Sustainable urban development under climate change and resource scarcity

A Doctor of Philosophy Dissertation

Marta Olazabal
Queens’ College Cambridge

2015
Author's Declaration

This thesis is submitted according to the requirements of the Degree Committee of the Department of Land Economy of the University of Cambridge. It does not exceed the regulation length of 80,000 words including footnotes, references and appendices. It is the result of my own work and includes nothing that is the outcome of work done in collaboration.

Marta Olazabal

First submitted April 22, 2014

Final approval April 9, 2015
Acknowledgements

This dissertation may be the biggest piece of work that I have ever attempted. I am proud to have come this far. I am glad that I felt the need to face this challenge.

Nevertheless, it would never have been possible to conduct this research without the help and support of various private and public sector organisations, or without the support of my supervisors, my colleagues, my friends and my family.

My doctoral research would not have been possible without the financial support of various institutions such as the European Scientific Foundation (through the COST Action TU0902 – Integrated assessment technologies to support the sustainable development of urban areas), the Queens’ College Conference Attendance Grants programme, Tecnalia, the Provincial Council of Bizkaia and the Basque Centre for Climate Change. Between them they have enabled me to partly fund maintenance, tuition fees, conferences, field trips and meetings, which I wish to acknowledge here.

I would like to thank the Department of Land Economy and especially my co-supervisor Franz Fuerst. I am highly indebted to many people in Bilbao and the Basque Country who have kindly shared their time and knowledge. The methods that I have used are unusual and seldom applied in urban studies. I would like to thank Martin Wildenberg, Michael Banhhofer, Diana Reckien, Aiora Zabala and Amaia Albizua for their support and advice, for sharing their knowledge and experience with me and for helping me understand the methods and therefore the design of the studies and the interpretation of the data collected. Also, I would like to thank Joseph Spadaro, Iñaki Arto, Eneko Garmendia, Roberto Bermejo, and Miklós Antal for their valuable comments concerning parts of this work.

Many thanks to those who have suffered my joys and sorrows and have supported me against all odds. This includes my BC3 colleagues (specially the PhDs) and all my friends and family; no matter how far away you are, thank you. You have all had your role, big or small, in this story.

Lastly and most importantly, I would like to thank my main supervisor Unai Pascual for his unconditional support and advice over the years regardless of the many obstacles that this dissertation has had to overcome.
To my parents Maria Luz and Eduardo, to my sister Paula and my brother Edi.

Especially to Keni and our fast-growing little angel. Mis dos amores.

In memory of Arantzazu Urzelai, my first ever mentor.
The urgent need to transform our patterns of urban development has been expressed not only by the scientific community but also in the policy arena. Current concerns relate to increasing urbanisation and global environmental trends in regard to resource scarcity, climate change and degrading environmental quality. Urban complexity, cross-scale impacts, socio-institutional diversity and adaptability become crucial when thinking about alternative development pathways. This dissertation seeks to explore why and how cities face change in this context by revisiting the concepts of resilience, sustainability and transformability. It is structured in two parts. Part I focuses on conceptual analysis and explores the theories of resilience and transformation applied to urban systems, looking at how they relate and couple with urban sustainable development goals. It makes use of theories related to the resilience of socio-ecological systems, transition management research and ecosystem service frameworks to illustrate the complexity of urban systems. Part II takes the city of Bilbao (Basque Country) as a case study to help understand resilience and transformation capabilities and explore their applicability in the field of energy. It focuses especially on the role of the cognitions of stakeholders and decision-makers in the uptake and management of sustainability transitions. Two participatory and semi-quantitative methodologies are used to understand stakeholders’ discourses and cognitive understanding of the urban energy system: the Q method and Fuzzy Cognitive Mapping. Conclusions drawn from the conceptual and empirical contributions to this dissertation highlight that resilience and transformability are key concepts in sustainable urban development. How decision and policy makers understand the complexities, i.e. the connections and interdependencies in urban system dynamics, is key in the process of defining transition pathways. Multidisciplinary, integrated, participatory approaches in the governance of sustainable urban transformation are crucial if unintended policy impacts are to be avoided and stakeholders are to be engaged in the quest for sustainability and resilience under climate change and resource scarcity.
Dissertation outputs

Parts of this thesis dissertation have been published or submitted as follows:

**Peer-reviewed:**

Olazabal M. and Pascual U. Applying fuzzy cognitive mapping to explore the cognitive dimension of urban resilience and transformation. Submitted/In review (February 2014)


**Non peer-reviewed:**


Books and book chapters:


Parts of this dissertation have been also used in conference contributions and proceedings as follows:

Olazabal M. Capturing and modelling cognitive knowledge to inform urban low carbon transitions. Urban Integration Conference. 6-7 March 2014, Sheffield, UK


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<th>Full Form</th>
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<tbody>
<tr>
<td>CAS</td>
<td>Complex Adaptive Systems</td>
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<tr>
<td>ES</td>
<td>Ecosystem Services</td>
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<td>ESF</td>
<td>Ecosystem Service Framework</td>
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<td>FCM</td>
<td>Fuzzy Cognitive Mapping</td>
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<tr>
<td>FUS</td>
<td>Final Urban Services</td>
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<tr>
<td>GDP</td>
<td>Gross Domestic Product</td>
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<tr>
<td>IEA</td>
<td>International Energy Agency</td>
</tr>
<tr>
<td>INE</td>
<td>Instituto Nacional de Estadistica / Spanish National Institute of Statistics</td>
</tr>
<tr>
<td>IS</td>
<td>Intermediary Services</td>
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<tr>
<td>MEA</td>
<td>Millennium Ecosystem Assessment</td>
</tr>
<tr>
<td>MLP</td>
<td>Multi-Level Perspective</td>
</tr>
<tr>
<td>OECD</td>
<td>Organisation for Economic Co-operation and Development</td>
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<tr>
<td>SEAP</td>
<td>Sustainable Energy Action Plan</td>
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<tr>
<td>SES</td>
<td>Socio-Ecological Systems</td>
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<tr>
<td>STS</td>
<td>Socio-Technical Systems</td>
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<tr>
<td>UA</td>
<td>Urban Audit</td>
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<tr>
<td>UBI</td>
<td>Urban Built Infrastructures</td>
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<tr>
<td>UN</td>
<td>United Nations</td>
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<tr>
<td>UNA</td>
<td>Urban Natural or semi-natural Assets</td>
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<td>URS</td>
<td>Urban Resilient Sustainability</td>
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<td>URST</td>
<td>Urban Resilient Sustainability Transition</td>
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<td>US</td>
<td>Urban Services</td>
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<td>Urban Service Framework</td>
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<td>Urban Service Providers</td>
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<td>USPU</td>
<td>Urban Service Providing Units</td>
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<tr>
<td>TEEB</td>
<td>The Economics of Ecosystems and Biodiversity</td>
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<td>TM</td>
<td>Transition Management</td>
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Chapter 1

Introduction

URBAN SUSTAINABILITY REQUIRES INSIGHTS FROM RESILIENCE AND TRANSFORMATION

“[…] all cities, whether old or new, can be made to be more sustainable.”

(Pickett et al. 2013, p. S20)
Chapter 1. Introduction

1.1. Urban sustainable challenges

1.1.1. Urban and environmental trends

It is widely accepted that cities\(^1,2\) are population attractors, and as such are responsible for many of the unsustainable trends that are pushing the planet beyond its ecological boundaries (Alberti 1999; Folke et al. 2002a; Bai et al. 2005; Lee 2006; Liu et al. 2007a; Grimm et al. 2008a; Rockström et al. 2009; Satterthwaite et al. 2010; Seto and Satterthwaite 2010). Cities are likely to continue contributing to global environmental change, as the urban population is expected to increase by 72 per cent by 2050, leading to a global population of 9.3 billion, two thirds of which will be living in cities (UN 2011). Seto et al. (2011) report that the urban population doubled from 1970 to 2000 but the total worldwide urban land area might well have quadrupled. Currently, urban land is estimated to occupy between 0.2 and 2.4 per cent\(^3\) of the earth’s surface (Seto et al. 2011) and shelter more than 50 per cent of the world’s population (UN 2011). Half of this urban population is living in cities with less than 500,000 inhabitants (see Fig. 1.1). However, according to United Nations (UN) world population prospects (UN 2012a), the

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1 I use ‘cities’ and ‘urban areas’ interchangeably. According to Satterthwaite (2011), there is no universally accepted definition for ‘urban area’ or for ‘city’. For example in Europe each country has a different definition of what a city is, which usually depends on population size, density, on urban functions, on having a city charter or on being a recipient of national funds (Dijkstra and Poelman 2012). As this dissertation looks at the underpinnings of current urban policy and governance, I refer to urbanised areas with more than 50,000 inhabitants (following the definition of a city in Dijkstra and Poelman 2012) within their administrative limits. When I use the concept ‘urban system’ I am placing particular emphasis on connected elements, flows, processes and functioning regarding energy, materials and information in urban areas.

2 Hereinafter, ‘city’ or ‘urban area’ is understood to mean a limited administrative area formed by a social community network made up of citizens, associations and organisations, companies, governance institutions and service providers plus the network of natural and built infrastructure elements and the flows of energy, matter and information derived from their interdependencies.

3 Depending on the models used (for further explanation see Seto et al. 2011)
population is expected to become increasingly concentrated in cities of more than 1 million inhabitants. In 1970 the world only had two megacities\(^4\): Tokyo and New York; today there are 23 megacities around the world and their number is expected to increase to 37 by 2025. Regions with limited economic and institutional capacity will be the centres of urban expansion in the next 20 years. Half of the total expansion envisages is set to occur in Asia (Elmqvist et al. 2013). For the reasons above, cities of less than 1,000,000 inhabitants will be crucial for future urban development, as it will be in those cities where the population will be more and more concentrated.

![Figure 1.1 Total population in millions by city size class, 1970, 1990, 2011 and 2025 (UN 2012a)](image)

Global environmental trends in increasing resource availability and consumption (Krausmann et al. 2009; Huang et al. 2010), especially in relation to fossil fuels (Campbell and Laherrre 1998; Tsoskounoglou et al. 2008; Newman et al. 2009), the potential risk from human settlements due to climate factors (IPCC 2007), especially in those urban areas that are increasingly concentrated along coastlines (Elmqvist et al. 2013) and falls in the quality of the urban environment (UN-Habitat 2011) all exert

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\(^4\) A megacity is an urban agglomeration with 10 million inhabitants or more according to UN (2012a)
pressure on urban development. At the same time, according to the IPCC’s last report (2013), the warming of the climate system is unequivocal and the likelihood of further changes ranges from high to certain.

Studies estimate that by 2030 global demand for food, water and energy will increase by 50 per cent, 30 per cent and 73 per cent respectively (IEA 2008; Bruinsma 2009). 12 per cent of the population are currently living in slums (UN-Habitat 2011). Moreover, the UN (2012a) highlights that 60 per cent of the population living in urban areas with 1 million inhabitants or more (where poverty is usually concentrated) are currently highly exposed to at least one natural hazard, with flooding and droughts topping the list. With urbanisation as a central driver of global environment change (Seto and Satterthwaite 2010) and an indicator of vulnerability (Garschagen and Romero-Lankao 2013), urban policy must align with efforts to address regional and global environmental problems (Bai et al. 2010).

1.1.2. Revisiting urban sustainable development

In spite of the achievements in moving towards sustainable development over the past twenty years in line with a number of the Millennium Development Goals, according to the **Common statement by the UN System Chief Executives Board for Coordination (CEB) on the Outcome of the United Nations Conference on Sustainable Development (Rio+20)**


(Last accessed September 6, 2013)
to formulate long-term strategies to achieve climate-resilient and pollution-free environments. Unexpected events can occur due, for example, to migrations, market shifts, environmental degradation or natural disasters. The positive response of cities to the problem of solving inequalities and socioeconomic problems, e.g. by generating employment and centralising services, may also be a driver of unsustainability in the form of, for example, rural-urban migration or urbanisation. Figure 1.2 shows this through a DPSIR approach (Drivers-Pressure-State-Impact-Response). The figure illustrates how current response strategies may turn into a vicious circle that needs to be broken for strategies to be redirected towards greater sustainability.

Figure 1.2 A DPSIR approach (Drivers-Pressure-State-Impact-Response) to depict unsustainable patterns in cities

Aside from the degree of sustainability that cities can ideally achieve, there is no doubt that there is a need to reorient policies and shift towards more sustainable patterns that can guarantee wellbeing for future generations in the form of resources, security to
climate impacts, and equitable socioeconomic opportunities, as per the original definition of ‘sustainable development’ in the Brundtland report (UN 1987). There exist different models of ‘sustainable development’ and a variety of visions of what a sustainable city is, however it is necessary to recognise the diversity of pathways in which sustainable urban development could be achieved in an attempt to accommodate the different social and political interests that need to find a shared goal in the long-term run (Rydin 1999, 2010).

1.1.3. Urban resource-demanding metabolism

There are studies which evidence that cities are demanding consumers of energy and matter (Bai et al. 2005; Satterthwaite 2008; Satterthwaite et al. 2010). Since the founding of the urban metabolism theory (Wolman 1965), multiple studies originally grounded in industrial ecology research have focused on identifying and quantifying energy, matter and information flows in (macro) urban areas with the objective of defining more sustainable policies on an urban scale (see Barles 2010 for a review). Other studies from the field of urban ecology research (see Alberti 2008) have focused on identifying the role of cities and areas within cities in altered biogeochemical cycles (Pataki et al. 2011). However, most of these studies are incomplete in that they only focus on bio-geophysical trends (Kaye et al. 2006) and thus ignore socioeconomic considerations. This limits their usefulness for urban planning and policy making (Sahely et al. 2003). Additionally, although the role of urban morphology in determining the urban metabolism has been addressed (Alberti 1999; Pickett and Cadenasso 2008), key issues such as the role of the socio-institutional context of urban areas and the cross-scales interactions have been mostly overlooked (Ernstson et al. 2010b).

Resource consumption is a key, strategic issue in urban areas because of the concentration of demand and the embodied needs that it implies (Satterthwaite 2008; Satterthwaite et al. 2010), e.g. increases in infrastructures and agricultural land. For example, Weisz and Steinberger (2010) assert that energy and material consumption per capita are more than twice as high as one hundred years ago. Extensive dependence on external resources that cities cannot provide within their own boundaries hinders their ability to contain environmental impacts (Rees and Wackernagel 1996), and this in turn reduces the ability of cities to respond if there is a resource shortage.
Four main strategies are highlighted in the literature that examines this metabolic challenge: (i) maximising resource use efficiency, taking rebound effects into account (Gillingham et al. 2013); (ii) decoupling resource use from economic development (Haberl et al. 2011); (iii) promoting self-sufficiency to guarantee resource and service availability (Agudelo-Vera et al. 2012); and (iv) promoting changes in urban lifestyle patterns, policy-making and implementation (Weisz and Steinberger 2010).

Additionally, increasing urbanisation means that natural assets need to be conserved as critical elements whose services are hard to replace. Urban areas long ago crossed the critical limits where substitutability of those natural assets could be considered (Ekins et al. 2003; Dietz and Neumayer 2007). As a result, strong sustainability-guided policies have long been required (in contrast to weak sustainability policies where substitutability is considered). Ecosystem Services (ES henceforth) play a central role in sustainable strategies for adaptation to global environmental change (Rechkemmer and von Falkenhayn 2009) and this also needs to be translated into the urban context.

1.1.4. Urban climate action responsibility

It is increasingly recognised that, now more than ever, urban areas are pivotal to global climate change mitigation and adaptation efforts (Rosenzweig et al. 2010; Acuto 2013; Johnson 2013; Reckien et al. 2013b). In regard to mitigation, there are few studies that provide comparable data on the precise contribution of cities to global emissions (Dodman 2009), but cities are widely seen as responsible for around 80 per cent of global primary energy demand and their CO₂ emissions are expected to increase to 76 per cent of the total by 2030 (see e.g. Dhakal 2010). Regarding adaptation, Rosenzweig et al. (2011) argue that the sectors expected to suffer most from the impacts of climate change in most cities are: (i) the local energy system; (ii) water supply, demand, and wastewater treatment (iii) transportation; and (iv) public health. This is not only because the infrastructures that provide these services need to be adapted to the impacts of climate change (EC 2013) (such as, for example, the adaptive capacity of water infrastructures in storm prone urban areas), but also because new challenges may arise (such as with regard to health risks). Additionally, cities need to face further cross-cutting challenges related to governance and planning, land use management and green infrastructure which might
considerably magnify or reduce the impacts of climate change (Blanco et al. 2011). These issues, which include the study of the implications of land markets, property rights and fiscal and legal issues, have been poorly addressed to date even though they have a great impact on the potential success of climate change strategies (Blanco et al. 2011). Although cities are widely claimed to be climate leaders (Rosenzweig et al. 2010), there being good examples of successful climate actions (Rosenzweig et al. 2011; Castán Broto and Bulkeley 2013), there is no archetype of right actions because of highly contextual differences between cities. Moreover, urban climate governance is increasingly initiated not only by local authorities but also by a wider range of actors and processes, particularly by social movements such as the Transition Towns initiative (Bulkeley and Betsill 2013) and public-private partnerships (Castán Broto and Bulkeley 2013). These new forms of urban climate governance need to be considered in our understanding of the potential of cities. How and why cities respond to global environmental challenges in the context of increasingly competitive economies needs to be researched further (Acuto 2013; Johnson 2013).

1.1.5. Urban competitiveness

Cities face the need to maintain their competitiveness if they are to survive. Historically, urbanisation has been driven by the concentration of opportunities for investment, development and employment. Cities now concentrate industrial, technological and intellectual productivity (Kamal-Chaoui and Robert 2009). It is a fact that firms concentrate in cities because there is more access to skills and resources there. Around 50 per cent of the world’s financial services (ESPON 2010) and 80 per cent of the world’s gross domestic product (GDP) (UN 2012a) are generated in urban areas. As a result, urban development and renewal has become a key marketing factor (Leitner et al. 2007; Muñoz 2010) as it attracts investments, development and contracting opportunities and therefore, diversity of interests among stakeholders.

According to Kamal-Chaoui and Robert (2009), cities can lose competitiveness due to the environmental costs of high levels of urbanisation. This turns into an opportunity to develop win-win strategies for both the socioeconomic survival of cities and the environment which need to be taken into account in drawing up alternative development
pathways. Cities need to evolve from economy-based competitiveness strategies and integrate cross-scale social and environmental criteria into policy and planning decision-making processes, while acknowledging regional and global market dynamics. Businesses and firms can take advantage of this situation and engage in environmental responsibility through long-run innovation (Kamal-Chaoui and Robert 2009).

It is important in this regard for social and economic interests to be aligned with environmental interests in the short-, medium- and long-term by, for example, recognising the benefits of high environmental quality for the attractiveness of a city or finding new economic opportunities when environmental and socioeconomic interests do not coincide (e.g. in the case of carbon emission regulation and financing instruments).

Responding sustainably to environmental change in cities is complex. Apart from reactions to direct impacts, there are also spontaneous and planned responses sparked by many other non-environmental or climate-related factors such as socioeconomic processes, changes in land use or land cover, technological development, social behavioural change, etc., which directly or indirectly influence other sectors and climate variables (Parry et al. 2007). There is an increasing body of literature on the role of cities as hubs of change, experimentation and transformation, which looks at how advocated environmental, social and/or economic crises can be turned into opportunities (Seto and Satterthwaite 2010; Evans 2011; Romero-Lankao and Dodman 2011; UN-Habitat 2011; Whiteman et al. 2011; EEA 2012; Hodson and Marvin 2012; Castán Broto and Bulkeley 2013). In this regard, the success of cities in taking advantage of this situation depends on their improving their recognition of their own potential as well as on political will at both national and local level (Satterthwaite and Mitlin 2011).

1.2. Research questions and objectives

In line with the state of the art described above, I have identified the following three research questions and corresponding objectives which I set out to explore in this dissertation:
1. Introduction

- **Exploring sustainability and resilience links**: Given the need to conceptualize new theories to support the development of sustainable long-term strategies, I would like to identify in which ways sustainability thinking as currently applied in urban policy practice can benefit from resilience theory and its emerging adaptation to urban studies, hypothesising that this can help to frame sustainable urban transformation (this question is extended in Section 1.2.1 and address in Chapter 3). To this end, I would like to firstly address this issue from an integrated point of view by analysing the existing literature on socio-ecological systems and socio-technical systems, particularly regarding the concept of transformation and change (this integrated approach is further discussed in Section 1.2.2 and address in Chapter 2).

- **Addressing urban complexity**: As complexity influences the different alternative pathways leading to sustainable urban development, not taking it into consideration might cause loosing opportunities. I would like to explore how the inherent complexity within human and natural complex nested systems can be taken into account in decision-making processes regarding transformation and change. This question is extended in Section 1.2.3 and generally taken into account along the dissertation. Specifically, Chapter 4 addresses the connections of human and natural systems in urban areas and Chapters 6 and 7 analyse how complexity materialises through the eyes of a group of stakeholders in a case study.

- **Exploring the cognitive dimension**: Finding a shared goal that accommodates the different interests existing in cities requires understanding how experience and knowledge of the actors involved affect decision-making processes about sustainability and transformability. Using a case study, I would like to particularly (i) explore how cognitions can delineate potential transition alternatives in cities and (ii) evaluate the use of actors’ knowledge to identify best alternative pathways in terms of sustainability and resilience. This question is extended in Section 1.2.4 and address in Chapters 6 and 7.

These questions are extended and set out as objectives in the following sub-sections:
1.2.1. Linking sustainability and resilience

Early sustainability studies were driven primarily by concern for ecological wellbeing (Costanza and Daly 1992). As a result, urban environmental strategies have reflected the philosophy of sustainable development by focusing on how to manage current resources in a way that guarantees future welfare. In a way, this establishes a pathway for equitable, fair development. Sustainability policies have been practiced at city scale by means of multiple sets of indicators\(^6\) and instruments, such as Local Agenda 21, which seek to establish a balance between economic development, environmental quality and quality of life.

In the wake of the *Brundtland* report (UN 1987), resilience started to gain importance as a necessary step in building sustainability (Levin 1993). Today, the concept of resilience as a critical factor for sustainability has gained popularity in a number of different policy domains (Davoudi et al. 2012). In this dissertation, resilience theory is proposed as a useful approach to long-term sustainability thinking through the concept of transformation.

Resilience thinking encompasses the way in which change, drivers of change and reorganisation are conceptually understood. In academia, many disciplines use the term ‘resilience’ to address the concept of shocks and rebound mechanisms, but the link between environmental systems and human drivers comes from research into socio-ecological systems. Ecological definitions of resilience include “the magnitude of disturbance that can be absorbed before the system changes its structure by changing the variables and processes that control behaviour” (Gunderson and Holling 2002, p.4) and “the capacity of a system to experience shocks while retaining essentially the same function, structure, feedbacks, and therefore identity” (Walker et al. 2006, p.2).

\(^6\) Such as the Global City Indicators Facility (http://www.cityindicators.org/) and the European Common Indicators (http://ec.europa.eu/environment/urban/common_indicators.htm) just to mention some examples.
Resilience can be seen as a useful approach for meeting the challenge of sustainable development. Holling (2001) states that sustainability includes the capacity to create, test and maintain adaptive capability, whereas development is the process of creating, testing and maintaining opportunity. He follows this up by defining ‘sustainable development’ as development that fosters adaptive capabilities and creates opportunities to maintain prosperous (desirable) social, economic and ecological systems (see also Folke et al. 2002a). This explains the above assertion.

While the resilience of a social-ecological system is measured in terms of its capacity to adapt to shocks and reorganise (Walker et al. 2004), transformability requires society to view itself as being locked into an undesirable state and in need of reconfiguring a given system by means of new system components and dynamics. Hence, resilience management is about making it possible to deliberately alter the fundamental properties of the system and about undertaking a process of transformation in order to better cope with emergent conditions (Nelson et al. 2007). Promoting resilience means changing the nature of decision-making to recognise the benefits of self-sufficiency and new forms of governance which focus more on social equity, learning and the capacity to adapt (UN 2012b). Resilience plays a crucial role in achieving sustainability (Brand and Jax 2007) and has the potential to bridge different disciplines, stimulating dialogues between natural and social sciences, and between science and policy (Brand and Jax 2007; Deppisch and Hasibovic 2011; Davoudi et al. 2012).

As argued by Elmqvist et al. (2013) sustainability is insufficient to reflect the dynamics of resilience and transformation incurred by urbanisation processes. Motivated by this and the above, I argue in this dissertation that the complexity inherent in cities (Ruth and Coelho 2007; Bai et al. 2010) means that a shift is needed from current indicator-type sustainability evaluation-based approaches such as metabolic flows (Newman 1999) to complementary approaches such as resilience thinking. As a result, this dissertation builds on resilience and transformation theories, seeking to develop a conceptual understanding of sustainable urban development that involves transformability.
1.2.2. Fostering integrated approaches

To understand the behaviour of urban systems components and the links between them, i.e. the complexity of cities, the main multidisciplinary approaches which are currently being used by scientists (adapted from Bulkeley et al. 2010) analyse (i) the link between society and nature and the resulting urban metabolism processes as a part of a process of socio-ecological change; and (ii) socioeconomic and technological processes as part of a process of socio-technical change towards sustainability in a context of resource depletion and climate change.

The first of these analyses sees a city as a metabolic socio-ecological system. It studies biogeochemical flows within cities (Kaye et al. 2006) and the influence of human activities on those flows, depending on their intensity (Alberti et al. 2003). It also examines socio-ecological networks (Ernstson 2011) and assesses ecological inputs within urban areas (MEA 2005; TEEB 2011). The second analysis has been adapted to the urban context more recently. Socio-technical transitions and politics of transition (Rotmans et al. 2000) have been analysed in a wide range of historical cases, but only on regional and national scales. Recent research shows that it may be appropriate and beneficial to use this perspective also on the scale of cities (Hodson and Marvin 2010; Nevens et al. 2013).

Approaches i and ii both acknowledge the complexity of cities and the need to adapt gradually and transform urban structures and processes towards sustainability.

Indeed, a transformation approach to the study of urban systems suggests that the (in)stability and (un)sustainability of cities and urban networks, as complex socio-ecological systems, depend on multiple, multifaceted linear and non-linear feedbacks which have major effects on structures and performance. The extent to which cities are capable of transforming is therefore a matter of a combination of multiple factors that should complement each other to lead towards sustainable development (McCormick et al. 2013).

In this dissertation, the principles of sustainability and resilience are taken as the ideal framework for urban development and the philosophical basis for change. Theories on
transformation from research on socio-ecological and socio-technical systems are reviewed\(^7\) and adapted jointly to the context of cities, thus bridging disciplines and building an integrated approach\(^8\). The hypothesis put forward is that both approaches may be complementary since they look at cities from different angles, where economic and socio-institutional dynamics (from global to local individual level) inevitably play a central role. In order to address concerns as to the future sustainability of cities, socio-ecological change must embrace socio-technical change and vice versa in a context of global development. Consequently, integrated approaches which consider insights from both fields of research are required.

### 1.2.3. Addressing urban complexity and change

Cities and urban networks in this dissertation are seen as complex socio-ecological systems. It is therefore that complexity gains a relevant role in this work.

Complexity starts with the definition of the urban area itself. Satterthwaite (2011) asserts that there is no widely accepted definition for an urban area or for a city; that assertions attributing population or consumption data to cities are often incorrect due to definition divergences. Urban areas vary in size, domestic economy, urbanisation patterns, etc. These differences are frequently influenced by geo-political needs, history and cultural heritage among other factors. Together with lifestyle patterns, they determine to a large extent the energy and material consumption levels that can be credited to urban areas. Urban areas that are undergoing shrinkage or expansion face different challenges which affect the urban development strategies and the resources available to support them.

Even when the huge divergences in cities’ social, ecological, economic and institutional resources and their stages of development are acknowledged, not all cities are equally complex. Given that the challenges and targets regarding sustainability and resilience in cities are context-dependant, this dissertation addresses the problem in ordinary medium-

\(^7\) See Chapter 2, p. 33
\(^8\) See Chapter 3, p. 69
Cities and the systems of cities can be understood as bringing together human and natural complex nested systems (Liu et al. 2007a; Ernstson et al. 2010b). This view is required to encapsulate the dynamics of the following three dimensions: (i) natural biophysical processes and metabolic flows generated by the demands of urban users; (ii) the effects on human wellbeing of changes in the flow of ecosystem and human services; and (iii) the gradual reactive socio-technical and economic adjustment of cities to shifts in their contextual landscape such as those that may arise in the context of global economic and environmental change.

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From this point of view it is important to discuss what it means to understand a city as a system. In the context of complexity thinking and systems theory, cities are often observed as complex adaptive systems (hereafter CAS) (see e.g. Alberti et al. 2003; Ernstson et al. 2010b), similar to ecosystems themselves.

The concept of CAS has a certain level of abstraction and is understood differently by mathematicians and physicists and by biologists. The most important characteristics of CAS that arise from both understandings is that complexity may be hidden in a very simple system, and that complex global systems patterns may emerge from interactions at local

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9 Depending on the context, cities can be classified as small, medium, large or extra-large. Cities of less than 500,000 people are defined as small according to the UN (2012a). In the context of Europe, the OECD (Dijkstra and Poelman 2012) defines cities of less than 500,000 inhabitants as ranging from small (between 50,000 and 100,000) to large (between 250,000 and 500,000). From now on, we use the term ‘medium-sized cities’ to define cities of less than 500,000 inhabitants.
level (called emergence) (Lansing 2003). Also, the property of self-organization that characterises CAS is relevant for our discussion. In this context, CAS evolve through four phases of transformation: conservation (K), release or collapse phase, reorganization or renewal phase (α), and exploitation or consolidation phase (r) (Holling 1986). A new conservation phase starts again forming what is understood as the adaptive cycle10.

As CAS, cities are seen as microstructures that gather forming systems of cities that work better and adapt in better conditions as a macrostructure rather than individually. Therefore, when urban areas are understood as social and ecological complex and adaptive co-evolving systems, the scale of the social network becomes relevant, especially regarding its energy, material and information flows. Any city is part of a ‘system of cities’ which gives rise to particular cross-scale interactions between the technical and social networks that tie urban areas together and sustain those energy, material and information flows (Ernstson et al. 2010b).

For this reason, focusing on the local (administrative) scale has its pitfalls, as it fails to take account of cross-scaling feedbacks from urban areas, given the globalisation of resource provision. As argued above, urban areas are not self-sufficient, sustainable units (Rees and Wackernagel 1996; UNU/IAS 2003b), and the ES provision on which they depend is often on a scale that extends well beyond the urban administrative boundaries where local interventions take place. Likewise, the environmental impacts of urban activities cannot be considered as contained within those boundaries. This makes the analysis of cities challenging, especially since they operate as open systems from the viewpoint of metabolism (Grimm and Redman 2004). These system dynamics cause the complexity which characterise urban areas presenting multiple challenges to decision-makers and therefore to those that aim at studying urban change (see Grimm et al. 2000; Pickett et al. 2001).

In line with the above, and recognising the social and environmental challenges that cities need to deal with, Prasad (2009) asserts that the new operational tools need to be provided to support long-term urban decision-making if global environmental change is

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10 The adaptive cycle concept will be further discussed in Chapter 2 (see p. 47).
to be tackled. This is partly translated into analytical frameworks to help understand the complexity of the interdependencies in ecological, social and economical systems across scales and time which could help forecast and avoid unintended effects (Holling 2001; Kinzig et al. 2006). This dissertation attempts to fill this gap from a conceptual and empirical point of view, by the use of innovative approaches that recognise such interdependencies.

1.2.4. Exploring the cognitive dimension

Cognitive processes are mental processes of perception, memory, judgment and reasoning, and are related to the action of acquiring knowledge and understanding through thought, experience and the senses. Individual and collective knowledge, experience, values and perceptions are important to sustainability, resilience and transformation in two regards: (i) the relevance of learning and knowledge in resilience thinking and (ii) the importance of stakeholders’ cognitions in urban decision-making processes.

- On the one hand, the use of learning, knowledge and experience in governance processes is core to resilience thinking (Lebel et al. 2006). From this point of view, the process of learning from past experiences to gain knowledge about how to face future challenges becomes crucial and helps to build a shared vision about the future. As discussed, sustainable urban development is about accommodating the different interests of stakeholders in order to build a common vision of how a sustainable pathway might be. In this mission, there are huge implications of the different discourses, perspectives, theories and beliefs (Wenger 2000). In this regard it is also imperative to recognise the importance of social learning as a process of gaining individual and collective knowledge and experience.

The importance of the cognitive dimension for resilience building in cities is in fact being increasingly recognised, especially when ecological memory and human connection with the environment are considered (Colding and Barthel

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1. Introduction

The role of cities as hubs for change and transformation requires that new types of knowledge be acquired for robust resilience management (Beratan 2007) and transition management, i.e. for planning and managing the process of urban change (van de Meene et al. 2011; Nevens et al. 2013). This includes information about stakeholders’ knowledge of how urban systems work and how they might react to certain stimuli. Complexities and uncertainties in regard to cities are often not reflected in approaches based on statistical methods or physical analysis, and experience and knowledge of stakeholders are crucial to conceive alternative sustainable transition pathways. Institutionally diverse participatory approaches are critical in this regard as they help to enhance learning processes which are critical for resilience management (Carpenter et al. 2001; Gunderson and Holling 2002).

- On the other hand it is equally important to learn how, why and to what extent decision-making processes related to resilience and transformation management are influenced by values and cultural contexts (Adger et al. 2012).

Complexity in cities is also a result of the fact that urban change manifest through processes in space and time (Batty 2007). Although drivers of this change (i.e. of urban development) might have different natures (such as historical, physical, natural or comparative advantage), also, random decision-making is important to understand how urban development evolves (see again Batty 2007). Linked to this idea, in this dissertation I try to understand this randomness by exploring how cognitions affect decision-making in cities and its processes of change.

The matter of whether cognitions in the form of heuristics, biases and previous experiences affect decision making processes, including those related to the environment and the human-nature relationship, and if so how, has been also

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12 Clarifying note: this dissertation does not include a review of the literature linking (social or institutional) participation and (urban) resilience. Notwithstanding, the mentions to the need of building social learning through mechanisms such as robust participation processes is more and more recognized in the literature. For this reason, to my consideration, this requires further and deeper research in the future.
discussed previously in the relevant literature (see e.g. Schwenk 1988; Antal and Hukkinen 2010). As previously argued, discourses may have huge implications when building a shared vision of what sustainable urban development involves. Boulanger (2005) also explores cognitive issues in sustainability assessment. He argues that it is hard to see policy-making as purely rational, and that approaches that include a cognitive dimension are appropriate.

In the field of climate change it has been argued that social behaviour, lifestyles, culture and values have an important role as enablers of climate action but also as hinderers of it at both community and institutional levels (Azevedo et al. 2013). Acceptance of the need for a change in attitudes, understanding of values and recognition of capacities are key to enhancing capacity for adaptation (Adger et al. 2012). In this context, it is argued that the influence and potential of social capital in the mechanics of climate action need to be analysed in order to elucidate successful pathways of change and transformation (Westley et al. 2011; Adger et al. 2012; Park et al. 2012).

As illustrated in Figure 1.4, knowledge and understanding of experiences, observations and perceptions affect the decisions to be made, and therefore the actions to be implemented, which subsequently feed back to the former. The extent to which individual cognitions influence strategic decisions might vary depending on the context, but it is often a very important factor and is never an irrelevant one13.

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13 Personal communication from Miklós Antal through the Ecological Economics Mailing List of the Autonomous University of Barcelona on January 8, 2014.
In general, understanding these processes can help to better inform processes of adaptation and transformation (Adger et al. 2012), particularly by means of participatory approaches which integrate diverse perceptions and multiple scales. Such approaches might be based, for example, on discourse analysis (e.g. the Q Method or the Delphi technique), on mental models (e.g. agent-based or fuzzy modelling) or on multi-criteria evaluation (e.g. social or participatory MCA). In this dissertation I attempt to fill the current gap in this matter by addressing resilience and transformation from a cognitive perspective using suitable participatory, semi-quantitative methods.

1.2.5. General research objective

To sum up then, this dissertation sets out to study the inner mechanics of complex urban systems and explores urban climate and environmental governance from the perspective of resilience and transformation in a context of sustainable urban development. To achieve this general aim, I explore new approaches from a conceptual and empirical point of view that:

- may help to frame adaptive and transformative processes (Elmqvist et al. 2013);
- can address and manage both natural and human capital, seeing urban systems as socio-ecological complex adaptive systems (CAS) (Biggs et al. 2012);
• can better represent interconnections, systemic complexities and unsustainable lock-ins (Ernstson et al. 2010b); and

• can take into account the perceptions, values and understanding of the actors involved in the system as enablers or withholders of processes of transformative change (Adger et al. 2009; Adger et al. 2012)

The next section describes the structure of the dissertation.

1.3. Structure of the dissertation

The dissertation is structured in two parts which sum up the research objectives described above as follows:

1. Part I presents a conceptual analysis of what resilience and transformation mean in the urban context from a multidisciplinary point of view, what they involve in terms of governance processes and how they can be helpful in establishing a sustainable development framework in cities, (Part I comprises Chapters 2, 3 and 4)

2. Part II presents an empirical analysis and explores the transformative capacities of cities through a case study, by analysing the role of cognitions in decision-making processes and in the understanding of the structure and processes of urban systems from a resilience and sustainability perspective, (Part II comprises Chapters 5, 6 and 7).
Part I utilises frameworks of resilience from research into socio-ecological systems (henceforth SES), transition management (henceforth TM) (see Chapters 2 and 3) and from ecosystem service research (see Chapter 4) to build an integrated conceptual approach to sustainable urban transformation for policy and planning practice.

Part II uses a case study to provide an understanding of resilience and transformation capacities from a decision-making perspective and to explore the applicability of the conceptual analysis developed in Part I. The city of Bilbao, in the Basque Country (northern Spain) is selected as a representative case study of a small European city with less than 500,000 inhabitants, given the importance of cities of this type for future urban development, as discussed in Section 1.1. This city is particularly interesting as it has undergone a successful process of transformation from an industrial to a service-based city in the recent past and is now in need of an environmental transformation focused on its energy model, given current consumption trends and policies lacking in sustainable direction (see Chapter 5). Through the city of Bilbao, Part II focuses on the role played by the cognitions of stakeholders and decision-makers, in the form of perceptions, values,
culture, past experiences and expert knowledge, in the uptake of sustainable transitions and in resilience and transformation governance. Two participatory and semi-quantitative methodologies are used to provide an understanding of stakeholders’ discourses and cognitive understanding of the urban energy system: the Q method (see Chapter 6) and Fuzzy Cognitive Mapping (see Chapter 7). A brief description of each chapter in Parts I and II follows.

Part I

Chapter 2 “Theories of resilience and transformation” (p. 33) seeks to contextualise the concept of resilience in sustainable development and transformation theories. First, it explores the concept of resilience and how it is seen in the study of SES, reviewing the concepts of thresholds, adaptive cycles and multiple states, which are key to understanding resilience theory. Second, it analyses the notion of transformation from two perspectives: (i) from the resilience and adaptive management perspective; and (ii) from the contributions made by TM and innovation studies to the understanding of transformation in socio-technical systems. It concludes by stating that the two approaches are complementary and that they need to be integrated in the study of urban sustainable transformation.

Chapter 3 “Resilience, adaptability and transformability of cities” (p. 69) presents urban resilience perspectives and argues that these theories concur with the need to stimulate adaptability and transformability of urban systems. The chapter argues that urban societies need to realise the importance of creating new opportunities by integrating the abilities to manage adaptability and transformability so as to maintain (positive and general) resilience amidst accelerated changes in the global environment. By presenting cities as complex coupled social, ecological, technological and economic systems, this chapter explores the essentials of an urban transformation framework in the context of sustainability. The chapter aims to help determine the factors that underpin a proactive approach to urban governance, which helps to break out of locked-in states and creates opportunities to move towards more resilient, more sustainable urban systems. The chapter concludes by identifying research areas which are further explored in subsequent chapters: (i) reconsidering the opportunities of the natural and built environment (see
Chapter 4; (ii) identifying practical, context-specific barriers to transformation (see Chapter 6); (iii) engaging actors in the process of change by providing tools for visualising the required transformation towards sustainability and resilience (see Chapter 6 and 7), and (iv) gaining knowledge about the structure and functioning of urban systems (see Chapter 7). Figure 1.5 illustrates these connections.

Chapter 4 “Integrating ecosystem services in urban decision-making” (p. 101) addresses the need to integrate natural and human capital in urban decision making. It argues that this must be done by understanding the dynamics and feedbacks of urban social-ecological systems and thus by acknowledging, managing and offsetting the effects that decisions regarding urban form and resource management can have on costs and benefits for the wellbeing of current and future generations. Here I look at the city in a systematic way as a coupled social-ecological system where services are provided by natural or semi-natural providing units, by built infrastructures or by a combination of the two, so that services are co-produced.
Part II

Chapter 5 “Data and methods” (p. 145) presents the case study of the municipality of Bilbao (Basque Country), focusing particularly on the city’s urban energy system. To that end, it briefly reviews recent literature regarding urban low-carbon transitions and the associated institutional, social and technological challenges. It then goes on to describe the case study and the particular challenges regarding the uptake and governance of a low-carbon transition in the city of Bilbao. The last two sections describe the methods used and how the data for implementing them was collected in Bilbao.

Chapter 6 “Discourses in urban low-carbon transitions: A Q analysis” (p. 191) analyses the social and institutional determinants of transformation. Here it is hypothesised that it is social behaviour patterns related to scepticism, closed-minded attitudes, traditional economic models, lack of trust in institutions and in one’s own capabilities that limit the potential for transformation in cities. Bilbao (Basque Country) is used to illustrate barriers to and hidden opportunities for an urban low-carbon transition through an analysis of the cognitive dimension of such transitions. This is done by applying the Q Method, a semi-quantitative methodology which investigates stakeholders’ perceived capability for change. This results in four distinct discourses with direct implications in regard to the potential for transformation of the city.

Chapter 7 “A fuzzy cognitive modelling approach to urban resilience and transformation” (p. 211) argues that the complexity of the structure and processes in urban systems can often cause strategic decisions to have unintended impacts, especially given the plurality of interests and views held by stakeholders. Fuzzy Cognitive Mapping is proposed as a way of advancing towards an understanding of the cause-effect relationships in an urban system that are influential when planning for change. Through a participatory method, FCM can bring together knowledge from different experts and provide a method for getting closer to the policy domain. In the particular context of urban decarbonisation, FCM is applied to understand the resilience and transformability of the urban energy model of the city of Bilbao based on its impact on sustainability and resilience management objectives.
Chapter 8 “Conclusion” (p. 239) closes by summarising the contents of the dissertation, and highlighting the main results. It also includes overall concluding remarks, policy implications and other research questions that remain for further research.

Chapters 2 to 7 end with a summary which highlights their main arguments, results and conclusions.
Part I
Chapter 2

Theories of resilience and transformation

HOW DO SYSTEMS FACE CHANGE?

“[…] the increased vagueness and malleability of resilience is highly valuable because it is for this reason that the concept is able to foster communication across disciplines and between science and practice.” (Brand and Jax 2007)
Chapter 2. Theories of resilience and transformation

2.1. Introduction

This chapter looks at the concept of resilience and transformation through a review of the relevant literature, seeking to explore how these notions couple with the concept of sustainable development. I analyse the origins and theory of resilience and transformation from the perspective of socio-ecological systems research and from the knowledge gained through the study of transitions of socio-technical systems. This chapter then constitutes the baseline for Chapter 3 (see p. 69). It also responds to some of the research questions posed in the introductory Chapter 1: The objective is to create a context in which an integrated multidisciplinary framework adapted to the urban context can be generated and to identify the main criteria for developing a robust urban resilience and transformation framework that deals also with the concept of sustainable development, as addressed in Chapter 3. In the present section I motivate and explain the structure of this chapter.

2.1.1. The multiple perspectives of resilience

I have briefly introduced the concept of resilience from the perspective of socio-ecological systems research in Chapter 1. However, it has been often argued that the term ‘resilience’ is ambiguous (Brand and Jax 2007). Over the past three decades, different disciplines ranging from social and ecological science to engineering and computer networking science have taken the concept and applied it to meet their interests. Yet the term also has both older and newer meanings: for example, in computer networking science\(^{14}\), resilience is understood as the ability to provide and maintain an acceptable level of service in the face of faults and challenges to normal operation. In law resilience is related to the tendency of a person to engage in criminal behaviour (Kennedy 2007). According to the Dictionary of Animal Behaviour in Natural History (McFarland 2006) resilience is “the extent to which an activity is resistant to pressures of time”. In these

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\(^{14}\) See the wiki of the network promoted by The University of Kansas (US) and Lancaster University (UK): ResiliNets: Resilient and Survivable Networks (https://wiki.ittc.ku.edu/resilinets_wiki/) (Last Accessed: August 27, 2013).
terms “low-resilience activities are those that are curtailed when time is short, because other (high-resilience) activities take priority”. In Sports Science and Medicine (The Oxford Dictionary of Sports Science & Medicine 2007) resilience is defined as the “measure of a body's resistance to deformation” and as “the work required to deform an elastic body to its elastic limit divided by the volume of the body”.

