%20urban%20food%20provisioning%3B%20lessons%20to%20be%20learned%20from%20the%20global%20South%20RUAF-SUPURBFOOD.pdf) accessed 22 November 2015.

Refsgaard, K. and Magnussen, K., 2009, 'Household behaviour and attitudes with respect to recycling food waste — experiences from focus groups', *Journal of Environmental Management*, 90(2), 760–771 (DOI: 10.1016/j.jenvman.2008.01.018).

Roorda, C. and Wittmayer, J., 2014, *Transition management in five European cities — An evaluation*, Dutch Research Institute for Transitions, Rotterdam.

Rubik, F., Gossen, M., 2011. CORPUS Discussion Paper 2 on Policy Instruments for Sustainable Mobility (http://www.scp-knowledge.eu/sites/default/files/Rubik%20and%20Gossen%202011%20Sustainable%20Mobility%20-%20Policies.pdf) Accessed 15 March 2013.

Rygaard, M., Binning, P. J. and Albrechtsen, H.-J., 2011, 'Increasing urban water self-sufficiency: New era, new challenges', *Journal of Environmental Management*, 92(1) 185–194.

Røpke, I., 2009, 'Theories of practice — New inspiration for ecological economic studies on consumption', *Ecological Economics*, 68(10) 2 490–2 497.

Saurí, D. and del Moral, L., 2001, 'Recent developments in Spanish water policy. Alternatives and conflicts at the end of the hydraulic age', *Geoforum*, 32(3) 351–362.

Sauri, D. , 2013, Water Conservation: Theory and Evidence in Urban Areas of the Developed World, *Annual Review of Environment and Resources*, Vol. 38: 227-248.

Schaffnit-Chatterjee, C., 2011, 'Where are food prices heading? Short-term drivers, trends and implications', *Deutsche Bank Research* (https://www.dbresearch.com/PROD/DBR_INTERNET_EN-PROD/PROD0000000000270746/Where+are+food+prices+heading%3F+Short-term+drivers,+trends+and+implications.pdf) accessed 18 November 2015.

Schmidt, M., 2008, 'Rainwater harvesting in Germany — New concepts for the substitution of drinking water, flood control and improving the quality of the surface waters', paper presented at the Third Brazilian Symposium on Capture and Rainwater Management.

Schwarz, N., 2010, 'Urban form revisited — Selecting indicators for characterising European cities', *Landscape and Urban Planning*, 96(1) 29–47.

Seltzer, E., Smith, T. W., Cortright, J., Bassett, E. M. and Shandas, V., 2010, *Making ecodistricts. Concepts and methods for advancing sustainability in neighborhoods*, Portland Sustainability Institute, Portland, OR.

Sievers, J., Puchta, M. and Faulstich, S., 2006, *Guidelines to promote CHP concepts with heat accumulators — Research project DESIRE* (https://www.f07.th-koeln.de/imperia/md/content/fakultaet07/iet/laboratorien/regenerativeenergien/unterlagen/d2_4_final.pdf) accessed 22 November 2015.

Smart Cities, 2013, *Smart thermal grids* (https://eu-smartcities.eu/content/ki-smart-thermal-grids) accessed 18 November 2015.

Stahel, W. R., 2008, 'The performance economy: Business models for the functional service economy', in: Misra, P. K. B. (ed.), *Handbook of performability engineering*, Springer, London, pp. 127–138.

Suzuki, H., Dastur, A., Moffatt, S., Yabuki, N. and Maruyama, H. (eds), 2010, Eco2 cities: *Ecological cities as economic cities*, World Bank, Washington, DC.

TCPA and CHPA, 2008, *Community energy: Urban planning for a low carbon future*, Town and Country Planning Association and Combined Heat and Power Association, London.

Tillie, N., Aarts, M., Marijnissen, M. and Sternhuijs, L., 2012, 'Rotterdam – people make the inner city', Fifth International Architecture Biennale, Rotterdam (https://www.yumpu.com/en/document/view/25864843/rotterdam-a-people-make-the-inner-city-gemeente-rotterdam) accessed 22 November 2015.

Tirado Herrero, S. and Ürge-Vorsatz, D., 2012, 'Trapped in the heat: A post-communist type of fuel poverty', *Energy Policy*, 49 60–68.

Transport for London, 2010, *Travel in London — Report 3* (http://content.tfl.gov.uk/travel-in-london-report-3.pdf) accessed 19 November 2015.

Truong, N. L. and Gustavsson, L., 2014, 'Cost and primary energy efficiency of small-scale district heating systems', *Applied Energy*, 130 419–427.

TRUST, 2014, *Baseline and best in urban water cycle services*, Transitions to the Urban Water Services of Tomorrow (https://www.trust-i.net/downloads/index.php) accessed 22 November 2015.

