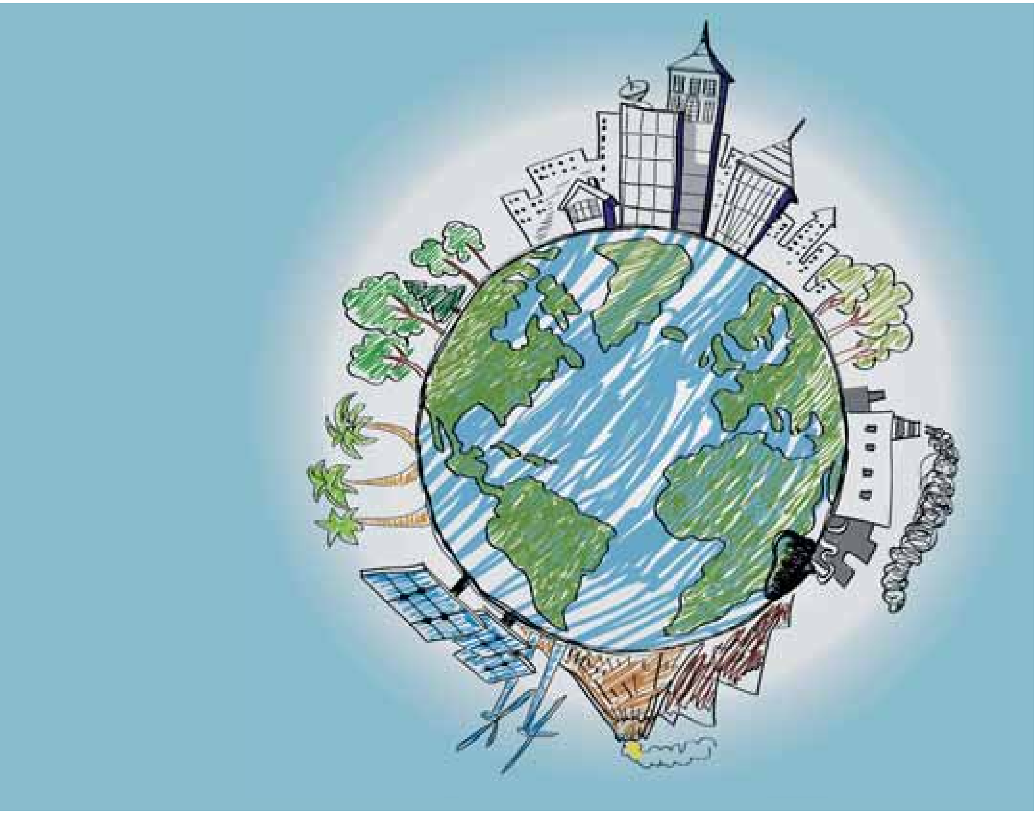
UNITED NATIONS ECONOMIC COMMISSION FOR EUROPE

Climate Neutral Cities

How to make cities less energy and carbon intensive and more resilient to climatic challenges



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Foreword

Cities and towns play a crucial role in the social and economic development of countries. Strong urban economies are indispensable for generating the resources needed for public and private investments in infrastructure, education, health, improved living conditions and, particularly, poverty alleviation.

The depletion of natural resources and the impact of a changing climate have become serious challenges to the full realisation of the socio-economic contribution that cities can make. These challenges entail huge costs, resulting in enormous inefficiencies in the use of local resources, with the poorest and most disadvantaged people suffering the most. In this regard, disaster preparedness - through risk assessments, participatory spatial planning, infrastructure maintenance and building codes - will be critical to increasing urban resilience in the event of natural and climate related disasters. Charting a path between promoting socio-economic growth and tackling environmental challenges requires the joint efforts of policymakers, urban planners and dedicated authorities, as well as the private sector and NGOs.

In many UNECE member countries, cities are already leading the transition towards a green economy and low-carbon development. Due to their compact urban form and high population density, urban areas are natural testing grounds for achieving resource-efficient and green economic growth.

This report outlines a range of systemic interrelated measures for a progressive transformation towards low-energy, low-carbon, highly resilient and ultimately climate neutral cities. Its recommendations fall under four main headings, with coordination through a well-managed city-level framework being perhaps the most essential ingredient for success.

Waste management: Options and criteria for recycling, the production of biofuels and incineration.

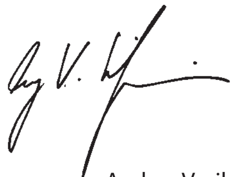
Low-carbon mobility: Disincentives for using cars, along with the promotion of non-motorised and good public transport, and the introduction of alternative fuels infrastructure.

Urban energy infrastructure: Incentives to stimulate increased use of renewable energy, and promote energy-efficient technologies and intelligent electric grid systems for city facilities.

Urban form and green spaces: Techniques to reduce and prevent sprawl, while preserving and expanding green and open spaces, mitigating the urban heat island effect.