In general ‘resilience’\(^\text{15}\) can be described as the ability of a living body, a system or a material to recover from a shock or disturbance. Each discipline has defined the terms in which that recovery takes place. Three of the disciplines mentioned are particularly relevant in the context of cities: engineering, social science and environmental science.

In engineering, ‘resilience’ measures how a system approaches the steady state after a disturbance. It is also measured as the inverse of return time (Holling 1986). In social science, social resilience is the ability of a community to cope with external disturbances caused by a social, political and environmental change (Adger 2000). In environmental science, resilience is generally understood as “the rate at which a system regains structure and function following a stress or perturbation” (Park 2007, no page). Seminally, Holling (1973) describes resilience applied to ecological systems as follows:

> “Resilience determines the persistence of relationships within a system and is a measure of the ability of these systems to absorb changes of state variables, driving variables, and parameters, and still persist. In this definition, resilience is the property of the system and persistence or probability of extinction is the result.” (Holling 1973, p. 17)

As set out in Chapter 1, one of the objectives of this dissertation is to contextualise the concept of resilience in sustainable development and transformation theories. In that regard it is interesting to explore how those theories are seen within resilience theories and what other approaches might complement the insights provided. Although Holling’s

\(^{15}\) The etymological origin of the word resilience is the Latin word resiliens, from the verb resilire (coined between 1620 and 1630), which means to spring back or rebound (re- "back" + salire "to jump, leap") (Dictionary.com 2009).
(1973) seminal definition is important in the history of resilience research, it sheds little light on how to integrate these concepts. To that end it is necessary to explore the application of resilience theory to social-ecological systems and particularly to climate change, as it is that the purpose of this dissertation. It is then that the idea of sustainability appears in the political agenda (UN 1987) and the need for transformation emerges.

2.1.2. Socio-ecological resilience, sustainability and transformation

In the field of ecology the theory of resilience was founded to focus on the dynamics of systems when disturbed from their modal state (Walker et al. 2004). Since late 1980s the concept has been increasingly used in the analysis of human–environment interactions, mainly focused on how an ecological system can be altered after an anthropogenic impact (one-off or persistent). According to resilience scholars (see e.g. Janssen et al. 2006a), Holling (1986) was instrumental in bringing the concept of resilience to the human dimensions of environmental change, leading to major papers on ecosystem management such as those by Walters (1990), Gunderson (1995), Berkes (2003) and Holling (1996) himself16.

To stress the strong connection between social and ecological systems in managed ecosystems, Berkes and Folke (1998) coined the term ‘social-ecological systems’ (widely referred to as SES). The terms ‘socio-ecological systems’ and ‘coupled human–environment systems’ are often used indistinctly, according to Janssen (2006). In this dissertation, I use the term ‘socio-ecological system’ or SES, in the meaning of a strongly complex, evolving system in which humans and their related dynamics (economy, technology development, etc.) are coupled with nature and have strong interdependencies.

In Chapter 1, I discussed complexity in the context of cities introducing the concept of CAS (see p. 15), however, it may be interesting to further explore how complexity is

16 These authors and others have organised themselves into an association named Resilience Alliance, dedicated to the study of the resilience of SES (Resilience Alliance 2014) which has become the major reference point for SES resilience-oriented literature.
broadly understood from the perspective of coupled human and ecological systems. According to Holling (2001), CAS are systems of people and nature in which complexity emerges while a certain level of self-organisation is maintained, characterised by foresight and planning as unique capacities of humans in contrast to ecological or physical systems.

In recent literature, the resilience of SES is interpreted as the “capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks” (Walker et al. 2004, p. 2). But resilience has also been seen as a magnitude. Holling and Gunderson (2002a) define ‘resilience’ as a measure of the magnitude of disturbance that a system can tolerate and still persist. Yet resilience is not only about being persistent or robust to such disturbances: it is also about the opportunities that disturbances open up in terms of recombining structures and processes, renewing the system and bringing to light new trajectories (Folke 2006).

In the light of the above and the fact that it is used to identify potential management options (Berkes et al. 2003; Nelson et al. 2007), resilience can be also understood as related to sustainability. This opens up a search for opportunities that can influence the movement of an SES towards a desired level of stability. In line with this, Holling (2001) uses the concept of ‘opportunity’ to unify resilience and sustainability theories. He asserts that the goal of sustainable development and the resilience theory have much in common. ‘Sustainability’ can be understood as “the capacity to create, test, and maintain adaptive capability” and ‘development’ as “the process of creating, testing, and maintaining opportunity” (see Holling 2001, p. 390). Combining the two, ‘sustainable development’ refers to the goal of fostering adaptive capabilities and creating opportunities, creating and maintaining prosperous social, economic and ecological systems (Holling 2001; Folke et al. 2002a).

Crucially, in contrast to sustainability, resilience may be desirable or undesirable (Carpenter et al. 2001). If a system is in a highly resilient but not desirable state, then it is difficult to move the system from that state to a more desirable one (Scheffer et al. 2001; Gunderson and Holling 2002; Walker et al. 2004; Folke 2006). Sustainability, however,
always involves the desirable characteristics of a system (Carpenter et al. 2001). On the other hand, controversially, in spite of the fact that they are essential for the discourse of sustainability, the aspects of resilience related to the capability for renewal, reorganisation and development have barely been explored in theoretical and applied research (Gunderson and Holling 2002; Berkes et al. 2003; Folke 2006).

In this regard, and in relation to the concept of transforming from one state to another, it is important to understand how resilience declines in an SES. The resilience of an SES depends largely on underlying, slowly changing variables such as climate, land use and nutrient stocks, along with social factors such as human values and policies (Carpenter et al. 2001; Walker et al. 2002). It is when the loss of resilience is related to the need to move towards more sustainable states that the idea of transformation emerges. According to Walker (2004), if resilience and adaptability have to do with the dynamics of a particular system (or a closely related set of systems), transformability refers to altering the nature of a system “when ecological, economic, or social (including political) conditions make the existing system untenable” and he also defines transformability as the process of “defining and creating new stability landscapes by introducing new components and ways of making a living, thereby changing the state variables, and often the scale, that define the system” (Walker et al. 2004, p. 5).

Although the idea of the need to cross tipping points and thresholds to move towards more sustainable states that can cope with global environmental change and climate change impacts and better deal with adaptation processes is not new in SES research (Folke et al. 2002a; Nelson et al. 2007), more and more scholars have recently asserted the urgent need to stimulate transitions and thus the need to provide policy tools that can support long-term successful sustainable development (Westley et al. 2011; Kates et al. 2012; Park et al. 2012; Scheffer et al. 2012; Boettiger and Hastings 2013; Werners et al. 2013).

Other transformation theories originating from a socio-technical systems (widely referred as STS) perspective and emerging from innovation and technology studies (Rotmans et al. 2001a) have also contributed to thinking about evolution and sustainable development. This field of research is known as ‘transition management’ (hereafter, TM). It has
developed its own model of a transition arena formed by regimes, landscapes and niches which stimulate long-term transitions that overstep administrative scales (Loorbach 2007). From this perspective sustainability transitions are in part about interactions between technology, policy/power/politics, economics/business/markets and culture/discourse/public opinion (Geels 2011): as such they fall short of including ecological dynamics.

For this reason, given the importance of technology, industry, economy and culture in urban development, exploring the complementary aspects of the two research areas (SES and STS research) may enable progress to be made towards an applied framework for the urban context.

### 2.1.3. Structure of the chapter

This chapter is structured in two parts. It first explores the theory of resilience and then, it navigates the idea of transformation from the perspective of socio-ecological systems and also from the perspective of socio-technical systems.

Therefore, to explore the meaning, operationalisation potential and applicability of resilience, Section 2.2 deals with the approaches used to measure resilience. It analyses concepts such as *panarchy*, thresholds and adaptive cycles. Section 2.3 then presents the concept of adaptive management, which is intrinsically related to the concept of transformation. Section 2.4 analyses the notion of transformation from the perspectives of: (i) resilience and adaptive management; and (ii) the contributions made from TM and innovation studies applied to STS research. Section 2.5 concludes by setting out a number of insights for adapting these frameworks to the urban context, which are addressed in Chapter 3. The last section is a recapitulation of the chapter. The structure of this chapter is illustrated in Figure 2.1.
2.2. Socio-ecological resilience: key concepts

2.2.1. Metaphors for resilience

The definition of resilience has changed over the last few decades, and so have the ways in which it is modelled and/or assessed. Modelling helps to understand the potential implications of situations that have never been experienced before with a view to forecasting and managing the resilience of the system to a predicted disturbance. According to engineering, resilience is based on how quickly a system recovers from disturbance and measures the recovery time (see top of Fig. 2.2). The current “ecological resilience” perspective considers the amount of disturbance necessary to change the state of an ecosystem, pushing it over the “ecological threshold” from state A to state B (see bottom of Fig. 2.2) (Groffman et al. 2006).
However, in general it is much more common to find studies where resilience theory is used as a metaphor than studies which examine its measurement (such as García 2013; Li et al. 2014, studies that addressed the measurement of ecological resilience in urban landscapes).

In either case, in order to assess a system’s resilience one must specify the system configuration \( (resilience \ of \ what) \) and the disturbances \( (resilience \ to \ what) \) to be considered (Carpenter et al. 2001). As far as the system configuration is concerned, resilience is commonly described through the basin metaphor (see Fig. 2.3) when disturbance is thought of as a physical force. The basin of attraction refers to a region in state space in which the system tends to be influenced by what can be thought of as the force of gravity (Resilience Alliance 2014).
2. Theories of resilience and transformation

Figure 2.3 Resilience depicted as “a ball in a basin” (Resilience Alliance 2014).

Notwithstanding, it is important to distinguish between resistance (which is measured by the external force or pressure needed to disturb — i.e. displace — a system by a given amount) and resilience (which is measured by the size of the basins of attraction) (Carpenter et al. 2001). The state of this tri-dimension system is represented by a ball (see Fig. 2.2). Gravity and the dynamics in place make the ball move towards the attractor i.e. towards the bottom of the basin (the darkest areas in Fig. 2.2). The system can change regimes either by changing the state or by changing the shape of the basin (which would mean a change in functions, structure and processes). A threshold (see Fig. 2.3) is a breakpoint between two regimes of a system (Walker and Meyers 2004). Thresholds limit the boundaries around a system state which, if crossed, represent a transition to another system state (Berkes et al. 2003).

2.2.2. Thresholds or tipping points

According to Walker and Meyers (2004) some characteristics or observations on thresholds should be considered. For example, they assert that:

- changes in the scale of analysis of a system influence resilience and therefore the positions of thresholds;
- threshold changes on larger scales (e.g. oceans) are rarer and more difficult to measure;
- as resilience declines, the amount of disturbance needed to cross the threshold declines; and
the consequences of crossing a threshold are context dependent: the threshold is sometimes known and the decision (by managers) on what to do about it depends on the consequences of crossing it.

Groffman (2006) describes three types of threshold in ecology: (1) dramatic and surprising “shifts in ecosystem state”, where a small change in a driver causes a marked change in ecosystem condition; (2) “critical loads,” which represent the amount of pollutant that an ecosystem can safely absorb; and (3) “extrinsic factor thresholds,” where changes in a variable at a large scale alter relationships between drivers and responses at a small scale.

When studying the dynamics of an SES, a key question is whether or not the system has, or is likely to have, thresholds which are not known in advance. According to some authors (see e.g. Carpenter 2003; Boettiger and Hastings 2013), thresholds are context-dependant and generic ones are unlikely to exist. Yet there is strong evidence of the existence of thresholds in many ecosystems (which does not mean that every ecosystem has a threshold for a specific disturbance) that influence their provision of services to human beings (Groffman et al. 2006). In fact, some of these thresholds are already used by policy makers (e.g. emission limits in policies on atmospheric pollution). In relation to the idea of identifying thresholds or warning signals before they are crossed, Carpenter (2013) states that important advances in the measurement of resilience in space (see discussion in Section 2.2.5, p. 47) have been made that may represent a major contribution to the determination of critical transitions.

In relation to these insights, it is crucial to note that resilience assessments should differ in two important ways from ecological indicators as they are usually constructed.

- First, resilience applies to the entire SES, not just the ecological subsystem, and must take into account the human, economic, technological and ecological systems coupled to it and their mutual interactions as CAS. In this line, studies should stress the nature of thresholds, i.e. whether they refer to general resilience or resilience specific to one part or process within the system (Scheffer and Carpenter 2003; Groffman et al. 2006).
• Second, resilience focuses on variables that could deteriorate ES provision, whereas other indicators often address only the current state of the system or service (Carpenter et al. 2001). This means that resilience studies reflect a long-term view.

The above ideas originate from ecology studies and refer mostly to the ES framework as the uptake of resilience management, focusing on the need for sustainable, continuous provision of ES to maintain human activities. Indeed, one of the most important arguments in resilience theory is the need to maintain ecosystem services as a source of resilience. And this translates into a strong focus of this theory in the understanding of the connections between human society and nature (see Olsson et al. 2014). This understanding would arguably help to stay within planetary boundaries. Considering connections between society and ecological systems into decision making processes would avoid trespassing planet ecological boundaries which is the only way of guaranteeing resources for future generations, i.e. guaranteeing sustainable development.

However, thresholds are not only ecological in nature: SES have a social nature too. Thresholds can also be expressed in socio-political terms (as done by Werners et al. 2013) which, although influenced by biophysical thresholds, are defined by socio-political factors such as those dependant on culture or values. These socio-political thresholds determine an adaptation tipping point where society must change the way in which it manages adaptation processes and actors may turn to alternative mechanisms that produce better outcomes and fit better alongside changes.

### 2.2.3. Multiple states and panarchy

Another fundamental contribution of resilience theory, and in line with complex systems theory is the understanding that most social-ecological systems, as complex systems (see Section 1.2.3, p. 15) can organise around a number of possible stable states (Holling 1973; Beisner et al. 2003; Berkes et al. 2003), all of which lie within the same function and structure. This means that a handful of alternatives might be possible around a desirable state. These alternatives are known as Multiple States.
Precisely because there are multiple stable states, to assess resilience one must specify what stable state is considered (Carpenter et al. 2001). An understanding of the dynamics of social-ecological systems which lead to one state or another, including the influence of individuals and societies that try to manipulate the SES to suit their own interests, knowledge, experience and goals, is essential when building resilience (Kinzig et al. 2000; Scheffer et al. 2000; Redman and Kinzig 2003). Temporal, social and spatial scales determine the configuration of the system and help to specify “resilience of what” and “resilience to what” (Carpenter et al. 2001).

In order to better specify the specific state on which the system relies, Walker (2004) proposes a framework for measuring resilience based on the basin metaphor and defines ‘latitude’, ‘resistance’, ‘precariousness’ and ‘panarchy’ as illustrated in Figure 2.3. **Panarchy** here means how the state of a system (in the focal scale) is influenced by the states and dynamics of the (sub) systems at scales above (coarser scale) and below (finer scale) the scale of interest (focal scale in Fig. 2.4).
2. Theories of resilience and transformation

As put by Holling et al. (2002b), a *panarchy* represents the cross-scale dynamic interactions between different system scales. *Panarchy* is thus a crucial characteristic in resilience theory as it expresses the need to define the broader context on which the system under analysis relies so as to forecast potential shifts that can influence the state of that system.

### 2.2.4. Resilience to what? Disturbances in resilience management

In the previous sections of this chapter I have explored how the system configuration is understood and modelled from a resilience perspective, i.e. “resilience of what”. As put by Carpenter et al. (2001), there is also a need to define “resilience to what”, i.e. to specify the disturbance that affects the system.

In order to identify what disturbances are of interest given a specific SES, several issues must be tackled before any attempt can be made to apply the concept of resilience to solve complex resource problems in the region where that SES is located. According to the Resilience Alliance (2007b) the following characteristics which describe the system dynamics should be considered: (i) system drivers; (ii) trends in major resources (soil,
water, biota) and major resource uses; (iii) the main ecological and social changes currently taking place; (iv) how changes have occurred over time (gradual ramp up, slow decline, rapid jump, collapse, oscillation); (v) characteristic disturbances in both the social and ecological domains at each relevant scale; (vi) possible changes in the patterns of those disturbances, i.e. in their frequencies or intensities; (vii) new kinds of disturbances that may emerge; (viii) attempts by managers to control or modify disturbance events (past attempts or attempts currently in place; and finally (iv) the changes in flows (goods, ES) caused by a modification in the system.

The Resilience Alliance Workbook (2007b) suggests that identifying all the aspects mentioned above enables the history of the system to be analysed and the times and periods of major events that changed the system to be identified. To deal with panarchy, it is useful to do this at each scale of analysis (the focal scale, below and above), and to identify cross-scale connections, i.e. how events at one scale either cause or result from events at another scale.

The likelihood that an SES will stay within a domain of attraction is related, in most cases, to slowly changing variables that determine the boundaries and the magnitude of disturbances that may push the system out or reconfigure the domain of attraction (Carpenter et al. 2001). Identifying hidden controlling variables that have caused or may cause changes in the SES is therefore an essential task.

As a result of panarchy, the temporal and spatial scales of the disturbance also have a considerable influence on the behaviour of the system and on its and reactions to disturbances. In most social or biophysical systems, external or internal disturbances elicit a number of reactions across spatial and temporal scales. Whether the system returns to its normal functioning or such cascade reactions affect the future dynamics of the system, pushing it to reconfigure itself, depends on the persistence of the disturbance as well as on the magnitude of its impact (Kinzig et al. 2006; Young et al. 2006). This leads to the assertion that the temporal and spatial scales of a disturbance are an important measure of the system’s adaptive capacity, robustness, resilience and vulnerability (Young et al. 2006).
2.2.5. Resilience in space and time: the adaptive cycle

Time and space play roles in resilience studies in two ways: first, within any assessment of resilience the spatial frequency of a process or structure over a specific period of time must be identified (Holling et al. 2002b). Second, based on this, and considering that resilience, as described, can be understood as the measure of the distance to a threshold, that measurement can be translated in terms of space and/or time. This could allow researchers to compare different systems or even anticipate or forecast impending transitions (Carpenter 2013).

Resilience scholars have developed a way to understand resilience in units of space and time through the metaphor of the adaptive cycle. This notion is meant to be a tool for understanding the cycles in which SES operate (Gunderson et al. 1995; Carpenter et al. 2001; Gunderson and Holling 2002). Dynamic systems (such as ecosystems, societies, corporations, economies, nations, etc.) go through adaptive cycles (Carpenter et al. 2001). In fact, the history of interactions between humans and nature includes many cyclical patterns (see example of Lake Mendota in Carpenter et al. 2001).

As introduced in Chapter 1 (see Section 1.2.3, p. 15), the adaptive cycle is a metaphor used to identify four commonly distinct phases of change (Holling 1986) (see Fig. 2.5). The first two, exploitation (r) and conservation (K) originate from the concept of succession in traditional ecology. The other two are creative destruction (also known as collapse or release) (Ω) and renewal or reorganisation (α).
According to this theory the dynamics of SES can be usefully described as follows (Walker et al. 2004): first comes a transition often described as the *foreloop*, from a growth and exploitation phase \((r)\) to a conservation phase \((K)\) which is a slow, incremental phase of growth and accumulation. Secondly there is a transition, known as the *backloop*, from \(\Omega\) (the collapse or release phase) to \(\alpha\) (the renewal phase), which is the rapid phase of reorganisation that leads to renewal. Systems can move back from \(K\) toward \(r\), from \(r\) directly into \(\alpha\), or back from \(\alpha\) to \(\Omega\).

The way in which adaptive cycles aggregate resources and are periodically restructured to create opportunities for innovation is a fundamental notion for understanding complex systems (Holling 2001). Adaptive cycles nest across time and across space, emphasising cross-scale interplays and helping to visualise the idea of panarchy (Gunderson and Holling 2002). In essence larger, slower components of the hierarchy provide actors which manage the resilience of the system with the memory of the past to allow recovery and adaptation (Resilience Alliance 2014).

Recently, novel experiments concerned with the behaviour of population communities (Dai et al. 2013) have explored how resilience performs in space and provided an index of resilience based on spatial deterministic factors. According to Carpenter (2013), this contributes significantly to resilience thinking because most studies use time-based indicators with no spatial information. In the same paper Carpenter (2013) states that
spatial indicators offer unique advantages, as they may enable data to be retrieved from historical aerial and satellite images for example. As discussed in Sect. 2.2, this would enable forewarnings to be given of impending or critical transitions in SES, thus helping to determine thresholds before they are crossed (Carpenter 2003; Scheffer et al. 2009; Scheffer et al. 2012; Carpenter 2013).

2.2.6. Adaptive management

In resilience and sustainability management some systems can critically be maladaptive and trigger poverty and rigidity traps (Holling 2001; Carpenter and Brock 2008). According to Lebel et al. (2006) this needs to be addressed by strengthening the ability of the actors to manage resilience so as to effectively pursue sustainable development by promoting the adaptation of the system. However, Lebel et al. (2006) also question the nature and role of such actors, who may well be the ones that have the power to decide what should be made resilient to what and what purposes are served. This undoubtedly introduces issues of governance.

According to resilience literature, adaptability is defined as the capacity of actors, social networks and institutions to influence resilience in a system (Walker et al. 2004; Lebel et al. 2006). This makes adaptation one of the main concepts intrinsically related to resilience in SES. To manage the resilience of a system one must build up the adaptive capacity to face foreseeable and unexpected changes which may affect the observed system conditions (Folke et al. 2010). The role of adaptive capacity in resilience management has been widely studied (Holling 2001; Folke et al. 2002a; Tompkins and Adger 2004; Adger and Vincent 2005; Smit and Wandel 2006).

While different authors attribute different characteristics to adaptive capacity (Yohe and Tol 2002; Brooks et al. 2005; Haddad 2005; Trejo Enriquez 2007; Bussey et al. 2012), there is general agreement that the main components of adaptive capacity to internal or external disturbances are closely associated with the levels of and tradeoffs between financial capital assets (e.g. savings), human-made capital assets (technology and infrastructure), social capital assets (e.g. information and knowledge networks, trust and the capacity to learn) and adequate natural capital assets or green infrastructure (Colding...
and Barthel 2013; Schäffler and Swilling 2013) that interact with co-evolving cultural norms and values (Adger et al. 2009; Adger et al. 2012).

If resilience can be used by decision makers as a concept for creating options for management (Berkes et al. 2003), it could be reasoned that a loss of adaptive capacity implies a loss of resilience which in the end translates into a loss of opportunity for sustainable development. A high level of adaptive capacity means that systems are able to reorganise and re-configure themselves, so they can maintain the crucial functions (e.g. primary productivity, hydrological cycles, social relations and economic prosperity) that give them their identity. Nelson et al. (2007) also argue that adaptive capacity has direct implications for the type and scale of adaptation that a system can achieve. This is also stated by Brooks (2003) when he argues that adaptive capacity represents potential rather than actual adaptation.

Walker et al. (2004) again suggest measuring adaptive capacity via threshold management and Carpenter and Brock (2008) suggest a model for assessing adaptive capacity which explains adaptation to fluctuating conditions as well as the emergence of pathologies such as poverty and rigidity traps (Gunderson and Holling 2002; Carpenter and Brock 2008). Lebel et al. (2006) suggest types of capability that strengthen adaptive capacity (see Fig. 2.6):
Here, the idea of self-organisation means that a system has the ability to re-organise and re-structure itself when disturbed. Learning is also central to resilience (Carpenter et al. 2001; Gunderson and Holling 2002): it is based on memory (Adger and Vincent 2005; Brooks et al. 2005; Folke et al. 2005). As new knowledge is gained, learning is advanced by institutions that can experiment safely, monitor results, update assessments and
modify policy (Carpenter et al. 2001). Indeed, the development of such learning institutions may be the greatest challenge in working towards sustainability (Berkes and Folke 1998; Carpenter et al. 2001; Gunderson and Holling 2002). Human systems are capable of learning, and learning how to learn (Bateson 1972). Self-organisation is a product of the natural capability to adapt, and learning is a process which contributes to this by generating opportunities for adaptation that the system cannot achieve by itself. In social systems, the existence of institutions and networks that learn and store knowledge and experience creates flexibility in problem solving, balances power between stakeholders and plays an important role in adaptive capacity (Scheffer et al. 2000; Berkes et al. 2003). Holling (2001) argues moreover that human systems exhibit at least three features that are unique and that distinguish them from others: foresight, communication and technology, all of which are enablers for adaptive capacity.

So how can policy take part in this process effectively?

Holling (2001) states that managing complex systems means confronting the multiple uncertainties which generally arise from technical considerations, such as models or analytic frameworks. Adaptation is a process of decision-making in which a set of actions are undertaken to maintain the capacity to deal with future change or perturbations (Nelson et al. 2007). Adaptive management is the process of creating adaptability and transformability in SES, and must take surprise and unpredictability into consideration. As explained by some resilience scholars (Walters 1997; Folke et al. 2002b) this is the main reason why the rigidity of existing governance institutions could represent a barrier to adaptive management. The process and dynamics of adaptive management enable different management policies to be tested, emphasising learning, monitoring and storing knowledge on the way, and enable behaviour and modus operandi to be continually adjusted in order to match the dynamics of the system (Folke et al. 2002b).

Through an analysis of the relevant literature it is possible to highlight a set of essential characteristics that institutional structures and decision-making processes must have if they are to empower adaptive management:
2. Theories of resilience and transformation

(i) **Flexible social networks and organisations** that proceed through learning-by-doing are better adapted for long-term survival than rigid social systems (Folke et al. 2002b);

(ii) **Multidisciplinarity:** In addition to scientific information, adaptive management requires the involvement of resource users, decision-makers and other stakeholders (Ostrom 1999; Berkes et al. 2003)

(iii) **Institutional diversity in decision making processes** enables rules to be tested at different scales and helps create institutional dynamics which are important to adaptive management (Folke et al. 2002b)

(iv) **The ability to store knowledge and empower learning** which constitutes the greatest challenge on the way to sustainability (Berkes et al. 1998, Carpenter et al. 2001a, Gunderson et al. 2002), and

(v) **Coping with uncertainties and surprises** (Walters 1986; Gunderson et al. 1995; Ostrom 1999; Holling 2001; Folke et al. 2002b).

These characteristics are not only essential for managing adaptation but also for avoiding unintended transitions and leading processes of deliberate transformation.

**2.2.7. The role of knowledge and learning in resilience thinking**

As the following chapters and the empirical work developed will prove, in this dissertation, the role of knowledge, experience and perceptions of stakeholders in processes of resilience and transition management is seen critically important.

The concept of adaptive management, discussed in the previous section, helps to understand this significant role that learning, knowledge and experience have for resilience thinking (Lebel et al. 2006). In order to be able to cope with the uncertainties, knowledge and experience gained from past events is critical in the process of dealing with future unpredictability and in the process of considering alternative pathways of future development. Decision-making processes involved in the governance of socio-ecological systems are greatly influenced by values and cultural contexts (Adger et al. 2012). Knowledge and experience are gained in these contexts and it is therefore significant the degree in which discourses and beliefs for example around technology and...
development affect decisions to be made regarding alternative pathways and development opportunities.

Learning processes are therefore critical in this regard. In Chapter 1, I argued that sustainable (urban) development was greatly influenced by the different discourses, perspectives, theories and beliefs of the stakeholders involved in (urban) decision-making processes (see Sect. 1.2.4, p. 18). Indeed, in the context of cities, complexity also emerges from the fact that decision regarding urban development might be also random, i.e. not responding to general questions such as competitiveness with other cities or availability of resources. And because sustainable development is about building a shared vision, the process of social learning referring to that one that allows gaining individual and collective knowledge, is crucial. Eventually, in Chapter 1, it was argued as well that for (urban) resilience and sustainability transformation, where the links between human and natural systems is key, new forms of knowledge acquisition are required.

All in all, we can say that stakeholders’ knowledge and experience (including biases or beliefs) affect decision-making processes, including those related to the environment and the human-nature relationship, and this is critical in the process of adaptive governance and to elucidate successful pathways of change and transformation.

It is thus relevant at this point to discuss the benefits that research and practice related to learning can provide to resilience and the links between them. Learning has become a key issue in the last two decades, not only for the most obvious disciplines such as education or psychology, but also for politics or economy (Illeris 2008). There are many theories of learning (for a review see Illeris 2008) that can be grouped in behaviourists, constructivist, cognitive and social learning theories and activity, organizational and socialization theories (as put by Wenger 2000). Together with Lave Wenger himself has coined a new concept “communities of practice” (Lave and Wenger 1991) that refers to the old common human habit of learning through practice, interaction, experience and identity (see e.g. Wenger 2000; Wenger 2002). Communities of practice are groups of people who interact and engage in a process of collective learning towards a shared vision. This concept has been used in the context of resilience research before (see e.g. Barthel et al. 2010). In these communities, the use of socio-ecological memory i.e. the
use of memory about ecological past management practices to aid the regeneration of the ecosystems and their services, is a source for resilience (see the example of allotment gardens in Sweden in Barthel et al. 2010).

The above shows just one of the links between learning theories and resilience theory and just grasps the potential of this combination. As Ison et al. (2013) argue for the particular case of social learning and socio-ecological systems, this kind of approaches certainly help to create new spaces for innovation and add flexibility that adaptive management and CAS require.

2.3. Theories of transformation

2.3.1. Socio-ecological resilience and transformation

As discussed earlier in this chapter, another attribute that can be used for SES in conjunction to resilience and adaptation is transformation. It is intrinsically related to adaptation management as a strategy for achieving adaptation. At some point in the management of SES it may be necessary to configure a new state which has basic differences from the previous one in terms of its structure, functions and processes. As argued by Walker et al. (2004), transformability means altering the nature of a system. As indicated above, transformability is thus defined as the “the capacity to create a fundamentally new system when ecological, economic, or social (including political) conditions make the existing system untenable. Transformability means defining and creating new stability landscapes by introducing new components and ways of making a living, thereby changing the state variables, and often the scale, that define the system” (Walker et al. 2004, p. 5).

Transformation includes the act or process of transforming, which entails a change in the form, appearance, nature or character of the element being transformed. The same determinants identified for adaptive capacity can be seen as providing the system or the system actors capable of being transformed into different stable states. This assumes that
transformation is partly defined by the occurrence of continuous adjustments leading to a change in the system structure and *leitmotiv* (Chelleri and Olazabal 2012b).

When transformation is understood as a possibility within a process of continuous adaptation, two processes may come into play:

(i) **incremental adjustments** of the system (as a result of adaptive management carried out by institutions); and

(ii) **transformation**, which involves more radical change, which may be deliberate (a product of resilience maintenance through adaptation or self-organisation) or non-deliberate (inadvertent or unintentional, implying a touch of surprise) (Nelson et al. 2007; O'Brien 2012) (see Fig. 2.7).

![Figure 2.7 Characteristics, processes, and results of adaptation actions.](From Nelson et al. (2007)

Under normal conditions SES naturally avoid vulnerable states which imply structural changes. The maintenance of a required degree of resilience (or adaptive capacity) may take the form of spontaneous or self-generating processes which would lead to a deliberate transformation (Young et al. 2006). On the other hand, the capacity to foresee untenable situations in the long run is necessary in order to effectively plan and manage such processes of transformation. This is when the concept of thresholds and the identification of warning signals of critical transitions in SES become important, as discussed in Sect. 2.2. This can also help to deliberately take a state of crisis as an opportunity to transform into a more desired state (Folke et al. 2005).
But what capacities provide SES with the potential to open windows of opportunity? The intrinsic properties and key characteristics of SES, such as resource availability, climate conditions and geo-political context, largely determine the ability to trigger opportunities of adaptation and transformation, but in the end it is in a society’s ability to take advantage of them that resilience resides. For instance, in the context of climate impacts in vulnerable regions, Kates et al. (2012) argue that along with the costs and benefits of anticipatory actions, the main barriers to transformative adaptation lie in current institutional inertia and significant uncertainties regarding future impacts which affect the position of decision-makers.

### 2.3.2. Transition management: a socio-technical perspective

Adaptive management applied to SES and TM applied to STS have much in common, although they have different roots. TM has its roots in innovation and technology studies dating from the late 90s (Rotmans et al. 2000) and has a long history in the Netherlands, where it emerged out of a socio-political need to face environmental degradation and the huge costs of mitigation investments (Van der Brugge and Van Raak 2007). In spite of divergences in their origins, both approaches attempt to provide an understanding of CAS and emphasise the importance of continuous processes of learning and adjusting (Van der Brugge and Van Raak 2007).

Because TM considers transitions as long-term processes of change (20-25 years) during which a society changes fundamentally (Rotmans et al. 2000; Rotmans et al. 2001b), it tends to have a broader approach to sustainability in that it addresses the multi-dimensional *interactions* between industry, technology, markets, policy, culture and civil society (Geels 2012). Indeed, the theory of TM was founded to provide governments with tools to mainstream efforts to govern such processes of change and direct them towards a desirable state.

From the TM perspective, transitions are non-linear processes where a slow change (predevelopment) is followed by a rapid change (take-off and acceleration) when things reinforce each other. This is again followed by a slow change (stabilisation) in the new equilibrium (see Fig. 2.8). As Loorbach and Rotmans (2006) recognise, it is not
misguided to see this process as similar to the 4 phases of change illustrated by the adaptive cycle (see Sect. 2.5, Fig. 2.5).

![Figure 2.8 Stages of a transition process (Rotmans et al. 2000)](image)

TM scholars have also developed an analytical approach that furthers the understanding of TM mechanisms and conceptualises the overall dynamic patterns in socio-technical transitions. This is known as the Multi-Level Perspective (MLP) on socio-technical transitions (Geels 2002). In the MLP, scale levels and dynamics are represented by nested landscapes, regimes and niches (see Fig. 2.9). Landscapes operate at the macro-level and are the slowest-changing external factors which affect societies. At niche level there are individual actors, technologies and local practices. It is at this level where the radical innovation starts and new ideas on technologies, ways of acting, etc. arise. The meso-level consists of regimes of rules that enable and constrain activities within communities (Geels 2002), such as interests, social norms, belief systems that affect the organisation of companies, the strategies of institutions and the policies of political institutions (Loorbach and Rotmans 2006)
2. Theories of resilience and transformation

How niche innovations can generate new regimes is shown in Figure 2.10. This figure reflects also the phases of predevelopment-acceleration-stabilisation defined by Rotmans et al. (2000). In the MLP, Geels (2002; 2011) distinguishes seven co-evolving dimensions of socio-technical regimes: technology, user practices and application domains (markets), symbolic meaning of technology, infrastructure, industry structure, policy and techno-
scientific knowledge. Tensions may arise between these dimensions caused by differences in opinions or periods of uncertainty. It is at this point when radical innovations in niches, which do not normally find ways to succeed, may break in and generate a technological transition. These are called ‘windows of opportunity’. However, as pointed out by Geels (2002), in addition to being opened by regime tensions, windows of opportunity can also be created by shifts in the landscape, such as for example cultural changes, demographic trends or broad political changes.

As mentioned, TM seeks to offer governance tools for managing these transitions, i.e. to be able to operate and handle processes at different levels in order to foster a desired transition. Loorbach and Rotmans (2010) argue that such management of transitions requires:

(i) dealing with uncertainties;
(ii) keeping options open;
(iii) Taking a long-term view and using it for short-term policies;
(iv) paying attention to the international aspects of change processes and finding solutions on the right scale; and
(v) creating governance by stimulating, mediating, and engaging.

This view of how to stimulate processes of transformation and manage them in time and space scales fits with the definition of sustainability put forward by Holling (2001, p.390), i.e. “the capacity to create, test, and maintain adaptive capability, whereas development is the process of creating, testing, and maintaining opportunity”.

From the TM perspective, transitions to sustainability have both an institutional approach and a social and community dimension. As argued by Kemp and van Lente (2011), sustainability transitions\(^\text{17}\) have a socio-technical nature and as such involve two major

\(^{17}\) The terms ‘transformation’ and ‘transition’ are sometimes used interchangeably in the relevant literature (Yang 2010). In this dissertation, when I use “sustainable transformation”, the meaning related to the process of change is stressed. When I use ‘sustainability transition’, the possibility of defining different alternatives and options to achieve a sustainable state is stressed.
challenges: a long-term change in technologies and infrastructures and a the change in consumers’ options which is needed to support the first change.

All in all, discussions on how sustainable development contributes to studies on TM are of considerable interest at this time. Given that TM originally was originally intended to respond to environmental problems, sustainability is often an underlying interest in TM studies. Nevertheless, in my review of the relevant literature I have found no TM studies on the environmental dimension or the ES regime.

### 2.4. Conclusion

Resilience is understood as the ability of a system, or a part of it, to recover from a shock. In the field of the environment, resilience is a concept which was first mooted more than 40 years ago and coined by Holling (1973). From its original purpose in environmental studies, resilience has grown into a rather malleable, vague concept used in multiple disciplines. Although it is an important advantage for multidisciplinarity and communication between scientists, there is a need for the concept to be operative and practical (Brand and Jax 2007). This also applies to its application in urban research, where, as addressed in Chapter 3, there is neither a widely shared definition nor an operative approach to the notion of urban resilience.

To make the concept operative in decision-making, according to Brand and Jax (2007), the boundaries of the study need to be set by questioning the influential concept put forward by Carpenter et al. (2001) of “resilience of what/to what”. To that end, there is a need to understand the spatial and temporal dimensions in which the dynamics of the system occur not only at the specific scale of interest in each case but also at higher and lower scales. This leads to the concept of panarchy which provides a holistic approach to cross-scale interactions that might affect the development and trajectory of the SES under

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18 Source: Debates in Plenary Sessions at the International Sustainability Transitions Conference, 29-30 July 2012, Copenhagen, Denmark.
study. Given the cross-scale environmental, social and economic interactions and inherent complexity of cities, understanding how higher and lower scales affect the resilience of urban systems is particularly important.

Equally important are the concepts of adaptive management, system thresholds and transformation, which establish how, when and why actors in the system may influence its resilience management when untenable situations persist, undesirable states are foreseen or the need to move towards a more beneficial or productive state is stimulated. These concepts are especially relevant in explaining sustainability transitions in a context where global environmental change poses a great challenge for humanity and the urgent need to transform our social and economic systems is increasingly being recognised by the scientific community and in the social and political arenas.

Adaptive management of SES includes governing two different processes (adapted from Nelson et al. 2007; see also Kates et al. 2012): (i) incremental adjustments; and (ii) transformative adaptation, which can be deliberate or non-deliberate. Specifically, in the field of climate change (Kates et al. 2012; Park et al. 2012) and in the quest for sustainable development (Westley et al. 2011), scientists increasingly argue that incremental adjustment are no longer sufficient and that a radical transformation is needed at both global and local scales. Thresholds (also known as tipping points) thus become cornerstones for (i) informing policy-making (Werners et al. 2013); (ii) comparing the performances of different systems (Carpenter 2013); and (iii) providing warning signals of critical transitions (Scheffer et al. 2009; Scheffer et al. 2012; Carpenter 2013). However, thresholds are not generic but context-dependant, and are usually unknown until they are crossed (Boettiger and Hastings 2013). This suggests that a specific analysis and an assessment of the focal system are needed to identify critical thresholds where a transformation would be required. Specifically, and given the importance of planet ecological thresholds in sustainable development, the significance of the understanding of the connections between human society and nature has been pointed out in this chapter as a crucial focus of resilience thinking. Maintaining ES is a source of resilience and for this to be possible, natural systems should be integrated into human decision-making processes. The question on how to integrate ES in decision making is address in Chapter 4 in the context of urban systems.
Knowledge acquisition through learning processes has been highlighted in this chapter as one of the key areas in adaptive management and therefore for resilience thinking, as knowledge and experience about how the system works and how it may react to certain stimuli translated into best management practices, is a source for resilience. Additionally, perceptions and beliefs of stakeholders involved in decision-making processes is a source of complexity and they may influence the direction of the system development, i.e. they may affect decisions to be made regarding alternative pathways of development. Both perspectives on how knowledge and experience influence resilience and transition management in the context of sustainable urban development will be addressed in the following chapters from a conceptual (Chapter 3) and empirical (Chapters 5, 6 and 7) point of view.

Together with resilience thinking and its concept of adaptive management applied to SES, this Chapter has also explored other theories such as TM focused on the study of transitions of STS, which help to understand how to govern processes of transformation. TM scholars have drawn up theories (Geels 2002) which include conceptualising how radical innovations that occur at micro-level can break into more stable states at meso and macro levels. This contributes to transformation theories based on resilience thinking by allowing technology, industry and the economy to take on more weight. It is recognised that sustainability and climate change challenges require an urgent transformation, and that transformation can be fed by both technological change and socio-institutional change, which includes changes in policy making and social behaviour (Kemp and van Lente 2011). The need to address policy and behavioural change has also been argued repeatedly in the urban context (see e.g. Weisz and Steinberger 2010), which further supports the need to bring together adaptive and transition management. The two areas of research have much in common and can provide fruitful insights into adapting urban needs to achieve more sustainable states.

The next chapter looks at how to translate this to the urban context and how to reveal the effective role of cities in sustainability transitions. Coupled human-ecological systems such as cities are complex (Holling 2001; Berkes et al. 2003; Liu et al. 2007b). As a result, modelling such systems and using the information obtained to govern and manage them is a complex undertaking. In this context, urban resilience management requires (i)
the adaptive capacity to deal with uncertainty and surprises (Resilience Alliance 2007a); (ii) the ability to seize positive opportunities, including those for transformation, that change may bring about (Berkes and Folke 1998; Barnett 2001); and (iii) the ability to reduce vulnerability to such changes (Folke et al. 2002b; Folke et al. 2002a; Resilience Alliance 2007a). This reasoning suggests that if a city is to be resilient it would have to be an insatiable resource-consuming machine. This calls into question the need for resilience theory applied to the urban systems. However, resilience theory acknowledges that there may be undesirable resilient states (Carpenter et al. 2001) and that unintended transitions to those states should be avoided (Nelson et al. 2007)

One general message can be portrayed from this review: in order to effectively inform policy making, a forward-looking, multidisciplinary approach that brings together social, ecological, economic, institutional and technological dimensions is required. The theories of resilience and transformation can help to draw up such a new policy and governance framework mainly based on increasing cross-scale and multidisciplinary knowledge about the structure and functioning of systems.

**2.5. Summary**

The highlights of this chapter can be summed up as follows:

- This chapter reviews the theories of resilience and transformation from the point of view of socio-ecological systems (SES) and socio-technical systems (STS) research, in order to critically analyse their applicability to the urban context.
- Resilience is understood as the ability of a system, or a part of it, to recover from a shock. It is now a rather malleable, vague concept used in multiple disciplines and yet lacking in operative terms.
- To help make resilience a more operative concept it is critical to characterise the system configuration, define potential disturbances that can result in system shifts and determine what cross-scale interactions can influence the state and dynamics of the system under analysis.
2. Theories of resilience and transformation

- Adaptive management is an important contribution of resilience thinking. It consists of the ability of actors to manage the resilience of the system for their own interests, which might include deliberate transformation.
- Learning processes are key for resilience and transition management and help opening up the spaces for innovation and help seeking the opportunities that sustainable development requires. The role of knowledge and experience in urban resilience and transition management will be addressed in the following chapters from a conceptual and empirical point of view.
- Transformability is commonly defined as the ability to create new systems by introducing new components or new ways of acting when current conditions are untenable. It is one of the potential alternatives in adaptive management of SES. However, transformation can be deliberate or non-deliberate, so the identification of thresholds as warning signals of critical transitions is crucial.
- In the context of climate change and sustainable development, scientists increasingly hold that incremental adjustments are no longer sufficient and that a radical transformation is needed at both global and local scales. Finding new ways of fostering sustainable transitions is identified as a new and urgent challenge.
- Transition Management (TM) research contributes to transformation theories coming from resilience thinking by giving more weight to technology, industry and the economy.
- TM seeks to offer governance tools for managing transition processes, i.e. to be able to operate and handle processes at different levels to work towards a desired transition. The theory relies on keeping options open, on a long-term view and on the importance of creating governance through stimulation, mediation and engagement.
- Through the concept of sustainability, which relies on opening new windows of opportunity for future generations, these theories have much in common and can help to conceive a new policy and governance framework based on increasing cross-scale and multidisciplinary knowledge about the structure and functioning of systems.
- In their quest for sustainability, urban systems are characterised by being complex, having multiple interactions within and outside their boundaries and
coupling environmental, technological, economic, social and institutional systems. As such they seem to be appropriate arenas for adapting resilience and transformation theories. This is addressed in Chapter 3.
Chapter 3

Resilience, sustainability and transformability of cities

HOW CITIES FACE CHANGE WHILE FOSTERING SUSTAINABILITY

“Whether or not resilience is a desirable attribute of [...] cities depends on the definition of the concept”. (Klein et al. 2003, p. 42)
Chapter 3. Resilience, sustainability and transformability of cities

3.1. Introduction

This chapter aims to set urban resilience and sustainable transformation research in context, following key principles outlined in SES and STS research and derived applications to the urban context. As indicated in Chapter 1, complexity, the quest for sustainability and vulnerability to resource scarcity and climate change pose a threefold challenge which must be effectively addressed on the urban policy agenda. As a result, urban policy must address changes that are not only gradual but fundamental (Haberl et al. 2011), especially regarding how and to what extent cities interact with the surrounding (economic, social and ecological) systems that sustain them and how this influences them in the long term. In terms of the complexity of cities, this requires an understanding of cross-scale spatial and temporal interactions and, accordingly, of the cost, benefits and trade-offs of the decisions to be made (Bai et al. 2010). As a result an integrated approach is required that can capture insights from resilience, sustainable development and transformation. As described in Chapter 2, an approach of this nature should not only involve processes of learning and adapting but also create opportunities for transformation to more desirable sustainable states in view of potential shifts.