UNEP, 2004, 'Rainwater harvesting and utilisation — An environmentally sound approach for sustainable urban water management: An introductory guide for decision-makers', United Nations Environment Programme (http://www.unep.or.jp/ietc/publications/urban/urbanenv-2/1.asp) accessed 30 March 2015.

UN-Habitat, 2012, *Optimizing infrastructure — Urban patterns for a green economy*, UN-Habitat, Nairobi.

Urbact, 2013, *LINKS: Future-proof historic centres — Local action plans*, Urbact, Saint-Denis (http://urbact.eu/sites/default/files/import/Projects/LINKS/outputs_media/urbact_links_final_report.pdf) accessed 20 November 2015.

URB Energy, 2011a, *Holistic strategies for energy efficient refurbishment of the housing stock and renewal of the related energy supply system*, URB Energy, Berlin.

URB Energy, 2011b, *Integrated urban development approach — Targeting at energy efficient residential areas*, URB Energy, Berlin.

Växjö Kommun, 2011, Climate strategy of Växjö (http://www.vaxjo.se/upload/www.vaxjo.se/Kommunledningsf%C3%B6rvaltningen/Planeringskontoret/Milj%C3%B6dokument%20och%20broschyrer/Energiplan_eng_webb_2011.pdf) accessed 22 November 2015.

Vidal, M., Domene, E. and Saurí, D., 2011, 'Changing geographies of water-related consumption: Residential swimming pools in suburban Barcelona', Area, 43(1) 67–75.

Walker, R., Thomson, H. and Liddell, C., 2013, *Fuel poverty 1991–2012 — Commemorating 21 years of action, policy and research*, Ulster University, Londonderry.

WERF, 2011, *Energy production and efficiency research — The roadmap to net-zero energy*, Water Environment Research Foundation, Alexandria, VA.

WHO, 2007, *Housing, energy and thermal comfort — A review of 10 countries within the WHO European Region*, World Health Organization, Geneva.

Williams, I. D. and Cole, C., 2013, 'The impact of alternate weekly collections on waste arisings', *Science of the Total Environment*, 445–446 29–40.

Williams, P. T., 2013, *Waste treatment and disposal*, John Wiley & Sons, Chichester.

Wong, A. And Hallsworth, A., 2012, 'Farm-to-fork: A proposed revision of the classical food miles concept', *International Journal on Food System Dynamics*, 3(1) 74–81.

WRAP, 2009a, *Case study food waste collection trials — food waste collections from multi-occupancy dwellings*, WRAP, Banbury (http://www.wrap.org.uk/sites/files/wrap/Case_study_-_multi-occupancy_housing.a7a6067a.5879.pdf) accessed 20 November 2015.

WRAP, 2009b, *Evaluation of the WRAP separate food waste collection trials*, WRAP, Banbury (http://www.wrap.org.uk/sites/files/wrap/Evaluation_of_the_WRAP_FW_Collection_Trials_Update_June_2009.pdf) accessed 20 November 2015.

WRAP, 2011, *Valuing our clothes — The true cost of how we design, use and dispose of clothing in the UK*, WRAP, Banbury (http://www.wrap.org.uk/sites/files/wrap/VoC%20FINAL%20online%202012%2007%2011.pdf) accessed 20 November 2015.

WssTP, 2010, *Strategic research agenda*, The European Technology Platform for Water, Brussels (http://wsstp.eu/wp-content/uploads/sites/102/2013/11/SRA2010.pdf) accessed 20 November 2015.

WssTP, 2011, *Leakage management. Strategic vision and research needs*, The European Technology Platform for Water, Brussels.

Wunder, S., 2013, *learning for sustainable agriculture: Urban gardening in Berlin*, Solinsa. (http://www.ecologic.eu/10308) accessed 22 November 2015.

Zaman, A. U. and Lehmann, S., 2013, 'The zero waste index: A performance measurement tool for waste management systems in a 'zero waste city' ', *Journal of Cleaner Production*, 50 123–132.

Zaucha, J. and Świątek, D., 2013, *Place based territorially sensitive and integrated approach*, Ministry of Regional Development, Warsaw.

European Environment Agency

**Urban sustainability issues — Resource-efficient cities: good practice**

2015 — 93 pp. — 21 x 29.7 cm

ISBN 978-92-9213-711-3
doi:10.2800/69420

TH-AK-15-024-EN-N
doi:10.2800/69420

European Environment Agency
Kongens Nytorv 6
1050 Copenhagen K
Denmark

Tel.: +45 33 36 71 00
Web: eea.europa.eu
Enquiries: eea.europa.eu/enquiries

Publications Office

European Environment Agency