Looking back on history, modern cities might be conceived as seemingly perfect resilient systems (Campanella 2006), but that does not necessarily imply that they are sustainable. In fact, cities are a very paradox of sustainability. The impacts that cities cause on the environment are negative not only to ecosystems but to the life path of cities themselves (Fischer-Kowalski 2011), producing serious consequences for human livelihood, vulnerability, and security (UN-Habitat 2011). However, although cities are drivers of impacts, as hubs of innovation and development they are nevertheless drivers of change, which raises their profile in the promotion of global sustainability (see Rees and Wackernagel 1996; UNU/IAS 2003a; Romero-Lankao and Dodman 2011; Romero-Lankao 2012). The search for sustainability in cities requires input from social innovation and transformation (Lee 2006) and must involve policy making which acknowledges urban development through adaptation and also processes of transformation. Conceptually, cities follow the non-equilibrium view of resilience (Pickett et al. 2004),...
which involves the ability to adapt and adjust to changing internal or external processes. This view of resilience is not only possible but imperative when calling for sustainable urban transformation as it enables the long-term dynamic angle that urban planning and design requires to be adopted.

Following Leichenko’s definition (2011), in this chapter I define “Urban Resilient Sustainability” (URS henceforth) as long-term urban sustainability which guarantees the provision of ES and satisfies social and economic needs for future generations. I also define the concept of Urban Resilient Sustainability Transitions (URST), thus engaging with the notion of urban transformation. Recent literature has addressed the research topic of urban transitions and governance of urban transformation in the urban context from different but complementary perspectives all of which pursue to some extent the sustainability of the system (for example Ernstson et al. 2010b; Dawson 2011; Hodson and Marvin 2012; Naess and Vogel 2012; Rijke et al. 2013). If one takes sustainability as the desirable state, the idea of URS implies helping cities to face, resist or adapt to changes as an opportunity for maintaining or transitioning to more sustainable states. URS should then be stimulated by urban governance methods that explore the consequences and acknowledge risks and surprises, leaving behind the static, deterministic view of urban sustainability. Still, despite the many advantages offered by embracing resilience as a form of governance, the literature on resilience theory does not in itself provide robust, practical guidelines for identifying opportunities for transitions and for stimulating and governing the process of transition. The benefits of a multidisciplinary approach to a sustainable urban transformation are clear. Accordingly, this chapter focuses on the concepts of sustainability and resilience on one hand, and their integration with the idea of transformation, which is inherent in both of them.

The chapter is structured as follows: Sect. 3.3 reviews the emergent body of literature on resilience applied to cities. Sect. 3.4 proposes a framework in which resilience and sustainability are understood in the context of transformation. Section 3.5 concludes with the main highlights of this trans-disciplinary field of research. The last section summarises the chapter.
3.2. A review of urban resilience literature

3.2.1. An emerging research area

The theory of resilience and its application to urban environmental governance have drawn the attention of the urban-research community because of two distinct but complementary issues: (i) the idea of vulnerability to climate change and natural disasters and the resulting need for urban response capability building (see e.g. Romero Lankao and Qin 2011); and (ii) the idea of ES and urban metabolism (see e.g. Agudelo-Vera et al. 2012; Jansson 2013) and the need to build up resource security in cities. Both build on the idea of cities as CAS and on the need to generate sustainable opportunities from adverse situations.
However, the applications of the concept of resilience are not limited only to environmental governance. Urban resilience theory is a burgeoning research topic (Davoudi et al. 2012; Shaw and Maythorne 2013). Since the seminal papers in 2004 (Alberti and Marzluff 2004; Pickett et al. 2004) (which are influential although limited in their specific ecological perspective), there has been an exponential increase in the number of papers published per year using resilience theory in urban studies (see Fig. 3.2). This provides some evidence of the potential shift in the understanding of complex urban systems, although it is perhaps not yet operationalised (Deppisch and Hasibovic 2011).

![Figure 3.2 Articles published on urban resilience and citations.](source)

*Source: Thomsom and Reuters Web of Knowledge database. Search criteria applied: Title=((resilient OR resilience) AND (city OR cities OR urban OR local)) NOT Topic=(mental OR psychological OR medical). Results found: 344 publications; 1842 times cited without self-citations. As of January 16, 2014*

There is a rather abstract understanding of the concept of urban resilience. As with socio-ecological resilience, there are many approaches (Shaikh and Kauppi 2010). However, as argued by Leitchenko (2011), only by questioning how (in what context) it is applied to urban areas, can one ensure that it retains its utility for rethinking and reorienting urban studies. As illustrated in Fig. 3.2, there is a vast, growing literature on urban resilience, much of which is so recent that it is hard to guess how it will influence future urban studies.
The concept of resilience must be seen as a bridge that spans different disciplines in pursuit of a single purpose (Brand and Jax 2007). "Diversity is a key tenet of resilience theory, and the diversity of approaches to urban resilience [...] is a testament to the flexibility and adaptability of this burgeoning research area” (Leichenko 2011, p.166). Thus, either because of the need to advance towards sustainability or because of the need to move from rhetoric to action in the field of climate change (Romero-Lankao 2012), cities need to manage their resilience through transformative processes.

However resilience is applied to urban research, this new outlook onto urban governance complements sustainability science by providing new, longer-term perspectives (Leichenko 2011). Leichenko (2011) defines Urban Resilient Sustainability (URS) as long-term sustainability, and it is this definition that I follow in this dissertation.

In the next two sections I explore the different applications of the concept of urban resilience as found in the relevant literature, and attempt to draw lessons in the context of sustainable urban transformation which are then explored in Section 3.3.

3.2.2. From urban resilience to sustainable transformation

According to the Resilience Alliance (2007a), urban resilience focuses on the amount and kinds of disturbances that urban areas can absorb without shifting to other, less desirable regimes. Among other assumptions it is key to assume that cities are highly dependent, open systems which means that their resilience is contingent on the resilience of coevolving (sub)systems in accordance with the ‘systems of cities’ idea emphasised by Ernstson et al (2010b). This socio-ecological approach sees urban resilience as a balance between urban and ecological functions (Alberti and Marzluff 2004) following the MEA (Millennium Ecosystem Assessment) approach (MEA 2005; TEEB 2008). It highlights the role of metabolic flows in sustaining urban functions, human wellbeing and quality of life. It also stresses the importance of governance networks and “the ability of society to learn, adapt and reorganise to meet urban challenges and the social dynamics of people [...] and their relationship with the built environment which defines the physical patterns of urban form” (Resilience Alliance 2007a). Overall, this approach offered by the
Resilience Alliance, was the first integrated approach to urban resilience. However, there has been little follow-up on it by scholars as it lacks an operational approach.

The concept of urban resilience can be seen in the context of risk and vulnerability assessments, institutional and social governance structures, resilience in (or of) different sectors (e.g. ecosystems, economy, etc.) and transformations of urban areas. It has been reflected in many research areas, e.g. planning (Karrholm et al. 2012; Wilkinson 2012), ES (Barthel and Isendahl 2013; Jansson 2013) and economics (Christopherson et al. 2010; Simmie and Martin 2010). This gives a better idea of the myriad factors that define ‘general resilience’ as opposed to ‘specific resilience’ (Folke et al. 2010) when urban systems are dealt with which has to do with the nature of the thresholds or tipping points (see discussion in Chapter 2, p. 41). These approaches are not always limited to cities: some also cover surrounding peri-urban and rural areas to consider certain cross-scale dynamics which provide the setting, for example, for ecosystem or economic dynamics and planning practices. They are all influential and relevant to the interest of urban resilience assessments.

The oldest, most widespread application of resilience in cities can be found in disaster management studies which focus on the capacity of cities to recover after disasters (Campanella 2006; Wallace et al. 2007; Cutter et al. 2008; Wallace and Wallace 2008) and build on the idea that cities have inherent societal capabilities for rebuilding themselves (Campanella 2006). Following this, urban resilience has been adopted particularly in the context of climate change (Leichenko 2011; Bulkeley and Tutsb 2013). It is being used primarily as a conceptual framework for assessing social and structural vulnerabilities involving urban physical structures, functions and services (Prasad et al. 2009; da Silva et al. 2012; World Bank 2012). Flooding in particular has been the focus of many recent urban resilience studies (Gersonius et al. 2010). Research on urban resilience and climate change also focuses on the development of new models for governance and policy making, in which adaptive governance based on flexibility, learning, experimentation and, ultimately, transformation is decisive in the process of building resilience (Leichenko 2011; Davoudi et al. 2012). Nevertheless, reference to resilience is also made in adaptation planning, policy development and implementation at different administrative levels, not only with respect to urban climate policy (Davoudi et al. 2012).
Research on urban resilience is paying more and more attention to the consequences of demographic changes, especially regarding urban planning and shrinkage processes (Haase 2008; Blanco et al. 2009; Kotoriainen et al. 2013; Sánchez-Moral et al. 2013; Zingale and Riemann 2013). Here the study of the impacts of infrastructure provision and land-occupation policies on sustainable use of resources is of great importance to urban sustainability. This analysis is, furthermore, of especial interest due to the role of population displacements induced by climate change and future research will have to put great emphasis on this unexplored domain (de Sherbinin et al. 2011; Romero Lankao and Qin 2011).

Transformation is an underlying idea which is often present in urban resilience research. Innovation (and technological change) is seen as a fundamental element in the process of change. Although specific research on local (sectoral) transitions is important (see e.g. low carbon transitions in Hodson and Marvin 2012), urban resilience thinking should also include the concept of transformation in the broader context of sustainability. So far, however, few studies have shed light on the question of how to integrate these concepts into practical urban decision-making. However, some of them deserve special attention as they are not based solely on resilience thinking but also incorporate insights from other research fields, especially urban ecology and socio-technical transitions. For example, after contributing to resilience and transformation theory through extensive research in the field of climate change (Pelling 2010), Pelling and Manuel-Navarrete (2011) tentatively analyse urban governance structures and how they address transformation, with explanations in terms of the adaptive cycle. This is an important contribution which maps the relations of social power into the discourses of resilience, sustainability and transformation.

There are also two more complementary approaches in recent literature with their roots in urban ecology research which connect the concepts of resilience, sustainability and transformation.

Pickett et al. (2013) build on principles of urban ecology (Grimm et al. 2000; Pickett et al. 2004; Pickett and Cadenasso 2006) and assume that the key to resilient, sustainable transitions is the successful integration of ecological principles into urban management.
Although this approach is helpful in working towards the integration of ecosystems services into urban development, it sheds little light on urban policy practises as it is still at a conceptual stage. In any event, the authors provide helpful insights that help to provide a setting for sustainable urban transformation as they argue that resilience is a tool for urban transformation to sustainability as a normative social goal which has two sides: one related to achieving inter- and intra-generational equity and the other related to achieving resilient social economic and environmental processes. In line with the idea that there is a need to move towards more sustainable patterns, as argued in Chapter 1 above, Pickett et al. (2013) assert that “sustainability is an ongoing process rather than an endpoint” and that “urban systems can become more sustainable than they currently are”.

From a more pragmatic perspective, Romero-Lankao and Gnatze (2013) build an approach to conceptualize and put into practice urban transformations in which insights of urban political ecology (metabolic flows within urban networks) are contextualized in an STS transitions framework where transformations are stimulated at niche level and need favourable landscapes for the uptake of innovations. They illustrate these through two Latin-American cities where there are similar sustainability and resilience challenges: one where innovation was stimulated via a top-down approach (scientists, technical experts and entrepreneurs, actors with decision-making power) and the other where systemic changes were promoted through a bottom-up, more participatory, more innovative approach. The results show that more profound systemic changes were achieved in the case that used the top-down approach.

3.2.3. Analysis of urban resilience capability building determinants

One of the main criticisms of resilience theory is that the many different definitions of resilience do not facilitate the development of a shared assessment approach, so it is of little use for decision-making (see e.g. Brand and Jax 2007). Among the different methodological approaches which could be used to assess resilience, the literature focuses on indicators. In this context, Birkman et al. (2012) review examples of indicators and criteria used to assess general resilience in different contexts such as ecological and socio-ecological resilience, psychological resilience, critical infrastructure resilience, organisational and institutional resilience and community resilience. In the urban context
however, few studies specifically define critical determinants of urban resilience. Building mainly on Ahern (2011), Albers and Deppisch (2013), Ernstson (2010b) and Tyler and Moench (2012), I have selected the main determinants, which are shown in Table 3.1. As pointed out by Albers and Deppisch (2013), some of them may have tradeoffs and conflicts with each other. Following up on this point, I also identify in Table 3.1 the main trade-offs to be found.
<table>
<thead>
<tr>
<th><strong>1. Multifunctionality</strong></th>
<th>References</th>
<th>Context</th>
<th>Potential trade-offs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ahern (2011)</td>
<td>In a context of limited space and ecological and socioeconomic resource scarcity, cities need to search for multifunctional spaces and processes which can provide services to as much of the population and in as many situations as possible to optimise response capacity.</td>
<td>A trade-off is here identified when certain elements or processes concentrate too many functions and the system therefore come to dependant too much on those elements or processes. This represents a hidden vulnerability and must be managed as such.</td>
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<tr>
<th><strong>2. Diversity (in relation to biological, social and built realms)</strong></th>
<th>References</th>
<th>Context</th>
<th>Potential trade-offs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ahern (2011), Albers and Deppisch (2013), Tyler and Moench (2012)</td>
<td>Diversity has always been a key tenet of resilience (Folke et al. 2004). A higher number of elements in an urban system providing the same or similar function (higher response diversity) makes the system more resilient. This applies to the physical, biological, social and economic realms.</td>
<td>Diversity will always be a desirable characteristic of new pathways provided that it does not imply a loss of competitiveness and response capacity. For diversity to be successfully implemented at city scale, it must rely on urban networks and connectivity to other systems of cities. This may create conflicts with redundancy and safe-failure principles (see below).</td>
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<th><strong>3. Redundancy and modularisation</strong></th>
<th>References</th>
<th>Context</th>
<th>Potential trade-offs</th>
</tr>
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<tbody>
<tr>
<td>Albers and Deppisch (2013), Tyler and Moench (2012)</td>
<td>Redundancy is a desirable characteristic in urban systems as it generates buffering capacity, resourcefulness and reduces vulnerabilities.</td>
<td>However, in economic terms, if redundancy means specialising to gain competitiveness, it might create a hidden vulnerability if the market changes. A lo, redundancy can erode response diversity, which has always been a key tenet of resilience (Folke et al. 2004).</td>
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<tr>
<th><strong>4. Self-sufficiency, interdependency and safe-failure</strong></th>
<th>References</th>
<th>Context</th>
<th>Potential trade-offs</th>
</tr>
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<tbody>
<tr>
<td>Albers and Deppisch (2013), Tyler and Moench (2012)</td>
<td>Cities should search for self-sufficiency to guarantee resource security (food, water and energy security) and maintain service provision in the face of shocks.</td>
<td>A trade-off might be found depending on how self-sufficiency, interdependency and safe-failure are gained. It may be through redundancy of elements that provide the same services or through diversity in the provision of services, which leads to Question 2 above.</td>
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<tr>
<th><strong>5. Multi-scale networks and connectivity</strong></th>
<th>References</th>
<th>Context</th>
<th>Potential trade-offs</th>
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<tbody>
<tr>
<td>Ahern (2011), Ernstson (2010)</td>
<td>Intra and inter-connectivity in and of cities is a key characteristic in resilience thinking. Given that cities cannot provide 100 per cent of the resources that they consume within their own boundaries, they need to rely on other nearby cities to maintain their level of provisions. The same happens within their own boundaries.</td>
<td>Redundancy, self-sufficiency, multi-scale networks and connectivity are inherently linked and must be planned following the same interests: social equity, environmental quality and wellbeing. A trade-off might be found when high connectivity means that a shock spreads more widely and quickly and produces a higher number of failures due to a high number of connections between its elements.</td>
<td></td>
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<tr>
<th><strong>6. Flexible, adaptive policy making, planning and design</strong></th>
<th>References</th>
<th>Context</th>
<th>Potential trade-offs</th>
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</thead>
<tbody>
<tr>
<td>Ahern (2011), Albers and Deppisch (2013), Tyler and Moench (2012)</td>
<td>Flexibility and adaptability are essential for urban resilience building. This characteristic provides the critical capability to learn from experiences, prepare for shocks and self-organise after an expected or unexpected change.</td>
<td>Flexibility and adaptability can be built up through many aspects and should serve multifunctionality in order to avoid conflicts with redundancy and guarantee safe failure.</td>
<td></td>
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</table>

**Table 3.1. Urban resilience determinants and potential trade-offs**
From the review in Table 3.1 it can be observed that the joint management of multifunctionality and connectivity within a city or a system of cities seems to be a critical urban resilience determinant for guaranteeing climate safety (vs. vulnerability) and resource security. It can be argued that these concerns are moving urban resilience research. Although this statement clearly needs to be backed up by case studies, in practise these characteristics are used to build indicators which can provide information during decision-making processes.

Following this, and as it will be proved in Chapter 7, connectivity seems to be a double-edged sword for urban resilience. Although it may be a source for resilience (Ahern 2011), it may also lead to a rigid system difficult to manage when facing unpredictable shifts or changes (Holling 2001). This will be further discussed in Chapter 7 through the case study of low-carbon energy transitions in the city of Bilbao.

Apart from the 6 determinants shown in Table 3.1, innovation and creativity are mentioned in the relevant literature as key in supporting the resilience of cities (see Ernstson et al. 2010b; Ahern 2011). In particular the idea of strengthening cities as hubs of a new culture of innovation is stressed (Ernstson et al. 2010b; Ahern 2011; Evans 2011). There is a need to define this new culture of innovation in the context of resilience. For example, in climate change adaptation research some authors call for new urban governance techniques (Anguelovski and Carmin 2011; Evans 2011) through innovative ways of approaching planning. URS certainly needs further development in planning culture based on scientific evidence (Evans 2011), precautionary principles (Haigh 1993; Iverson and Perrings 2011) and the limits of ecosystem service provision (Alberti and Marzluff 2004; Pickett et al. 2004).

In relation to this last idea of the existence of limits in the provision of ES to cities, the study of urban resilience thresholds (e.g. Garcia et al. 2011 study city size thresholds) is lacking in terms of empirical studies and experiences. According to Kinzig (2006), managers who are focused too strongly on one domain or one scale will not see the interdependencies between scales or the likelihood that a new, resilient, and possibly less desirable system will emerge. Definitively, research into the dependency of the resilience
of cities on the resilience of adjacent systems (Resilience Alliance 2007a; Ernstson et al. 2010b) is needed to define adequate measures to co-ordinate actions.

The URS research agenda should pay attention to the provision of operative tools at the science-policy interface to confer knowledge and support decisions to be made in cities. In this context, a clear conclusion which is inferred from this review is that in practice actors often lack an understanding of the causes and sources of their vulnerabilities and adaptive capacities (Romero-Lankao and Dodman 2011) which make it hard work and sometimes impossible to draw up efficient measures and adequate pathways of transformation. This may well lead to maladaptations and undesirable transitions. In order to prevent these undesirable outcomes knowledge is required related to the study of cross-scale interactions (in space and time), interdependency between ecosystems and urban demands, patterns of societal metabolism and scenarios of development. Finally, the study of how institutions and stakeholders affect pathways of transformation is still underdeveloped, although some advances have been made in this respect (e.g. Pelling and Manuel-Navarrete 2011).

3.3. Urban resilience and sustainable transformation

In this section I extend the concept of URS by incorporating the idea of transformation. I define Urban Resilient Sustainability Transitions (URST) as transformation processes leading to long-term sustainability. Building on previous research, I develop ideas regarding how URST should be structured and what key aspects need to be tackled in URST.

3.3.1. Contextualising the concept of sustainable urban transformation

According to several authors (Hodson and Marvin 2010; Smith 2010; Truffer and Coenen 2011; Westley et al. 2011), cities have a limited role in global transitions to sustainability due mainly to their lack of competencies in policies in many sectors, e.g. energy policy and critical infrastructure planning. Up to now, research on the determinants, driving
forces and mechanisms of sustainable transformation has focused on higher scales rather on the urban scale (Yang 2010). However, there is still consensus that, regardless of who should be the agency of change, if cities are hubs of development and places where consumption and production take place then urban sustainability transitions are critical in the quest for global sustainability (Nevens et al. 2013; Ryan 2013).

Here, I argue that cities need to take on a more active role in sustainability transitions. As resource consumers, cities might be drivers of impacts, but they can be also drivers of positive change. As asserted by Dawson (2011, p. 183), “there is an urgent need to adapt our cities to first reduce their impacts, but also to transform them into positive economic, social and environmental forces”. However, hidden interests in cities may foster a steady-state environment that locks them into unsustainable resilient patterns, following the theory that resilience, unlike sustainability, can be desirable or undesirable (Carpenter et al. 2001). An important question is thus raised: how can transitions towards resilient, sustainable patterns be encouraged?

3.3.2. The socio-technical vs. the socio-ecological approach

Research on the application of the socio-technical approach to transitions for fostering urban sustainability is currently emerging (see e.g. Naess and Vogel 2012; McCormick et al. 2013; Nevens et al. 2013). While the overall contribution of this research and its integration into the existing debate have not yet been articulated, it provides useful insights into the management of transition processes (Loorbach 2007) and the innovation needed to stimulate niches which can upscale sustainable transformations (Nevens et al. 2013) (as explored in Chapter 2, p. 57). From this perspective, as argued by Kemp and van Lente (2011), sustainability transitions involve two major challenges: long-term change of technologies and infrastructures; and changes in the options facing consumers, which are needed to support the first change. These insights come from broad experience in the study of socio-technical transitions (Geels and Kemp 2007; Geels 2011).

Geels (2012) states that cities may play a role in technological transitions in three ways: (1) city governments and agencies may be important actors for specific sustainable interventions related, for example, to transport, water, waste management, etc.; (2) cities
may be the locations for experiments with low-carbon innovations; but (3) cities might have a limited role compared to market dynamics and other actors. In this line, he argues that as regards technology, successful transitions exclusively focused on cities cannot be guaranteed.

Clearly, market dynamics and technology dynamics are much bigger than cities or systems of cities and often drive (un)sustainable development by establishing certain consumption patterns or providing new ways of solving environmental, economic or social problems. However, the point here is that cities are CAS formed by coupled economic, technological, social and environmental networks. This means that whatever the scale that drives the agency of change in sustainable (technological) transitions may be, cities need to engage with it in a sustainable way, driving and controlling the transformation at local level so that it spreads into other systems too. As argued above, it is in cities that innovation, development and consumption take place. This deserves special attention and specific agents to enable them to be articulated.

Although the literature on the linkages between transition research, sustainability and resilience is recent, the need for a common approach to them as applied to the urban context is increasingly argued (see Hodson and Marvin 2010; Smith et al. 2010). On the positive side, research and experience gained in socio-technical transitions research and the socio-ecological resilience theory provide good frameworks for the development of an adapted framework for sustainable urban transformation. As discussed in Chapter 2 (p. 55), from a SES research perspective transformability is seen as the capability for “defining and creating new stability landscapes by introducing new components and ways of making a living” (Walker et al. 2004, p. 5) which is motivated by the idea of generating more resilient states. When coupled with the concept of sustainable development, the emphasis is on the need to define thresholds in sustainable terms so that robust transformation can persist (Folke et al. 2010; Haberl et al. 2011). This raises the need to define a new term that brings together URS and alternative transition pathways. I therefore coin the term “urban resilient sustainability transitions” (URST) to describe specific processes of transformation that guarantee long-term sustainability. The need then arises to establish sustainable management objectives and specific characteristics of these processes that can support sustainable transformation.
3.3.3. Conceptualising urban transition alternative pathways

When the local scale rather than the global one is considered, the responsibility of the actors shifts from facilitation to implementation (Klein 2004). As earlier discussed, it is important to recognise the variety of pathways to achieve sustainability because of the diversity of urban futures built through different combinations of technical, social and economic dynamics (Rydin et al. 2013). Pathways for transitions refer to the alternatives found when the processes of transformation are implemented. Such pathways can achieve different degrees of sustainability.

The first step in a USRT process is to break out of existing unsustainable traps by providing elements to bring enough flexibility and adaptability to the system for it easily to embrace the process of transformation. However, there are many possible sustainable, resilient states. I illustrate this idea of multiple alternative states as explained in Chapter 2 (see p. 43) in Figure 3.3. Multiple states are represented by red dots, in four types of regime in urban systems characterised by their degree of resilience and sustainability (1.- Low sustainable and low resilient, LS+LR; 2.- Highly sustainable and low resilient, HS+LR; 3.- Low sustainable and highly resilient, LS+HR; and 4.- highly sustainable and highly resilient, HS+HR).

![Figure 3.3 Characterisation of desirable states and alternative pathways of transformation.](image-url)
Red dotted arrows symbolise a theoretical illustration of examples of transformation pathways in cities towards the most desirable regime (represented by 4 in Fig. 3.3). To break out of unsustainable states (1 or 3 in Fig. 3.3) it is important for policy makers and in particular managers to focus on the costs and benefits of fostering major transformations in the urban system rather than trying to trigger the adaptive processes necessary to maintain the status quo.

Clearly, for transitions to be stimulated at city level cities need to cross thresholds, which can sometimes be contextualised as crises (collapse phase: see Chapter 2, p. 47). Adapting previous literature (Foliente et al. 2007; Loorbach 2007), Fig. 3.4 introduces the idea of potential pathways to URST and identifies three potential pathways for urban transformation depending on the type of governance used when facing (or perceiving) a crisis (or the need to change). With favourable conditions and clear instruments and in a context of innovation and maximisation of opportunities, a successful transition path can be taken, thereby saving critical (human and natural) resources and time.
Figure 3.4 Potential transition pathways in cities. Adapted from various sources

PATH 1: Easy and natural process to a low-carbon, sustainable and resilient city based on long-term planning supported by a participative learning process.

PATH 2a: Low-carbon, sustainable and resilient city achieved through a longer process with high costs for human welfare, environment and economic development. $T =$ Time difference with Path 1

PATH 2b: Medium sustainability and small adaptations enough to maintain the environmental quality. No stimulation for real transition. No change in lifestyles and steady-state urban model.

This is represented by **Path 1** in Fig. 3.4, which offers the most sustainable outcome, as it is strongly driven by socio-technical transformation, innovation and creativity where collective efforts stimulate change. **Path 2** is associated with crisis and is embraced within policies on optimisation of resources and efficiency, though short term planning is still present in urban management and planning. This can lead potentially to two paths: **Path 2a**, where a slow process of social behavioural change improves sustainability but at greater cost than on Path 1, and **Path 2b**, where urban planning lock-in hinders sustainable development. Finally, in **Path 3** the crisis is ignored and unsustainable patterns are maintained. Fig. 3.4 is latter used in Chapter 6 to frame the different discourses found around the transition to a low-carbon energy in the city of Bilbao.

But transitions in urban areas have not only been the focus of resilience or transition management literature. In connection with complexity studies (see discussion in Section 1.2.3, p. 15) and the idea of urban transformation, it is important to introduce here the concept of ‘urban phase transition’ and to discuss how the questions posed in this dissertation can also be synchronised with this body of literature. As discussed, processes of equilibria and transition are inherent to cities. In urban studies, cities are seen as non-linear complex systems which dynamics can be modelled. Models of this kind have three characteristics (from Wilson and Dearden 2011): multiple equilibria, ‘path dependence’ over time and phase transitions. These three characteristics have much in common with the resilience and transformation theories. To our interest here, the concept of ‘phase transition’ is perhaps the most interesting. Technological and behavioural shifts can affect cities leading to major transformation changes which are understood as phase transitions. Linking back to complexity, this type of discontinuous change can affect global patterns. As Batty (2007) explains, an example of this is the process of change from an industrial city to a post-industrial city.\(^{19}\) Also, here, further research is called to focus on developing models that can predict undesirable changes and plan desirable phase transitions (Wilson and Dearden 2011) and this is also the objective of the present piece of work.

\(^{19}\) Interestingly, the city of Bilbao, case study of the empirical research undertaken in this dissertation, has undergone a process of transformation from an industrial city to a services-led city.
3.4. Challenges of urban resilient sustainability transitions

URST management entails actors taking decisions on multiple possible pathways and weighing up the pros and cons involving where and how those pathways will be taken and by whom. Multiple interests come into play in urban transitions (Bulkeley et al. 2011; Hodson and Marvin 2012) as sustainable urban transformation is not only about technology, building processes or markets but also about how culture and social values influence the path towards a transformation (McCormick et al. 2013). In this regard, transitions can be initiated from top-down or bottom-up approaches or a combination of the two. While the key role of communities in transitions (Smith 2010) must be acknowledged, there is also a need to recognise the importance of a cascading top-down strategy to support urban transitions (Cruz-Peragon et al. 2012). According to Rijke et al. (2013), informal networks are good for the early stages of transitions, where testing and innovation is important, whereas formal networks and centralised policy decisions enhance the uptake of innovation through knowledge sharing and through the efficient use of resources.

URST and the adaptive processes involved include management, monitoring, policy reorientation, which must also encompass continuous adaptations (intensive or extensive) and mitigation of impacts (of policies and interventions). They are defined by a set of actions and a management structure in which experimenting, learning, timing, governance and financing are key influences.

In this regard, I would like to focus here on three challenges here that interact significantly with the above and need to be taken into account in URST governance processes. These challenges, which I address in the following chapters from a conceptual and empirical point of view, are (i) investing in technology and infrastructures as critical in supporting urban transitions (Hodson and Marvin 2010) while understanding the role of green infrastructures and ES in sustainable urban transformation (Gill et al. 2007; Jansson 2013; Lovell and Taylor 2013); (ii) understanding institutional culture and consumption choices (McCormick et al. 2013); and (iii) storing knowledge of the system, covering both socio-technical and socio-ecological elements and their interactions (Rijke et al. 2013).
3.4.1. **Investing in technology, critical infrastructures and ecosystem services**

Technology and infrastructure networks are closely linked to the demand for consumption from society and to the legal and financial framework in place. In fact, technology neither can nor should be prioritised as the main guiding principle for a transition (Azar and Sandén 2011). Kemp (1994) argues that a change in technology induces fundamental changes in production, organisation and the way in which people live their lives, which adds more complexity to the operation of urban systems and makes it harder to understand them (Liu et al. 2007b). Both Jacobsson (2011) and Azar (2011) argue that in some cases where there is a high level of self-knowledge, technology-specific policies are necessary (although as regards climate change, at higher levels technology-neutral policies are recommended). This seems to be the case of cities too, where self-knowledge and historical data can help bring about robust, well-informed decisions about technology development investments in urban areas. In fact, cities are in a far better position to weigh up the individual costs and benefits of using different technologies for highly specific purposes, as revealed by Kemp (1994).

Historically, critical energy, water, waste and transport infrastructures have been fundamental in supporting urban transitions (Hodson and Marvin 2010). The role of technology is essential to support the construction and use of resilient, efficient infrastructures, means of transport and services, looking to energy and matter flows, their generation sources, processes of production, uses and interdependencies among the elements of the technological network. Although this has been seen to date as a challenging engineering and administrative issue, new pressures such as urban growth, climate change and resource scarcity call for a reconfiguration of these networks (Hodson and Marvin 2010). Governing and planning for sustainable transitions in infrastructures systems and technologies is essential with a view to supporting change in society.

In this regard, a new perspective that can capture opportunities at better costs is required. Green and blue infrastructures and the resulting ES in cities seem to represent such an opportunity, as pointed out in Table 3.1 above. As argued by Chapin III et al. (2010), recognising the social–ecological interdependencies of human activities and ES is crucial in identifying opportunities for managing transformation to a long-term sustainability that
guarantees ES for future generations. This also follows one of the main guiding principles of the resilience theory where ES need to be guaranteed from a perspective in which the connection of human and nature is essential to understand a sustainable transformation (see discussion in the introduction of Chapter 4, p. 101). This assertion follows Leichenko’s definition of URS (2011). Focusing on ES as the uptake of resilience management in cities (Jansson 2013) and relating this to the built infrastructures there should be the focal point of URST governance based on the need for sustainable, continuous provision of ES to maintain human activities in cities.

Following this, Chapter 4, focuses in the challenge of integrating ES in urban decision-making by developing a conceptual framework that connects built-infrastructures with natural assets in urban areas.

### 3.4.2. Understanding institutional culture and consumption choices

Institutions are defined as “all the mechanisms and structures for ordering the behaviour and ensuring the cooperation of individuals within society” (Barbier 2011, p. 60). As highlighted in Chapter 2 (see p. 49), adaptive management for resilience requires institutions that are flexible, multidisciplinary, diverse, store knowledge and empower learning (see next Section 3.4.3) and cope with uncertainties and surprises.

Barbier (2011) argues that as societies develop they become more complex, and consequently their institutions are more difficult to change. This institutional inertia is thus one of the challenges which URS practices must face when planning for transitions. Civil society is also a crucial driver for sustainability transitions as its actions are driven by maximum utility choices. Individuals, as causal agents, also influence urban inertia towards unsustainable consumption patterns. Choices are assumed and fixed by market drivers which establish patterns of growing consumption (Mishan 1967; Schumacher 1973; Fournier 2008). In a context where current sustainable policies only sustain the unsustainable (Blühdorn 2007), “the politics of sustainability transitions requires a redefinition of societal interests” (Meadowcroft 2011). Transitions should be accompanied by changes in people’s values and beliefs, and society must acknowledge the consequences of individual decisions in costs and benefits for health, competitiveness,
environmental quality and global environmental change. However, the consequences of individual actions are not taken on board by society and are often attributed to bad governance and management practices. Over the last decade, there has been an upturn in community-led initiatives which are seen as a key ingredient for successful transitions at city level (Smith 2010). The work done to date by the *Transition Towns* movement, whose philosophy can be found in the *Transitions Handbook* (Hall 2012), is a key part of this discourse. More and more initiatives all around the world are emerging and this can be seen as an opportunity to stimulate top-down strategies to support them too.

Stakeholders and private actors have a role in URST too, as their objective is to maximise profit from their activities, which affects how and when transitions should take place. There is an evident need to engage businesses to reorient their innovation-related and economic activities (Geels 2010b; Evans 2011) and influence general economic conditions and consumer practices (Geels 2010b). In line with this, Whiteman (2011) stresses the need to better understand what conditions can encourage effective bridging activity by companies with a view to facilitating stronger networks of actors and to more tightly couple information flows.

In decision-making, new ‘sustainability’ criteria have to be internalised, and for this theory the criteria and methods used to meet the desires of people and attain sustainability transition goals need to be reviewed (Geels and Kemp 2007; Kemp and van Lente 2011). Thus, it becomes necessary to analyse vested interests in cities and how they can influence decisions to be made in a context of potential transformation²⁰.

The practical barriers to transformation for decision makers continue to be strongly associated with uncertainty about success before interventions are decided, especially as transformative decisions are often seen as politically risky with benefits being accrued in the medium to long run (Kates et al. 2012) and thus not generally in tune with electoral cycles. To this end TM research (Loorbach 2007; Loorbach and Rotmans 2010) offers a basis for understanding the activities involved in transitioning (Park et al. 2012) and is key for the planning, follow-up and reorientation of the process.

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²⁰ This question is specifically addressed in Chapter 6, p. 185
Best practices are a necessary input to guide urban decision makers in the quest for effective adaptation and transformation. But the practical context-specific barriers to both processes evidence a lack of established models for successful transition initiatives. Cultural values, business models and lifestyles (Geels 2012) all generate path-dependent dynamics which influence the ability to adapt and transform. It is for this reason that continuous experimentation and learning are central in urban resilience management (Evans 2011; Dieleman 2013). Cities as laboratories and innovation hubs will prove essential in promoting robust transition processes (Ernstson et al. 2010b; Hodson and Marvin 2010; Smith 2010; Dawson 2011; Evans 2011).

All in all, as discussed in Chapter 1 (see Section 1.2.4, p. 18) stakeholders’ discourses, perspectives, theories and beliefs have great implications for sustainable urban development. In this, learning (see next Section 3.4.3) is a critical process that leads to gain the knowledge and experience that will later influence urban development.

In Chapter 6, I use the case study of the city of Bilbao to analyse how different discourses related to the potential of an alternative pathway to sustainability may influence the actual transition. That is, how stakeholders’ interests, experience and knowledge have a crucial role in the city’s capability to transform. Specifically, I use the case of a low carbon energy transition and identify the discourses of a group of stakeholders against the URST framework developed in this Chapter (see Section 3.3.3, Figure 3.4, p. 83).

3.4.3. Fostering knowledge generation and management

Any process of decision making related to sustainable urban development requires the identification of options for sustainable management that enable different management approaches to be tested while emphasising learning, monitoring and continuous knowledge acquisition (Folke et al. 2002b; Berkes et al. 2003).

As discussed in this and previous chapters, there is a growing consensus as to the importance of obtaining knowledge of the system in resilience management (Levin et al. 1998; Olsson et al. 2004; Cumming et al. 2006; Beratan 2007; Polasky et al. 2011; Park et al. 2012) and in transition management (Knapp et al. 2011; van de Meene et al. 2011;
Both, the social-ecological and socio-technical perspectives, attempt to understand complex systems and emphasise the importance of continuous processes of learning and adjusting (Van der Brugge and Van Raak 2007) and the need to innovate in means for knowledge acquisition (see e.g. Beratan 2007; Nevens et al. 2013). The ability to store knowledge and empower learning constitutes one of the greatest challenges on the way to sustainability (see e.g. Lebel et al. 2006). In addition, transition management requires stimulating, mediating and engaging stakeholders in the process of transformation (see e.g. Loorbach and Rotmans 2010). As a result, both resilience and transition management research, recognise the importance of participatory processes in governance approaches to motivate and engage stakeholders in the process of dealing with change. Furthermore, stakeholders’ knowledge and experience is also seen as necessary to better plan for any system’s transformation, in order to foster understanding and develop a shared vision for alternative pathways required by resilience and transition management (see e.g. Holling 2001; Loorbach and Rotmans 2010). This, points out directly at the need to recognise the importance of the cognitive dimension, mediated by values and cultural contexts, to analyse drivers of change towards resilience and transformation management, especially in complex and uncertain decision-making environments.

Decision-makers often need to define policies which must meet multiple objectives (social, economic and environmental) while balancing scientific information with socioeconomic and policy evidences. It is in such cases that scientists need to realise that consistency with the end-use is essential (Fisher 2009). There is an underlying feeling that local decision makers hardly grasp existing knowledge and use it to inform and orient decisions to make sustainable interventions.

Expert knowledge21 is essential in gaining an understanding of the non-linearities, interdependencies and complexities characteristic of urban systems. Informed decisions

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21 Understood as a specific and profound knowledge in a particular field, not necessary involving a specialist or an authority.
influencing these systems must take into account such complexities in order to avoid unintended impacts and plan alternatives or compensation measures accordingly. Resilience, adaptation and transformation management require new types and methods of knowledge acquisition (see Beratan 2007; Adger et al. 2012), e.g. discourse analysis and mental maps (see the empirical studies presented in Chapters 6 and 7).

In practise, cities still lack operative tools applied to the urban context which can address the need to model transitions and build maps of alternative actions (Hodson and Marvin 2010). However there are some recent studies which should be analysed for further replication in actual practice (see e.g. Gusdorf et al. 2008). It is unclear how this challenge should be addressed because, as argued by Dawson (2011), it would be naïve to pre-define sustainable transitions when uncertainties and surprises need to be addressed through flexible strategies.

The idea of visions in TM is deemed critically important for developing strategies and giving direction to learning processes (Geels 2005). New tools now include methodologies for generating visions of low carbon urban futures or the so called “transition arena” (Nevens and Roorda 2014). First and foremost, identifying the need to think about potential scenarios is a cornerstone of successful pathway envisagement (Hodson and Marvin 2012). However, this very first step is already affected by knowledge and cognitions and, as discussed earlier in this dissertation, both are influenced by values and culture and may determine adaptation and transformation capacities in cities.

In this context, the assessment of potential alternatives and the implementing of monitoring processes along with the transition plan could provide good support for governance and prevent undesirable outcomes, enabling transition policies to be forecast and reoriented and abatement/mitigation measures to be put in place to offset negative indirect impacts. This way crucial processes of learning and adaptation can take place through evaluation processes drawn up from a long-term, multi-scale, cross-sectoral perspective (Dawson 2011). Yet knowledge does not only influence policy making. Data availability and transparency is a key issue in social participatory resilience building (World Bank 2012) as society’s choices are often influenced by a lack of information.
3.5. Conclusion

While multiple, isolated combinations of approaches enrich the study of urban resilience, there is a lack of a basic shared approach, and indeed of a widely accepted definition of urban resilience. More empirical and analytical work at urban level is needed. The existing studies are mainly related to disaster-risk reduction (e.g. Wallace et al. 2007) and resilience to climate change (e.g. Eakin and Wehbe 2009; Lomas and Ji 2009). Applications tend to vary depending on the space and time boundaries for the resilience phenomena being analysed (Pendall et al. 2010). To this end, it is useful to ask the heuristic question: resilience of what to what? (Carpenter et al. 2001) and supplement it with a clear definition of the spatial and temporal scales involved (Chelleri and Olazabal 2012a). It is also evident that most of the focus on resilience has been on higher levels of governance: less emphasis has been put on the role of urban networks, social behaviour and local institutional structures.

Global sustainability pivots largely on cities (UNU/IAS 2003a), and accordingly urgent changes are needed in urban policy making and planning. Although there tends to be a natural resistance to change (Keith and Pile 1997), given existing power structures and current cultural values, it is necessary to reflect on what opportunities a radical change might bring for the longer-term performance of cities. Drastic transformations might affect the evolution of urban structures (e.g. planning, land-use and landscape), functions (e.g. design, basic services, infrastructures and economic activity) and/or processes (e.g. social networks performance, governance processes, consumption-related behaviour). To make this transition possible, cities need to seed the ability to transform using learning and knowledge management as their main tools for resilience management (Lebel et al. 2006; Folke et al. 2010; Dieleman 2013). This is especially so because these tools can provide the ability to identify potential barriers and break out of locked-in states. All in all, there is a unique opportunity for cities to be taken as laboratories of innovation and experimental action where science meets social needs and private investors, and actions can be started “on the ground” (see for instance Ernstson et al. 2010b; Evans 2011; Castan Broto and Bulkeley 2012; McCormick et al. 2013).
From an extensive review of the literature, this chapter seeks to answer three core questions: what is the added value of a urban resilience approach? And, how might sustainable urban transformation be stimulated and what are the main challenges?

On the one hand, sustainability policies at urban scale are not enough to tackle current challenges, mainly because they lack a long-term view. I conclude from the analysis in this chapter that resilience complements sustainability approaches by providing a framework (with empirical experience in managed natural systems) where capacities for learning, adaptation and transformation are strengthened so that the long-term view that sustainable policies lack is obtained. An evident need to deliberately lead urban transitions towards more desirable states and/or avoid undesirable transitions at city scale emerges.

In answer to the second question, the following assumptions can be made regarding URST (Urban Resilient Sustainability Transitions):

- Transitions are context-specific: there is no archetypal sustainable city; rather, cities should seek to become sustainable in the context of their own environment and challenges (Dawson 2011). This is also supported by the idea that values and culture might limit the potential of processes of adaptation and transformation (Adger et al. 2009) and enhance the need to address specific problems in specific contexts.
- Transitions may be unknown, but strategic directionality can be established and sustained (Dawson 2011). Processes of diagnosis, screening, assessment, monitoring and reorienting are crucial for this.
- Transitions can be stimulated from top-down and/or bottom up (community led) initiatives and obtained through a combination of technology development and mobilisation of society (Bermejo 2010).
- Finally, the level of success of transitions depends on the combination of measures, the timing of the implementation, the engagement of different socioeconomic groups, their will to change and the ability to foresee opportunities. Local institutions have a responsibility to move from rhetoric to
meaningful action (Romero-Lankao 2012) and generate the conditions to engage society and stakeholders in a process of change.

Nonetheless, cities still need to ‘learn how to learn’ and learn how to manage uncertainties in decision making to generate the flexibility that true implementation of urban transition requires in a rapidly changing, urbanised, technocratic world. The urban resilience and urban transition research communities need to continue encouraging the adaptability of cities, but also to stimulate transformation thinking and practice. Conventional approaches to the governance of cities are largely inadequate (McCormick et al. 2013). We are at a juncture where cities must move away from traditional management approaches and towards innovative urban planning and management approaches. This must necessarily involve a transformative change in the way that urban users in general perceive new norms, regulations, institutional practices, investments, incentives and lifestyles (Samet 2013). The question is whether urban societies are ready to take up the baton of resilience thinking and action.

The chapters that follow respond to some of the challenges identified in Section 3.4 above by providing novel approaches and tools to aid in decision making on URST. For example, to finalize the conceptual research developed in Part I, Chapter 4 (p. 101) focuses on drawing up an integrated approach for considering ES in urban decision making and planning processes, so as to engage with sustainable urban transformation. Part II, then, presents the empirical research: the city of Bilbao, in the Basque Country (see Chapter 5, p. 145), is used to explore how cognitions affect transformation potential in cities (Chapter 6, p. 191) and how they can be used to better grasp urban system feedbacks which closely affect resilience, sustainability and transformability (Chapter 7, p. 211).
3.6. Summary

The main points of this chapter can be summed up as follows:

- Cities are CAS that have the opportunity to manage their resilience towards sustainability through processes of transformation.

- Urban resilience is a burgeoning research area. The concept has been applied in many different disciplines (climate change, disaster risk reduction, planning, economy, sociology and psychology) which enrich the study of its tenets. Yet there is a lack of a shared framework, and indeed of a widely accepted definition of urban resilience, and a lack of an operative approach.

- This chapter identifies the most common characteristics of urban resilience as found in the relevant literature (such as multifunctionality, redundancy, and modularization, self-sufficiency, interdependency and safe-failure, multi-scale networks and connectivity, diversity - in relation to the biological, social and built domains - and flexible and adaptive planning and design). Some of these might be drivers of resilience but might also originate trade-offs one against another that do not benefit sustainable or resilient paths.

- The concept of Sustainable Urban Transformation is proposed to provide a conceptual framework for resilience and transformability and answer the questions of why and how cities should plan and manage their processes of change towards sustainability.

- Challenges regarding technology and infrastructures, ES, knowledge storage, institutions and behavioural change become crucial in sustainability transitions, and have direct implications on the governance of cities.

- The following aspects are considered relevant for advancing research on sustainable urban transformation: reconsidering the opportunities offered by the natural and built environments, obtaining a more advanced understanding of the complexity of urban systems, identifying practical, context-specific barriers to transformation and engaging actors in the process of transformation towards sustainability and resilience. These points are addressed in the following chapters.
Chapter 4

Integrating ecosystem services in urban decision-making

LINKING NATURAL ASSETS TO THE BUILT ENVIRONMENT

“...loss of ecosystems in cities may involve high long-term economic costs and severe impacts on social, cultural, and insurance values associated to ecosystem services. [...] Loss of green infrastructure can also lead to decreases in resilience-related insurance values, increasing the vulnerability of cities to shocks such as heat waves, flooding events, storms, landslides, and even food crises.”

(Gómez-Baggethun and Barton 2012, p.244)
Chapter 4. Integrating ecosystem services in urban decision-making

4.1. Introduction

4.1.1. Ecosystem Services and Urban Resilient Sustainability

Why is it important to integrate nature in urban decision-making?

As pointed out in Chapter 2 (see p. 41), one of the most important focus of resilience thinking is the significance that this theory puts on the connection of nature and human society (see Olsson et al. 2014). Arguably, this human-nature complex connection helps understanding how a sustainability transformation can take place within planetary boundaries, i.e. without trespassing critical planetary ecological thresholds. An integration of nature and its services in urban decision-making would help, thus, to conceive sustainability transformations guaranteeing future ecological services.

In line with this, Chapter 3 above restates that green and blue infrastructures and resulting ecosystem services (ES) in cities represent an opportunity for sustainable, resilient transformation. In fact, the need to identify the opportunities represented by ES by recognising the social–ecological interdependencies of human activities and ES (aligned with Chapin III et al. 2010) has been highlighted as a challenge in URST based on the analysis developed in Chapters 2 and 3. As reasoned above, this is because increasing urbanisation requires the conservation of natural assets as critical elements whose services are hard to replace. In most cases however, land use changes in urban areas in favour of transport infrastructures or buildings prevail. Certainly, most if not all urban areas long ago surpassed the critical limits where the substitutability of their natural assets could be considered (Ekins et al. 2003; Dietz and Neumayer 2007), and policies based on strong sustainability are now called for (in contrast to weak sustainability policies where substitutability is considered). On the other hand, ES play a central role in strategies for sustainable adaptation to global environmental change (Rechkemmer and von Falkenhayn 2009) and their conservation and maintenance also represent a critical move in climate change adaptation and mitigation strategies (see Demuzere et al. 2014; Ojea 2014).
This justifies the idea that guaranteeing ES for future generations in cities is critical to URS (Leichenko 2011; Jansson 2013) and is therefore an essential criterion for transformation management. In fact, the link between urban resilience and ES prevails in some of the earlier definitions of the concept as analysed in Chapter 3: from an ecological perspective (as defined in Resilience Alliance 2007a), urban resilience should seek a balance between urban and ecological functions (Alberti and Marzluff 2004) following the Millennium Ecosystem Assessment (MEA) approach (MEA 2005; TEEB 2008), by stressing the role of metabolic flows in sustaining urban functions, human wellbeing and quality of life.

4.1.2. Aim of the chapter

It is therefore the aim of this chapter to explore the connections of natural assets and human society in urban areas and how these sustain urban functions, human wellbeing and quality of life by providing a new conceptual framework to integrate ES and supporting built infrastructures in decision-making in cities as a way of furthering understanding of how to engage with sustainable urban transformation.

To fully understand the scope of this challenge it is necessary to recognise the gradual substitution of natural capital that urbanization has entailed. Natural capital has been replaced by built infrastructures that provide similar services with a human origin in to a greater or lesser degree (for example, natural fresh water filtration is replaced by water treatment plants). This has been a necessary step for urban development as ecosystems were no longer able to provide sufficient services to satisfy the demand from an increasing population and from the increasing social and economic activities that come together in cities. Local ecosystems do not have the capacity to support the great load of environmental impact and waste that urbanisation involves. In this process of urbanisation, goods and services coming from urban and peri urban ecosystems are often also disregarded and their benefits (i.e. those that green and blue infrastructures provide such as air quality, safety, flood protection and climate regulation) are overlooked mainly because their total value is not captured by the markets in place (e.g. real estate market). This leads to the substitutability of urban natural or semi-natural assets (UNAs henceforth) (i.e. green and blue areas) by other urban built infrastructures (UBIs
henceforth) which can bring more direct economic benefits. In other cases, space is so scarce in densely populated and urbanized areas that UBIs can be more cost-effective than maintaining or restoring extensive natural systems -Baggethun and Barton 2012).

However, as mentioned above, ecosystems services are critical for resilient, sustainable development and global environmental change, and substitutability is no longer an option. ES represent an opportunity to build climate-proof cities (e.g. by providing flood buffering areas), to reduce resource needs (e.g. vegetation decreases air conditioning needs) and at the same time to provide cultural, wellbeing, health and spiritual services to the population, guaranteeing multifunctionality (key determinant for urban resilience as identified in Chapter 3, Section 3.2.3, p. 76).

The idea of considering natural and human capital as both playing roles in ecosystem services provision has recently been highlighted by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), which has introduced the notion of co-production of benefits between nature and societies (UN 2013). Here ‘human capital’ or ‘anthropogenic assets’ refer to “built-up infrastructure, health facilities, knowledge (including indigenous and local knowledge systems and technical or scientific knowledge, as well as formal and non-formal education), technology (both physical objects and procedures) and financial assets, among others” (UN 2013, p.4). For instance it states that “institutions and governance systems and other indirect drivers also affect the interactions and balance between nature and human assets in the co-production of nature’s benefits to people, for example by regulating urban sprawl over agricultural or recreational areas.” (UN 2013, p.6).

One necessary step for integrating ecosystem and “human”

services into urban decision-making processes is to help city managers to see ES in the same way that they see other critical infrastructures that provide services to citizens. The main objective of this chapter is thus to develop an **Urban Service Framework (USF)** by distinguishing

22 Those that originate from human capital or built infrastructures.
the multiple pathways for obtaining urban wellbeing from natural and human (built) capital, which are necessarily coupled in urban areas.

4.1.3. The coupled nature of natural and built infrastructure

Urban social-ecological systems are multifaceted, prone to unexpected features and hard to illustrate “cleanly” due to the complexity of identifying cause-effect patterns between their elements. In turn, this also makes it more difficult to aggregate smaller or larger behaviour patterns into the desired scale of analysis. Research on the role of urban ecology has advanced the understanding of the role of urban ecosystems in providing services to population and in illustrating the benefits that this has for human wellbeing (Alberti 2008).

To continue with this perspective, based on the idea of the co-production of services between nature and societies, services in urban areas (US for short) are not just provided by UNAs or by the UBIs independently, but also by interactions between them as a result also of the provision of services by ecosystems outside the boundaries of the urban system. In most cases, this interaction takes place through the organisation of social entities or communities that manage, at urban scale, the service provision. This suggests that not just the coupled biogeochemical cycles that exist in urban areas (Pataki et al. 2011) but also the way in which UBIs affect and interact with them (Kaye et al. 2006) should be studied.

To give an example, in urban areas water consumption depends on the existence of natural water resources (stored e.g. in reservoirs, often outside the limits of the city) but also on the existence of human-made infrastructures for water collection, distribution and treatment, which make it possible to provide (capture, distribute and supply) drinking water in urban areas. Water companies (public or private depending on the legal competencies given by regional authorities) operate these processes and establish how, when and at what price drinking water is available to urban populations. However the quantity, quality and availability in time and space of water depend on climate conditions and on the health of the urban/regional ecosystem. Likewise, the quantity and quality of natural water influence treatment needs and the distribution infrastructures required, and
thus affect the real cost of providing water. Only through urban (and regional) policies which develop, protect and maintain natural assets, built infrastructures and the interactions between them can adequate flows of drinking water be sustained.

Furthermore, understanding the above might help urban planners and decision makers to reflect about the limits of US provision. Policy makers, stakeholders and local managers often need to look for resources outside their urban administrative boundaries, thereby making it harder to assess the environmental impacts which consumption of such resources creates.

The development of a USF requires a clear set of definitions including ‘urban service (US)’ and ‘benefit of US’ among others, and the identification of the interaction between human and natural components within urban areas from which US are delivered for the benefit of urban populations.

This said, an integrated USF may well further understanding of certain research issues currently on the table in the relevant literature such as (i) integrating human and environmental models in the analysis of urban areas (Pickett et al. 1997; Kaye et al. 2006) in a way that is useful for urban decision making; and especially (ii) assessing and highlighting the benefits of US to stimulate the conservation and/or creation of green and blue infrastructures in urban areas (TEEB 2011; Depietri et al. 2012; Jansson 2013).

4.1.4. Approach and structure of the chapter

The framework proposed in this Chapter seeks to complement and build on the Ecosystem Service Framework (ESF) encapsulated by the MEA (2005). A simplified framework of US is proposed to illustrate that such services arise through the interaction of natural resources and public resources managers with so-called Urban Service Providing Units (USPU), made up of urban natural or built capital. These US are then transformed into benefits to urban users in a context of cross-scaling interactions.

The USF developed in this Chapter combines insights from ES research (e.g. Luck et al. 2009) and urban ecology (e.g. Alberti and Marzluff 2004). New concepts are defined to distinguish the roles of the different actors in the provision of urban services, from their
generation to the benefits obtained. A couple of examples concerning flooding and energy management are used to illustrate its potential, as critical action areas in cities regarding resource scarcity and climate change adaptation and mitigation.

Considering current urban management and planning needs, this framework is conceived to help urban decision-making processes to acknowledge this complexity by looking at the city in a systematic way as a coupled social-ecological system where services are provided by natural or semi-natural providing units, by built infrastructures or by a combination of the two. It distinguishes the services provided by each natural or built infrastructure and can be used to distinguish the synergies and trade-offs that can occur between them. Thus, it helps to identify and compare the benefits that natural and built service providing units provide in urban areas. Advancing towards an integrated framework of natural and built capital urban policy needs are addressed directly by: (i) helping identify the set of options available in decision-making processes (Bai et al. 2010; Bastian et al. 2012); and (ii) providing a set of criteria for decision-making by identifying what benefits are obtained and by whom (Bai et al. 2010; Ernstson 2013) i.e. identifying which services provide which benefits to which social groups.

The structure of this chapter is illustrated in Figure 4.1. The next section takes stock of the Ecosystem Service Framework (ESF henceforth) from the MEA and some complementary developments to assess the role of ES in natural and semi-natural environments and introduces some of the ideas behind the conceptualisation of a USF. Section 4.3 then develops the USF conceptual approach and builds on it to propose how to link USP (urban service providers) and benefits to urban populations. Then Section 4.3 discusses the assumptions made in developing the USF and illustrates its application through a couple of examples involving (1) urban flood management and (2) urban energy management. The benefits and costs of services provision are then discussed, and how they should be internalised in decision-making processes. The section finishes by debating how the USF contributes to URS. Section 4.4 sums up the conclusions and Section 4.5 summarises the chapter.
4.2. Moving from the Ecosystem Services Framework to an Urban Service Framework

As introduced in Section 4.1, the concept of US used here is based on the ESF developed by the MEA (2005), which mainly considers environmental processes. However, as in the ESF, assessing benefit flows derived from ES requires an explicit description and proper assessment of the links between the structures and functions of natural and human systems and the benefits derived from the goods provided by the services (Heal et al. 2005, p. 2). To complement the ESF associated with natural or semi-natural areas, here a companion USF is developed which is adapted to the needs of urban complexity and decision and policy making processes. First, Section 4.2.1 describes useful advances in ES research and new concepts beyond MEA. Then Section 4.2.2 describes the advances made so far in research on urban ES, presenting relevant insights for the development of USF which are subsequently addressed in Section 4.3.
4.2.1. Systematic approaches beyond the Millennium Ecosystem Assessment

Regardless whether or not this is recognised in human preferences and social markets (Folke et al. 2002b), societal development depends on ecosystems to generate goods such as food, timber, genetic resources, medicines, clean water, a safe environment, air quality and thermal comfort, and to provide aesthetic and cultural benefits (Costanza et al. 1997; Daily 1997). Irrespective of the suitability of the economic valuation of ES as an assessment tool (Pimm 1997; Sagoff 1997; Pearce 1998), the recognition of how conservation can be justified economically via the valuation of non-marketed services is increasingly considered as a key success of ES research (Turner and Daily 2008; Barbier et al. 2009). This is also recognised by international initiatives for assessing global biodiversity loss such as The Economics of Ecosystems and Biodiversity (TEEB) initiative (TEEB 2010) and other national and regional assessments (i.e. UK NEA 2011).

The concept of ES originated as a metaphor in which nature is seen as a stock of capital that can sustain a limited flow of ES. For conservation purposes, this market metaphor was used to engage a public disconnected from nature whose choices were running under an economic prism (Norgaard 2010). The main foundations can be traced back to the Millennium Ecosystem Assessment (MEA 2005), designed to meet the needs of decision-makers based on scientific information regarding the consequences of ecosystem change for human wellbeing. Scenarios were considered as a promising tool for building up an understanding of the logical consequences of different actions involving the allocation, mobilisation, devastation or modification of natural or managed environments and their resources (Carpenter et al. 2006a; Carpenter et al. 2006b). In this way, MEA was successful in attracting attention from policy makers around the world.

MEA (2005, p. 27) defined ‘Ecosystem Services’ as the “benefits people obtain from ecosystems”, that is, the flows derived from natural capital that people rely on for food production, climate stabilisation, pollination, drinking water and cultural, recreational and other non-material benefits. It goes on to define ‘wellbeing’ as having “multiple constituents, including basic material for a good life, freedom of choice and action, health, good social relations, and security” (MEA 2005, p. 27). Such elements of wellbeing are subjective since they are perceived by people in different ways depending
on their location, culture, education and environmental conditions. Finally, although MEA recognises the potential usefulness of assessing ES through ‘valuation’ as “the total contribution that ecosystems make to human wellbeing”, it falls short of using economic valuation approaches for such assessment (Norgaard 2010). Instead, the MEA offers a more general conceptual framework for linking changes in ES with human wellbeing in terms of security, basic materials, health, social relations and freedom of choice and action.

However, soon after the MEA provided a classification of ES and an assessment approach, both were criticised (see for example Costanza 2008; Fisher and Turner 2008; Turner and Daily 2008; Wallace 2008; Carpenter et al. 2009b; Daily et al. 2009; Fisher et al. 2009). The criticisms were mainly related to the availability of information, loose definitions, assessment methods and political framework. For instance, a variety of operational shortcomings have been identified (Boyd and Banzhaf 2007; Costanza 2008; Fisher and Turner 2008; Turner and Daily 2008; Norgaard 2010), concerned mainly with three aspects: first, the inconsistency on the definitions of ES, functions, processes, benefits and values; second, the likelihood of double counting in ES valuation; and lastly, the need for standardised units for accounting purposes.

New proposals include the replacement of the term ‘ecosystem function’ with ‘ecosystem process’ and the differentiation of final and intermediary services to avoid double counting. The latter is evident since some services embody others: for example the fish population in a lake, which according to the MEA is a provisioning service for a community, depends on the quality of water, which in turn is linked to regulating water services. When the benefit to the community from the lake is assessed one should not count both services, as otherwise double counting of benefits would occur. It has been suggested that benefits should be valued in terms of final services and not intermediate services.

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23 For example, accounting for air pollution mitigation and also human health benefits including good air quality. If both are valued, the air quality service will be double counted.

24 ‘Ecosystem processes’ are defined by Wallace (2007) as the complex interactions (events, reactions or operations) between biotic and abiotic elements of ecosystems that lead to a definite result. In broad terms, ecosystem processes involve the transfer of energy and materials.
ones (Boyd and Banzhaf 2007; Wallace 2007; Costanza 2008; Fisher and Turner 2008). In this context, ‘final ecosystem services’ would be defined as the components of nature directly enjoyed, consumed, or used to provide human wellbeing (Boyd and Banzhaf 2007). Fisher (2008; 2009) and Wallace (2007) also suggest using the terms ‘intermediate service’ and ‘final service’ to support the operational implementation of the concept of ES for valuation purposes. It is also pointed out that aesthetic values, cultural contentment and recreation are not ES per se but benefits as they have a direct impact on human welfare (Boyd and Banzhaf 2007; Fisher and Turner 2008).

However, post-MEA advances have been made, particularly concerning the double counting issue. A case in point is the methodological approach used in the UK National Ecosystem Assessment (Mace et al. 2011), which incorporates both information which economists need for monetary valuation and the flexibility required to allow a non-monetary valuation of those services that cannot be meaningfully assessed in monetary terms.

Besides the debate about the classification of ES (Wallace 2007; Costanza 2008; Fisher and Turner 2008; Wallace 2008; Fisher et al. 2009), there are other, complementary approaches to the valuation of ES based on novel accountability units. For instance, Luck et al (2009) use a definition of the concepts of Service Providing Units (SPUs) and Ecosystem Service Providers (ESPs) to emphasise the need to identify and quantify an “organism’s characteristics” that provide services. The objective is to be able to assess the levels of service provision relative to the demands of human beneficiaries, or in other words the capacity to provide services. This need has also been raised by other authors (Bastian et al. 2012; Polishchuk and Rauschmayer 2012). They argue that this approach is more helpful to policy makers and land-managers since most of their decisions are based on accountability from a market point of view (i.e. supply and demand).

According to Luck et al (2009, p. 224), Service Providing Units (SPU) are “the collection of individuals from a given species and their characteristics necessary to deliver an ecosystem service at the desire level” and Ecosystem Service Providers (ESP) are “the populations, communities, functional groups, interaction networks, or habitat types that provide ecosystem services” (ibid. 2009, p. 224). In their view, defining SPU and ESP
4. Integrating ecosystem services in urban decision-making

provides the baseline required for ecosystem service accountability. They also stress the definition of beneficiaries to document the cost-benefit trade-offs of service provision. Their approach addresses the complexity of the demand and provision feedbacks and the drivers involved within the process of interaction between communities and ecosystems. I return to this point later in Section 4.3, where the main components of the USF are introduced based on the ESF and on the approach of Luck et al. (2009). This is done by offering a consistent view of how structural properties and components of urban social-ecological systems determine the levels of US.

**4.2.2. Foundations of an urban services framework**

Ecosystems provide services and goods directly to humanity in non-urbanised areas and indirectly support human services in urbanised ones (Daily 1997; Alberti and Marzluff 2004). The ability to maintain the flow of US depends on human activities and the development patterns of human settlements in urban areas (Alberti 2007). If undesirable urban patterns exist, unwanted states may emerge in urban areas, such as habitat degradation, fragmentation and the subsequent loss of ES in urban areas (Colding 2007). Such loss of ES in cities may bring long-term economic costs because of the substitution of green infrastructure by built infrastructures to provide the same services and “severe impacts on social, cultural, and insurance values associated to ecosystem services” (Gómez-Baggethun and Barton 2012, p. 9).

There is a growing literature on urban ES but it represents only 10 per cent of the total output of ES research (Hubacek and Kronenberg 2013). This review classifies these urban studies in five categories: Modelling Studies, Governance, Tools, Economics and Social, with those focusing on modelling and governance being predominant (~70 per cent of the total).

Additionally, for the purposes of this review it is particularly relevant that the literature that has focused on US mostly hinges on identifying and valuing services provided by

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UNAs within urban areas (for instance Lundy and Wade 2011 focus on services provided by urban water bodies), and usually focuses on one or two types of services (for instance Bastian et al. 2012 evaluate recreational and climate regulation of urban green areas in Leipzig). In order to encapsulate trade-offs and interactions between urban ES, there have been recent attempts to develop spatial tools to deliver the right information to policy makers to support more effective negotiations (see Grêt-Regamey et al. 2013). Only a few studies (e.g. Ernstson et al. 2008; Barthel et al. 2010; Connolly et al. 2013) have focused on the role of social networks in maintaining or even raising the value of those services, yet in practice the empirical evidence brought by these studies focuses on single types of ecosystems that provide a limited number of services.

Such UNAs and embedded environmental processes, although managed by humans, are referred to as urban ecosystems, e.g. street trees, lawns/parks, urban woodland, cultivated land, wetlands, lakes/sea, and streams (Bolund and Hunhammar 1999). This has contributed mainly to research on “ecology in the city” rather than the “ecology of the city” (Douglas 2012) following the concepts defined by Pickett (2004).

Not accounting for the human dimension provides little help in understanding the dynamics of ecosystems and their ability to generate services (Folke and Rockström 2009). Moreover, urban areas are intensively transformed ecosystems rather than intensively managed ecosystems such as those which are studied in ES research. Focusing on urban areas as urban social-ecological system, thus taking account of the social and economic dimensions in urban ecosystem management, is an alternative (Elmqvist et al. 2003; Borgstrom et al. 2006; Elmqvist et al. 2008; Ernstson et al. 2008) which also involves taking into account the technology which has been developed to substitute ES as urbanisation has increased and the needs for services have surpassed the limits of localised ecosystems.

Alberti and Marzluff (2004) first incorporated the human perspective through the description of the changes in environmental conditions associated with urbanisation, such as the contamination of watersheds, loss of biodiversity and change in climate. Urbanisation leads progressively to a decline in ES and an increase in human services as illustrated in Figure 4.2 by the threshold. This decline can be seen as the process by
which humans replace environmental services, for example natural water purification by wastewater treatment in plants.

However, this substitutability of environmental services by human services as urbanisation increases is often poorly addressed by local authorities, planners and stakeholders due to the lack of comprehensive information about the costs and benefits of such changes or substitutions. Likewise, the synergetic effects that such changes can have for ES provision and human wellbeing are not taken into account. Some well-known trade-offs are for example related to urban form, which seriously affects resource flows in urban areas (Alberti 1999; Alberti and Marzluff 2004) both directly, by redistributing solar radiation and mineral nutrients (Arnfield 2003; Grimm et al. 2008b), and indirectly, by determining the resources needed to support human activities (Band et al. 2005) in terms of, for example, transport infrastructures, water pipes, or energy networks. The urbanisation pattern is a remarkably relevant factor that influences the demand for resources in urban areas. Moreover, as it determines the spatial distribution of natural and built elements and how they are interconnected, it affects the way in which such services are delivered (how, from how far and when they are delivered and who benefits). In essence, this means that the flow of costs and benefits from US to communities and urban users is affected by urbanisation patterns.
Urban sprawl is a good example of how urban morphology patterns determine US. When urbanisation sprawls, longer water pipes and more storage tanks are required, also affecting the cost to the public purse of the distribution of domestic water. By contrast, the accessibility of green and blue areas depends on their location. Residents closer to these areas will have more chance to benefit from them. These two examples suggest that urbanisation patterns and infrastructure management greatly affect equity and justice in the provision of US.

Inspired by earlier work (Alberti and Marzluff 2004; Alberti 2008) and addressing the need to integrate the value of urban natural assets and services into urban planning and decision making (Gómez-Baggettun and Barton 2012), the USF proposed in this chapter includes human and environmental services as well as the idea of synergies, trade-offs and limits of services provision in urban areas. For this reason, following an accountability of capital assets approach, the identification of Urban Service Providing Units (USPUs) (following Luck et al. 2009 and adapting it to the urban context of natural and man-made units) would be more useful to decision-makers and planners as a tool for prioritisation than, for example, a classification based on TEEB-cities (2011) (The Economics of Ecosystems and Biodiversity (TEEB) manual for cities), which is more oriented towards valuation purposes.

In the light of this, on one hand some US, e.g. carbon sequestration, recreational activities and thermal comfort, can be seen as being delivered by UNAs (e.g., urban forests or green parks) that do not directly depend on UBIs. These services are an input to the production of final goods enjoyed by urban populations. Some of these services tend to be overlooked by urban planners and decision makers despite their beneficial and substantial contribution to the urban environment (Elmqqvist et al. 2008). Others, which come rather from green areas, are more commonly valued and perceived by the urban population and stakeholders, such as aesthetics, enjoyment and recreation (Gobster 2001).

Additionally US can be provided by UBIs that may complement and even substitute environmental processes from UNAs. For example, UBIs are needed to provide clean water and consumable energy as well as to collect, treat and dispose of the waste
generated via its consumption. Hence, human services complement environmental processes such as waste assimilation by soil through natural biodegradation processes.

From the MEA (2005) and subsequent conceptual developments (Boyd and Banzhaf 2007; Costanza 2008; Fisher and Turner 2008; Turner and Daily 2008), four aspects required to build a coherent classification of US are identified and to some extent adapted here:

- First, any measure of US should be thought as an indicator of change in US provision using clear and coherent units of accountability. This means that a measure of an US is not a quantification of the provision itself, but rather a measure of changes in it, in order to assess the effects that a decision on urban planning or management can have on the wellbeing of the urban population. Furthermore, the benefit obtained from a US should be a measure of the perception of the change in its provision.
- Second, US ought to be associated with final rather than intermediary services, to avoid the problem of double-counting of services.
- Third, US should be seen as the result of the interaction of corresponding environmental and built anthropogenic intermediary services, rather than isolated processes or functions of the urban system.
- Fourth, unlike ES which are regarded as non-spatially explicit (Boyd and Banzhaf 2007), some US might be also spatially explicit. For instance US can be delivered to each residential block or dwelling (e.g. waste collection – spatially explicit and its use value is subject to distance-decay) or can cover larger areas within urban areas (e.g. wellbeing as a result of an unpolluted environment – spatially inexplicit). The spatial character of US makes it harder to assess and systemise it.

Urban users demand services, as they are inputs for the provision of final goods needed for human wellbeing in urban areas. City managers need information about the demand for services by such users, which they can translate into the quantity of resources required by a certain group of the urban population to allocate either UNAs, for example, green

\[26\] However, establishing units of accountability or proxies lies outside the aims of this research work.
areas, or UBIs such as domestic waste collection points. As argued above, the framework of Luck et al. (2009) is thus helpful since it lends itself to the definition of ‘urban service providers’ and ‘urban service providing units’, both of which are useful terms for urban management and planning decision making.

As discussed, the demand for US increases with urbanisation, and creates social, economic and environmental pressures on the supporting social-ecological system, both within and outside urban areas, hence affecting the quantity and operating quality of the UBIs needed to substitute UNAs. Accordingly, it is essential to help decision-makers to understand various questions:

- What are the benefits of US?
- What urban infrastructures provide the services which generate those benefits?
- What services are co-produced jointly by natural assets and built infrastructures?
- Where do the benefits of those processes accrue?
- Who are the beneficiaries?
- Where do the costs of management actions occur? and
- What is the spatial distribution of the costs and benefits of US supply?

The next section presents the USF developed in an effort to help envision these questions.

### 4.3. An Urban Service Framework for decision-making

#### 4.3.1. Conceptual Approach

The conceptual contribution of this chapter is informed by both the idea of urban areas as social-ecological systems and the idea of the progressing human substitutability of ES. This chapter contributes to the relevant literature by developing an integrated USF that accounts for both human-based and ecological-based services, and the interactions between them.

The proposed components of the USF are further explored in the following section.
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4.3.2. The Urban Services Framework

Figure 4.3 develops the USF, which entails six different sets of key components: (1) Urban Service Providers (USP); (2) Intermediary Services (IS); (3) Urban Service Providing Units (USPU); (4) Final Urban Services (FUS); (5) Goods; and (6) Benefits accrued for the urban population.

Figure 4.3 Urban Services Framework (USF)

Figure 4.4 builds on this conceptual framework and links USP and benefits. It provides a simplified classification under the USF. This classification does not seek to be exhaustive but rather to visualise the main urban flows and provide an initial approach for more detailed developments.
Figure 4.4 Linking Urban Service Providers (USP) and benefits

Urban service providers (USP) (see Fig. 4.4, Column 1) may involve (a) natural resources from ecosystems which the urban population requires to generate consumable...
4. Integrating ecosystem services in urban decision-making

energy and materials such as soil, vegetation, fauna, raw materials, atmosphere, etc, as well as cultural values; and (b) Public resource managers, including stakeholders such as private and public companies, communities and public authorities, concerned with the urban management infrastructure, for example, energy, water or waste utilities, city councils and non-for profit organisations such as schools. USPs often originate some of the main cross-scale interactions that influence final urban services. Indeed, while some stakeholders may be actors at regional scale, their decisions and management determine certain services at UA level. Similarly, some natural resources might (i) be influenced by ecosystems at upper levels; (ii) provide goods outside the urban boundaries which are then imported into urban areas, e.g. materials used in construction of buildings or roads; or (iii) provide intermediary services outside the urban boundaries which are later transformed into final services through urban infrastructures, for example, lakes that capture rain water which is then treated in a water treatment plant.

USPs generate final or intermediary urban services through the regulation and the operational control of urban service providing units.

**Intermediary Urban Services (IUS)** (see Fig. 4.4, Column 2) are associated with intermediary processes that enable a final urban service to be provided. They may entail anthropogenic intermediary services, e.g. policy and management processes where decisions about built environmental infrastructures and the management of urban managed ecosystems are taken. Examples of such services include urban planning and design, social and economic policies and transport management. Natural intermediary services, in turn, consist of natural processes which are part of biogeochemical cycles that operate at local scale such as water assimilation by the soil, nutrient formation, carbon sequestration by vegetation in UA, etc. Intermediary US (IUS) are influenced in most cases by higher or lower scales. For instance local urban planning is in general underpinned by a spatial planning regulatory framework at the local scale, but it is also often determined by regional planning decisions, for example, strategic decisions regarding the development of energy or transport infrastructures. In the case of biogeochemical processes, interventions at larger or smaller scales significantly influence the performance of environmental and biogenic processes at local scale, for example, river basin management.
Urban Service Providing Units (USPU) (see Fig. 4.4, Column 3) are the set of urban infrastructures (UNAs and UBIs) and their characteristics required to deliver US at the desired levels. USPUs constitute the urban capital stocks which deliver the flow of final urban services. USPUs can be natural managed units such as open green and blue spaces, for example, green parks, urban woodland, urban rivers, etc. or built environment infrastructures such as waste collection facilities, water infrastructures, dwellings, industries, roads, etc. Generally, USPUs are located within the boundaries of the municipality, although sometimes, for cost-efficiency reasons, infrastructures such as waste treatment and water treatment plants and energy generation facilities provide service to several municipalities and costs are thus shared.

A Final Urban Service (FUS) (see Fig. 4.4, Column 4) is the result of the interaction between the USP (column 1) and the USPUs (column 3), through intermediary urban processes (column 2). FUS are inputs for the production of urban goods which are translated directly or indirectly into benefits for the urban population. Final services may be a product of a single USPU or the product of the interaction of multiple USPU. Examples of FUS are waste collection, health, mobility, employment, energy consumption, etc.

Urban goods (see Fig. 4.4, Column 5) are an output of FUS. They are the result of access to either energy or material flows (in the form of consumable energy, water, residences, etc.) or information flows (such as the opportunity to enjoy education and knowledge, access to places, etc.). The value of changes in the provision of goods is the Benefit (Column 6) of the FUS. Thus, it is associated with changes in wellbeing. However, it should be noted that the concept of benefit is not exclusively tied to a monetary metric. For instance, benefits of US provision produce a change in well-being which is linked to the perception of changes in provision of US e.g. comfort, mobility and accessibility or in the enjoyment of recreational activities. Significantly, when it comes to benchmarking the value conferred on such changes will depend on the social and economic context of each urban area.

The co-production of services and therefore goods is clearly visualised in the simplified USF. For example, comfort and a clean environment are generated either by FUS
4. Integrating ecosystem services in urban decision-making

provided by UNAs such as green and blue infrastructures (climate comfort and air quality) or by FUS provided by UBIs such as waste treatment and collection infrastructures.

4.3.3. Assumptions and limitations of a simplified framework

Some issues which cannot be covered in Figure 4.4 are the following:

- The effects of ecosystem disservices in urban environment as illustrated by some authors -Baggettun and Barton (2012), for example damage to infrastructures by trees, humidity, accidents, allergies, view or landscape alteration, noise, dirt, etc.

- Urban agriculture: In the notion of USF proposed here, urban agricultural areas (within city limits) used directly for food consumption are not taken into account. This significantly reduces the framework and helps to better visualize the role of the different actors and urban elements. Exports and imports of food and derived products are massive in medium-size and large urban areas and food is generally obtained in commercial areas and public markets and imported from any part of the world within days. In the proposed USF, these services are taken into account by representing the commercial and industrial USPUs. The employment generated in such activities is considered too.

The USF developed here is based on assumptions related to scale and system boundaries as well as on a simplified framework of the understanding of what drives urban planning decisions, so its complexity can be reduced enough for it to be better understood and for its to be turned into information relevant for urban planning decisions in a feasible and manageable way. Yet, since full comprehension of urban social-ecological systems may not come from a meticulous analysis but from an overall assessment, any development under the guidelines of this USF should cover any relevant interaction at any relevant scale concerning changes in human wellbeing at local level. Certainly, scale interactions (Elmqvist et al. 2003; Borgstrom et al. 2006; Ernstson et al. 2010b) are an important issue to consider in urban areas. As argued by Elmqvist (2008), mismatches between spatial and temporal scales of USP and IUS related to environmental and social processes of
monitoring and decision making have limited understanding of environmental processes in urban areas and the integration of urban-environmental knowledge into urban planning.

As previously discussed, although US are provided in urban areas this does not mean that IUS or USPUs are actually located within the limits or boundaries of urban areas. This leads to the consideration of each UA as a sub-network inside a bigger urban network within a regional or national context. Thus, one can argue first that spillovers of benefits or costs are likely to affect higher and lower spatial scales, and second that the IUS and USPUs are likely to be shared among several urban areas. If efficiently managed, this can save a great deal in terms of resources (e.g. water treatment plants).

Related to the potential cross-scaling nature of UPS and USPUs a range of concerns emerges related to the specificities of each city: who are the anthropogenic service providers (energy stakeholders, water stakeholders, etc.)? What key stakeholders operate at higher levels? What are the key environmental resources in the UA? Are those natural service providers within the urban boundaries? Where are the USPUs (roads, rail network, water reservoirs, etc.) located? Does the UA borrow services from USPUs located in other urban areas or at a larger regional scale? The resilience of future service provision within the city depends on how these issues are questioned, identified and managed.

In general, the importance of considering larger-scale behaviour and the panarchial network approach (see Chapter 2), i.e. cross-scale interactions, is acknowledged, but this requires advanced investigation. The USF presented in this chapter at least identifies the major components of the urban system in terms of how urban services and their benefits for urban populations are delivered. Essentially, a USF should be comprehensible and thus useful to urban decision-makers, managers and planners and should reflect up-to-date scientific knowledge. It should be useful in identifying further opportunities that green and blue infrastructures can represent for URST and, as such, it should help to identify synergies and trade-offs between urban infrastructures and ES supporting areas, co-benefits of green and blue infrastructures and limits of provision of ES, and should facilitate the incorporation of human wellbeing criteria (in the form of goods and benefits from FUS) into urban decision making.
4.3.4. Examples of the Urban Services Framework: flood and energy management

This section helps to illustrate the potential application of USF through two examples involving urban flood management (Section 4.3.4.1) and urban energy management (Section 4.3.4.2). These two examples are chosen because both are critical for climate change adaptation and mitigation and are also linked to resource scarcity.

4.3.4.1. Urban flood management

Table 4.1 lists elements of the USF that are related to water management in urban areas. The different colours of the columns echo those of Figure 4.4, which classify the different elements in the USF.
Table 4.1 Components, services and benefits of the urban system: an example from water related urban services

<table>
<thead>
<tr>
<th>USP</th>
<th>Intermediary Services</th>
<th>USPU</th>
<th>FUS</th>
<th>Goods</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bodies of water</td>
<td>Water management</td>
<td>Water Treatment Infrastructures</td>
<td>Water Supply</td>
<td>Drinking Water</td>
<td>Perception of the change in the provision of water</td>
</tr>
<tr>
<td>Soil</td>
<td>Flood Management</td>
<td>Water Supply Infrastructures</td>
<td>Flood regulation</td>
<td>Comfort and Safe environment</td>
<td>Perception of the change in the comfort of the environment</td>
</tr>
<tr>
<td>Vegetation</td>
<td>Rainfall, filtration and natural storage</td>
<td>Water Disposal Infrastructures</td>
<td>Climate regulation</td>
<td>Health</td>
<td>Perception of the change in health</td>
</tr>
<tr>
<td>Atmosphere</td>
<td>Land use management, urban planning and design</td>
<td>Water collection infrastructures</td>
<td>Access to recreational activities</td>
<td>Opportunity to enjoy recreational activities</td>
<td>Perception of the change in the enjoyment of blue spaces</td>
</tr>
<tr>
<td>Local Authority</td>
<td>Flood Containment infrastructures</td>
<td></td>
<td>Employment</td>
<td>Purchasing power</td>
<td>Perception of the change in purchasing power</td>
</tr>
<tr>
<td>Public Water Company</td>
<td>Water storage Infrastructures</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regional and National Authorities</td>
<td>Flood regulation natural areas: green areas</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Flood regulation natural areas: blue areas</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In this example the natural USP that can be identified include bodies of water, soil, vegetation and the atmosphere, which together make up the ecosystem needed for the water cycle to operate (see Column 1 in Table 4.1). Public water providers may typically include the local authority, water utility companies and regional and national authorities, who may decide upon some policies regarding water management. These public water providers may be responsible for water policies and for the development of built (engineered) water infrastructures under given frameworks of water and flood management plans. Additionally, natural ecosystems allow processes at local level such as rainfall, filtration of water and natural storage in natural groundwater systems. Both
environmental and socioeconomic processes (classified as Intermediary Services in Column 2) allow interaction with USPUs and also new developments of USPUs. Regarding water, USPUs (see Column 3) include among others water treatment infrastructures, water collection, storage, supply and disposal infrastructures and flood containment infrastructures, but also natural USPUs such as natural flood regulation/mitigation areas which act as buffers, e.g. open green areas (which filter water), watersheds and open “blue” spaces such as lakes or rivers. These natural USPUs provide FUS (see Column 4) such as water supply and flood regulation but also access to recreational and cultural activities which may be associated with aesthetic values. Altogether, these FUS are inputs for the production of drinking water or health. They also allow a certain level of comfort and safe environment and the opportunity to enjoy such “green and blue” spaces as urban goods, which when valued by urban users translate into benefits (see Column 5 and 6).

However, there are cases when for example a) there is no need for UBIs to supply water because good quality water is consumed directly from the natural source, e.g. in low urbanised areas; b) part of the water consumed is directly collected from rainfall, e.g. new urban developments with eco-design; and c) water is directly collected from natural sources and not treated before being consumed, or disposed of directly back into bodies of water due to the lack of appropriate infrastructures (mostly in rural areas and in developing countries). All of these particularities can still be defined and analysed through the USF in each specific case.

Table 4.2 illustrates an example of multifaceted benefits (co-production of services) from natural areas by contrast with those from the single purpose built infrastructures for the case of flood management.
Table 4.2 Example of multifaceted benefits coming from natural areas by contrast with those from built infrastructures for urban flood management

In this table I have shaded in grey the UBIs that act as USPUs and in purple the UNAs that act as USPUs i.e. that provide final services. In this example, it can be observed that FUS and respective goods and benefits are co-produced by both UBIs and UNAs. They are therefore shaded in both colours.

<table>
<thead>
<tr>
<th>USP</th>
<th>Intermediary Services</th>
<th>USPU</th>
<th>FUS</th>
<th>Goods</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bodies of water</td>
<td>Water management</td>
<td>Water Treatment Infrastructures</td>
<td>Water Supply</td>
<td>Consumable Water</td>
<td>Perception of the change in the provision of water</td>
</tr>
<tr>
<td>Soil</td>
<td>Flood Management</td>
<td>Water Supply Infrastructures</td>
<td>Floods regulation</td>
<td>Comfort and Safe environment</td>
<td>Perception of the change in the comfort of the environment</td>
</tr>
<tr>
<td>Vegetation</td>
<td>Precipitation, filtration and natural storage</td>
<td>Water Disposal Infrastructures</td>
<td>Climate regulation</td>
<td>Health</td>
<td>Perception of the change in health</td>
</tr>
<tr>
<td>Atmosphere</td>
<td>Land use management, urban planning and design</td>
<td>Water collection infrastructures</td>
<td>Access to recreational activities</td>
<td>Opportunity to enjoy “green and blue” spaces</td>
<td>Perception of the change in the enjoyment of blue spaces</td>
</tr>
<tr>
<td>Local Authority</td>
<td>Flood Containment infrastructures</td>
<td>Water storage Infrastructures</td>
<td>Employment</td>
<td>Purchasing power</td>
<td>Perception of the change in purchasing power</td>
</tr>
<tr>
<td>Public Water Company</td>
<td>Flood regulation natural areas: Green areas</td>
<td>Floods regulation natural areas: Blue areas</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regional and National Authorities</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

This example shows that UNAs (shaded in purple) and UBIs (shaded in grey) both provide final urban services related to flood and climate regulation. Added to this, UNAs provide a recreation service that UBIs do not. On the other hand, building flood containment infrastructures may have higher financial costs for the municipality and taxpayers than developing (or maintaining/ensuring adequacy) of green and blue areas from which citizens can benefit not only in terms of flood mitigation (Brody and Highfield 2013) but also through the perception of their recreational, spiritual, cultural values and through the health improvement that there is good evidence that green areas provide (Douglas 2012). It is important to note, once again, that this example is not exhaustive: for example green and blue areas might bring other non-marketed benefits such as community building and social networking (see for example Kazmierczak 2013).
and also disservices related to maintenance and watering, damage related to storms and
wind, noise and others (see Gómez-Baggethun and Barton 2012).

4.3.4.2. Urban Energy Management

An example involving urban energy management is given below along the same lines as
the one for urban flood management, Table 4.3 shows the elements of the USF related to
energy management in urban areas.
Table 4.3 Components, services and benefits of the urban system in an example from energy related urban services

<table>
<thead>
<tr>
<th>USP</th>
<th>Intermediary Services</th>
<th>USPU</th>
<th>FUS</th>
<th>Goods</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bodies of water</td>
<td>Water management</td>
<td>Hydropower plants</td>
<td>Energy Supply</td>
<td>Consumable Energy</td>
<td>Perception of the change in the provision of energy</td>
</tr>
<tr>
<td>Soil and Fossil Fuels</td>
<td>Radiation and energy transfer natural processes</td>
<td>Gas and oil production industries</td>
<td>Employment</td>
<td>Purchasing power</td>
<td>Perception of the change in purchasing power</td>
</tr>
<tr>
<td>Sun</td>
<td>Energy management</td>
<td>Compost plants, landfills and incinerators</td>
<td>Climate regulation</td>
<td>Thermal Comfort</td>
<td>Perception of the change in the energy use needs</td>
</tr>
<tr>
<td>Local Authority</td>
<td>Land use management, urban planning and design</td>
<td>Solar technology Infrastructures</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regional and National Authorities</td>
<td>Biogeochemical cycles</td>
<td>Geothermal energy infrastructures</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy Facilities</td>
<td></td>
<td>Electricity Supply points</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Individuals and cooperatives</td>
<td></td>
<td>Petrol and gas supply points</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Electricity distribution infrastructures</td>
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<tr>
<td></td>
<td></td>
<td>Green and Blue infrastructures</td>
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</tr>
</tbody>
</table>

Natural USPs here include bodies of water, soil and sun as the main natural resources needed to generate energy. Public energy providers may typically include the local authority and regional and national authorities, which may decide upon some of the policies regarding water management. On the other hand, USPs typically include energy facilities owned by private companies, individuals who own self-generation technologies and social cooperatives as groups of individuals that manage energy facilities (see Column 1). Column 2 in Table 4.3 illustrates the intermediary services. Here all natural and human processes that link USPs with USPUs are captured. On one side, natural intermediary services mainly relate to water management, radiation and energy transfer.
through natural processes and in biogeochemical cycles especially related to the processes through which green and blue infrastructures in cities provide thermal comfort through the regulation of temperature and humidity. On the other side, policies and processes related to energy management and land use management, urban planning and design affect USPUs and determine whether and how they provide FUS.

As in the flood management example, USPUs can be UBIs (related to production, distribution and supply of energy, including but not limited to hydropower plants, gas and oil production plants, compost plants, landfills and incinerators, solar technology infrastructures, geothermic energy infrastructures, electricity supply points, petrol and gas supply points and electricity distribution infrastructures) or UNAs such as green and blue infrastructures which are more or less managed (see Column 3). As FUS (see Column 4) I have identified the following here: energy supply, employment and climate regulation, which provide goods (Column 5) such as consumable energy, purchasing power and thermal comfort respectively. These are translated into their perceived benefits (see Column 6). Table 4.4 illustrates the co-production of services.
Table 4.4 Example of benefits coming from natural assets and built infrastructures in urban energy management

In this table I have shaded in grey the UBIs that act as USPUs and in purple the UNAs that act as USPUs i.e. that provide final services. In this example, it can be observed that UBIs and UNAs produce different FUS and respective goods and benefits. The FUS provided by each are coloured in grey (UBIs) and purple (UNAs) respectively.

<table>
<thead>
<tr>
<th>USP</th>
<th>Intermediary Services</th>
<th>USPU</th>
<th>FUS</th>
<th>Goods</th>
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</thead>
<tbody>
<tr>
<td>Bodies of water</td>
<td>Water management</td>
<td>Hydropower plants</td>
<td>Energy Supply</td>
<td>Consumable Energy</td>
<td>Perception of the change in the provision of energy</td>
</tr>
<tr>
<td>Soil and Fossil Fuels</td>
<td>Radiation and energy transfer natural processes</td>
<td>Gas and oil production industries</td>
<td>Employment</td>
<td>Purchasing power</td>
<td>Perception of the change in purchasing power</td>
</tr>
<tr>
<td>Sun</td>
<td>Energy management</td>
<td>Compost plants, landfills and incinerators</td>
<td>Climate regulation</td>
<td>Thermal Comfort</td>
<td>Perception of the change in the need of energy use</td>
</tr>
<tr>
<td>Local Authority</td>
<td>Land use management, urban planning and design</td>
<td>Solar technology Infrastructures</td>
<td>Geochemical energy infrastructures</td>
<td>Electric energy supply points</td>
<td></td>
</tr>
<tr>
<td>Regional and National Authorities</td>
<td>Biogeochemical cycles</td>
<td>Geothermic energy infrastructures</td>
<td>Electric energy supply points</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy Facilities</td>
<td>Electric energy distribution infrastructures</td>
<td>Petroleum and gas supply points</td>
<td>Electricity distribution infrastructures</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Individuals and cooperatives</td>
<td>Solar energy supply points</td>
<td>Solar energy supply points</td>
<td>Green and Blue infrastructures</td>
<td></td>
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</tr>
</tbody>
</table>

4.3.4.3. Discussion and comparison

From the two examples it is possible to observe the great complexity of service provision in cities and the importance of approaches that facilitate and support the identification of services providers (natural and human) and providing units. This helps to illustrate the benefits of FUS and whether there is co-production of services by natural assets and built-in infrastructures, both of which are critical for urban decision-making.
In contrast to the example of flood management, in the energy management example there is no co-production of single services at the urban scale, since energy needs technology to be produced. However, co-production does exist at larger scales, where bodies of water (rivers, reservoirs, the sea) and fossil fuels are natural resources used to produce energy through natural or human-induced processes. This might explain why it is hard for the urban population to perceive and value the costs of energy provision.

Although urban interventions are usually implemented within the administrative boundaries of urban areas, the full benefits and costs of US do not generally fit within the same “artificial” boundaries, as the energy provision example shows. It is a question of spatial scale, policy responsibility and social awareness. Therefore, as these two examples show, it is important to identify the scale at which these services should be assessed and it is crucial to acknowledge the spillovers of US from one urban area to another, and even those between urban-rural interfaces. As with the ESF developed in MEA (2005), the USF should be flexible to account for such scaling issues.

4.4. Discussion

4.4.1. The contribution of the Urban Services Framework to urban resilient sustainability

Urban social-ecological systems are complex networks of interacting elements, which exchange energy, material flows and information concerning human, built and social capital (Costanza et al. 1993; Pickett et al. 2008). Changes in economic, social and biophysical parameters outside urban boundaries affect the structure and function of the urban area and therefore the services delivered. Furthermore, changes at smaller scales (at neighbourhood, building and community level) can vary the demand for services, which is likely to affect the structure and function of urban areas.

A fundamental objective of urban planning and management is to increase human wellbeing, which depends on both the perception of benefits from US and on reinvesting part of the benefits (in monetary and non-monetary terms) to maintain the flow of
valuable US. Such reinvestment helps to build resilience by developing the capacity to adapt to unexpected changes and the ability to open up opportunities for development (Holling 2001; Folke et al. 2002b; Folke et al. 2002a). These are opportunities to improve health, transportation, enjoyment of nature and culture, social relations, etc. which may become opportunities to adapt and adjust to changes or to transform, fostering a more desirable state. This is, in essence, precisely the philosophy behind sustainable (urban) development (Holling 2001). Also, it is interesting to explore how complexity influences US management. According to Carpenter (2009b) if one aims to develop a US management strategy, some key issues for analysis also arise. First, as urban areas are complex social-ecological systems it implies that it is hard to isolate any single service. Therefore, one must analyse what combinations of services can flow sustainably from a particular city. Secondly, as in general, the demand for US is a driver of the supply of US, it is important to understand the way the preferences for services of the urban population evolve, acknowledging again the importance of the value that those US have for beneficiaries. Similarly, it is important to know the way human choices and actions affect local flows of US and spillover to affect other urban areas. In contrast to more ecologically grounded approaches, the USF should be used with a wider and integrated perspective where all USPUs (to be planned, managed, allocate etc.) should be taken into account, irrespective of their natural or man-made character, and thus, reflecting the complexity of urban systems. Of course, eventually a focus on urban governance is called for to understand which institutions, incentives, or regulations are effective in sustaining flows of valuable services or in making them more adaptable to the change in supply of other services or to exogenous perturbations.

As earlier discussed, envisaging the importance of providing information to decision makers on what the benefits are, who the beneficiaries are and what USPUs (UNAs or UBIs) (or what combination of them) provide such services them, is decisive. This provides support for drawing up more robust strategies to transition to more resilient sustainable cities.

In this line, the TEEB-cities report (2011, p.3) points out that the importance of maintaining a healthy urban environment relies on the existence of ‘tipping points’ “at which a degraded ecosystem will cease to supply the ES that we rely upon, and it can be
4. Integrating ecosystem services in urban decision-making

extremely expensive, time-consuming, or sometimes even impossible to restore the ecosystems and/or find an alternative solution”. The USF developed here may help to identify tipping points in ecosystems that urban areas rely on, which, if crossed, may erode the resilience of the whole urban social-ecological system. In this way, and, as it was the aim of this chapter, USF like the one proposed here advance sustainable urban development by enabling the reflection that will help to better anticipate the consequences of decisions or policies.

4.4.2. The cognitive dimension of an Urban Services Framework: link to Part II

Although the study of the ecosystem services in cities is not new (see e.g. Elmqvist et al. 2003; Wackernagel et al. 2006; Ernstson et al. 2010a) it needs further efforts to help recognise the significant role that urban areas have in the operation of the biosphere (Elmqvist et al. 2013). Precisely, the main aim behind the development of a USF is to allow the reflection about the complexity of urban areas. In cities this complexity is translated into the many connections between the natural capital and the human society.

The complexity of cities makes it difficult to develop frameworks that deeply illustrate the complex connections that exist in urban areas. This at the same time complicates the ecosystem services governance in cities. Services are difficult to isolate and the general lack of cooperation between local authority departments evidenced in several studies (as argued in Elmqvist et al. 2013) does not help. The USF has been developed in order to bridge research and policy practice. It has a linear approach which simplifies the complex interactions and feedbacks that may occur in urban development processes. The USF uses as a cornerstone the Service Providing Units concept to unify urban policy practice with ecosystem services research.

This framework thus helps to initiate a reflection about how to develop a kind of policy practice that takes into account natural capital existing in cities and the human and built capital that supports the provision of critical services in cities (such as water or energy). In this mission, the perception that stakeholders have on the benefits that they receive from the natural or the built environment is critical. Indeed, a deeper consideration about
the co-production of services and about the importance that urban processes have on the ecosystem services provision worldwide, helps to visualize alternative pathways of transformation that help to guarantee resources for future generations and thus, to engage with sustainable urban transformation.

A USF ideally supports the reflection on the needs of actual decision-making processes, and helps to realize about the importance of stakeholders realizing/perceiving the benefits of US (both from the natural and the built environment). The provision of US depends on the demand of beneficiaries for such services, and demand is satisfied depending on how well the service is provided and how benefits are perceived. Controversially, the demand for services is a driver of environmental and land use change (Luck et al. 2009), and exerts direct pressure on US support systems (the social-ecological system) which, in turn, conditions the supply of US. This implies that the demand for US needs to be controlled by for instance reallocating US to decrease throughput or by directly influencing demand and promoting sustainable consumption. In this, spatial redistribution, and often the subsequent change in cost and benefit perception from these services, is highly relevant. This evidences the importance of the cognitive dimension in URS management. Knowledge and understanding of the system by actors influence decision-making processes. How benefits are perceived and valued affects decisions to be made in relation to the management of US.

The significant role that perceptions of stakeholders have for sustainable urban development has been earlier discussed (see Chapter 1, Section 1.2.4, p. 18). Prevailing discourses that do not take into account natural assets or take for granted the flow of ES in cities, may act as a barrier for sustainable transformation. Researchers and practitioners need to idealize tools for decision-makers that help them to perceive the benefits from ES and therefore to integrate natural assets in decision-making, adding the value that these assets deserve.

This links to Part II of this dissertation. In the following chapters of this dissertation I emphasize the role of cognitions in decision-making process using a case study where a scenario of a low carbon energy transition has been chosen. Energy is not a granted resource and transitions to low carbon societies are required. Through the case study, the
methods chosen to uncover discourses and perceptions about how the energy system works will help to realise about the importance of cognitions in sustainable urban transformation.

4.5. Conclusion

The theory of resilience emphasizes the need to take into consideration the connections between nature and human society in decision-making processes so that the sustainability of alternatives pathways is guaranteed. This chapter explores the connections between natural and human capital in cities and offers one framework to integrate ecosystem services in decision making in cities as a way to advance sustainable urban transformation.

In cities, benefits from human and natural services are not perceived and valued similarly and therefore might not be taken into account in decision-making processes related to the management of urban areas. This chapter develops an Urban Services Framework (USF) which is used to help classify and integrate human-based and natural urban services and the goods and benefits from their provision with an urban planning and management focus.

The USF proposed borrows concepts and frameworks mainly from ecosystem services research, but also from research into CAS and urban ecology research. Regarding the former, the MEA (2005) and its Ecosystem Service Framework are generally used to assess ES and to better understand the limits and consequences of losses of and changes in biodiversity, and of the actions needed to maintain or restore those ES for human wellbeing (Carpenter et al. 2009b). In line with this, it is argued here that addressing the flow and better understanding urban services (US) can also help stakeholders, and urban service providers (USP) in general, to make better decisions in the context of urban planning and management, and more specifically in areas where urbanisation and associated decisions on transport and housing require further resources and may have important implications for the future sustainability of the region. This is even more
important in urban areas where responding to societal needs regarding basic urban services such as clean water, air quality and safe environment is crucial due to rapid urbanisation processes which are likely to erode ecosystems and their dynamics.

Urban built infrastructures (UBIs) complement and often substitute urban natural assets (UNAs) in the provision of US. The vulnerability of urban areas due to the decline of valuable US has not only a social or ecological dimension but also a technical one, because such infrastructures either depend on environmental resources for their inputs or are not flexible enough to adapt to continuous variations of demand in urban areas. Furthermore, urban areas are complex systems whose dynamics and cross-scale impacts are often case-specific, and decisions regarding the substitutability of UNAs by UBIs must be carefully studied. This chapter and the examples used to illustrate the applicability of the USF help make the concept of co-production of services (UN 2013) easier to visualise.

Yet if the framework is to be made operational and helpful, it is necessary to shift from concepts and theory to practical integration into decision-making in a way that, as stated by Daily and Matson (2008), is credible, replicable, scalable and sustainable. This could be done through standardised techniques and models and through the development of appropriate institutions (Mäler et al. 2008; Tallis et al. 2008) which can translate benefits and values of urban services into decisions. The perception of benefits by urban users should be transmitted to public resource providers (human USPs) through information, communication and stakeholder participation approaches, which should be simple, transparent and reliable, and should also be adapted to the target urban groups, taking account of existing formal and informal networks.

A USF that integrates built and natural elements in urban decision-making is a necessary step in the transition to more sustainable, more resilient cities. It captures the costs of the substitutability of natural green and blue areas in cities and the hidden (non-marketed) benefits of interventions which promote them. Nevertheless, failing to account for the spatial and temporal dimension of the benefits and costs of US (that is, who benefits and who pays the costs) can significantly affect equity and justice in urban service provision,
in terms of both the distribution of services and the internalisation of the impacts of that provision.

Internalising interior and exterior impacts and long-term costs (and benefits) in urban areas is a challenge which, if sufficiently well addressed, can bring to light hidden values of natural capital conservation and hidden costs of resource management. This helps to avoid the mainstreaming culture of privatising (economic) benefits and socialising (environmental) costs of human activities. Moreover, it aids in building social equity and resilience in urban landscapes which, according to Ernstson (2013), will be gained not only through the proper management of ES but also through the analysis of how ES are prioritised and who benefits from them. Such information is thus critical in urban decision-making processes.

Notwithstanding its limitations, it is possible to argue that this proposal, along with others that might pursue the same integrative objective, can bridge research and urban policy practise by (i) addressing complexity in urban service provision through an integrated view of human and environmental services in urban areas, encapsulated here as US; (ii) acknowledging the limits of such provision; (iii) addressing human wellbeing in urban decision making; (iv) preserving natural and semi-natural environments in cities as essential service providers; (v) foreseeing potential trade-offs between urban infrastructures and ES supporting areas; (vi) capturing the complexity of the urban system and understanding the synergies and trade-offs influencing benefits and costs for wellbeing, and consequently (vii) highlighting the relevance of the cognitive dimension for URS and sustainable urban transformation.

In conclusion, there is a need to recognise that we are moving towards an even more urban world (UN 2011), and this will implicitly involve an increase in demand for natural resources (Huang et al. 2010). In order to make a change towards sustainable urban development paths possible, urban institutions need to consider and integrate the value of natural and human capital into their decisions. This chapter and the Urban Service Framework (USF) that I have developed seek to contribute to this goal.
4.6. Summary

The main points of this chapter can be summed up as follows:

- Human and natural capitals have a role in the co-production of benefits from ecosystem services in cities. The role of human capital intensifies as urbanisation increases.

- This chapter seeks to explore the interconnections between natural and human capital in cities from an ES perspective. I develop an Urban Services Framework (USF) which integrates human and natural capital and is used to help classify and integrate human-based and natural urban services, goods and benefits of their provision.

- The USF borrows concepts and frameworks from the Ecosystem Service Framework and the literature based on it, from research into CAS and from urban ecological research.

- Urban built infrastructures (UBIs) complement and often substitute Urban Natural or semi natural Assets (UNAs) in the provision of US. This is how both contribute to the co-production of urban services (US).

- How benefits are perceived and valued is a critical point in decision-making processes. The provision of US depends on the demand of beneficiaries for such services and that demand is satisfied depending on how well the service is provided and how its benefits are perceived. This is how the cognitive dimension is again highlighted as an important aspect of (individual and collective) decision-making that should be further explored.

- This conceptual framework is a necessary step in the transition to more sustainable, more resilient cities. It helps to visualise the costs of the substitutability of natural green and blue areas in cities and the hidden (non-marketed) benefits of interventions which promote them.

- To make this framework operational and helpful would require shifting from concepts and theory to practical integration into decision-making, possibly through standardised techniques and models and through the development of appropriate institutions.
Urban institutions need to consider the value of natural and social capital and integrate it into their decisions. This is only possible through the valuation of the benefits which US provide and by identifying the natural or built elements that provide such services. This helps to recognise the relevance of the cognitive dimension in URS management and consequently for sustainable urban transformation.
Part II
Chapter 5

Data and Methods

AN INTRODUCTION TO THE CASE STUDY OF BILBAO

“Low-carbon urban transitions are then about competing views of the role of the city, the type of transition that is deemed to be required, the politics of participating in producing a “vision” of the future, how to translate that vision, and, therefore, the variability of the consequences of a transition.” (Hodson and Marvin 2012, p. 425)
Chapter 5. Data and Methods

5.1. Introduction

5.1.1. General structure of Part II and of this chapter

As discussed in Chapter 1, sustainable urban development is about finding shared interests existing in cities while maintaining competitiveness without compromising actual and future resources. This mission requires understanding the cognitive dimension behind decision-making processes and taking into account the experience and knowledge of the actors involved.

Thus, one of the objectives that I have set up in this dissertation (see Chapter 1, Section 1.2, p. 10) is to (i) explore how cognitions can delineate potential transition alternatives in cities and (ii) evaluate the use of actors’ knowledge to identify best alternative pathways in terms of sustainability and resilience. This double objective is addressed in Part II of the dissertation which starts with the present chapter.

Part II presents an empirical analysis and explores the transformative capacities of cities through a case study, by analysing the role of cognitions in decision-making processes and in the understanding of the structure of urban systems and processes from a resilience and sustainability perspective. It comprises Chapters 5, 6 and 7. This chapter presents the case study and the methods which are then applied in Chapters 6 and 7. Of the many challenges that cities face in regard to sustainable transformation, Part II specifically focuses on energy as a critical sector in terms of both climate change and resource scarcity. As argued in Chapter 4, energy is not a granted resource and transitions to low carbon societies are required. Prevailing discourses that take for granted the flow of ES and do not consider energy as a critical resource may act as a barrier for resilience and sustainable transformation. I have chosen a special case study to explore the role of cognitions in decision-making processes regarding the transformation capacities to low carbon energy.

The city of Bilbao in the Basque Country (northern Spain) is taken as a case study representative of a medium-size European city of less than 500,000 inhabitants, given the
importance of this type of city for future urban development, as discussed in Chapter 1. This city is particularly interesting as it has already undergone a successful process of transformation from an industrial to a service-based city. It now requires an environment-related transformation focused on its energy model given current consumption trends and the lack of a sustainable direction in policy (see Section 5.2 for case study description). Having identified this problem, Part II discusses pathways for sustainable urban transformation focused on the energy sector of this city. To contextualise the specific challenges facing the urban energy sector, Subsection 5.1.2 explores the challenges faced by cities in terms of low-carbon transitions and the main determinants in the process of change.

Thus the case study is used throughout the chapters that make up Part II to provide an understanding of resilience and transformation capacities in the context of energy management and to explore the applicability of the conceptual analyses developed in Part I. To that end, two participatory, semi-quantitative methods are used: the Q method (see description in Section 5.3 and application to the case study of Bilbao in Chapter 6) and Fuzzy Cognitive Mapping (FCM) (see description in Section 5.4 and application to the case study of Bilbao in Chapter 7). In Chapter 6, the Q method is used to uncover the complexities of the cognitive dimension of transition management by identifying the key discourses of actors in Bilbao regarding the city’s energy transformability potential. In Chapter 7, FCM is used to uncover the complexities of the urban energy model in Bilbao by translating the knowledge, perception and experience of leading experts and actors into a map (or network) which represents states of the system and the weighted cause-effect relations between the elements that it contains. FCM is used to assess the main features of the network in terms of resilience and transformability and to evaluate scenarios of policy options and transition pathways alternatives in terms of sustainability.

Figure 5.1 illustrates the structure of this chapter:
5.1.2. Urban low-carbon transitions

Energy systems are strongly coupled to urban SES and are also highly complex. If resilience is about creating multifunctionality, redundancy and modularisation, (bio and social) diversity, multi-scale networks and connectivity, adaptive planning and design (see Chapter 3), when it comes to energy urban resilience generally involves increasing diversification of energy sources, greater reliance on renewables and increasing self-dependency and technical security, all through a transition to a low-carbon city.

The idea of urban low-carbon transitions is for cities to move toward a new, decarbonised socioeconomic system. Urban energy transition experiences have built up in the form of individual actions and through collective actions in networks such as the C40 cities network\textsuperscript{27} and the Covenant of Mayors\textsuperscript{28} (CoM), and ambitious targets have been set for

\textsuperscript{27} C40 is an international network of megacities around the world which takes action to reduce greenhouse gas emissions and address climate risks and impacts locally and globally. URL: \url{http://www.c40cities.org/} (Last accessed March 11, 2014).
low or even zero-carbon (carbon neutral) emissions (see e.g. Reckien et al. 2014 in Europe). Yet, in practice, concerns about the role of cities in energy transitions relate mostly to the means and resources that cities might have to achieve their carbon objectives in the form of organisation, knowledge, technology and action (see e.g. Hodson and Marvin 2012).

Such urban low-carbon transition experiments form part of the global sustainability transition approach to climate change (Goldthau and Sovacool 2012), but the role of cities in global sustainability transitions is far from straightforward. On the one hand, the lack of local capability to directly impact on energy policy or transport planning is usually considered as a barrier to developing local transition pathways (Westley et al. 2011). In this case, cities may be seen as passive actors in sustainability transitions rather than niches of change (Geels 2010a). On the other hand, it is often argued that the role of cities as hubs of innovation, development and knowledge enables them to turn crises into opportunities (see Chapter 3). The emerging literature on resilience, transformability and urban sustainability tends to agree that there is a unique opportunity for cities to become laboratories of innovation and experimental action given their exceptional capacity to kick-start actions on the ground linking scientific knowledge and community participation29 (see for instance Ernstson et al. 2010b; Evans 2011; McCormick et al. 2013).

Regardless of whether cities are seen as active or passive players in a global sustainability transition, their responsibility in global environmental change is significant. Some argue that over the next couple of decades urban management will greatly influence global energy demand (Madlener and Sunak 2011). Cities demand 70 per cent of global primary energy (IEA 2008) and although few agree on their precise contribution to global emissions (Dodman 2009) cities are widely seen as responsible for around 80 per cent of

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28 The Covenant of Mayors is a mainstream European movement involving local and regional authorities, who voluntarily commit to increasing energy efficiency and using renewable energy sources on their territories. By their commitment, Covenant signatories aim to meet and exceed the European Union 20 per cent CO₂ reduction objective by 2020. URL: http://www.eumayors.eu/ (Last accessed March 11, 2014)

29 See footnote 12.
global greenhouse gases (GHGs) (see e.g. Dhakal 2010). These trends are likely to continue in the future given that 80 per cent of the world population is expected to live in cities by 2050 (UN 2011).

Concerned by this situation, nations and regions are developing policies to support cities in the challenge of reducing their energy consumption and improving their energy performance. The European Commission, for example, has launched a robust strategy towards a low carbon future (EC 2011a, 2011b) and has funded a variety of projects to explore alternatives and technological requirements to implement its 2050 zero-carbon vision (Amerighi et al. 2010; Gnamus 2011; Hafner et al. 2011). Also, there is a growing literature that explores the physical and technological capacities of cities to improve energy systems and energy governance while mitigating and adapting to climate change. For example, on the technology side, many studies have helped to further understanding of the potential of solar energy in the urban context (see e.g. Gadsden et al. 2003; Ramachandra et al. 2005; La Gennusa et al. 2011; U.S. Department of Energy 2011; Millstein and Menon 2012; Vettorato et al. 2012). Others have focused on advancing knowledge of other alternatives for energy efficiency measures and technologies (Chong et al. 2012; Jovanovic et al. 2012; Millstein and Menon 2012; Morlet and Keirstead 2013). Some studies focus on the role of green infrastructures (e.g. Hall 2012) or in general on the implication that energy transitions may have for urban planning in the context of achieving more efficient, renewable, more social energy networks (see e.g. Andrews 2008). Particularly, various studies have addressed the issue of low-carbon transitions in the suburbs of cities in Australia and the USA (Dodson 2013) as well as in Europe (Petrova et al. 2013). These authors argue that urban sprawl requires an approach different from that used in compact, dense areas given the challenges posed by mobility and service provision. Others have focused on the institutional capabilities that cities need in order to effectively manage low-carbon transitions (see an example of Mexican cities in Paez 2010). The users’ point of view is also acknowledged, by for instance exploring social behaviours and what it takes to change them (see e.g. the case of biodiesel in Giraldo et al. 2010).

Urban low-carbon transitions are a complex undertaking not only because of the complexity of the energy system, but because of the complexity of the governance system
too. Many actors interact in the governance of urban low-carbon transitions, including the so-called ‘intermediary actors’ (Hodson et al. 2010; Hodson et al. 2013), i.e. the diverse actors at multiple scales of energy systems governance, seeking to accommodate their interests and coalitions. They include government and semi-government energy agencies, nongovernmental organisations, consultancy firms, researchers, etc. Other types of actor include those working on awareness raising, education, training, and networking. The competing views and perceptions held by these actors regarding the need for, methods for and objectives of transition management may be considered as either barriers to or opportunities for the desired low-carbon transitions (Hodson et al. 2010; Hodson and Marvin 2012).

Because of the many different interests listed above, it is essential to understand stakeholders’ perceptions and cognitions in order to identify barriers to and opportunities for transformation. The way in which actors’ cognitions in the form of heuristics, biases and previous experiences affect decision-making processes, including those related to the environment and the relationship between human beings and nature, has been discussed in the relevant literature (see Schwenk 1988; Antal and Hukkinen 2010). Adding a cognitive dimension to transition research can help to better inform processes of adaptation and transformation in practice, particularly through participatory methodologies which integrate different perceptions and multiple scales (Adger et al. 2012). This kind of methodologies has been used to analyse the case study as Chapter 6 and 7 show. The methods are described in Section 5.3 and 5.4 of this chapter.

5.2. The case study of Bilbao

5.2.1. Physical environment and demographics

Bilbao is a medium-sized city with a surface area of 41 km² and a population of 349,900 as per 2013. It stands in the Autonomous Community of the Basque Country in northern Spain, 10 km from the coast (see Fig. 5.2). Bilbao is the capital of Bizkaia, one of the
three provinces in the Basque Country. Its Metropolitan Area$^{30}$ comprises 35 municipalities and contains almost half the total of 2,190,230 people who lived in the Basque Country in 2013.

![Figure 5.2 Location of Bilbao](image)

Bilbao is conditioned by its mountainous surroundings, a high population density (8,601 inhab./km$^2$ in 2013) and its compactness (114.15 dwellings per residential hectare in 2012). Figure 5.3 shows the urbanised area, the riverside, the parks and the urban woodland around the urban fabric.

$^{30}$ Note that this is different from the definition of ‘Bilbao (greater city)’ used by the European Commission (Dijkstra and Poelman 2012), according to which Bilbao (greater city) comprises only three municipalities: Bilbao, Barakaldo and Getxo. The Bilbao Metropolitan Area is an administrative unit used in the Basque Country.
The terrain and the lack of land available for urban sprawl have made Bilbao one of the most densely populated cities in Europe. Figure 5.4 compares the population densities of a selection of cities in the Urban Audit (UA) database of Eurostat\(^\text{31}\). Bilbao is near the top of the list.

\(^{31}\) The UA database is compiled by the European Commission, Eurostat and the national statistical offices. UA cities comply with the following criteria: 1) approximately 20 per cent of the national population ought to be covered; 2) national capitals and, where possible, regional capitals are to be included; 3) large (more than 250,000 people) and medium-sized urban areas (minimum 50,000 and maximum 250,000 population) are to be included; and 4) urban areas should be geographically dispersed within countries. UA cities are assumed to be a balanced and regionally representative sample of cities across Europe. The entire UA database comprises 357 cities from 30 countries across Europe: 329 variables (covering matters such as demographics, society, the economy, the environment, transport, the information society and leisure) are
Figure 5.4 Population density per square km of a selection of European Urban Audit cities in 2008. Source: Urban Audit database (Eurostat)

collected. The database is updated every three years. URL: http://www.urbanaudit.org/ (Last accessed March 12, 2014)
According to the Spanish National Institute of Statistics (Instituto Nacional de Estadística – INE) the population of Bilbao increased by about 500% between 1900 and 1981 due to industrialisation. A similar process was undergone by other Spanish cities such as Barcelona. It reached 433,030 inhabitants, though that number has dropped by around 90,000 inhabitants in the past 30 years, probably because of the process of deindustrialisation from the 80s onwards.

5.2.2. The post-industrial transformation of Bilbao: key determinants and current economic context

This is probably one of the most interesting historical processes of Bilbao as a city, and one that put the city on the international map. Bilbao is one of the many post-industrial cities that have undergone transformations after an industrial decline (e.g. many UK cities such as Cardiff, Manchester, London and Liverpool).

Bilbao was founded in the year 1300 as a trading port. From the late 19th century until the major industrial slump of the 1980s its economy was based on steel making and shipbuilding. Over that time, the Metropolitan Area of Bilbao attracted economic development and internal migrant labour from all around Spain. The industrial crisis of the 80s hit the area hard. The high degree of specialisation of the city’s industry turned against it and led to high levels of unemployment and a physically damaged, unattractive environment including heavily polluted soil and water (Garrido Martínez 2004). Serious flooding in 1983 and deep social and economic damage highlighted the lack of sufficient, adequate infrastructures to support urban regeneration (Garrido Martínez 2004).

This situation and the fact that Bilbao was a critical urban area in the Basque Country meant that a process of revitalisation was needed. This process was promoted through private-public partnerships and led to the preparation and implementation of the Greater Bilbao Strategic Plan. The plan was based on seven main lines (Garrido Martínez 2004):

32 The National Institute of Statistics is the official organisation in Spain that collects statistics about demographics, society, economy and the environment. URL: http://www.ine.es/ (Last accessed March 15, 2014)
(i) investment in human resources; (ii) a service-led metropolitan area in a modern industrial region; (iii) mobility and accessibility; (iv) environmental regeneration; (v) urban regeneration; (vi) cultural centralisation; and (vii) coordinated management between public administrations and the private sector.

After long-term investment in infrastructures and strategic areas, mainly from the public sector (Rodriguez and Martinez 2001), including for example the Bilbao Guggenheim Museum (which opened in 1997), Bilbao has transformed itself into a service-led city. The profound transformation in the 1990s also included the renovation and revitalisation of its riverside waterfront, in a project which has become a role model for radical restoration (Gonzalez 2011), involving river water treatment and soil decontamination resulting in significant improvements in environmental quality (see Bilbao before and after the transformation in Fig. 5.5, more photos in Annex 2).
Bilbao Ria 2000, the public company that has led the urban transformation of Bilbao and other municipalities in the metropolitan area, has now been wound up amidst debts caused by the crisis that has affected the construction sector over the past 6 years. This has also affected the City Council of Bilbao, as a 15% stockholder of the non-profit company, together with other public administrations. Regardless of this, the management of the City Council of Bilbao is seen as exemplary (see Fig. 5.6) in the current context, in which many Spanish municipalities have got into more and more debts.

33 “La transformación urbana de Bilbao en imágenes” EITB. URL: http://www.eitb.com/es/noticias/sociedad/transformacion-de-bilbao/ (Last accessed March 18, 2014)
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Today the city is seen as one of the most important economic hubs of the Basque Country and in Europe, at least according to the Financial Times, which has ranked Bilbao as the 4th southern European city and 9th in the overall European ranking in attracting direct foreign investments. Currently, Bilbao employs more people than it has residents in work, so it acts as an employment attractor (Marcos 2006). Nevertheless, the economic crisis of the last 6 years has doubled unemployment in the city, which stood at 13.5% of the population aged between 16 and 65 in 2012 (Basque Government 2013a).

GDP per capita in the Basque Country was 32 per cent higher than the European regional average in 2010 (Eurostat 2010). GDP per capita in the city of Bilbao was about €28,943 at that time, with around 85 per cent of it being generated by the service sector (Basque Government 2013b). As shown in Figure 5.7, GDP per capita in the city of Bilbao in 2007 (the latest data available in the database consulted) was higher than in 78 per cent of

Figure 5.6 Taxes, investment and public debt per capita in Bilbao (2002-2012)

Drawn up from data published in Udalmap (Basque Government) and by the Ministry of Economic Affairs and Public Administration of the Spanish Government.

[Graph depicting Municipal revenue per inhabitant (Euros), City’s outstanding debt per inhabitant (Euros), Net investment per inhabitant (Euros)]

the European cities in the UA database. There are no data available to compare the current situation to that of other European cities, and although the GDP has dropped slightly due to the economic crisis in the past 4 years, the same can be expected to have happened elsewhere. It is also interesting to note that UK cities that have experienced a similar transformation now have a comparable economic context (see light blue arrows pointing out the UK cities mentioned in Fig. 5.7).
Figure 5.7 GDP per capita of a selection of European UA cities in 2007.

Source: Urban Audit database (Eurostat)

The graph on the top right shows the GDP percentile distribution of UA audit cities in 2007. Bilbao’s GDP was around €32,000, i.e. above the 78th percentile.
5.2.3. Governance, institutional structure and implications for energy planning

Since the late 1970s and early 1980s, Spain has had a high level of decentralisation, with a great deal of power being devolved to the regional governments of its 17 “Autonomous Communities”. The country has evolved from being one of the most centralised states in Europe to being in many ways a federal state (De Gregorio et al. 2014). There are four levels of government: the Central Government, the autonomous communities, the provinces and the municipalities. The Spanish Constitution guarantees the autonomy of the last three levels, but they do not have the same degrees of autonomy (Parkinson et al. 2012): on the one hand, provinces and municipalities are local tiers of government with administrative autonomy, which basically means that they are responsible for the development of secondary legislation and the management of urban public services; on the other hand, Autonomous Communities have real political autonomy, with legislative power on a relevant number of issues guaranteed by the Constitution.

Thus, strategic planning in Spain is also mostly undertaken by regional governments. In the case of the Basque Country this means Act 4/1990 on Ordenacion del Territorio del Pais Vasco (the main piece of legislation regulating land use planning). The main spatial planning instruments regulated by the regional government cover sectoral and partial spatial planning on for example specific sectors such as energy infrastructures, agriculture, waste and soil, land use and specific spatial areas of regional interest. For instance the Greater Bilbao Spatial Plan, which was initially approved in July 2003, covers the spatial planning for the whole functional area of Metropolitan Bilbao (see Fig. 5.8) which, as mentioned above, comprises 35 municipalities.
On a municipal level there are other instruments such as urban master plans, supplementary regulations (supplementing urban master plans), subsidiary regulations (with regional responsibility, affecting various municipalities or parts of municipalities without master plans and covering land use, land protection or urban and building matters) and finally special plans dealing with special issues such as infrastructures or landscape protection.

Bilbao is currently in the process of renewing its Urban Master Plan. The last one dates from 1995 and has been amended through local regulations and special plans. One of the main challenges of urban planning in Bilbao is the scant availability of land. Nevertheless, over the last 30 years of urban development since the industrial crisis of the 80s the city has earned itself a name as an icon of urban regeneration around the world (Gonzalez 2011).

In relation to the energy sector, cities in Spain are significantly affected by regional and national decisions related to energy strategies and also by the private sector through market energy dynamics and lobbies. Nonetheless, while Spanish energy policy is a

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national and regional competence, other sectors that influence energy consumption such as urban planning, transportation and urban regulations are still in the hands of cities.

In the particular case of Bilbao, there is no Energy Department as such and energy management is tackled at different degrees by different City Council departments in charge of urban planning, waste management, water management, public works and services and intra-administration management. Figure 5.9 shows the organization chart of the City Council in Bilbao. There are 6 main areas of action (shaded in light pink) that depend directly on the City Mayor and deal with diverse urban policies. From these, only two areas, the Urban Planning Policy Area and the Spatial Policies Area somehow tackle energy issues. However only one of its departments (the Public Works and Services Department, shaded in dark grey in Figure 5.9) has been officially assigned to plan and manage the energy strategy of the city. This is done in no cooperation with the rest of the departments.
This kind of internal organization results in a clear administrative barrier to successfully deal with the high transdisciplinary nature of energy issues.

37 Bilbao City Council. URL: http://www.bilbao.net (Last accessed September 29, 2014)
5.2.4. **Sustainability planning in Bilbao: climate change, environment and energy**

With a well-established Local Agenda 21 that was initiated with the signing of the Aalborg Charter in 1998 (Hernández Aja 2003), the local government declares itself to be committed to sustainability. Nevertheless there are some issues that remain a challenge in the city.

As an economic engine of the Basque Country and a tourist hotspot, motorised transport is prevalent in Bilbao (Siemiatycki 2005). Yet, the location of the city alongside the River Nervión (see Fig. 5.3 above) allows a certain degree of air circulation that improves the thermal comfort and the mix of air layers, reducing high levels of localised air pollution.

Although public areas have been cornerstone of the regeneration of Bilbao during the 90’s and 20’s, the greening of the city (i.e. the promotion of parks and other green areas) has not been particularly addressed. The lack of land is a fact that has partly influenced this type of development. For this reason, the strategy in reference to the green infrastructure within the urban fabric has not gained a significant role in the development of the city during the past few decades. Now the City Council is starting to address this concern through initiatives to restore the peri-urban green infrastructure (Bilbao’s Green Belt), which has been instrumental for the renewed urban development processes of the greater Bilbao area (Casado-Arzuaga et al. 2013).

Additionally, in the past 4 years the City Council has initiated a firm strategy on climate change and sustainable energy. This is exemplified by the Climate Change Plan approved in 2010, which was subsequently superseded by the Sustainable Energy Action Plan or SEAP (Bilbao City Council 2012) approved under the CoM agreement. The local authority was willing to introduce a couple of district heating projects into the SEAP, but a strong negative reaction by the public forced them to drop the measure. Thus, at the moment, the plan is mostly a compilation of ongoing initiatives related to climate change mitigation and energy efficiency, suggesting a business-as-usual strategy rather than a strategic change towards a sustainability transition.
Regardless of these initiatives, electricity consumption per capita in Bilbao continues to increase while the size of the population remains approximately the same (Fig. 5.10). The total consumption in the municipality increased by 7 per cent from 2003 to 2012 even though consumption by industry decreased by around 18 per cent, mostly due to the economic crisis. There has been a significant intensification in electricity consumption by the non-industrial sector, accounted for mostly by the residential and services sectors, with the increase in the latter being 9 per cent per capita.

![Figure 5.10: Trends in electricity consumption per annum per inhabitant in Bilbao. Data source: Basque Government (2013a)](image)

An important milestone in Bilbao’s low-carbon initiative was the creation of the Climate Change Office in 2009. This Office has recently been closed down and its responsibilities transferred in theory to the Public Works and Services Department, which now deals with environmental issues including noise, air quality, green infrastructures, sustainable building and public areas. This department is now responsible for the SEAP. Nevertheless, the Climate Change Office seems to be maintaining its virtual dissemination activity through its website and social networks.
The planning of the city (including the Urban Master Plan in development) has not yet included energy criteria\textsuperscript{38}. Some trace of interest by Bilbao’s city council in energy efficiency issues can be found in the participation of the city in experiments and research studies such as the ICE-Wish 7FP project on energy and water reduction in social housing. Other local initiatives include the rehabilitation of buildings through Surbisa, a public-authority-owned local company with regional and local funding that has built up a wealth of experience in the old quarters of Bilbao. However, the economic recession and the associated cuts in public expenditure are limiting such public-led initiatives.

\textbf{5.2.5. Energy management in the city: infrastructures, pricing and actors}

Figure 5.11 illustrates the local trends related to the presence of renewables within the urban administrative limits of the municipality of Bilbao. Renewables only cover 2 per cent of the total energy demand.

\begin{figure}
\centering
\includegraphics[width=\textwidth]{Figure5.11.png}
\caption{Trends in installed power from different types of renewables (+hydraulic) in Bilbao. Data source: Basque Government (2013a)}
\end{figure}

\textsuperscript{38} City Council. Personal communication. April 15, 2013
The rest of the energy (electricity and gas) is supplied by private energy utilities which have their share in the renewable energy production at the national level. Table 5.1 shows the energy infrastructures that satisfy the energy demand of the Basque Country. The table also shows the infrastructures located within the city limits.

**Table 5.1. Energy Infrastructures in the Basque Country and in the municipality of Bilbao**

<table>
<thead>
<tr>
<th>Energy type</th>
<th>Infrastructures in the Basque Country</th>
<th>Infrastructures located in the municipality of Bilbao</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil</td>
<td>CLH</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>ESERGUI</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>PETRONOR</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>TEPSA</td>
<td>-</td>
</tr>
<tr>
<td>Biogasolineras</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Gas</td>
<td>Bahia de Bizkaia Gas</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>La Gaviota</td>
<td>-</td>
</tr>
<tr>
<td>Wind Energy</td>
<td>Badaia</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Elgea-Urkilla</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Oiz</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Parque Eólico del Puerto de Bilbao</td>
<td>(Actually located outside the city)</td>
</tr>
<tr>
<td></td>
<td>(Wind Park of Bilbao’s Port)</td>
<td></td>
</tr>
<tr>
<td>Solar Energy</td>
<td>Photovoltaic</td>
<td>48 installations; 194,093 KWp</td>
</tr>
<tr>
<td></td>
<td>Thermal</td>
<td>10 installations; 281,379 KW</td>
</tr>
<tr>
<td>Biomass</td>
<td>BioArtigas</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Biocombustibles de Zierbena</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Biodiesel Bilbao</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>BioGarbike Igorre</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>BioGardelegi</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>BioSanMarkos</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>BioSasieta</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Zabalgarbi</td>
<td>The electricity production of Zabalgarbi equals to 40% of the domestic electricity consumed in</td>
</tr>
</tbody>
</table>

the province of Bizkaia. This electricity is sold to the energy utilities (not consumed directly). In 2011, this landfill plant produced 682.6 million net kWh (waste + natural gas).

<table>
<thead>
<tr>
<th>Hydraulic power</th>
<th>C.H. Barazar</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>C.H. Sobrón</td>
<td></td>
</tr>
<tr>
<td>Mini-hydraulic power</td>
<td>1 installation; 350 KW</td>
</tr>
</tbody>
</table>

| Cogeneration infrastructures | 9 installations; 19,132 KW |

<table>
<thead>
<tr>
<th>Power plants</th>
<th>Bahía de Bizkaia Electricidad S.A.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bizkaia Energía S.A.</td>
</tr>
<tr>
<td></td>
<td>Central Térmica de Pasaia</td>
</tr>
<tr>
<td></td>
<td>Ciclo combinado de Santurce a Central</td>
</tr>
<tr>
<td></td>
<td>Térmica de Santurce I y II</td>
</tr>
</tbody>
</table>

Since the energy market was opened in Spain in 2009, consumers of less than 10 KW of installed power (most households) are entitled to choose between two types of energy rates: one fixed, established by the Spanish Ministry of Industry, Commerce and Tourism, called ‘Tariff of last resort’ or ToLR (Tarifa de Ultimo Recurso, or TUR in Spanish), or contracting a rate in the open energy market, which can vary depending on the offer and demand. Both can be contracted to the usual energy companies. There are two types of energy companies: traders and suppliers. Suppliers are in charge of energy infrastructures and energy consumption readings. Traders access to the energy network and buy the energy in the market to offer it to the consumers. Energy suppliers can be traders, and with the liberalisation of the energy market the number of energy traders has grown. According to the last report by the National Energy Commission, the degree of liberalization of the energy market is quite slow for domestic energy consumption. According to this report, only 33% of the energy consumers are being supplied by a different supplier than the Supplier of Last Resort, i.e. under a free energy rate. At the same time, the electricity and gas price for domestic consumers is drastically increasing during the last years which might be the low degree of liberalization of the energy

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40 In 2012, last available data.
Figure 5.12 shows as an example the evolution of the domestic electricity price of Spain compared to the European average and other countries in Europe.

![Figure 5.12 Evolution of the electrical energy price in Europe for domestic consumers (exc. taxes and levies) from 2007 onwards - bi-annual data.](image)

Source: Eurostat

Lastly, it turns relevant here to talk about the stakeholders that may have a role now or in the future in the energy strategy of the city of Bilbao. The energy company that supplies most households in the city is Iberdrola S.A., which is also the company that is in charge of the energy services of the city. The Public Works and Services Department of the City Council is responsible for the energy management of the city and is in charge of the Sustainable Energy Action Plan. The Urban Planning Department in turn, does not participate in drawing the energy strategy of the city at this moment, but it is actually incorporating energy indicators in the New Urban Master Plan. Researchers from private and public institutions are relevant stakeholders regarding the energy strategy through

their participation in European and local research projects where the city of Bilbao is case study or even a partner. Eventually, other stakeholders such as social and environmental NGOs, community representatives, architecture studies and social innovation small enterprises generally participate in the discussions initiated by the City Council regarding energy or sustainability issues. Representatives of all these institutions have participated in the studies developed in this dissertation i.e. in the interviews for the Q study (see p. 172) and for the fuzzy cognitive maps development (see p. 184).

5.2.6. The urban low-carbon challenge of Bilbao

Looking at the past transformation of the city of Bilbao, it seems reasonable to hypothesise that the city has enough resources, authority, experience and infrastructure to lead another transformation. Regardless of this, the energy and climate change strategies led until now by the City Council on one hand show that there is interest in this issues, but do not prove any real engagement in the shift towards a low-carbon transition, either from the local authority or from the citizens.

The future development of the city and of the Metropolitan Area of Bilbao requires a radical change in terms of energy consumption and diversification of energy sources, to lead the urban area towards sustainability and resilience to climate change and to resource scarcity. This dissertation seeks to explore how the cognitions of actors may be affecting the process of change, and how at the same time those cognitions (knowledge and understanding of the system held by actors) may help to uncover the complexity of the energy model and identify potential transition pathways for the city. The methods selected to address these two questions are described in Sections 5.3 and 5.4.

5.3. Q method

5.3.1. Method description and applicability

The Q method is a semi-quantitative method that seeks to capture the viewpoints and discourses of a set of individuals or actors (Dziopa and Ahern 2011). We use this method
5. Data and methods

in Chapter 6 to reveal the barriers to and opportunities for bringing about a low-carbon transition in the city of Bilbao by interviewing a number of actors related to energy management, generation etc., i.e. intermediary actors.

The Q method is commonly described as an approach for the systematic study of subjectivity (Brown 1993). The application the Q method requires a step-by-step process. Typically, it aims to explore the most widespread discourses about a certain topic (Q topic), for which a representative set of statements is elaborated. This process is called Q sampling and involves the collection of a range of views on the topic under investigation from multiple sources (Dziopa and Ahern 2011) (including interviews, a review of the relevant literature, the media, etc.) in such a way as to obtain a broad representation of the existing viewpoints (Asah et al. 2012). That set of statements is then presented to a larger group of people, who are asked to rank them according to their preferences (Brown 1993). Finally, in a Q study, this larger set of actors is grouped by similar viewpoints and information related to the similarities and differences in their viewpoints is obtained (Van Exel and de Graaf 2005). These groups represent the concurrent discourses about the topic under investigation.

Unlike other methods, the Q method does not seek to use a representative sample of the population but rather to collect representative information on how respondents articulate their opinions on a certain topic (Robbins and Krueger 2000). The respondents are chosen from among those groups that have something to say about the topic in question. Hence, the Q method does not intend to provide empirical objectivity but to emphasise the subjectivities associated with a topic (Robbins and Krueger 2000). The terminology specific to Q as used here is summarised in Table 5.1.

Table 5.2 Main terminology used in the Q method

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q topic</td>
<td>Topic of the Q study.</td>
</tr>
<tr>
<td>Q sample</td>
<td>Collection of representative statements (S) on a certain topic selected from initial interviews, or from different sources such as scientific literature, press or media, etc.</td>
</tr>
<tr>
<td>P-set</td>
<td>Group of respondents who are focus of analysis and will participate in the Q sorting process.</td>
</tr>
</tbody>
</table>
Each Q study designs a specific matrix in the form of an inverted pyramid. This allows respondents to place the statements in different columns according to their preferences/perspectives (process known as Q sorting, see below). The particularity of this method is that it limits the number of possible answers at the extremes.

**Q sorting**
Process of placing each statement in the column of the Q matrix. Q sorting can be undertaken during a personal interview, through a questionnaire or electronically.

**Q sort**
This represents each respondent’s final matrix translated into a ranking.

**Factor**
Correlation of Q sorts of similar types (according to their agreements or disagreements) using either Principal Component Analysis (PCA) or centroid extraction. Factors can be interpreted as discourses.

**Factor loading**
Extent to which each Q sort is associated with each factor (Van Exel and de Graaf 2005). It defines a perspective.

**z-score**
Weighted average of the scores of those respondents who define that factor (or perspective) (Van Exel and de Graaf 2005).

**Factor scores**
Also known as q-score, this is the normalised z-score of the respondents who define that factor (Van Exel and de Graaf 2005). It can be understood as the value that an ideal respondent’s 100 per cent loading on that factor would give to that statement.

**Flagging**
Process of identifying significant Q sorts within a factor through rotation of factors (through manual or automatic rotation).

### 5.3.2. Data collection in the case study

In the case study of Bilbao, performed in 2013, I followed a four-stage process (Figure 5.11). In *Stage 1* a small group of stakeholders representing different and possibly extreme perspectives were interviewed (Group 1) in regard to potential barriers to and opportunities for a low-carbon transition in Bilbao (Q topic). An analysis of the context and a review of the local press and media were also carried out. After this, representative statements were identified in relation to the determinants of the transformation of the energy model of Bilbao. These were related to local regulations, economic incentives, lifestyles, etc. In *Stage 2* a larger group of stakeholders (Group 2 or the P-set in Q terminology) was used: each member of this group was asked to order the statements (called Q sorting) in accordance with their perceptions and opinions following the standard Q methodology. *Stage 3* encompassed the analysis of the rankings (called Q sorts) and their interpretation to categorise the different discourses related to the potential determinants for the transformation of Bilbao into a low-carbon city. In *Stage 4* the main
discourses identified as relevant to urban low-carbon transitions and to UST in general were interpreted.

Figure 5.13 Application of the Q method: a four-stage process

In Stage 1, 15 stakeholders were interviewed face to face. A further 32 stakeholders responded to the Q sorting in Stage 2. As a sample of actors involved in energy management, representative stakeholders from different levels of decision making (Bilbao and Basque Country) with authority or interests in energy matters were invited to participate in the interviews. They included people who were connected to grassroots associations, consultancy firms, research organisations, local authorities, the media, nongovernmental organisations, political parties, public development agencies, regional authorities and regional public institutions and energy-utility companies. The regional authority was also included to check the possibility of network governance as a significant mode of governance in transition management.

66 statements were drawn from Stage 1, including some taken from local media sources. Of these, 32 were finally selected (see Table 6.2 in Chapter 6) after a process of cleaning.
and refining based on the following criteria: (i) avoidance of duplicates; (ii) avoidance of multiple perspectives within the same statement; (iii) clarity and understanding of the wording; and (iv) representation of the study interests (areas included: pressures, barriers/obstacles, solutions, lobbies, governance, citizens/behaviour, technology/regulations).

As a special characteristic of the Q method, in Stage 2 a matrix is used to rank the statements. Each Q study designs a specific matrix in the form of an inverted pyramid. This allows respondents to place statements in different columns according to their preferences or perspectives. In this case, a matrix with a range of \([-3;+3]\) levels of agreement and a \([2;4;6;8;6;4;2]\) column depth was used (see Figure 5.11) to allocate the 32 selected statements. Following a Likert-scale approach, but with a seven-option scale, this matrix provides more space for doubt (as only a limited amount of statements can be placed in each level of agreement), which drives respondents to reconsider their views in a more defined way. The matrix as shown in Figure 5.12 has three main opinion areas: an area of agreement (which allows different levels of agreement from +1 to +3), an area of disagreement (which also allows different levels of agreement from -1 to -3) and a neutral area (level 0) where participants can locate statements on topics on which they have not yet formed an opinion or that they do not prioritise over the other statements.
Figure 5.14 Q Matrix definition

The Q ranking interviews were performed through an on-line platform. Several options were considered (including Google forms) but the special requirements of the method and the rigidity of the free online tools available for designing polls or questionnaires were critical in opting for a Q sorting board developed in Microsoft PowerPoint™ (see Figure 5.13). The electronic board was tried out first on a test-group (including advanced and beginner PC users).
<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly disagree</th>
<th>Disagree</th>
<th>Slightly disagree</th>
<th>Neither agree or disagree</th>
<th>Slightly agree</th>
<th>Agree</th>
<th>Strongly agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1. Climate change is not caused by humans, it is part of a natural cycle.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S2. Fossil fuels are running out.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S3. Bilbao is vulnerable to climate change.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S4. Energy strategy discourse makes no sense at the regional/national level.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S5. I don’t even want to think how much electricity and gas will cost in 10 years.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S6. We consume too much energy. More than needed.</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>S7. Energy is one of the priorities of the urban strategy of Bilbao City Council.</td>
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<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>S8. During an economic crisis, there is nothing we can do.</td>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S9. Regulatory frameworks which enforce energy efficiency and renewables are essential.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S10. Improvements in energy efficiency are not as effective as they are advertised.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S11. I believe that technical and scientific support is needed in order to develop urban strategies.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S12. The City Council has the power to turn Bilbao into a low-carbon city.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S13. Energy is one of the priorities of the urban strategy of Bilbao City Council.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S14. Too much dependency is not good for an economy. Self-sufficiency is better.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S15. Many public services are not efficient because they are operated by private interests.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S16. I believe that the interests of the government lie elsewhere than in their investments.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S17. The citizens of Bilbao are very individualistic.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S18. The City Council must take the lead and it will do so only under pressure/demand from the public.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S19. Energy is one of the priorities of the urban strategy of Bilbao City Council.</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S20. If there were more social participation, decisions would be better supported and justified.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S22. The citizens of Bilbao are very individualistic.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S23. Energy is one of the priorities of the urban strategy of Bilbao City Council.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S24. Citizens of Bilbao are environmentally concerned.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S25. The electricity/gas bill is as easy to understand as a supermarket receipt.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S26. I often think: “All in all, taking into account monthly expenses, electricity and gas are not such a big deal.”</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S27. Environmentalists want us to “go back to the caves.”</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S28. If there were more social participation, decisions would be better supported and justified.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S29. I believe that technical and scientific support is needed in order to develop urban strategies.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S30. If there were more social participation, decisions would be better supported and justified.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S31. I would rather improve the insulation of my facade than install solar panels.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S32. I would rather improve the insulation of my facade than install solar panels.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S33. Fossil fuels are running out.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S34. The City Council has the power to turn Bilbao into a low-carbon city.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 5.15 Q sorting electronic board (in PowerPoint™)**

On the left, the statements; on the right, the matrix where the statements should be placed according to the preferences of the respondent.
Once it had been validated, 46 potential respondents were invited to participate in March 2013. 32 of them agreed to do so (70 per cent response rate) and 75 per cent of that number sent their responses in the first week, as illustrates Figure 5.14.

![Figure 5.16 Q sorting responses over time]

To implement the first part of Stage 3 i.e. analysis of Q sorts, the PQmethod was used with MS-DOS software\textsuperscript{42}. The analysis of these data, its interpretation and conclusions (Stage 4) are addressed in Chapter 6.

5.4. Fuzzy cognitive mapping

5.4.1. Method description and application

The FCM approach is generally used to represent the behaviour of complex systems through causal reasoning. It is considered a useful tool for setting management objectives, communicating and learning (van Vliet et al. 2010), especially in the context of scenario planning applications driven by high uncertainty and complexity (Kok and van Vliet

\textsuperscript{42} PQmethod – 2.20 (December 2011) by Peter Schmolck (URL: http://schmolck.org/qmethod/) Last accessed March 11, 2014.
FCM has recently been applied in different fields associated with spatial analysis (Liu 2003), forest management (Kok 2009), energy (Jetter and Schweinfort 2011) and markets and economics (Azadeh et al. 2012).

An FCM integrates accumulated experience on the operation of a complex system. It is the result of the aggregation of the knowledge obtained from experts who have their own understanding about how the system operates and how it behaves under different circumstances (Stylios et al. 1997). Fuzzy cognitive maps do not represent systems as physical models do, so the conclusions derived might not concur with existing scientific knowledge (Hobbs et al. 2002; Isak et al. 2009). As stated by Özesmi and Özesmi (2004), although fuzzy cognitive maps are “ideal tools for theory development, hypothesis formation, and data evaluation, [they] are not substitutes for statistical techniques; they do not provide real-value parameter estimations or inferential statistical tests”. Their main advantages include the potential to include multiple perspectives and a high level of integration. One key disadvantage is that time scale is weakly incorporated (Kok 2009; van Vliet et al. 2010).

‘Fuzzy’ is used to denote something that is vague or unclear. The term ‘fuzzy logic’ was first used by Zadeh (1965) who defined the ‘fuzzy set’ as a "class with a continuum of grades of membership". In fuzzy logic values can be classified mathematically in a gradual way so that fuzzy variables range from zero to one. Fuzzy logic permits a reasoning closer to the human cognitive realm, which often makes use of vague ideas using classes such as “very”, “little”, etc., in contrast to more conventional or traditional membership methods that set values in ‘true’ or ‘false’ such as binary sets.

Cognitive maps are originally attributed to Tolman (1948) and consist of “concepts about aspects of the decision environment and beliefs about cause-effect relationships between them” (Schwenk 1988). In the context of human systems, the idea of the ‘cognitive map’ was developed by Axelrod (1976), who argued that cognitive maps are not meant to illustrate the whole belief system but the part that is associated with a certain decision. Cognitive maps can represent an individual or a shared decision environment (Langfield-Smith 1992) (see Fig. ).
Bart Kosko, considered the ‘father’ of fuzzy cognitive mapping, introduced the notion of fuzziness into cognitive maps and created the theory of FCM (Kosko 1986). He argued that FCMs represent causal reasoning by stating that most knowledge can be conceived as classification and causes and that both are uncertain and fuzzy. He suggested the applicability of FCMs to those knowledge domains that involve a high degree of uncertainty or so-called soft knowledge domains, such as organisation theory and political science. Since then, there have been important advances in this area of research and its applications have expanded into many disciplines (Glykas 2010).

Due to its semi-quantitative nature, FCM searches for the benefits of both qualitative approaches (capturing complex issues) and quantitative approaches (consistency and reliability) (Creswell 2003). FCM outputs are quantitative but can only be interpreted qualitatively, i.e. as a degree of change relative to the baseline (Kok 2009).

5.4.2. Fuzzy Cognitive Mapping for environmental management

The application of FCM in the field of environmental science and decision-making is quite recent. Table 5.2 presents a selection of emergent literature on this topic. An earlier conceptual study on the potential of FCM in environmental decisions was conducted by
Hobbs et al. (2002), who proposed the use of FCM in ecosystems management. Özesmi and Özesmi (2004) compared FCM to other methods for eliciting expert knowledge in ecosystem modelling and concluded that FCM are more accessible and easier to undertake, can accommodate a higher degree of complexity and a higher number of knowledge sources in very different disciplines.

Among other applications of FCM, in resource management Isak et al. (2009) develop a manual for the use of FCM for conservation, Kok (2009) applies FCM in forest management in Brazil and Kafetzis et al. (2010) apply this approach in the context of two watersheds. More recently, Lopolito (2011) applies FCM to draw up policy options for the development of bio-refineries in rural areas. In the field of risk management, Giordano and Vurro (2010) apply it to analyse different strategies regarding drought management in Italy and Wildenberg et al. (2010) gather together the results of six case studies in different European countries and apply FCM from the perspective of landscape modelling. Kontogiani et al. (2012) discuss the application of FCM to environmental valuation, focusing particularly on non-marketed services. Jetter and Schweinfort (2011) test the potential for the deployment of PV solar panels by means of FCM. This study and Kok’s experiment (2009) on scenario development in Brazil constitute the first steps towards an extended application of FCM in complex system scenario planning. New studies such as those by Zhang et al. (2013), who aggregate 57 stakeholders’ coal-mine maps, Vanwindekens et al. (2013), who carry out 49 interviews with farmers, and Reckien et al. (2013a), who use 134 maps of different socioeconomic groups in New Delhi, are the reviewed case studies with the highest level of stakeholder participation. Lastly, it is interesting to note that FCM has also been used in climate change research. The impacts of climate change as perceived by stakeholders in New Delhi have been studied recently by Reckien et al. (2013a) with the purpose of developing adaptation options, while Murungwene et al. (2011) have assessed the vulnerability of different types of livelihood.
Table 5.3 Environment-related literature on FCM and main features

<table>
<thead>
<tr>
<th>Context</th>
<th>Focus on....</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Management</td>
<td>✓</td>
<td>Hobbs et al. 2002</td>
</tr>
<tr>
<td>Ecosystems modelling</td>
<td>✓</td>
<td>Özesmi and Özesmi 2004</td>
</tr>
<tr>
<td>Natural conservation</td>
<td>✓</td>
<td>Isak et al. 2009</td>
</tr>
<tr>
<td>Forest Management</td>
<td>✓</td>
<td>Kok 2009</td>
</tr>
<tr>
<td>Urban systems</td>
<td>✓</td>
<td>Habib and Shokoohi 2009</td>
</tr>
<tr>
<td>Water management</td>
<td>✓</td>
<td>Kafetzis et al. 2010</td>
</tr>
<tr>
<td>Drought management</td>
<td>✓</td>
<td>Giordano and Vurro 2010</td>
</tr>
<tr>
<td>Landscape modelling</td>
<td>✓</td>
<td>Wildenberg et al. 2010</td>
</tr>
<tr>
<td>Environmental change assessment</td>
<td>✓</td>
<td>Rounsevell and Metzger 2010</td>
</tr>
<tr>
<td>Environmental industry</td>
<td>✓</td>
<td>Lopolito et al. 2011</td>
</tr>
<tr>
<td>Environmental technology</td>
<td>✓</td>
<td>Jetter and Schweinfort 2011</td>
</tr>
<tr>
<td>Vulnerability Assessment</td>
<td>✓</td>
<td>Murungweni et al. 2011</td>
</tr>
<tr>
<td>Economic Valuation</td>
<td>✓</td>
<td>Kontogianni et al. 2012</td>
</tr>
<tr>
<td>Climate change impacts</td>
<td>✓</td>
<td>Reckien et al. 2013</td>
</tr>
<tr>
<td>Farming as socio-ecological system</td>
<td>✓</td>
<td>Vanwindekens et al. 2013</td>
</tr>
<tr>
<td>Environmental assessment of mines</td>
<td>✓</td>
<td>Zhang et al. 2013</td>
</tr>
</tbody>
</table>

- CS: Case Study included, b M: the paper is focused on improving the Methodological process, c P: the paper stresses the Participatory technique, d S: the paper highlights the applicability of FCM for Scenario creation

Resilience management is a promising application of FCM (Kok 2009) as it has the potential to model the non-linear dynamics of socio-ecological systems which are emphasised in resilience approaches (see e.g. Folke 2006). However the use of FCM for urban decision-making has not yet been sufficiently explored, despite the fact that urban systems and their governance have all the necessary ingredients of complexity that make the application of FCM particularly interesting (Habib and Shokoohi 2009).

### 5.4.3. Structure of Fuzzy Cognitive Maps

FCMs consist of concept nodes \( (C_i) \) that can be interpreted as variables. These concepts are related through direct edge or arcs \( (C_i, C_j) \) that are signed and weighted \( (w_{ij}) \) and can be graphically visualised. FCMs thus represent causal relationships with feedbacks and
can incorporate self-loops. The existing knowledge on the behaviour of the system (or at least that provided by the experts) is stored in the structure of the nodes and their interconnections (Groumpos 2010). The weight assigned [-1;+1] represents how strongly concept $C_i$ influences $C_j$, and the positive or negative sign indicates whether the relationship is direct (+) or inverse (-).

The state vector $A = (A_1, A_2... A_n)$, represents the state values of the FCM concepts, $A_i$ (between zero and one), at the initial stage or after several iterations. Lastly, the ‘adjacency matrix’, $E$, represents the weights of the edges ($w_{ij}$) (see Kok 2009). An example is shown in Figure 5.16.

![Diagram of FCM structure](image)

**Figure 5.18 Example of Fuzzy Cognitive Map structure and formulation of the adjacency matrix $E$**

FCMs can be built in different ways depending on how and when experts intervene in the process and how their knowledge is decoded and dumped (Groumpos 2010). For example, experts can identify the elements of the system ($C_i$) as a group; later, individually, they can draw the connections between the elements and the magnitude of their influence through weighting ($w_{ij}$). The maps can then be aggregated. Another way to build FCMs is via a completely independent process where experts find their way and map their mental perceptions separately. Here, experts individually identify elements and draw their own maps. This provides experts with more freedom and flexibility as they can represent the “problem” from their own perspectives, avoiding the need to follow a consensus. All their individual thinking is later merged and aggregated into a single map. Yet, as noted by Reckien et al. (2013a), the individual process is operationally more challenging as the researcher must decipher the elements and connections in the process of aggregation (i.e. by merging concepts $C_i$ from different experts’ maps which
presumably, according to the interpretation of the researcher, represent the same variable). This latter approach is applied in the case study of Bilbao used in this paper.

The dynamics of the state vector $A$ are calculated by focusing on the influence of each factor on the others over a number of iterations, or time steps ($k$), normally, 20-30 iterations (Kok 2009). This is represented by Eq. 1 (Wildenberg et al. 2010):

\[
\text{Eq. 1}
\]

where $A_i^{(k+1)}$ is the value of concept $C_i$ at time step $k+1$; $A_i^{(k)}$ is the value of concept $C_i$ at time step $k$; $A_j^{(k)}$ is the value of concept $C_j$ at time step $k$; and $w_{ij}$ is the weight on the influence from $C_i$ to $C_j$.

Eq. 1 is used to analyse the dynamic behaviour of the network and enable scenarios to be built up upon the establishment of certain fixed conditions (defined here as alternative transition pathways). The state vector $A$ of the baseline scenario is calculated by initially setting the state values of all the concepts in the network to one. Different scenarios can then be modelled (Kok 2009).

The network characteristics can also be analysed through indicators such as density ($D$), centrality ($C_t$), out-degree ($O$) and in-degree ($I$). $D$ is an indicator of the general connectivity of the network, estimated by dividing the number of existing connections by the total number of possible connections between all the variables ($N$) (see Eq. 2).

\[
\text{Eq. 2}
\]

It is often assumed that a higher value for $D$ indicates more possibilities of change, as there are more connections in the network which, if perceived by the stakeholders, these can turn into “catalysts of change” (Özesmi and Özesmi 2004). $C_t$ denotes the importance of each concept. It is also used as a measure of the specific connectivity of each concept (Reckien et al. 2013a). Here, $C_t$ is calculated as the sum of a concept’s in- and out-degrees (see Eq. 3).
where, \( O_i \) is a measure of the strength of the influence of one concept \( C_i \) on others, regardless of the sign of the arcs (see Eq. 4), and \( I_i \) is a measure of the strength of the influence of other concepts on \( C_i \) regardless of the sign of the arcs (see Eq. 5) (Özesmi and Özesmi 2004).

\[
\text{Eq. 3}
\]

\[
\text{Eq. 4}
\]

\[
\text{Eq. 5}
\]

Equation 1 is used in the case study to generate scenarios based on three potential transition pathways (see Section 5.4.2). Equations 2-5 are used in the network analysis of the case study (see Section 5.4.1).

There are many approaches for dealing with the process of eliciting information from stakeholders to build an FCM, such as questionnaires, reviews of media and written information and interviews (Özesmi and Özesmi 2004; Isak et al. 2009; Wildenberg et al. 2010). The maps then need to be processed, i.e. digitised, analysed, visualised and lastly interpreted (Wildenberg et al. 2010).43

### 5.4.4. Data collection in the case study

In this case study, 14 stakeholders (hereafter called ‘experts’) were requested to develop an FCM for the use of energy in the city of Bilbao. This was done through a face-to-face interaction. The experts that took part in the study came from a variety of backgrounds and included people from the civil administration, NGOs, representatives of the general public, academics and private companies with diverse technical backgrounds, e.g. law, planning, sustainability, social behaviour, building, energy infrastructures and

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43 There are various software applications which use these or similar formulas and which have been programmed to facilitate the building, execution and analysis of the dynamics of FCMs. (e.g. Jose and Contreras 2010)
management. The key engaging topic/question (Q) used to stimulate participants was: “What do you think influences the use of energy in Bilbao and what are its impacts?”

As these experts were interviewed, we obtained individual maps containing the concept elements \( C_i \), their interconnections \( C_i \sim C_j \) and also the weights of those relationships \( w_{ij} \) which are inputs to the adjacency matrix \( E \). To that end, each stakeholder followed a specific step-process to create their individual map (see Isak et al. 2009; Reckien et al. 2013a). First, they listed the elements that might have a role concerning the topic Q and placed the main element in the middle of a blank sheet of paper. Then, they placed the rest of the elements around the first one, making the appropriate connections and indicating whether the relationship was positive or negative. Finally, they weighted each relationship on a scale from zero to 1 \((0;1]\) (0 meaning no causal relationship).

FCMapper was used in this study, based on worksheets in VBA coding (Bachhofer and Wildenberg 2009). To aggregate the individual maps, the weights of the connections were added up and then the entire matrix was normalised (examples of original maps are shown in the Appendices in Figure A1). For this process of aggregation, each map is first translated into a matrix and then, after a process of merging similar concepts and renaming ambiguous ones, the maps are aggregated into a single composite matrix. In this case the exercise resulted in a matrix of 86 merged concepts from a total of 139 in the original phase.

The analysis of the resulting network and the simulation of the different alternative scenarios are addressed in Chapter 7.

**5.5. Conclusions**

The literature shows that there might be socio-economic or technological reasons that represent barriers to low-carbon transitions, for example high investment costs of new technologies, or enablers, for example political commitments to environmental innovations (Pandis Iveroth et al. 2013). There are also numerous actors that influence energy management and their interests and perceptions are key to understanding the
transformability potential of urban areas. In the case of Bilbao there is a lack of previous studies and clear contextual background to explain why Bilbao is still on the threshold of urban energy transformation. However, the past experience of the city in being part of the team that led a successful urban transformation suggests that there is potential for making a change on this level of engagement.

In Part II of this dissertation, two semi-quantitative methods are implemented in the city of Bilbao to answer the questions of (i) what the main discourses towards a low-carbon transition in the city of Bilbao are; and (ii) how the knowledge and perceptions of actors can be used to test different scenarios of transition pathways against principles of resilience and sustainability and to identify unintended policy impacts.

Chapter 6 applies the Q method. As argued above, in USTs it is essential to generate a transformation engine supported by institutions including influential societal groups. This means accepting the need for change and trusting institutional and societal capabilities to move ahead. The question is whether hidden barriers to a low-carbon transition associated with specific perceptions exist in Bilbao, and if so what they are. Chapter 7 applies Fuzzy Cognitive Mapping to elicit cognitive information from stakeholders to understand from an integrated point of view how the system works and what the main interconnections and feedbacks are. The question here is whether there would be unintended effects on the system depending on what different transition pathways are taken.

5.6. Summary

The main points of this chapter are summed up as follows:

- When it comes to energy, resilience generally means greater diversification of energy sources, greater reliance on renewable energy and greater self-dependency and technical security. In urban sustainability terms, this means transitioning to a low-carbon city
Low-carbon transitions form part of the quest for global sustainability transitions as they aspire to transform an entrenched carbon-based economy into a dematerialised, zero-carbon economy. The concept of energy transition relates to a fundamental change in the quality, quantity and structure of energy production and use. It is now a climate change motive.

The role of cities in low-carbon transitions is arguable from a theoretical, conceptual and empirical point of view, if one weights the means and resources that they have for attaining their carbon objectives in the form of organisation, knowledge and technology, and action. In any event, the authority that cities have in certain energy matters (especially in urban planning and design) and the fact that they are hubs of development and innovation, suggests that they need to take up the cause of moving towards a low-carbon transition too.

A wide range of social coalitions working at different scales, with different levels of responsibilities and different interests, envision what a low-carbon city should look like and how it should be achieved. Their knowledge and understanding is critical to understanding the potential of cities and moving towards a low-carbon transition.

This dissertation uses the case study of Bilbao to explore whether stakeholders see a low-carbon transition in Bilbao, and if so how. Bilbao is a medium-sized European city which has undergone a major economic transformation after an industrial decline. It is now a service-based city whose GDP is above the European average.

Although Bilbao is an icon of urban regeneration, the sustainability objectives of the city are hardly transferred at all to meaningful change and energy challenges still persist.

To answer the question of what the main discourses of actors are in regard to whether a transition exists in Bilbao, the Q method is applied in Chapter 6. The Q method is a semi-quantitative method that seeks to group stakeholder perspectives around a number of viewpoints. From interviews and reviews of media and newspapers, 32 statements related to the potential transformation of Bilbao into a low carbon city were extracted. 32 stakeholders participated in this study by prioritising these statements. The results are analysed in Chapter 6.
To answer the question of how knowledge and understanding of the energy system may influence transformability, resilience and sustainability pathways, Fuzzy Cognitive Mapping (FCM) is applied in Chapter 7. FCM is a participatory semi-quantitative method which is able to integrate the accumulated experience of experts or actors in the decision environment concerning the structure and non-linear functioning of the complex system. 14 stakeholders participated in the data collection. The results are analysed in Chapter 7.
RESULTS OF THE APPLICATION TO THE CASE STUDY OF BILBAO

“Local authorities usually have various opportunities to mobilize action towards local sustainable development, using their competences as planners, policy makers and energy users.” (Azevedo et al. 2013, p.895)
Chapter 6. Discourses on urban low-carbon transitions: a Q analysis

6.1. Introduction and structure of the chapter

Following recent studies (see e.g. Azevedo et al. 2013) this chapter seeks to identify the cognitive barriers to transformation in the context of urban low-carbon transitions through a case study in the city of Bilbao. It explores how the perceptions and values of actors involved in energy planning and management influence the opportunities that cities have to undertake low-carbon transitions. The case study explores the perceptions of a range of actors concerning the need for change, the possibility of embarking on an energy transition and their potential level of engagement in the process.

A Q method analysis (see method description and data collection process in the case study in Chapter 5) is applied to identify the key discourses of actors in Bilbao regarding the city’s energy transformation potential. The analysis and results are intended to inform researchers, urban planners and urban environmental managers interested in urban transition research in similar settings.

This chapter proceeds as follows: Section 6.2 describes the process for analysing the data collected (see Chapter 5). Section 6.3 presents the results. Section 6.4 identifies the salient discourses about the transformability of the high-intensity energy system of Bilbao. Section 6.5 sets these discourses into the UST framework (see Chapter 3, p. 83). Section 6.6 discusses the potential barriers to and opportunities for sustainable urban transformation as learnt from the case study. Section 6.7 presents conclusions and Section 6.8 summarises the chapter.
6.2. Data analysis

To analyse the Q sorts collected from the interviews (see Chapter 5), the PQmethod is used with MS-DOS software. As a statistical program tailored to the requirements of the Q method, it enables the Q sorts to be input and provides results, allowing enough flexibility for the number of factors to be selected.

Following specific criteria as suggested by Zabala and Pascual (2013) (see Appendix, Table A1), we selected four factors. In this four-factor preferred option, we meet at least four out of the six supporting criteria listed by Zabala and Pascual (2013) as follows: the Eigenvalue is bigger than one; two or more respondents are flagged in each factor; the percentage of variability explained is larger than 50 per cent and there is enough feasibility in the interpretation of the four factors and parsimony.

Each factor represents the correlation of Q sorts of similar types. Factors are later interpreted into concurrent discourses. Their main characteristics are shown in Table 6.1. Each Q sort, which represents the preferences of an individual respondent, has a specific

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loading in each of the four factors and some of them are more strongly represented (higher loadings) in a given factor (see the complete list of Q sorts and their loadings in the Appendix, Table A2).

**Table 6.1 Characteristics of rotated factors**

<table>
<thead>
<tr>
<th></th>
<th>Factor A</th>
<th>Factor B</th>
<th>Factor C</th>
<th>Factor D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of defining sorts</td>
<td>3</td>
<td>10</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Average reliability coefficient(^a)</td>
<td>0.8</td>
<td>0.8</td>
<td>0.8</td>
<td>0.8</td>
</tr>
<tr>
<td>Composite reliability</td>
<td>0.923</td>
<td>0.976</td>
<td>0.941</td>
<td>0.923</td>
</tr>
<tr>
<td>Standard error of factor z-scores</td>
<td>0.277</td>
<td>0.156</td>
<td>0.243</td>
<td>0.277</td>
</tr>
<tr>
<td>% of variance explained</td>
<td>15</td>
<td>25</td>
<td>17</td>
<td>9</td>
</tr>
<tr>
<td>Σ (% of variance explained)</td>
<td></td>
<td></td>
<td></td>
<td>66</td>
</tr>
</tbody>
</table>

\(^a\) The default reliability coefficient in the PQ method is 0.80 (Brown 1980)

### 6.3. Results

To enable the different factors to be interpreted and the differentiated discourses to be built up, factor scores (q-sc) associated with each statement are calculated. These scores represent the value that an ideal respondent 100 per cent correlated to that factor would give to that statement in a Q sorting process. Factor scores are normalised z-scores (z-sc) of respondents who define that factor, and a z-score is the weighted average of the scores of those respondents who define that factor (Van Exel and de Graaf 2005).

Table 6.2 below shows the complete list of statements and their scores (q-sc and z-sc) for each of the four factors (A, B, C and D). Identifying similarities and disagreements between factors helps to draw up discourses. As Asah et al. (2012) note, the revelation of consensus areas and the prioritisation of issues within those areas is an important facet of the Q method. The PQMethod identifies consensus statements (those non-significant at p>0.01, which are not distinguishing statements between any pair of factors) and distinguishing statements (statistically significant at p<0.05) (Van Exel and de Graaf 2005). Distinguishing statements are used to characterise the distinctive perspectives...
between the four different factors. Consensus can be found when stakeholders are in agreement, in disagreement or when they do not prioritise a specific topic. In Table 6.2, the statements and scores that are distinguishing in each factor (see raw results in Table A3 in the Appendix) and which may be coincident between a group of factors (see e.g. S7) are highlighted in bold. Those statements identified as consensus statements (see detailed results in Table A4 in the Appendix) are shaded. These serve as a basis for their interpretation as discourses.

**Table 6.2 Complete list of Q statements, factor scores (q-sc) and z-scores.**

*Statements have been classified in seven areas of study: Pressures, barriers/obstacles, solutions, lobbies, governance, citizens/behaviours and technology/ regulations. Distinguishing statements and related scores are highlighted in bold. Consensus statements are shaded.*

<table>
<thead>
<tr>
<th>S#</th>
<th>Factors</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>q-sc</td>
<td>z-sc</td>
<td>q-sc</td>
<td>z-sc</td>
</tr>
<tr>
<td>S1</td>
<td>Pressures</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S2</td>
<td>Climate change is not caused by humans. It is part of a natural cycle.</td>
<td>-3</td>
<td>-1.9</td>
<td>-3</td>
<td>-1.55</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S3</td>
<td>Fossil fuels are running out.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S4</td>
<td>Bilbao is vulnerable to climate change.</td>
<td>2</td>
<td>1.48</td>
<td>2</td>
<td>1.41</td>
</tr>
<tr>
<td>S5</td>
<td>The Basque Country has enough energy resources.</td>
<td>-1</td>
<td>-0.74</td>
<td>-2</td>
<td>-1.48</td>
</tr>
<tr>
<td>S6</td>
<td>I don’t even want to think how much electricity and gas will cost in 10 years.</td>
<td>0</td>
<td>0.09</td>
<td>-1</td>
<td>-0.35</td>
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<tr>
<td>S7</td>
<td>We consume too much energy. More than needed.</td>
<td>2</td>
<td>1.19</td>
<td>2</td>
<td>1.44</td>
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<tr>
<td>S8</td>
<td>Barriers/obstacles</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S7</td>
<td>Energy strategy discourse makes more sense at regional/national level than at local level.</td>
<td>-2</td>
<td>-1.48</td>
<td>1</td>
<td>0.34</td>
</tr>
<tr>
<td>S8</td>
<td>During an economic crisis, there is nothing we can do.</td>
<td>-3</td>
<td>-1.61</td>
<td>-2</td>
<td>-1.28</td>
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</tbody>
</table>
Factors

<table>
<thead>
<tr>
<th>S#</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
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<td></td>
<td>q-sc</td>
<td>z-sc</td>
<td>q-sc</td>
<td>z-sc</td>
</tr>
<tr>
<td>S9</td>
<td>2</td>
<td>1.52</td>
<td>2</td>
<td>1.46</td>
</tr>
<tr>
<td>S10</td>
<td>0</td>
<td>0.38</td>
<td>-1</td>
<td>-0.7</td>
</tr>
</tbody>
</table>

Solutions

| S11 | I believe that technical and scientific support is needed in order to develop urban strategies. | 3 | 2.01 | 2 | 1.05 | 1 | 0.59 | 0 | 0.02 |
| S12 | The City Council has the power to turn Bilbao into a low-carbon city. | -2 | -0.94 | 0 | -0.2 | 2 | 0.98 | -2 | -1.1 |
| S13 | Solutions such as district heating projects are appropriate. | 1 | 0.49 | 0 | 0.29 | 0 | 0.12 | 1 | 0.6 |
| S14 | Too much dependency is not good for any economy. Self-sufficiency is better. | 1 | 0.58 | 1 | 0.35 | 1 | 0.74 | 1 | 0.41 |

Lobbies

| S15 | Many public services are not efficient because they are underpinned by private interests. | 1 | 0.58 | 1 | 0.43 | -2 | -0.9 | 0 | 0.04 |
| S16 | I believe that the interests of governments lie where they have their investments. | 0 | -0.02 | 1 | 0.87 | 0 | 0.14 | 0 | 0.3 |
| S17 | Energy lobbies support energy savings. | 0 | -0.05 | -3 | -1.93 | 0 | -0.02 | 0 | -0.15 |

Governance

<p>| S18 | The City Council must take the lead and it will do so only under pressure/demand from the public. | -2 | -0.94 | 0 | -0.05 | -1 | -0.67 | 0 | -0.28 |
| S19 | Energy is one of the priorities of the urban strategy of Bilbao City Council. | 1 | 0.45 | -1 | -1.06 | 0 | 0.2 | 1 | 0.32 |</p>
<table>
<thead>
<tr>
<th>S#</th>
<th>Factors</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>q-sc</td>
<td>z-sc</td>
<td>q-sc</td>
<td>z-sc</td>
</tr>
<tr>
<td>S20</td>
<td>If there were more social participation, decisions would be better supported and justified.</td>
<td>0</td>
<td>0.18</td>
<td>1</td>
<td>0.99</td>
</tr>
<tr>
<td>S21</td>
<td>I believe that information is sometimes manipulated.</td>
<td>0</td>
<td>0.16</td>
<td>3</td>
<td>1.6</td>
</tr>
<tr>
<td>S22</td>
<td>Aesthetics is prioritised over practicality and cost in the long term.</td>
<td>0</td>
<td>-0.05</td>
<td>0</td>
<td>-0.09</td>
</tr>
<tr>
<td>S23</td>
<td>The citizens of Bilbao are very individualistic.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S24</td>
<td>Citizens of Bilbao are environmentally concerned, and if there is no difference in cost, they would choose the lower consumption option.</td>
<td></td>
<td></td>
<td>-1</td>
<td>-0.71</td>
</tr>
<tr>
<td>S25</td>
<td>The electricity/gas bill is as easy to understand as a supermarket receipt.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S26</td>
<td>I often think: “All in all, taking into account monthly expenses, electricity and gas are not such a big deal.”</td>
<td></td>
<td></td>
<td>-2</td>
<td>-1.43</td>
</tr>
<tr>
<td>S27</td>
<td>Environmentalists want us to “go back to the caves.”</td>
<td></td>
<td></td>
<td>-1</td>
<td>-0.58</td>
</tr>
<tr>
<td>S28</td>
<td>The installation of photovoltaic panels does not make sense in Bilbao due to the climate conditions.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S29</td>
<td>I know the difference between solar thermal technology and solar photovoltaic technology.</td>
<td></td>
<td></td>
<td>1</td>
<td>0.52</td>
</tr>
<tr>
<td>S30</td>
<td>Citizens of Bilbao do not know what measures improve the energy efficiency of a dwelling, for example where heaters</td>
<td></td>
<td></td>
<td>0</td>
<td>0.38</td>
</tr>
</tbody>
</table>
6. Discourses on urban low-carbon transitions: a Q analysis

Factors

<table>
<thead>
<tr>
<th>S#</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>q-sc</td>
<td>z-sc</td>
<td>q-sc</td>
<td>z-sc</td>
<td>q-sc</td>
</tr>
<tr>
<td>S31</td>
<td>I don’t trust solar technology and its guarantees.</td>
<td>-1</td>
<td>-0.31</td>
<td>-2</td>
</tr>
<tr>
<td>S32</td>
<td>I would rather improve the insulation of my facade than install solar panels.</td>
<td>2</td>
<td>0.85</td>
<td>0</td>
</tr>
</tbody>
</table>

6.4. Low-carbon transition discourses in Bilbao

After a process of interpretation, we identified four distinct archetypical discourses. These discourses represent existing perspectives held by the actors interviewed. They are referred to here as follows: Discourse A or ‘follower’, Discourse B or ‘visionary’, Discourse C or ‘pragmatist’ and Discourse D or ‘sceptic’, interpreted from factors A, B, C and D respectively.

The follower discourse is highly driven by disbelief in one’s own ability to act and by the need to follow others in relation to energy decisions. However, respondents do think that energy is a local issue. This discourse accepts that resource scarcity and climate change arise due to anthropogenic causes and recognise the vulnerability of Bilbao in relation to them. Furthermore, this discourse views regulatory frameworks as critical and believes that any action at local level would be difficult without the support of scientific research. Additionally, action should be shared with higher institutional levels. Stakeholders following this discourse feel a great deal of social empathy. However they lack experience and knowledge about the thinking and motivations of social communities. As a result, they do not think that social communities have a key role to play in a potential transition to a low-carbon scenario. For them action is a top-down issue.

The visionary discourse is strongly driven by a forward-looking attitude. This discourse has a clear socio-technical profile: it is driven by distrust in the determination of formal institutions and in radical positions about energy matters. Visionaries believe action is
required now and that institutions are failing to assume their responsibility in leading the process of change. Particularly, the proponents of this discourse are concerned about the priorities set by the local authority, given that energy efficiency issues are not reflected in local government plans. The stakeholders who hold this discourse believe that information to the public might be manipulated to serve political gains. This discourse is also characterised by high levels of confidence in bottom-up actions and in the ability of cities to stimulate niches of innovation and transformation. It is also associated with strong pro-social and environmental attitudes. Stakeholders with this vision believe in the need for regulatory frameworks as key stimuli and in the need for scientific support to formulate energy transition strategies.

The pragmatists are mainly characterised by short-term, problem-oriented thinking. They place a high level of trust in public institutions and governance processes. Proponents of this view form a discourse whereby responsibilities in an energy transition should be shared at urban and regional government scales. This discourse is the only one that strongly believes in local ability to start a transition. Its proponents view regulations as key instruments and represent a group at the interface between science and policy. They also believe in top-down action, and social participation is not central to this discourse. Instead they believe in individual ability to change the status quo but prefer not to rely on grass-roots social movements as catalysts of change. They do believe in the anthropogenic causes of climate change, which distinguishes them from the sceptic discourse.

Stakeholders who do not believe that climate change is anthropogenically driven make up the sceptic discourse. Consequently, they do not believe that Bilbao is vulnerable to such impacts. Yet this discourse is based on the perception that fossil fuels are increasingly scarce and that current energy demand is relatively too large. It mainly represents an economically driven viewpoint, as for the actors in this group the economy is believed to be the central motive for encouraging action towards an energy transition. In terms of alliances, they do not value scientific knowledge and think that the local scale has neither a significant role nor enough legal power in energy matters. Bottom-up actions, individuals and communities are not prioritised in their line of thinking although they trust in individual actions to improve local energy performance. They mainly place the
responsibility for potential change in the hands of regulatory frameworks. Interestingly, this discourse is also based on the idea that even in times of financial crisis it is possible to make structural changes towards an energy transition.

We find consensus between the discourses in terms of both agreement and disagreement (see results in Tables A4 and A5 in the Appendices). Some of these findings are remarkably interesting: there is a high degree of agreement regarding the ideas that in the Basque Country more energy is consumed than necessary (see S6 in Table 3) and that fossil fuels are scarce (S2). Because of this, and also somehow motivated by the aspiration of achieving an economically independent region (S14), all discourses agree that some kind of action is needed. If part of the solution lies is energy efficiency and renewables, there is a wide consensus that it must be accompanied by regulatory frameworks (S9) that set minimum requirements and make certain measures compulsory for the building sector, industries, etc.

The four main discourses identified in the analysis also concur in the view that practical measures such as the development of district heating plants should be neither rejected nor prioritised. This lack of positioning contrasts with the fact that such measures have a long history in other regions such as Scandinavia and are currently being promoted throughout Europe (Hawkey et al. 2012). Finally, all four discourses agree that the cloudy weather in Bilbao is not the cause of the relatively low level of implementation of solar photovoltaic (PV) systems in the city (S28). In fact, Bilbao has optimal irradiation conditions according to the PVGIS\textsuperscript{45} estimates of long-term monthly averages (Grauthoff et al. 2012).

Other statements representing social behaviour (about the individualism of the citizens of Bilbao, S23) and participation (about the need for social participation to improve the decision making process, S20) lie in non-prioritised or almost neutral areas in all four discourses. This suggests that the role of local communities in contributing to the co-

design and co-development of the city is not yet shared in the discourses and cognitions of key actors at this time.

6.5. Placing discourses from Bilbao within the Sustainable Urban Transformation framework

The discourses identified through the Q-method can be used to provide a cognitive input in a UST framework. Arguably, the predominance of the ‘visionary’ framework can be considered to contribute the level of creativity, innovation and experimentation that a process of change needs. It would lead to a transition type Path 1 (see Chapter 3, Fig. 3.4, p. 80) which results in the higher degree of sustainability and the higher degree of change in the short term. This discourse can be thought of as essential for being able to engage those sharing a ‘follower’-type approach by generating a self-confidence arena. In addition while those stakeholders who have a more practical approach to problem solving also need to be actively involved as they can bring to the process the faith in institutions that it requires, ‘sceptics’ may be the key barrier to urban low-carbon transitions.

Although a Q study neither requires a representative population sample nor provides empirical objectivity about the population’s understanding of the world (Robbins and Krueger 2000), in this study we set out to bring together a wide variety of stakeholders with interests in energy management (intermediary organisations). Correlating the different discourses with the types of stakeholder might help to determine the gap between stakeholders with different levels of responsibility and power (e.g. local and regional authorities) and those who could be drivers of the process of transition. Figure 6.2 illustrates this correlation and Table 6.3 provides information about the number of interviews made to each sector or type of actor.
Discourse A: follower
- Local Authority, 2
- Consultancy, 1

Discourse B: visionary
- Citizens Associations, 1
- Research organisation, 4
- Consultancy, 3
- Public Development Agency, 1
- NGO, 1

Discourse C: pragmatist
- Research organisation, 2
- Consultancy, 1
- Local Authority, 1

Discourse D: sceptic
- Regional Authority, 3

Figure 6.2 Bilbao stakeholders represented in each discourse

Table 6.3 Number of interviews (count of Q sorts) made to each type of stakeholder and stakeholders flagged in each discourse A, B, C and D.

<table>
<thead>
<tr>
<th>Type of stakeholders</th>
<th>Count of Q sort</th>
<th>Count of Flagged A</th>
<th>Count of Flagged B</th>
<th>Count of Flagged C</th>
<th>Count of Flagged D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Citizens Associations</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Consultancy</td>
<td>5</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Local Authority</td>
<td>4</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Media</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Nongovernmental organization</td>
<td>4</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Political Party</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Public Development Agency</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Regional Authority</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Research organisation</td>
<td>7</td>
<td>0</td>
<td>4</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Social movement</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Energy Cooperative</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Grand Total</td>
<td>32</td>
<td>3</td>
<td>10</td>
<td>4</td>
<td>3</td>
</tr>
</tbody>
</table>
Discourse D (sceptic) is closely related in Bilbao to actors who have some regional
decision making power. By contrast, those who work in the local authority are
represented more strongly by Discourse A (follower). This is not conclusive, but it
suggests a potential barrier between visionaries and pragmatists and decision-makers
which may possibly erode the creativity, innovation and experimentation processes that a
transition process would need. Based on this, we argue that the inclusion of Discourse B
(visionary) in decision-making processes by means of institutionally diverse and
participatory approaches may be the first step towards the development of the transition
arena. The potential problems are likely to be related to the uncertainties of scientific
knowledge and perceptions of risk, distributions of legal authority between local and
regional authorities and ways of engaging with grass-roots movements and communities
in the quest for a transition process.

### 6.6. Implications for Sustainable Urban Transformation policy practice: lessons from Bilbao

In line with this identified need to strengthen local and regional leadership, the literature
on urban climate governance (see e.g. Burch 2010; Carlsson-Kanyama et al. 2013)
highlights three key types of drivers of local climate action: (i) external institutional
support through for instance regional, national or international financial support or by
providing guidelines and training to decision makers about how to develop climate
strategies; (ii) commitment by local authorities in leading climate action and involving
stakeholders, (communities and individuals) in the development of urban plans; and (iii)
investing in local know-how on climate policies. Barriers and opportunities to UST can
be identified under these same determinants.

Most of the stakeholders in Bilbao highlight that in practice the economic recession is one
of the main causes of the decrease in investments in the energy sector and in better
environmental management. However, the results of the Q study show that stakeholders
also believe that this should not preclude action and that they might not be willing to
remain in a context of austerity. Nevertheless, in practice stakeholders are locked into the
reasoning that the main barrier is a lack of funding available to restructure the city’s energy model, blocking creative ways of starting an energy transition process. When there is a significant agreement regarding that action is needed to start a meaningful transformation, this evidences acceptance of the need to innovate, renew, and find alternative ways to change social and economic structures that are not uniquely dependent on fiscal budgets.

The signing of the Covenant of Mayors by the mayor of Bilbao and the development of the Sustainable Energy Action Plan have not yet sufficed to kick-start a transition processes. We concur with Hodson and Marvin (2010) that urban policy, at least with respect to local energy strategies, seems to be rooted in hidden, occasional interests that do not stem from a shared long-term vision of urban development, regardless of the strong potential of discourses based on achievable low-carbon visions, i.e. discourses B and C.

Mitigation actions are often more directly related to cost-savings, and thus are often seen as actions that are easily rewarded in the short run. Local authorities therefore prefer to invest in mitigation strategies (rather than adaptation), and are more willing to achieve cost-effective transformation through these means. However, in practice the change may not be significant if urban lifestyles and development patterns do not follow suit and transform themselves too. As one of the interviewees argued regarding household energy consumption: “If you find a 50 Euro note, would you take it? [...] With our way of consuming energy [in households] we are continually throwing away 50 Euro notes and nobody is picking them up. [...] It is easier to act on what we see than on what we cannot see”. Part of this situation is due to the lack of knowledge regarding how and where cost-effective alternatives might be found that can bring about real change in our use of and dependence on energy.

Previous studies show that although green commitments help to win votes at local scale (e.g. Crabbe and Robin 2006; Burch 2010), in the case of Bilbao there has been strong public rejection of potentially greener projects related to district heating. But it is the lack of information about possible options for the location of district heating plants that has been the key determinant for the rejection of these projects in Bilbao. This kind of action
aligns with the results of the Q method as it suggests that participation in Bilbao is not seen as an important or key process in decision making.

Based on the main discourses and on the timid action taken on the ground by the local government towards an energy transition I argue that both enhancing the flow of information to the public and strengthening technical training to the local administration could help make progress in the transition to a low-carbon city. This concurs with studies about the factors that determine the effectiveness of climate strategies (Arnell et al. 2005; Blanco et al. 2009; Tompkins et al. 2010; Polasky et al. 2011; Smith and Stern 2011; Asrar et al. 2012; Lemos et al. 2012; Ren et al. 2012).

Enhancing the understanding by local authorities of transition pathways has also been repeatedly identified as a way of overcoming barriers to climate action (Urge-Vorsatz et al. 2007; Amundsen et al. 2010) (in fact, I address this through the FCM analysis developed in Chapter 7). Regarding the role of technology in transitions, for example, in the case of Bilbao the four major discourses revealed by the Q method show considerable confidence in the role of technological solutions. Through the interviews I observed that in many cases people were confused as to the actual differences between PV and thermal technology and as to their benefits. This in turn created a negative view of solar energy (e.g. using the cost of maintenance as a criterion for rejecting PV installation). Interestingly though, the results of the Q method highlight that the perceived knowledge about technology is overestimated as all four discourses agree that understanding of technological solutions is not a barrier.

More importantly, the results of this study concur with the view that actions involving social behavioural change aimed at low-carbon strategies in cities have to be informed by downstream representatives (Parag et al. 2013), i.e. communities and social movements, in order for cost-effective and equitable solutions to be drawn up in the longer run. Higher doses of involvement by actors with different ideas about what a low-carbon transition is, in line with to their own interests, may perhaps help to strengthen social innovation experiments that provide complementary support for low-carbon transitions (Khan 2013).
Finally, from these finding we conclude that higher levels of stakeholder participation\footnote{See Footnote 12. Here I refer to stakeholder participation and not citizen or social participation processes in general.} and networking, in which knowledge, expertise and interests are shared, may help to bring about more effective engagement in transformation processes, as they enhance confidence in one’s own capabilities and increase the opportunities for partnerships that could eventually break unsustainable patterns in urban development.

### 6.7. Conclusions

This chapter has examined a context-specific setting by means of a case study in the city of Bilbao. We explore the perceptions and visions of different stakeholders in order to better understand the cognitive domain that underpins the barriers to and opportunities for a low-carbon transition.

The case of Bilbao highlights the importance of building networking mechanisms at local level. Participatory decision-making processes can help to link visionaries and pragmatists with decision-makers, thus aiding them to recognise the opportunities for a transition. We identify three main “hidden” viewpoints and contrasting opinions about (i) the role of science and knowledge as supports for the means for defining and guiding transformation strategies; (ii) the role of stakeholder participation in decision-making processes as a way of engaging actors in the process of transformation; and (iii) the role of local and regional regulatory powers and responsibilities in the development and implementation of actions in energy transition plans. Unless these three questions are addressed, key barriers to kick-starting a transition processes in Bilbao will remain.

Urban sustainability transitions require investment in collective action by citizens, researchers and public and private organisations and the full range of community stakeholders (Pickett et al. 2011). This can take the form of innovative experiments (Castan Broto and Bulkeley 2013) or partnerships (Frantzeskaki et al. 2014) that initiate a
change under a set of common objectives i.e. a shared cognitive base (Antal and Hukkinen 2010). Participatory approaches for urban sustainability management are crucial as they not only increase the chances of initiating transitions but also help actors feel that they are the owners of the results (Bailey et al. 2012). New tools now include for example methodologies for generating visions of low-carbon urban futures or so called “transition arenas” (Nevens and Roorda 2014). However, here we highlight the need to implement new ways of identifying social-cognitive barriers and opportunities that affect actors so as to initiate and negotiate such transitions. This chapter has sought to contribute to this shared effort.

6.8. Summary

The main points of this chapter can be summed up as follows:

- This chapter uses the case study of Bilbao to analyse whether stakeholders perceive a need for change, and if so how.
- The Q method is applied. This is a semi-quantitative method that seeks to group stakeholder perspectives around a number of viewpoints. From interviews and reviews of media and newspapers, 32 statements related to the potential transformation of Bilbao into a low carbon city were extracted. 32 stakeholders participated in this study by prioritising these statements.
- 4 main discourses were obtained: Discourse A (follower); Discourse B (visionary); Discourse C (pragmatist); Discourse D (sceptic).
- Discourses in the Q method are not meant to be representative of the population of Bilbao but representative of the perspectives that exist, even if they represent a minority.
- Discourse D is closely related in Bilbao to the regional decision-making level, and therefore to the regulatory power. Local authorities are, by contrast, highly represented in the ‘follower’-type discourse: this means that they will not be acting as drivers of transitions.
6. Discourses on urban low-carbon transitions: a Q analysis

- This study shows the need to strengthen institutionally diverse, participatory approaches in decision-making processes to activate the so-called transition arena in Bilbao.
- Urban sustainable transitions require collective action from both citizens and public and private organisations and this requires a shared cognitive base originating from a set of common objectives i.e. a common vision.
- The Q method has proven useful in identifying the main barriers to and opportunities for low-carbon transitions and in general in bringing to light the perspectives of actors when planning urban sustainable transitions.
- The chapter concludes that social-cognitive barriers and opportunities that influence actors to initiate and navigate such transitions need to be further considered in studies related to urban transition research.
Chapter 7

A fuzzy cognitive modelling approach to resilience and transformation

RESULTS OF APPLICATION TO THE CASE STUDY OF BILBAO

“Why (science-fiction writers take note) would we invent new categories and labels for things when we can aid comprehension by borrowing old ones, even if the physical resemblance is negligible?”(Ball 2013, p.425)
Chapter 7. A fuzzy cognitive modelling approach to resilience and transformation

7.1. Introduction and structure of the chapter

The conclusions of the conceptual and empirical analyses developed in the previous chapters point out to the cognitive dimension as an important influence factor in resilience and transformation management. Perceptions of stakeholders regarding what benefits are perceived from the environment (and in which way), are critical for the management process of sustainable urban transformation, as concluded in Chapter 4.

In general we can say that the cognitions and perceptions of decision-makers in the form of heuristics, biases and prior experience (Schwenk 1988), impact on strategic decisions, including those concerned with resilience and transformation management. Cognition affects leadership processes, policy-making and governance culture, three aspects which are critical in sustainable urban management. Cognitive processes are mental processes of perception, memory, judgment, and reasoning (see Fig. 1.4, Chapter 1, p. 18) and relate to the action of acquiring knowledge and understanding through thought, experience, and the senses. Sustainability policy-making is difficult to see as something purely rational, and a cognitive approach is considered appropriate (Boulanger 2005). Following Adger and others (2012), here it is argued that understanding these mental processes can help to better inform processes of adaptation and transformation, particularly by means of participatory approaches which aggregate diverse perceptions and multiple scales. Such approaches might be based, for example, on the Q method (see case study in Chapter 6, p. 191) or on mental models (e.g. fuzzy modelling) among others.

As discussed in Chapter 2, in the context of climate change, it is increasingly recognized that marginal changes towards adaptation might not be sufficient to deal with the challenges that climate change poses. Instead, radical transformation approaches are required (Kates et al. 2012; O'Brien et al. 2012; Park et al. 2012). Furthermore, transitions

to post-carbon economies require not only radical but also rapid implementation of policies that are socially and politically supported (Wiseman et al. 2013). Particularly, argued in Chapter 3 above (p. 69), the role of cities as hubs of change and transformation could potentially turn the anticipated climate crisis into new opportunities (see e.g. Seto and Satterthwaite 2010; Romero-Lankao and Dodman 2011; EEA 2012). According to various authors, this would require new types of knowledge acquisition for robust resilience management (Beratan 2007) and transition management i.e. to plan and manage the process of change (van de Meene et al. 2011; Nevens et al. 2013). In the context of cities, this includes information about stakeholders’ knowledge regarding how urban systems work and how they might react to certain stimuli.

This chapter adds to this discussion by focusing on an urban energy model drawn from the city of Bilbao as an example. It is based on the idea that collective expert knowledge enriches the process of decision making when planning for change, especially when radical transformation, i.e. involving significant impacts, is at stake.

Drawing on previous work on fuzzy cognitive modelling applied to the resilience management of social-ecological systems (Kok 2009) and on the potential of fuzzy thinking for addressing complex urban problems (Habib and Shokoohi 2009), this chapter applies the Fuzzy Cognitive Mapping (FCM) approach (described in Chapter 5) as a participatory tool for modelling the structure and dynamics of urban energy systems. In particular, I aim to use the FCM approach to visualise and interconnect the different elements that play a role in local energy use and its impacts in the city of Bilbao, Basque Country. How the data was collected has been described also in Chapter 5.

By using the FCM approach here stakeholders’ cognitions are captured on: (i) key components of the urban energy system; (ii) key connections between those components; and (iii) the strength of those connections. I argue that knowledge of these three issues, as stakeholders perceive them, is a key input for understanding the hidden mechanisms that affect urban decision-making and thus advancing understanding of the technological, social, institutional and ecological mechanisms of sustainable urban transformation.
processes (McCormick et al. 2013). The chapter also explores the benefits of FCMs in urban resilience and transformation management by generating scenarios based on alternative action pathways proposed to achieve a low carbon sustainable future in Bilbao.

The chapter is structured as follows: Section 7.2 presents the results in Bilbao and discusses the resulting network structure in the context of resilience and sustainability. Section 7.3 simulates various scenarios of alternative transition pathways. Section 7.4 compares these scenarios in terms of sustainability. Section 7.5 presents conclusions, highlighting the benefits of this approach. The last section summarises the chapter.

![Figure 7.1 Structure of chapter 7](image)

### 7.2. Modelling resilience and transformation using FCM

The FCM approach is generally used to represent the behaviour of complex systems through causal reasoning. Using this approach I respond to two questions posed in this

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48 See recent special issues such as ‘Cities, Urbanization and Climate Change’ in *Urban Studies* (Vol. 50 (7), May 2013), ‘Advancing sustainable urban transformation’ in *Journal of Cleaner Production* (Vol. 50, July 2013) and ‘Urban retrofitting for the transition to sustainability’ in *Building Research and Information* (Vol. 41, Issue 5, July 2013).
dissertation (see Chapter 1, p. 10): I address complexity in cities through a network approach understanding cities as systems of interconnected elements and I use cognitions of stakeholders to understand random decision-making related to their way of perceiving how cities work. The main output of the FCM approach is an aggregated network of concepts and weighted interconnections that may be also used for scenario development.

In line with the above and with the literature reviewed in Chapter 2 (see p. 33) on resilience management, the network perspective used in FCM, is also helpful to analyse complex environments (Janssen et al. 2006b) and it can complement other types of resilience analysis by exploring the structure of the social-ecological system itself. The complexity of operationalising the concept of resilience has been argued before in the literature (Cumming et al. 2005). This complexity also translates to urban systems, especially if one considers that in urban resilience is two-sided and cannot be seen as a normative positive concept (Chelleri and Olazabal 2012a; Waters 2012). Therefore, it needs to be assessed in current and alternative future conditions in ways that is coherent with the "non-equilibrium view" of resilience, as put by Pickett et al. (2004).

The network that results from FCM can be described mainly in terms of its density (D) and the centrality of its components (Ct) (see description of the method in Chapter 5, p. 181). D indicates the general connectivity of the network and it is the result of dividing the number of existing connections by the number of total potential connections. A larger number of concepts indicates a larger number of potential connections. It is thus often assumed that a higher density indicates more possibilities of change, as there are more connections in the network. Additionally, if these connections are perceived by the actors of the system, such actors might turn into “catalysts of change” (Özesmi and Özesmi 2004). Ct, indicates the level of connectivity of each concept (Reckien et al. 2013a) and is in turn an additive function of the concept’s in-degree (I), i.e., the strength of the influence of a concept on other concepts, and out-degree (O), the strength of the influence of other concepts on itself (Özesmi and Özesmi 2004). The strength of such influence is calculated as an additive function of the weights of the connections to or from the concept being analysed. This way, the larger the number of connections to or from a concept, the larger the possibilities Ct having a higher value, i.e. the concept being characterised as having higher connectivity in the network. In other words, a network with high levels of
As discussed in Chapter 3 (see p. 76), connectivity is often taken as a feature of resilience in the urban resilience literature (see e.g. Ernstson et al. 2010b; Ahern 2011). As argued by Ahern (2011), connectivity is generally high in the built environment where it allows the system to continue functioning in the face of shocks. It therefore correlates positively with increasing resistance, i.e. protecting the urban system against these unexpected impacts. Following this idea, an overconnected system can also lead to undesirable outcomes due to an increase of the rigidity in its control (Holling 2001). Elaborating on this, and as concluded in Chapter 3 when discussing urban resilience determinants (see p. 76) here I further argue that, either referring to the network in general or to specific elements, for connectivity to be beneficial in an urban resilience management context it must also be accompanied by a high degree of redundancy of elements in the network that provide the same services as those elements likely to be vulnerable to shocks.

In the context of transformation management, network connectivity is not necessarily a desirable property of the system. If connectivity increases, the number of non-linear feedbacks might also increase, and when planning for transformation this implies having to deal with a more complex system, since more variables and connections among variables would need to be controlled for and the number of possible futures might increase exponentially. For this reason, building scenarios can be helpful. Although, it is in fact one of the most interesting although not fully exploited applications of FCM, scenarios cannot be used for predictions. In this line, arguably, they do not offer sufficient information about the magnitude of the efforts in terms of policy actions. However, scenarios are suitable policy tools by providing “alternative and often competing ideas on which it [the future] may unfold” (Jetter and Kok 2014, p.11), being great policy tools.

The development of scenarios (using Eq. 5 in Chapter 5, p. 181) through the idea of connectivity can be based on the combination of policy measures which control a set of key elements of the network. Thus, they can be used to optimise the occurrence of positive (desired) impacts on the system. The scenarios that are built based on the modelled network can therefore be interpreted as what might happen in the future if
alternative sets of policy options are used. This is done in the context of the collective knowledge that best illustrates the complexity of the system. It follows that an alternative transition pathway is represented by a combination of policy options that condition the state of one or more key elements of the network. For modelling purposes, this is done by setting a fixed value on an outgoing influence of a variable, so that all incoming influences are also blocked. Variables can also be removed from the network given the assumption that they have no significant influence over the other elements in the network.

The following Section 7.3 analyses network characteristics. Based partly on the results of the discourse analysis developed in Chapter 6, Section 7.4 develops the scenarios chosen for this case study.

7.3. Network analysis in the context of resilience and transformability

7.3.1. Network development

As described in Chapter 5, 14 stakeholders were interviewed. FCMapper was used to aggregate the individual maps collected in these interviews. This process resulted in a network (or map) (see Figure 7.2) that comprises 86 concepts, hereafter referred to as ‘variables’, and 161 linear connections.

The variables are organised into nine groups according to thematic issues: (1) Environment & resources; (2) Innovation & opportunities; (3) Social behaviour; (4) Local competences; (5) Economy; (6) Lifestyle; (7) Governance; (8) The energy business (i.e. the corporate energy sector); and (9) Supply & demand. The network is represented as a visual map in Figure 7.2. Negative connections (negative $w_{ij}$) are represented by dotted lines. Positive connections (positive $w_{ij}$) are represented by solid lines.

This map represents the urban energy network as seen by a group of stakeholders with interests in energy management, production, supply and consumption in the city of Bilbao. An analysis of this network can provide information about the most important elements according to the stakeholders and also can provide information on the level of
7. A fuzzy cognitive modelling approach to resilience and transformation

connectivity $C_t$ and density $D$ of the network which is a measure of the complexity and intrinsically related to urban resilience. This analysis can be found in this section.

On the other hand, this network developed by the stakeholders can also provide information about how the system would perform under different scenarios which is a way to test different energy policy options. Moreover, if one establishes sustainability objectives, such scenarios can be compared and therefore, a learning process can be established as policies can be improved by developing negative impacts mitigation strategies or strategies that strengthen the positive impacts of such policies on sustainability. This information can be extremely helpful in urban decision-making being a great support to develop successful transformation strategies. The scenario analysis is developed in Section 7.3.
Figure 7.2 The cognitive urban energy map of Bilbao in graphic form.
7.3.2. Network analysis

The network has a density index (or $D$ index) of 0.022 (see Eq. 2 in Chapter 5). This means that 2.2 per cent of the maximum number of connections that could potentially exist in theory between the 86 concepts ($D_{\text{max}} = 1$) are actually made. Unless this value is compared to another network representing a similar topic (see e.g. livelihoods comparison in Murungweni et al. 2011), there is no way of knowing whether this is a low or high level of connectivity in an urban energy context. In general terms, given that the aim is to stimulate transformations towards a low carbon system, it is assumed that a high density is desirable. But of course, having the seeds to stimulate a change does not mean that the change will lead to desirable impacts. Controlling the agency of change or transformation is critical if the aim is to generate more sustainable and resilient urban energy systems.

Figure 7.3 compares the different levels of the indicators $C_t$, $O$ and $I$ (Centrality, Outdegree and Indegree, see Eq. 3, 4 and 5 respectively in Chapter 5) for those with significant a significant $C_t$ value (see complete list of network indices results in Table 7.2 in Section 7.3 of this chapter). For the sake of comparison, Figure 7.3 only shows the indices relative to the maximum $C_t$ i.e. $C_t$ max 13.25 observed in Energy price (households), which means that from the stakeholders’ perspective this is the most strongly connected variable. In general, the variables grouped under energy “Supply & demand” (Group 9) are more central. The high $C_t$ of some variables, such as Energy Lobbies, is due to their having a relatively high out-degree index, i.e. they have a high level of influence on other elements of the network. Conversely, other variables of the network, such as Energy Efficiency, owe their centrality to a high in-degree, I. Thus, Energy Efficiency plays an important role in the energy network of Bilbao because of its high sensitivity to changes in a large number of other variables in the network.
Discussion of the results

As I have previously argued, although debatable (see discussion in Chapter 3, p. 71 about the pros and cons of connectivity as a determinant of urban resilience) $C_t$ as a measure of connectivity is often taken as a feature of urban resilience. In the case of Bilbao, the high level of network connectivity in general, and specifically of some of the variables that are key entry points for low carbon management (for example energy use in households or energy use in transport), makes its energy system management complex, and is thus likely to hinder the establishing of smooth transition pathways.

It can be argued that variables with high connectivity ($C_t$) due to a high level of outgoing influence ($O$) and with a low level of incoming influence ($I$), can be used to control the behaviour of the system. In this case, it is not surprising to identify the variable Energy Lobbies as that one that has the highest control level of the energy system in the city of Bilbao. Other variables with high outgoing influence are: Energy price (households), Energy use in Households and Energy/Climate policies/regulations (see Figure 7.3).
However, these can be significantly influenced by other variables in a way that cannot be considered control variables as such. It is also interesting that, from the above mentioned variables, only, *Energy use in households* and *Energy/Climate policies/regulations* can be controlled through community action, social awareness strategies or urban policy actions. This translates into interesting potential scenarios of transitions stimulated at local level (see for example Scenarios B and C in the following section; see Table 7.1).

If we come back to the results of the study of the discourses around the potential of low carbon transitions in Bilbao (see Chapter 6, p. 197), this explains why, discourses such as Discourse D ‘sceptic’ can prevail if *Energy Lobbies* are seen by the stakeholders as those that have the most influential nature in the energy system of the city. It was also identified in the discourses study, that the predominance of the ‘visionary’ framework can be considered to contribute the level of creativity, innovation and experimentation that a process of change needs, and that it would arguably lead to a transition type Path 1 (see Chapter 3, Fig. 3.4, p. 83) which results in the higher degree of sustainability and the higher degree of change in the short term. This discourse should be strengthened in the city to gain control over the other most influential variables such as *Energy use in households* and *Energy/Climate policies/regulations*.

### 7.4. Scenario analysis

#### 7.4.1. Generation of scenarios

The generation of scenarios is a key process in decision-making and, as argued above, it is one of the most interesting applications of FCM. The development of scenarios linked to the idea of connectivity should be based on combined policies and measures that can control a set of key elements of the network and therefore maximise the occurrence of positive (desired) impacts on the system. The scenarios based on the modelled network can be interpreted as what might happen if sets of policy options are enhanced in line with collective knowledge that better illustrates the complexity of the system. Here, an alternative transition pathway is represented by a combination of policy options that
condition the state of one or more key elements of the network. For modelling purposes, this is done by fixing the value on the outgoing influence of one or various variables, i.e. by setting the value $A_i^{(k+1)}$ (see Eq. 1 in Chapter 5). By setting a fixed value on the outgoing influence of a variable, all incoming influences are blocked. Variables can also be removed from the network on the hypothesis that they have no influence over the other elements in the network.

Here three scenarios are proposed based on alternative action pathways intended to achieve a low carbon future in Bilbao, based on current debates on sustainable urban transitions. In Scenario A the focus is on the use of financial incentives. An approach of using subsidies established by local government for example, for the rehabilitating of buildings by lower income households, is maintained and the financial crisis is assumed to be overcome (Fixed value = 0, see Table 7.1). This scenario has been previously argued by stakeholders in the case study to be critical (see Chapter 6). In Scenario B, a transformation needs to be motivated by bottom up initiatives and the focus is placed instead on pursuing a strong public educational and awareness campaigns. In this scenario a combined strategy to increase information to citizens, education, and awareness is implemented with the aim of analysing the effect of social behavioural change towards a low-carbon transition. Lastly, in Scenario C, transformation needs to be catalysed by a top down policies and institutional motivation. This scenario is focused on strengthening local institutional initiatives so that local decision makers are the main drivers of change for example by strengthening the local policy framework favouring energy efficiency and climate action. Fixed values have been set arbitrarily for demonstration purposes but relatively high (between 0.7 and 0.9) or low (between 0 and 0.2) values are always maintained.

Table 7.1. Scenarios and fixed values used as input for the FCMapper software

*Fixed values range from 0 to 1, with 1 being the maximum influence and 0 no influence*

<table>
<thead>
<tr>
<th>SCENARIO A Optimisation of economic incentives</th>
<th>Fixed value</th>
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<tr>
<td>List of variables influencing Scenario A</td>
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<tr>
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<td>Economic Incentives</td>
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The extent of the change in each element of the network resulting from each of the three scenarios is shown in Table 7.2.

Table 7.2 Complete list of variables (classified in thematic groups) and main results of the FCM scenario and network analyses

Table A4 summarises the results of the experiment: network analysis (Section 7.2) and scenario generation (Section 7.3). The scenario results show the degree of change in each variable under the conditions of each of the Scenarios A, B, C and B&C. The parameter is scaled from +4 to -4, with +4 being the strongest positive change and -4 the strongest negative change. The tables also show each of the variable management objectives established in this experiment (‘+’ when a positive change is desirable and ‘-’ when a negative change is desirable). The analysis of the network includes the out-degree, in-degree and centrality of each variable, and whether they are purely transmitting or receiving variables. For example, Air pollution (Id.1), changes strongly in Scenario A until the maximum degree (+4) relative to its original value. This means that the levels of air pollution will increase strongly if alternative pathway A is taken. By contrast, Air Pollution levels significantly decrease (degree of change: -3) in Scenarios B, C and in the combined B&C.

<table>
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<th>NETWORK (b)</th>
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**VEHICLE COMMISSION**
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<td>GROUP 2 Innovation &amp; opportunities</td>
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<td>8</td>
<td>Business/economic activity generation</td>
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### 7. A fuzzy cognitive modelling approach to resilience and transformation

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<td>0</td>
<td>0</td>
<td>-</td>
<td>0.80</td>
<td>0.00</td>
<td>0.80</td>
</tr>
<tr>
<td>71</td>
<td>Public budget</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>+</td>
<td>0.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>72</td>
<td>Regional policy initiative</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>+</td>
<td>1.50</td>
<td>2.10</td>
<td>3.60</td>
</tr>
</tbody>
</table>

**GROUP 8 Supply & demand**

| 73 | Energy efficiency | 2  | 4  | 4  | 4   | +    | 1.20 | 5.40 | 6.60 |
| 74 | Energy price (households) | 2  | 3  | 3  | 3   | +    | 6.38 | 6.75 | 13.13 |
| 75 | Energy price (industry) | 2  | -2 | -4 | -4  | -    | 0.90 | 1.00 | 1.90 |
| 76 | Energy use in households | 4  | -4 | -4 | -4  | -    | 4.85 | 5.40 | 10.25 |
| 77 | Energy use in industry | 0  | 0  | 0  | 0   | -    | 0.50 | 0.00 | 0.50 |
| 78 | Energy use in municipal services | -2 | -2 | -4 | -4  | -    | 0.25 | 0.50 | 0.75 |
| 79 | Energy use in transport | 4  | -4 | -4 | -4  | -    | 2.20 | 3.70 | 5.90 |
| 80 | Energy used in non-material resources | 1  | -1 | -3 | -3  | -    | 0.00 | 0.25 | 0.25 |

**GROUP 9 Energy business**

| 81 | Energy lobbies | 0  | 0  | 0  | 0   | -    | 7.55 | 0.60 | 8.15 |
| 82 | Energy security | -1 | 1  | 1  | 1   | +    | 0.80 | 0.60 | 1.40 |
| 83 | Green/alternative energy availability | 4  | 3  | 1  | 3   | +    | 2.95 | 1.00 | 3.95 |
| 84 | Networks/infrastructures | -1 | 1  | 1  | 1   | n.a. | 2.30 | 0.50 | 2.80 |
| 85 | Specialised technical energy services | 0  | 0  | 0  | 0   | +    | 1.60 | 0.00 | 1.60 |
| 86 | Technical inspections | 0  | 0  | 0  | 0   | n.a. | 0.50 | 0.00 | 0.50 |

(a) Shaded cells represent the variables whose value is fixed for the generation of each of the Scenarios (see Table 7.2)
(b) M.O.: Sustainable Management Objectives: + (a positive change is desirable), - (a negative change is desirable), n.a. not applicable
(c) Network Characteristics: O=Out-degree, I=In-degree, Ct= Centrality
(d) Perceived quality of life is expressed in the negative sense, i.e. perceived worsening in quality of life
(e) This Spanish draft law, with provisions which are widely applied in other European countries, would benefit particular photovoltaic solar energy producers by allowing them to dump the excess onto the electricity infrastructure network and consume from it during night or low energy production hours.

### 7.4.2. Discussion of scenario results A, B and C

The percentage of variables that change under these scenarios is rather high (between 64 per cent and 74 per cent of change), which may be an indicator of the relatively high connectivity of the network, suggesting how complex it is to control a low carbon urban energy transition process as exemplified by Bilbao.
The results of Scenario A suggest a stimulus for the local economy. In this scenario, energy use declines as energy prices increase, mostly in lower income households. However, the results also show that focusing on such economic incentives does not sufficiently stimulate a change in lifestyles, which means that high-energy-consumption behaviour patterns are maintained. This suggests that strategies involving financial incentives should be accompanied by other measures for example actions to address a change in current lifestyle patterns. As shown in other sustainable urban scenario case studies (Naess and Vogel 2012) these results concur in revealing that consistent sustainability policies require multiple measures in many sectors and on many scales, not only institutionally but also socially-led. Scenario A also shows a perverse effect if the current financial incentives structure is maintained because, contrary to expectations, building rehabilitation decreases in Bilbao. According to various stakeholders, experience in Bilbao reveals that as financial incentives are not targeted at higher income households, their benefits (lower energy use, greater comfort) are often not sufficiently perceived by the majority of property owners, at least in the short term.

Scenario B is driven by strong education and awareness campaigns. It provides better results than Scenarios A or C. In this scenario, the strategy is designed to increase information to citizens, education, and awareness so that the benefits of potential social behavioural change and its contribution to a low-carbon transition can be studied. The results of Scenario B suggest that education, knowledge and awareness about current urban problems can result in the strengthening of local initiatives and an improvement in the local economy, especially in terms of attracting businesses related to renewable energy.

Scenario C is primarily focused on giving a key role to local authorities in driving the low-carbon transition by delivering energy and climate policies, regulations and building an urban strategy towards sustainability and resilience. This scenario also has good results but still suggests potential unintended effects such as an increase in household energy bills.

In line with the assertions of van Vliet et al (2010), some of the results of this analysis might denote a lack of rationality, as they lead to conclusions which might go against
existing scientific knowledge. As an example, the results of Scenarios B and C show an increase in High-energy consumption lifestyles. This might be seen as illogical given that the two scenarios result in a Change of lifestyles. Returning to the original aggregated matrix, it can be seen that the variable High-energy consumption lifestyles is isolated and not connected to others such as Change of lifestyles. This explains the irrationality and shows the need to review and complement these models with other sources of analytical approaches.

7.4.3. Optimising sustainability transitions

Given the large number of potential unintended effects of one-sided strategies which might, according to collective knowledge, result in undesirable or unstable transitions, and given the important role of social movements in building adaptive capacity (Barthel et al. 2013), I suggest a combined scenario: Scenario B&C (see raw results in Table A4 in Annex 3). This scenario combines Scenario B, representing bottom-up social action, and Scenario C, representing top-down local institutional action.

Figure 7.3 presents a comparison the ‘3+1’ scenarios created with a ‘sustainability reference scenario’ developed ad-hoc for the case study. In this scenario, the 86 variables are grouped into three sets (positive, neutral or negative) depending on the ‘desirable management objective’ in terms of sustainability for each variable (see Table 7.2, column “M.O.” meaning ‘Management Objective’). Clearly, this ‘desirable management objective’ must not be taken as a general reference as it serves merely for purposes of comparison in this study, in line with the authors’ experience in the specific context of Bilbao. According to this sustainability reference scenario, on the one hand there are variables that are associated with positive change (scaled from 1 (minimum change) to 4 (maximum positive change) relative to their original values) from a sustainability and resilience perspective (e.g. ‘Availability of resources’). These are referred to hereafter as positive-type variables. On the other hand there are variables that are associated with negative change (scaled from -1 (minimum change) to –4 (maximum negative change) relative to their original values) from a sustainability and resilience perspective (for example ‘Energy use in households’). These are referred to hereafter as negative-type variables.
Establishing a desirable sustainable objective for each variable might be difficult given that variables are not always verbalised in a positive sense (e.g. No local strategy). The FCM contains 51 positive-type variables and 29 negative-type variables under a Sustainability Reference Scenario for the Bilbao case study. Eight variables are considered ‘neutral’ i.e. they are not expected to undergo any significant change and their value is zero (see top of Figure 7.4). Positive-type variables are optimally located on the right side, which means that the more positive-type variables there are on the right hand side of the figure the greater the beneficial change that can be expected is. The most sustainable, most resilient location for negative-type variables would be the left hand side of the figure. Hence the more negative-type variables there are located on the left, the greater the beneficial change is in terms of a transition to a sustainable urban energy system in Bilbao.
The different figures represent the positive or negative changes caused by the variables in the network. The X-axis represents “strength”, which is the relative degree of change in the variable under the conditions of the new scenario. It ranges from +4 to -4, with +4 being the strongest positive change and -4 the strongest negative change. The Y-axis represents the number of variables. The graph shows positive-type variables (coloured in white and optimally > 0) and negative-type variables (coloured in black and optimally < 0). The grey bar shows the number of variables that do not suffer any change under the different scenarios.

Based on this assessment, the combined Scenario B&C provides better results than either B or C individually under two criteria: sustainability outcome and agency of change. In
Scenario B&C none of the positive-type variables decreases under the influence of the new system conditions. In addition slightly fewer negative-type variables increase. Both these facts result in a higher sustainability outcome. Also, the number of variables that remain unchanged significantly increases, which could be interpreted as the result of better control and agency in the process of transformation. All in all, this agency in Scenario B&C is achieved at the expense of a decrease in the number of positive-type variables that change positively.

7.5. Discussion

According to collective knowledge gathered through the individual fuzzy cognitive maps, the results of the case study in Bilbao suggest that a combination of top-down and bottom-up action provides greater sustainability in the new system. Factors such as the cost of implementing these policies and their robustness in the long run fall beyond the scope of this study, though they are critical if any energy transition plan is to be developed in a city.

One question still remains: do these policy options (or potential development pathways) guarantee that the system will change or that it will be resilient? The complexity of operationalising the concept of resilience has been argued before in the relevant literature (Cumming et al. 2005). It translates into the application of resilience to urban systems, especially if one considers that in this context resilience is two-sided and can no longer be observed as a normative positive concept (further explored in Chelleri and Olazabal 2012a; see Waters 2012). Therefore, it needs to be assessed in current and alternative future conditions (coherent with the "non-equilibrium view" of resilience, as put by Pickett et al. 2004).

Further, I find evidence of the two-sided perspective of resilience. As discussed in Section 7.2, connectivity of the network might be a double-edged sword. On the one hand, connectivity may be desirable as may translate into more seeds of change (Özesmi and Özesmi 2004) and could therefore provide more opportunities for self-organisation
after a shock if a process of transformation is undertaken. On the other hand, when there is a high level of connectivity, there might be more non-linear feedbacks, thus, change and transformation might be more difficult to control. As previously argued (see p. 213), this undesirability of a highly connected system is discussed by Holling (2001) arguing that an overconnected system can be rigid in its control thus increasing the vulnerability to unexpected disturbances. That is, when the number of direct and indirect drivers increases, the control in the agency of transformational change may become more complex and the change more difficult to manage. For example in Scenario A, due to high connectivity and the centrality of key elements of the network, the urban energy system in Bilbao may be highly resilient to financial changes i.e. in individual income or public budgets. But concurring with previous studies (Lopolito et al. 2011), I find that while economic incentives show a high level of connectivity within the network, the scenario analysis suggests that it can also lead to undesired impacts such as an increase in air pollution. In other words, the energy system is unlikely to undergo a process of transformation towards sustainability through economic incentives alone. In fact, such approach may lead to ‘mal-transformation’, restating dependency on energy consumption and thus leading to a deeper lock-in regarding unsustainable patterns of energy consumption. Also, reinforced positive impacts are obtained by combining local-institutional and community initiatives that fuel higher levels of environmental education, awareness and responsibility among citizens (i.e. Scenario B&C). Positively, in this combined scenario we have observed that there is an increase in the number of ‘neutral’ variables (variables that remain unchanged) which might also indicate a weakening in the connectivity of the system which might be seen as an uptake of a meaningful change towards a low carbon transition. The idea of reinforcing bottom action with top-down initiatives has been also found in recent research work in other case studies (see e.g the case studies of Hanover, Germany, and Växjö, Sweden in Emelianoff 2014; or the case study of Cape Down, South Africa in Jaglin 2014) where the combination or integration of initiatives is found to be more productive to achieve successful urban low carbon transitions.

Further investigation should focus on analysing the usefulness of these indicators, i.e. network characteristics, in the context of urban resilience and transformation research, as
7. A fuzzy cognitive modelling approach to resilience and transformation

they initially look promising in complex decision making environments such as urban energy futures.

7.6. Conclusions

In cities, processes of sustainable transformation are not merely a problem of technology development or deployment; politics, power relations, economics, culture and value systems all influence urban transformation (Pelling and Manuel-Navarrete 2011; McCormick et al. 2013). It is argued here that better understanding, expert knowledge and perceptions on the part of policy makers and stakeholders, understood as cognitions, can inform resilience and transformation management.

This dissertation contributes to the literature on resilience and sustainability transitions by, for the first time, to my knowledge, using a Fuzzy Cognitive Mapping (FCM) approach in the particular context of urban decision making to study resilience and transformability capacities. This is done by exploring the structure of an urban network and developing urban transition scenarios to generate hypotheses of combined policy actions conducive to sustainability. This study evidences the great complexity, dependence, coupled nature and connectivity of urban adaptive systems and shows the relevance of accounting for the different knowledge and perceptions of stakeholders and communities concerning the impacts of climate change and resource use.

As Dawson (2011, p.182) points out, while urban “transitions might be unknown [...], strategic directionality can be established and sustained”. Although the results of the FCM scenarios studied provide key insights on the directions of transitions to sustainability, arguably they do not offer sufficient information about the magnitude of the efforts in terms of policy actions required to change certain interventions, or about the degree of resilience of future states. The future of FCM as a method for studying resilience and transformability experiments should at least focus on: (i) combining FCM with quantitative data/models so as to build more targeted robust solutions i.e. sector targeted; (ii) exploring the applicability of FCM for testing innovative social approaches.
to transformation such as transition visions; and (iii) identifying the advantages and limitations of the application of FCM to the study of general vs. specific resilience (Folke et al. 2010) (see previous discussions in Chapter 2, p. 41 and Chapter 3, p. 73). Further investigation could also focus on the sensitivity of the network, as this could provide information about critical thresholds or tipping points.

All in all, extending the findings by Colding and Barthel (2013), the conclusion drawn here is to restate that higher and institutionally diverse participation levels from early stages of urban decision-making processes are crucial to gaining the knowledge needed to achieve resilience and sustainability in processes of systems transformation. Participatory cognitive approaches can be used to identify barriers to transformational policies in a shared and consensual way and to better communicate and visualise system dynamics (van Vliet et al. 2010). Both these uses contribute to the necessary learning process in resilience and transformation management. Last but not least, concurring recent findings in other case studies around the globe (see e.g. Emelianoff 2014; Jaglin 2014), it is noted that successful transformation in cities should pivot on a combination of top-down and bottom-up led actions to unlock resilient but unsustainable states, and that guarding against contextual dependencies might hinder the agency of change.

7.7. Summary

The main points of this chapter can be summed up as follows:

- In this chapter Fuzzy Cognitive Mapping (FCM) is used to aggregate different stakeholders’ views on the functioning and performance of the urban energy system of the city of Bilbao.
- Participants are required to translate their experience into a map (or network) consisting of nodes and weighted interconnections. FCM provides information on the main features (out-degree, in-degree and centrality) of the network but also

49 See Footnote 12.
enables scenarios of policy options or decision alternatives to be worked on over individual or aggregated maps.

- In the case of Bilbao, the urban energy network is analysed in terms of resilience and transformability by studying the degree of connectivity and its influence on both system characteristics.

- Three scenarios of policy options are simulated to weight their outcomes in terms of sustainability: Scenario A: Optimisation of economic incentives; Scenario B: Strong education and awareness campaigns; and Scenario C: Stronger local institutional initiatives.

- Scenario A shows a potential perverse effect if the current economic structure is maintained, even if the economic crisis is overcome.

- Combining Scenarios B and C provides the best results in terms of sustainability. This suggests that successful transformation in cities should pivot on a combination of top-down and bottom-up actions to unlock resilient but unsustainable states, and that special care needs to be taken when managing highly connected and/or influential elements of the system, as contextual dependencies might hinder the agency of change, particularly in the context of cities.

- Network characteristics, such as connectivity, can be useful indicators to inform resilience and transformation management, although the double-edge sword nature of connectivity should be noted.
Conclusions

Chapter 8

DISCUSSION ON THE OUTCOMES OF THE DISSERTATION AND FURTHER RESEARCH AREAS

“I myself know nothing, except just a little, enough to extract an argument from another man who is wise and to receive it fairly.” Plato, “Theaetetus”, 161b
Chapter 8. Conclusions

The goal of urban sustainability poses great challenges for urban planners and policymakers; the cross-scale nature of urban interactions and the increasing urban population in a context of climate change and resource scarcity places these challenges at the centre of global scale solutions. As argued in this dissertation, this means that urban transitions to more resilient and sustainable states are crucial for a global sustainable transformation. Even acknowledging that important work has been done over the past few decades to reorient unsustainable urban patterns, research efforts need to focus more strongly on stimulating and supporting cities in this process.

This dissertation seeks to explore the inner mechanisms of urban complex systems in the context of urban climate and environmental governance from the viewpoint of resilience and transformation. To that end, in the opening of this dissertation (see Section 1.2, p.10), I formulate three research questions associated with three challenges.

- **Exploring sustainability and resilience links**: Sustainable long-term strategies require new lenses to frame sustainable urban transitions. To explore this question, I use resilience and transformation theories by analysing the existing literature on socio-ecological systems and socio-technical systems in Chapter 2 and discuss its adaptation to urban systems in Chapter 3. This opens up a set of specific challenges in cities that will be addressed in the following chapters.

- **Addressing urban complexity**: In this dissertation I contribute to this challenge by exploring how the inherent complexity existing in human and natural complex nested systems can be taken into account in decision-making processes regarding transformation and change. Although the issue of complexity is taken into account through the conceptual and empirical analyses developed through the dissertation, specifically, Chapter 4 addresses the connections of human and natural systems in urban areas and Chapters 6 and 7 analyse how complexity materialises through the eyes of a group of stakeholders in a case study.

- **Exploring the cognitive dimension**: Through this question I try to understand how experience and knowledge of the actors involved affect decision-making processes about sustainability and transformability. This question is responded in
Chapters 6 and 7 using the case study of the city of Bilbao. Particularly, the question of low carbon energy transitions is analysed. Emerging discourses about the transformability of the city are discussed in Chapter 6, and scenarios modelled through the perceptions and experience of a group of experts are evaluated in terms of sustainability and resilience in Chapter 7.

By addressing these questions, this dissertation seeks to conceptually and empirically explore new approaches that, acknowledging the complexity of urban systems and their governance, can (i) be helpful in contextualising adaptive and transformative processes (Elmqvist et al. 2013); (ii) conceive and manage both natural and human capital, with urban systems being seen as socio-ecological CAS (Biggs et al. 2012); (iii) better represent interconnections, systemic complexities and unsustainable lock-ins (Ernstson et al. 2010b); and (iv) take into account the perceptions, values and understanding of the actors in the system as enablers or withholders of processes of transformative change (Adger et al. 2009; Adger et al. 2012).

Throughout the six chapters that make up parts one and two of this dissertation (excluding the Introduction – Chapter 1 - and the present chapter), I have addressed this objective from a conceptual point of view (Part I) and through empirical analyses (Part II).

My main findings are set out below.

8.1. Discussion of the main results and conclusions derived from each chapter

Part I comprises three chapters, and presents the conceptual analysis.

In Chapter 2 (p. 33), I review and explore resilience and transformability theories from the perspectives of research into socio-ecological systems (SES) and socio-technical systems (STS). An analysis of the relevant literature reveals that resilience has become a rather malleable, ambiguous concept that is used in multiple disciplines, and
that there is a need for operability and practicality. That said, resilience is also a multidisciplinary concept that can be used as a way to bridge different disciplines (see e.g. Brand and Jax 2007). In the case considered here the adaptive management approach used in resilience studies bridges with transition management research, which is also supported by the literature analysed (Van der Brugge and Van Raak 2007).

This chapter starts from the assumption that urban sustainability research, particularly regarding long-term strategies for sustainable transformation can benefit from both of them, since, as asserted in Chapter 1, traditional approaches to sustainability need to engage with resilience research (see e.g. Elmqvist et al. 2013). Indeed, as concluded in this chapter, from a resilience thinking perspective, the idea of multiple states and of panarchy (multi- and cross-scale interactions) is particularly relevant when planning for change. In the field of climate change (Kates et al. 2012; Park et al. 2012) and in the quest for sustainable development (Westley et al. 2011), it is argued that incremental adjustments are no longer sufficient and that a radical transformation is needed at both global and local scales. Transformability is then defined in a broad sense as the capacity to create or self-organise into a new system by introducing new components or new ways of doing things when current conditions are untenable (see Walker et al. 2004).

By analysing literature from both areas of research, I conclude this chapter by saying that transition management research contributes to transformation theories coming from resilience thinking by allocating more weight to technology, industry and economy, together with ecological and social systems. Also, transition management research provides a deeper insight into how to stimulate, plan and manage transitions in the long term and on multiple scales, while resilience thinking contributes to a more integrated view of coupled human and natural systems by including Ecosystem Services (ES) as a key aspect in resilience management.

Lastly, a general message emerges from this literature review: in order to effectively inform policy making, a forward-looking and multidisciplinary approach that brings together social, ecological, economic, institutional and technological dimensions is required. Theories of resilience and transformation can help to conceive this new policy and governance framework mainly based on increasing cross-scale and multidisciplinary
knowledge about the structure and functioning of systems. Sustainability approaches in themselves are not enough and resilience and transformation research ideas can add a longer-term, more complex, more integrated approach to support the planning and management of the processes of urgent change that cities need to undertake.

**Chapter 3** (p. 69) takes the premise that cities, as CAS, have the opportunity to manage their resilience towards sustainability through processes of transformation. Thus, in this chapter I review the recent literature concerned with fostering the links between urban resilience and sustainable transformation.

**Urban resilience** is a burgeoning but incipient research area, and accordingly seems to suffer still from the lack of a shared approach. Although the operational perspective and the features that affect urban resilience are still unclear (see Section 3.2.3, p. 76), the application of the concepts of resilience and transformation in cities looks to be not only feasible but appropriate in a time when transformational changes with meaningful long-term effects are required in cities.

Different authors shared the idea that the application of urban resilience concept should be done in a context-specific way; otherwise it may create “oversimplified goals for building resilience” (Elmqvist et al. 2013, p. 739).

In general and as reviewed in this chapter, the most common characteristics of urban resilience are multifunctionality, redundancy and modularisation, self-sufficiency, interdependency and safe-failure, multi-scale networks and connectivity, diversity and planning flexibility (see Ernstson et al. 2010b; Ahern 2011; Tyler and Moench 2012; Albers and Deppisch 2013). I find that some of these characteristics could have unintended impacts on sustainability and general resilience, so it is not clear whether they have a straightforward link with resilience. For example, connectivity within a city and with other cities is a driver of resilience in terms of service provision. However, greater connectivity increases the probability of failure dispersal, as more elements are connected and subject to changes. This example is evidenced in the case study of Bilbao in Chapter 7, which is discussed below.
Elmqvist et al. (2013) also argue that in relation to urban resilience and sustainability, research should be directed to understand transformative capacity and how governance might trigger urban transformations. This is partly the aim of this chapter, i.e. to explore the challenges that urban areas might face when planning for transformation. The concept of Sustainable Urban Transformation is then proposed in this chapter to provide a conceptual framework for the response of resilience and transformability to why and how cities should plan and manage their processes of change towards sustainability. After an analysis of the literature and of the links between urban resilience and sustainable transformation approaches, I conclude that Urban Resilient Sustainability Transitions might be achieved via various alternatives and different pathways, as sustainable development is about accommodating the different interests existing in cities (Rydin 2010) and because of this, understanding cognitions and perceptions of the stakeholders involved in decision-making processes becomes crucial. Challenges concerning (i) investments in technology, infrastructures and ecosystem services; (ii) knowledge generation storage; and (iii) how institutions and actors understand the system become crucial in sustainability transitions, and have direct implications for the governance of cities.

The chapter concludes by suggesting that transformation thinking and practice particularly requires further research on three areas which are addressed in the following chapters: (i) reconsidering the opportunities of the natural and built environment as elements for positive synergies in sustainable urban transformation, for example in relation to the provision of ES (Gill et al. 2007; Gómez-Baggethun and Barton 2012; Jansson 2013; Lovell and Taylor 2013) (see Chapter 4, p. 101); (ii) understanding institutional and social discourses (McCormick et al. 2013) while identifying practical, context-specific barriers to transformation (Geels 2012) (see Chapter 6, p. 191) and (iii) gaining knowledge about the structure and functioning of urban systems, their feedbacks and non-linear processes, obtaining a more advanced understanding of the complexity of urban systems (Ruth and Coelho 2007) and covering both socio-technical and socio-ecological elements and their interactions (Rijke et al. 2013) to improve transition pathway planning processes while accommodating different interests existing in cities (see Chapter 7, p. 211).
Following up on the idea of urban complexity discussed in the introductory chapter (see p. 15) (see e.g. Batty 2007) and seeking to advance knowledge on interconnections in urban systems to engage with sustainable urban transformation (Olsson et al. 2014), Chapter 4 (p. 101) focuses on the links between natural and human capital in cities. Exploring this aspect of urban system emerges as a key step in Urban Resilient Sustainability Transitions because: (i) ecosystem services are key in building resilience and sustainable transformation (Olsson et al. 2014); which means that the substitution of natural assets by built infrastructure in cities is no longer acceptable; and (ii) specially in cities, services are co-produced by both natural assets and built infrastructures (UN 2013), so both need to be considered in urban decision-making processes. This chapter stresses that in cities the value of ecosystem services needs to be acknowledged along with their benefits, co-benefits and costs (including those resulting from disservices).

Advancing an urban adaptation of the Ecosystem Services Framework (MEA 2005), I illustrate in this chapter the connections between the natural and built environments and how ecosystem services are linked to benefits for the urban population through a conceptual framework, helping thus to advance sustainable urban transformation as suggested in the literature (see e.g. Olsson et al. 2014).

The developed framework highlights how a combination of the natural and built environments is essential in the process of delivering services to the population. It also emphasises the intensive role of human capital in the co-production of ecosystem services in cities, while at the same time highlighting the importance of delivering decision-making tools which facilitate the inclusion and valorisation of natural capital (processes and assets) in urban and regional decision-making processes. In this chapter I propose a simplified framework of Urban Services to illustrate that such services arise through the interaction of natural resources and public resources managers with so-called Urban Service Providing Units, made up of urban natural or built capital. These Urban Services are then transformed into benefits for urban users in a context of cross-scaling interactions.

The Urban Services Framework is proposed as a way to integrate ecosystem services into urban policy and planning and as a significant step towards sustainable transformation. It also helps to anticipate the costs of the substitution of natural assets and the hidden (non-
(co)benefits of interventions that promote them. In order to accomplish this two aims, again the perceptions of the stakeholders involved in decision-making processes regarding urban strategies are critical. If and how stakeholders perceive the connections between the natural capital and the human society in urban areas, and the complexity behind them is essential to engage with resilience and to visualise new alternative pathways for sustainable transformation, as argued by Olsson et al. (2014).

This way, the USF helps to reflect about how to develop a kind of policy practice that takes into account natural capital existing in cities and the human and built capital that supports the provision of critical services in cities.

A couple of examples are used to illustrate the applicability of the Urban Services Framework in the context of Sustainable Urban Transformation and the co-production of services: flood management and energy management. These two examples help to visualize the benefits of Urban Services and to identify the Urban Service Providing Units that provide them, either natural or built. Comparing the two examples brings to light the different roles that natural capital may have in the co-production of services. Natural assets in cities are crucial in urban flood management and can have multiple co-benefits. In energy service production natural assets have a smaller role within the urban system but a critical role as service providers outside the limits of urban systems i.e. at regional and global level. This dichotomy makes the urban population unaware of the importance of resource availability to produce energy and therefore of the challenges that cities may face in the short term regarding for example fossil fuel scarcity. This issue is picked up in Part II, which focuses on the specific challenges of urban low-carbon transitions.

**Part II** focuses on empirical analyses. It contains three chapters: Chapter 5 describes the data and the methods used, and Chapters 6 and 7 develop the empirical studies and discuss the results. Based on the challenges described in the case study, Part II focuses specifically on the **cognitive dimension of sustainable urban transformation** particularly addressing the challenge of reducing energy use as one of its crucial aspects. In the particular case of energy transitions, although global energy strategies regarding sources and markets are critical, the fact that these transitions need to take place in urban
areas too is more and more recognised (Rutherford and Coutard 2014). Also, there exists a rather high level of agreement in that transitions are not mere processes of infrastructure and technological change, but also processes where political and cultural contexts have a strong presence and different interests may compete (see e.g. Hodson and Marvin 2010, 2012; McCormick et al. 2013; Rutherford 2014). Thus, coming back to the idea that understanding forms of governance of transitions to sustainability is critical, as argued by Elmqvist et al. (2013).

Part II of the dissertation discusses the opportunities for low-carbon energy transitions in cities. It is hypothesised that the cognitions and perceptions of stakeholders involved in sustainability-related decision-making processes need to be taken into account in very early stages, due to the strong influence that it may have for both the uptake of transitions and the visualising of opportunities and potential pathways of transformation.

Chapter 5 (p. 145) first describes the specific challenges entailed by urban low-carbon transitions. Then it presents the case study of Bilbao, in the Basque Country. Here I describe the main physical and socio-economic characteristics and the recent (last 30 years) process of transformation led by the public administrations through which the city has turned itself from an industrial hotspot to a services-led city. I also include a description of the energy management and sustainability challenges facing Bilbao, evidencing the need to move towards a low-carbon model. Bilbao’s success in transforming itself in the past and its apparent ability to lead another transition suggest the need to further explore (i) whether actors perceive the need to transform and whether they believe in the transformability of the city; and (ii) different low-carbon transition pathways. This chapter motivates the selection of the case of Bilbao, not only as a good example of a city on the threshold of urban transformation but also as a city in similar context to others (e.g. UK cities) that have been able to successfully transform from industrial to services-led cities. The chapter presents two semi-quantitative methods to answer these two questions. On the one hand, the Q method is proposed to identify potential cognitive barriers to transformation as seen by stakeholders in Bilbao through the analysis of main discourses on the need to transform and the ability to transform Bilbao into a low-carbon city. Then Fuzzy Cognitive Mapping is presented as a semi-quantitative method to aggregate different mental maps drawn up by a number of
individuals and to simulate policy options. Chapter 5 also describes the data collection process for the implementation of the two methods. The Q study covers 32 actors, 14 of whom also participated in the Fuzzy Cognitive Mapping process. The data were collected in the first half of 2013.

The Q study results discussed in Chapter 6 (p. 191) evidence the importance of existing discourses around low-carbon energy transitions and the need to understand them to seek opportunities to initiate processes of change. Looking to (i) complexity, in that discourses are important to understand how urban development evolves (Batty 2007) and (ii) competing interests in cities, as sustainable urban development is about finding a shared vision (Rydin 2010), this chapter gives light to the implications of existing perspectives, theories and beliefs for building collective and individual knowledge (Wenger 2000) and particularly, explore the implications for the governance process of sustainable urban transformation.

Four discourses based on actors’ perceptions and perspectives of the need and capacity to initiate low-carbon transitions are articulated. The results for Bilbao suggest key cognitive barriers towards low carbon urban transitions particularly localised in actors who are naturally involved in decision-making processes, i.e. local and regional authorities. Among them, the lack of confidence in their own abilities and in the role of social participation in decision making processes is noteworthy. According to these results, in order to turn cities such as Bilbao into transition drivers, social networking to link visionaries and pragmatists with decision-makers is essential. This study brings to light a general message: Urban Resilient Sustainability Transitions require a shared cognitive base grounded on a set of common objectives i.e. a common vision shared by the various actors in the system. This restates the need to develop and strengthen participatory approaches in decision-making processes.

The results of the Fuzzy Cognitive Mapping implementation in Chapter 7 (p. 211) prove that a more integrated, more holistic understanding of the system is achieved when participatory network approaches are used in complex decision environments. The implementation of a network and participatory approach to the conceptualisation of urban energy system dynamics in Bilbao provides important insights into (i) the
potential for a more in-depth exploration of the cognitive dimension of decision making; and (ii) the significance of participatory approaches in accounting for non-linear feedbacks that might erode or seed opportunities for change. This way, I advance the idea that infrastructure networks configure and are configured by urban responses to change (Bulkeley et al. 2014) by adding the cognitive dimension and how stakeholders perceive such networks to the complexity of governing transitions to sustainability. The results of the study in Bilbao show that transition actions pivoting on connected, influential elements of the system (as seen by the stakeholders) need to be carefully planned because, particularly in the context of cities, contextual dependencies might hinder the agency of change.

In Chapter 7 I look more closely at connectivity (Ct) as a key system characteristic. I discussed how connectivity of the network can be considered a double-edge sword. On the one hand, if more connections are perceived by the stakeholders, this may trigger transitions as change spreads quicker (Özesmi and Özesmi 2004), but on the other hand, from a resilience perspective, an overconnected system may turn rigid in its control, and thus, it may be difficult to manage unexpected shifts or changes. In the study developed in this dissertation, the energy network of Bilbao evidences that, as theorised in Chapter 3, higher levels of connectivity may hinder the agency of change in transitions, as change seeds more quickly. Concurring further with the existing literature on the benefits of a network approach (Janssen et al. 2006b), the results of the case study match existing conceptual approaches to urban transformability in which, under the hypothesis that agency of change is decisive, a combination of top-down and bottom-up led actions to stimulate transformation and unlock resilient but unsustainable states successfully meets sustainability management objectives.

Finally, the transferability of the methodology and the results of this dissertation to other simulation methods deserve a special discussion. Certainly, it is important to highlight the potential of the use of the results of this dissertation in studies that use more quantitative approaches and show a lack of field data. For example, as discussed in Chapter 5 (see p. 177), FCM is a semiquantitative method that can be used in combination with other more quantitative models/methods that require data that is not known, scarce or requires field investigation (see Özesmi and Özesmi 2004 for a deeper discussion). Here, I have
implemented FCM as a standalone methodology. However, with modelling purposes, its results can be used to feed relations between concepts or elements that are not known beforehand. This can be potentially done through calculation of the state of certain variables, when the value of one or a group of variables is fixed. In Agent-Based Modelling (ABM) for example, the interactions between agents or organizations and their behaviour might be unknown and may require field data (Balbi and Giupponi 2009). Methods such as FCM or the Q methodology where the stakeholders’ discourses define different behavioural patterns can be used in combination or as a source of empirical data to feed this kind of modelling techniques. Additionally, the use of these methods in combination with more robust simulation methods can help to overcome some of its methodological limitations. For example, in FCM the same iteration time is assigned to all connections, while in reality the lag between causes and consequences may differ (Olazabal and Reckien Forthcoming). Its use in combination with ABM can help to partly overcome this issue, given that most of the agent-based models are run for 100 years (Balbi and Giupponi 2009).

8.2. General considerations and conclusions

Reflecting on the conclusions of each chapter, some general considerations can be brought to light in regard to resilience, sustainability and transformability and their contribution to improving governance, development patterns and wellbeing in cities.

One cannot help but wonder about the meaning of these concepts and how they are currently applied. Do they just refer to the same idea with different words? The boundaries of the notions of resilience, transformation and sustainable development seem sometimes artificial. All three involve the idea of change and evolution, and all require a society that is ready to adjust, subject to forecast or experienced drifting from the desirable path. There is certainly redundancy in the meanings of the concepts as they all suggest both development and stabilisation. They began to be used as buzzwords in the political arena almost as soon as they emerged in scientific research, so their current applicability is sometimes confusing and unclear.
According to the Brundtland Report “Our Common Future” (UN 1987), pursuing sustainable development requires: “a political system that secures effective citizen participation in decision making; an economic system that is able to generate surpluses and technical knowledge on a self-reliant and sustained basis; a social system that provides for solutions for the tensions arising from disharmonious development; a production system that respects the obligation to preserve the ecological base for development; a technological system that can search continuously for new solutions; an international system that fosters sustainable patterns of trade and finance, and an administrative system that is flexible and has the capacity for self-correction”. This, to me, means evolution, adaptability, consideration of the limits of resources, innovation and equitability in the long term. According to the literature reviewed in this dissertation, sustainable development implies a resilient transformation of our way of living and doing.

Is it possible then that, in our determination to use new concepts such as resilience and transformation, we might be responding just to our frustration in conceiving ways to operationalise the long-sought goal of sustainable development? As put by Beck and Villarroel Walker (2013), these might be early days for the development and application of principles of these kinds. The plurality of heuristics and definitions of these concepts (see p. 33 and p. 55), the redundancy in their definitions and the underlying interests that can be found in their applications, may make the scientific community sceptical about the benefits of using such long-term-oriented, inaccurate, multifunctional, multicontextual concepts (Davoudi et al. 2012) which often lack operative assessment models (Albers and Deppisch 2013). Rejection and scepticism is exacerbated when they are applied jointly.

However, this dissertation has attempted to show that resilience and transformation research has much to offer to sustainability research and practice. The reviews, analyses and empirical studies presented here suggest that resilience and transformation provide more inspiration for politics though, as they can be applied as a way of generating policy options and alternative pathways. The need to provide policy tools that can support long-term successful sustainable development and move from adaptation to transformation has been widely raised (Westley et al. 2011; Kates et al. 2012; Park et al. 2012; Scheffer et al. 2012; Boettiger and Hastings 2013; Werners et al. 2013). Resilience and transformation
8. Conclusions

Theories seem a good framework for developing new decision-making criteria that can help to accelerate change towards sustainability. Recognising this urgent need to transform cities towards sustainability, an important conclusion of this dissertation is that theories of resilience and transformation can help to conceive a new policy and governance framework which is forward-looking, integrative and based on increasing cross-scale and multidisciplinary knowledge of the structure and functioning of systems.

Cities face two specific challenges when planning for Urban Resilient Sustainability Transitions: (1) the need to understand the interconnections within urban systems and the ‘system of cities’; and (2) the need to understand the role of the perceptions, experience and values of actors in the uptake of transitions. Both relate to the main aim of this dissertation: to understand the inner mechanisms of urban systems that may drive or hinder transformability, sustainability and resilience. This objective is critical once it is recognised that (see Chapter 3, p. 94): (i) transitions are context specific; (ii) transitions may be unknown, but strategic directionality can be established and sustained; (iii) transitions can be fostered via top-down and/or bottom up (community led) initiatives and gained through a combination of technology development and societal mobilisation; and (iv) the level of success of transitions depends on the combination of measures, the timing of their implementation, the engagement of the different socioeconomic groups, their will to change and their ability to foresee opportunities.

By developing and implementing innovative approaches and methods, I have shown throughout this dissertation how systematic and network approaches better illustrate the structure and the linear and non-linear feedbacks of the system that might be limiting or benefitting certain states or development patterns. Considering current urban management and planning integration needs, the Urban Services Framework is conceived to support urban decision-making processes in acknowledging this complexity, by looking at cities in a systematic way as coupled social-ecological systems where services are provided either by natural or semi-natural providing units, by built infrastructures or by a combination of the two.

In addition, the Urban Services Framework (and similar approaches addressing the same concern) helps to identify and compare the benefits of natural and built service providing
units, which can justify decisions in favour of sustainability, resilience and/or equity. On the other hand, the Fuzzy Cognitive Mapping study in Bilbao has shown how participatory approaches taking into account the perspectives and experiences of different actors help build more robust and integrated networks, which a critical step in identifying unintended policy impacts. A network approach is definitively helpful in providing a tool to assess the resilience of systems, at least from the point of view of connectivity, as this study has shown. A network approach also enables different transition pathways to be tested and their appropriateness to be assessed in terms of sustainability. Finally, a network approach enables the complexity of urban systems to be explored in its many forms, in as much depth as the design of the study allows.

Also, the key role of institutions and actors is recurrently highlighted in this dissertation. Chapters 2 and 3 stress that learning and experimentation are essential in resilience and transformation management. It is stated that Urban Resilient Sustainability Transitions should be based on innovation (Ernstson et al. 2010b) and on experimentation (Evans 2011; Hodson and Marvin 2012; Castán Broto and Bulkeley 2013) and that from a decision-making viewpoint transitions should account for a combination of scientific, institutional and local knowledge and provide a technological, economic and social alternatives portfolio (Dawson 2011) that is flexible enough to manage uncertainty and reorient the transformation in view of potential disruptions. To that end, I conclude that social and institutional learning is critical. The results of the application of the Q Method in Bilbao highlight precisely the importance of exploring the cognitive dimension.

The case study of Bilbao shows that values and perceptions affect decision-making processes and reveals how institutions and actors see and perceive potential alternatives and the ability and resources to play a critical role in the uptake of Urban Resilient Sustainability Transitions. The case study of Bilbao suggests that, regardless of the city’s great potential in social and economic terms for undertaking a change, if no measures to strengthen participation and interaction between actors with different views are taken then transitions are hardly stimulated at all and unsustainable lock-ins remain, especially if actors with decision-making power maintain passive or sceptical stances. This lesson can be transferred to other cities where conditions are the same as or similar to those in Bilbao: in short, how such small or medium-sized cities develop now will significantly
affect their future sustainability. In this regard, tools and approaches that help to understand the complexity of the systems, that generate and store knowledge and help to test different hypotheses, that facilitate learning from one’s own experience or that of others and that engage actors in the process of change can help actors to gain confidence, make better and more informed decisions and feel themselves to be the owners of the results (see ‘Main policy implications’ in Section 8.3).

Summing up, multidisciplinary, integrated, participatory approaches in sustainable urban transformation governance are crucial to avoid unintended policy impacts and to engage stakeholders in the quest for sustainability and resilience under climate change and resource scarcity.

**8.3. Main policy implications**

The 20th century was the time of the 'urban revolution' (UN 1987) but the 21st can be seen as the century of the ‘urban explosion’ (Nature News 2010). This poses major challenges to both scientists and policy-makers. In a context of climate change and resource scarcity, there is a need for urgent action, leaving rhetoric aside (Leichenko 2011). The increasing percentage of the population that live in cities means that informed, participative, anticipatory actions in affinity with the surrounding social, economic and ecological environment of each urbanised area must be taken. As raised in this dissertation, this entails accounting for the complexity of and in cities. Via this dissertation I restate that cities are complex and so is their governance (Bai et al. 2010). Cities are under the threat of a great many social, economic and ecological changes, and at the mercy of multiple, naturally diverse drivers such as markets, geopolitics, demographic change and the availability of technology. It can therefore be reasoned that decisions regarding when and how to plan and manage such actions are complicated and have important implications in the short-, medium- and long-term, given the cross-scale and widely diverse nature of the impacts of global and local environmental change.

In the context of sustainable urban development, there is a shared opinion that new operational tools need to be provided to further understanding of the nature and scale of
the impacts of global and local environmental change, and to support long-term urban governance (Prasad et al. 2009; Rosenzweig et al. 2011). In this regard, this dissertation seeks to explore new approaches that can acknowledge complexity, account for long-term implications, be integrative and consider the influence and key role of the knowledge and perceptions of actors in the uptake of transitions to resilient sustainability.

The environmental challenge implies a need for radical, widespread social and institutional changes (Lorenzoni et al. 2007). Clarifying and understanding the system from the perspective of policy and governance and providing tools to illustrate potential trade-offs and co-benefits are critical steps for sustainable urban transformation management. For this reason, providing novel, integrated approaches for policy and practice and understanding stakeholders’ perspectives and values regarding resilience and sustainability governance in cities is crucial to identify barriers to and opportunities for transformation. The case study of Bilbao evidences the high degree of complexity and dependence, the coupled nature and the connectivity of urban adaptive systems. It proves the relevance of accounting for the different perspectives that stakeholders and communities have regarding the impacts of climate change and resource use (in the broadest sense) and the importance of exploring how this cognitive dimension can influence unilateral decisions made, especially, in a non-collaborative atmosphere.

Indeed, the increasing complexity and connectivity in urban systems means that non-linearities need to be accounted for in a way that it is transferred to urban policy and practice.

Participatory approaches such as the ones used in this dissertation have proven useful in: (i) identifying opportunities for and barriers to transformational policies in a shared and consensual way; and (ii) communicating and visualising system dynamics (van Vliet et al. 2010), both of which contribute to the critical learning process in resilience and transformation management. Extending on Colding and Barthel (2013), here I restate that higher, institutionally diverse participatory levels are crucial from the early stages of URST planning to gain the knowledge needed to achieve resilience and sustainability through processes of system transformation.
One of the main contributions of this dissertation, and one which is identified as key for resilience and transformation management, is the provision of learning and knowledge generation tools. This has direct policy implications as it stands as one of the most important aspects of urban policy making. Not only does it become crucial to learn about the complexities of urban systems but also about the complexities of the urban governance system, as the many intermediary organisations and interests that come together in cities need to find consensus areas and learn from each other.

A combination of top-down (institutionally-led) and bottom-up (community-led) initiatives seems to provide better results in sustainability terms, assuming that education and awareness campaigns investments are made by local institutions. For this reason, the significant role of local institutions is acknowledged as key actors with the responsibility to shift from rhetoric to meaningful action (Romero-Lankao 2012) and generate the conditions needed to engage society and stakeholders in the process of change. However, the case study also shows that, in the case of Bilbao, local and regional institutions lack the leadership capabilities and motivation to start processes of transition. Again, this calls for participatory platforms where visionaries and pragmatists can come together with institutions and contribute the doses of creativity, innovation, vision, and confidence lacked by the actors with decision-making power.

Adding to the relevance of knowledge of the system for building more robust, better informed transition options, the level of success of transitions also depends on the combination of measures, the timing of their implementation and the engagement of the different stakeholders. The willingness of stakeholders to change and their ability to foresee opportunities are crucial in gaining their collaboration and implication in any process of transformation.

Transitioning to sustainable cities requires sustained effort and collaboration between researchers, policy makers and community stakeholders (Pickett et al. 2011). Cities are hubs of experimentation and innovation (Ernstson et al. 2010b; Evans 2011) and thus arenas where different actors have the capability for generating a fruitful and participative context for sustainability transitions. This requires actors to acknowledge the need for
change and to believe in their own abilities to act as drivers of the process of change and transformation.

Investing in urban resilience has long-term implications and therefore the main objective of resilience management in urban systems should be not only to strengthen adaptability to change but also to foster alternative opportunities that transformation might bring about. In particular, the transition to low carbon cities is and will be a challenge for decades to come. It is a crucial cornerstone in the global sustainability transition process. As argued by Milner et al. (2012), the opportunities for decarbonisation in cities are multiple and complex, but inevitably require combinations of technological development, infrastructure investments and behavioural change.

In general, the practical barriers to adaptation and transformation for decision-makers continue to be strongly associated with uncertainty about success before interventions are decided, especially as transformative decisions are often seen as politically risky with benefits being accrued in the medium to long run (Kates et al. 2012) and thus not attuned to electoral cycles. This is why transition management research (Loorbach 2007; Loorbach and Rotmans 2010) offers a basis for understanding the activities involved in transitioning (Park et al. 2012) and the key areas involved in planning, following up and reorienting the process of transformation.

Both the conceptual and analytical contributions of this dissertation highlight that the way in which decision-makers and policy-makers understand the connections and interdependencies in urban system dynamics is crucial in the process of defining transition pathways. Integrated, cross-scale, multidisciplinary, participatory approaches to sustainable urban development governance are essential to avoid unintended policy impacts, optimise sustainability and resilience and engage stakeholders in the process of change.
8. Conclusions

8.4. Limitations of this research

Various recommendations and policy implications are gained with the conceptual and empirical analyses performed in this dissertation; however, it is important to point out potential limitations and caveats that might restrict the applicability of the ideas and conclusions presented here.

I focus specifically on wealthy small or medium-sized cities with a high degree of urbanisation and do not therefore consider issues of poverty, social exclusion, or equity. This is a limitation of this study, and one that calls for further investigation on how to adapt these concepts and approaches to developing countries and rapidly urbanising areas.

The problem of shrinking cities in Europe is also very specific, but increasingly important, particularly in countries such as Germany. I assume from the outset of the study that there is a growing concentration of population in cities which will lead to future problems related to availability of resources and services to satisfy the needs of urban citizens, and because of this to a growing vulnerability to climate change. Thus, the findings of this dissertation are restricted to this kind of cities and do not account for the specific challenges entailed by other urban development patterns. Some general conclusions related to the need to obtain knowledge on the complexities of the system and account for the perceptions and experience of actors should be transferrable to other types of urban area. However, until a more in-depth exploration is carried out it is not reasonable to assume this directly, so investigation of these challenges is required.

In relation specifically to the studies developed in each chapter, some limitations need to be highlighted. In the Urban Services Framework in Chapter 4, for the sake of simplification important aspects in Urban Resilient Sustainability Transitions are left out, such as cross-scale interactions with other spatial and temporal levels, thus considering the adaptive cycle and a panarchial network approach. This is because of how difficult it is to translate this into a single table, and because I wished to take into account all potential services. However, obviously, this needs to be taken into account in specific studies. The same goes for the quantification of disservices and the revenues that can be
gained through benefits for the urban population. In this regard, one important gap is that the Urban Services Framework has not been empirically tested in a case study; nor have its elements been assigned proxies for measurement purposes. This would have required extensive resources and skills such as Geographic Information Systems and a huge data collection campaign. This issue, of course, requires further investigation (see Section 8.6).

The outcomes of the Q study and the Fuzzy Cognitive Mapping are limited to the number of interviewees: 32 and 14. A look at the results suggests that both would have benefitted from a larger number of participants, although for the purposes of this study the size of the sample was sufficient. Nonetheless it is important to note for example that in the Q study a larger number of actors from a more diverse range of institutions would have strengthened the results. In the case of Fuzzy Cognitive Mapping, a larger number of participants would have probably provided more interesting insights and alternatives. However, the innovative, experimental character of this exploratory study must also be acknowledged. Its objectives were to highlight the importance of accounting for the knowledge and perceptions of actors and to outline the benefits of a network approach to resilience and transformation management.

Lastly, it is important also to note that cognitions do not only affect decision-making. This study might be affected also by my own way of observing the urban system. As scientists try to measure things, their perception of the whole complexity of the problem that they are seeking to solve may be obscured first by the tendency to focus on the computable and neglect the non-computable; and second by the tendency to rely on dominant models, which may contain hidden inconsistencies with reality (Carpenter et al. 2009a). On one hand, this dissertation seeks to prove the usefulness and compatibility of resilience and transformation approaches to sustainable development. However there are other approaches, such as for example, societal metabolism approaches, that may potentially be able to account for complexity and cross-scale interactions in the same way. On the other hand, in my objective to illustrate the complexity of cities, I have also simplified the structure of the urban system, e.g. in the development of the Urban Services Framework, which might also contain hidden inconsistencies with reality. This is important and relevant to the transfer of these conclusions to other contexts. For this
reason, it is crucial to replicate the studies and implement the approaches and methods in other cities with the same challenges (e.g. urban low-carbon transition) and in cities with other challenges, to test and compare the results and discuss the similarities and divergences.

8.5. Further research areas

This study shows that resilience and transformability theories are useful for designing urban sustainable development and related governance strategies. However, these are only some of the ways of achieving this goal, and subsequent research studies one should not forget to explore other options that may arise along the way.

For instance, accounting for complexity and cross-scale interactions does not only require approaches that look at governance and policy-making, as this dissertation has mainly addressed. Further studies based on this one and built on other perspectives would benefit from gaining useful knowledge on the system. For example, a spatial perspective on urban resilience and transformation would require further research and would bring further interesting insights on e.g. how sustainable urbanisation should take place.

As highlighted in the previous section, in this dissertation I focus on wealthy, medium-sized cities. Further research should involve expanding resilience and transformation research to other types of urban challenges such as those intrinsically related to urban areas in developing countries and other cities with specific environmental, economic or social challenges e.g. shrinking, aged-urban population, highly polluted urban environments, high levels of crime and delinquency or high climate change vulnerability. It would be especially interesting to implement the methods used here in urban areas where social movements play an important role and see if local institutions are still critical in the uptake of transitions.

In short, urban resilience requires a shared operational approach, and further investigation of resilience determinants, indicators and assessment methods is needed. In this regard, in this dissertation I choose a network approach to explore resilience and transformability,
and on that basis I discuss connectivity as an example of a driver of both resilience and transformation. Further research should explore other resilience characteristics from a network approach and assess their applicability and coherency from this perspective.

Again, as pointed out in the previous section, this study lacks an empirical application of the Urban Services Framework, and this also stands for further research (see further details in Section 8.4).

Regarding the empirical analyses and the methods used in this dissertation, the Q method is a well-known, highly developed method. The results of its application to the case study of Bilbao need to be verified and compared to other cities in similar situations (on the threshold of transformation). The implementation of this method or others that enable different discourses and main perspectives to be captured is therefore important to further restate the conclusions of this study or identify other types of barriers to and opportunities for the uptake of urban low-carbon transitions.

Fuzzy Cognitive Mapping is still at an early stage of its methodological development. Moreover, its application to urban studies is incipient. There are many possibilities for improving and expanding the potential of this method, e.g. by innovating in how information is collected, how scenarios are built, how networks are visualised (i.e. individual, aggregated, by groups of stakeholders), among others. Moreover, a Delphi approach or similar could be taken i.e. giving back the results and collecting individual maps again to check for inconsistencies or to test whether the individual networks become more detailed, less partial, more robust or contain more elements. As pointed out in the conclusion of the application in Chapter 7, the future of Fuzzy Cognitive Mapping in particular as a method for studying resilience and transformability experiments should at least focus on: (i) exploring the transferability of Fuzzy Cognitive Mapping through its combination with quantitative data/models so as to build more targeted (i.e. sector targeted) robust solutions; (ii) exploring the applicability of Fuzzy Cognitive Mapping for testing innovative social approaches to transformation such as transition visions; and (iii) identifying the advantages and limitations of the application of Fuzzy Cognitive Mapping to the study of general vs. specific resilience (Folke et al. 2010), as introduced in the
review of the literature of resilience in Chapter 2 (p. 41) and discussed in the context of resilience in Chapter 3 (p. 73).

In conclusion, sustainable development requires the promotion of values that encourage consumption standards that are within the bounds of what is ecologically possible and to which all can reasonably aspire (UN 1987). Yet urbanisation is developing beyond the world's ecological means. Urbanisation patterns depend on perceived needs, which are socially and culturally determined. Past experiences, norms, values and expert knowledge affect decisions regarding future urban development. Also, perceptions regarding the impacts of urbanisation and lifestyles depend on how the urban system is conceived. Thus, bridging science and politics, further research should continue to focus on providing tools and practical approaches that increase knowledge of the system and thus facilitate urban decision-making processes in articulating more sustainable solutions.


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Annex 1: Additional figures and tables

*Table A1. Criteria for selecting rotating factors (from Zabala and Pascual 2013)*

*Meeting at least one of these 6 criteria supports the selection of the factors*

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Arguments that support a 4 factors’ selection</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.    Eigenvalue &gt;1</td>
<td>6 factors had Eigenvalue &gt; 1</td>
</tr>
<tr>
<td>2.    Two or more respondents are flagged in the QAnalyze module</td>
<td>Factor 1: 3 flags; Factor 2: 10 flags; Factor 3: 4 flags; Factor 4: 3 flags. Applying Qvarimax rotation, a preliminary selection of 6 factors, factor 3 resulted in one flag; a selection of 5 factors, factor 3 and 4 had only one flag each. Three and two factor selection gave good flagging results but they do not comply with criterion 6.</td>
</tr>
<tr>
<td>3.    PCA (diagnosis)</td>
<td>Not applied</td>
</tr>
<tr>
<td>4.    Percentage (%) of variability explained &gt; 50</td>
<td>Sixty-six percent (66 %) of variability explained</td>
</tr>
<tr>
<td>5.    Size of residuals &lt; 0.10</td>
<td>Not applied</td>
</tr>
<tr>
<td>6.    Feasibility in interpretation and parsimony</td>
<td>Four factors: reasonable interpretation. Results with three and two factors were difficult to interpret. Very different people in the same factors and ambiguous interpretation of the discourses</td>
</tr>
</tbody>
</table>
**Table A2. Factor loadings of each respondent/stakeholder’s Q sort**

This table illustrates the significance of the association of the stakeholders with each of the factors. Stakeholders’ loadings significantly associated with one factor are marked in bold. This process is called flagging. To identify significant loadings/sorts, the PQ Method uses two conditions: (a) the 5% level of significance, and (b) the factor explains more than half of the common variance (Dasgupta and Vira 2005).

<table>
<thead>
<tr>
<th>Q-sorts^a</th>
<th>Factor A</th>
<th>Factor B</th>
<th>Factor C</th>
<th>Factor D</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.3266</td>
<td>0.5168</td>
<td>0.4176</td>
<td>-0.1233</td>
</tr>
<tr>
<td>2</td>
<td>0.4172</td>
<td>0.6581</td>
<td>0.294</td>
<td>0.1871</td>
</tr>
<tr>
<td>3</td>
<td>0.477</td>
<td>0.5502</td>
<td>0.4497</td>
<td>0.0282</td>
</tr>
<tr>
<td>4</td>
<td>0.2454</td>
<td>0.7681</td>
<td>0.1813</td>
<td>0.3239</td>
</tr>
<tr>
<td>5</td>
<td>0.0405</td>
<td>0.52</td>
<td>0.5139</td>
<td>-0.004</td>
</tr>
<tr>
<td>6</td>
<td>0.4132</td>
<td>0.6611</td>
<td>0.1092</td>
<td>0.2243</td>
</tr>
<tr>
<td>7</td>
<td>-0.1513</td>
<td>0.4153</td>
<td>0.386</td>
<td>0.4259</td>
</tr>
<tr>
<td>8</td>
<td>0.0268</td>
<td>0.6891</td>
<td>0.3827</td>
<td>0.1253</td>
</tr>
<tr>
<td>9</td>
<td>0.475</td>
<td>0.5634</td>
<td>0.3664</td>
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<tr>
<td>10</td>
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\(^a\) Q sorts represent each respondent/stakeholder’s final matrix translated into a ranking.
Table A3. Distinguishing statements for each Factor

Shaded cells identify those distinguishing statements for each factor (p < 0.05; an asterisk (*) indicates significance at p < 0.01). Results for the other factors are shown for purposes of comparison. Factor Scores (q-sc) and z-scores (z-sc) are shown. See statements (S#) in Table 6.2 of Chapter 6.

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<tr>
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<th>z-sc</th>
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Table A4. Consensus statements

Consensus statements do not distinguish between any pair of factors. Statements (S#) are non-significant at p>0.01, and those flagged with an * are also non-significant at p>0.05. Factor Scores (q-sc) and Z-scores (z-sc) are shown. See statements (S#) in Table 6.2 of Chapter 6.

<table>
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Figure A1. Four examples of individual FCMs drawn up during the interviews.
Annex 2: Photographs of Bilbao\textsuperscript{50}


\textsuperscript{50} Copyright issues: photos have Creative Commons License: CC BY-3.0-ES 2012/EJ-GV/Irekia-Gobierno Vasco/Mikel Arrazola, except where other authorship is specified
Construction of the Palacio Euskalduna concert hall & convention centre as part of the revitalisation of the riverside (2011)

Guggenheim Museum Bilbao (2013)
Annexes

Estuary of the River Nervión (outside the municipality of Bilbao)

Bilbao’s new tram network

New urbanized area next to the Guggenheim Museum (2013)
Bilbao’s green belt (Arnotegi). Photo by Marta Olazabal, 2013

Buildings in Bilbao. Photo by Fernando Jimenez 2010
Green infrastructure surrounding the urban centre of Bilbao. Photo by Marta Olazabal, 2013