The report concludes by introducing a city roadmap for climate neutrality with guidelines for setting up an organisational framework and to developing priority actions.

I trust that this report will serve as a valuable guide and reference for those having the responsibility for tackling this great challenge of our time.



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Abbreviations

CCS	Carbon Capture and Storage
CHP	Combined Heat and Power
CN Net	Climate Neutral Network
CO_2	Carbon Dioxide
DHC	District Heating and Cooling
DOE	United States Department of Energy
EEA	European Energy Agency
EU	European Union
GEF	Global Environment Fund
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GIS	Geographic Information System
ICLEI	Local Governments for Sustainability
ICT	Information and Communication Technology
IEA	International Energy Agency
IPCC	International Panel on Climate Change
Mt	Million Metric Tonnes
NMT	Non-motorised transportation
OECD	Organisation for Economic Cooperation and Development
PV	Photovoltaic
R&D	Research and Development
THE PEP	Transport, Health and Environment Pan-European Programme
TPES	Total Primary Energy Supply
UCLG	United Cities and Local Governments
UHI	Urban Heat Island
UN DESA	United Nations Department of Economic and Social Affairs
UNDP	United Nations Development Programme
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
UN-Habitat	United Nations Human Settlements Programme
UNFCCC	United Nations Framework Convention on Climate Change
WHO	World Health Organisation
WMCCC	World Mayors Council on Climate Change

Executive Summary

This report, *Climate Neutral Cities*, provides an overview of the importance of cities for energy reduction, climate protection and climate adaptation. It discusses the actions that cities in the UNECE region need to undertake in order to mitigate their energy intensity and carbon footprint and to reduce their vulnerability to climate change and post-carbon energy transitions.

Climate neutrality as a new urban agenda in the UNECE region

The UNECE region is a major stakeholder in international climate and energy policies. It has less than 20 per cent of the world's population but is responsible for 60 per cent of the world's Gross Domestic Product (GDP), 45 per cent of energy consumption and 40 per cent of greenhouse gas (GHG) emissions. While addressing the challenge of post-carbon transformations, much interest is now directed at the role of cities. With 73 per cent of the UNECE population living in urban areas, this is where the region's social, intellectual and economic life is concentrated.

Cities are responsible for a significant part of GHG emissions – both directly as generators of such emissions and indirectly as end-users of fossil fuel based energies and other goods and services, the production of which generates emissions elsewhere. Cities should, therefore, be considered as strategic vehicles for climate change mitigation. But urban communities are also themselves vulnerable to climate change. Urban areas, concentrating people and infrastructure – often in hazard-prone areas – experience some of the largest impacts from both gradual climatic changes and abrupt natural occurrences and it is often the poorer and more disadvantaged people who suffer the most. Cities should also, therefore, embrace socially-oriented policies for adaptation.

Mitigation and adaptation are two sides of an urban strategy for *climate neutrality*. Such a strategy suggests that:

a. cities aim to move towards net zero emissions of GHG by reducing GHG emissions as much as possible and by developing trade-off mechanisms to offset the remaining unavoidable emissions; and,

b. cities aim to become climate-proof, or resilient to the negative impacts of the changing climate, by improving their adaptive capacities.

Climate neutrality presupposes a change from fragmented sectoral interventions to an interrelated matrix of comprehensive actions integrated at an urban scale. Urban strategy for climate neutrality is an important way to respond to the challenges of climate change, peak oil prices, energy security, but also social inequality.

Principles for urban governance

National governments need to delegate to urban governments sufficient enabling capacities, such as taxation, revenue generation authority and regulatory mandates, in order for them to be actively involved in building a coordinated response to climate change. Many cities in the UNECE region already show determination to transform themselves into sustainable and low carbon areas. Lack of political will, awareness and resources, along with fragmentation of the administration of larger urban areas across multiple municipal jurisdictions and a lack of horizontal coordination are serious barriers for such actions.

A proactive urban approach to address climate neutrality is usually underpinned by the following general principles:

- *Vision:* Climate-smart policies should be determined and based on a clear vision and strategy, oriented at actions and results. Keeping a proper balance between public and private sector interests is also important.
- *Cooperation:* Cooperation between authorities at different levels (national, regional, municipal) and between different city authorities is the key to delivering more effective policies for low carbon cities.
- *Participation:* A broad participation by stakeholders achieves common understanding and commitments; local governments should seek the involvement of the population in decision-making processes, but also consult with advocacy groups and organisations representing business.
- *Finance:* It is important to identify sustainable funding sources for climate and energy projects.

The role of spatial planning

Spatial planning finds itself at the heart of urban adaptation and mitigation measures. Urban layout, public transit provision and integrated district heat-electricity systems are some of the planning considerations that have long been acknowledged to be amongst the principal instruments to reduce urban energy intensity. Planning is also instrumental in identifying risk-prone zones and for providing spatial strategies to safeguard urban infrastructure. Urban planning and spatial strategies for climate neutrality should aim to:

- Limit urban sprawl and car-dependency by achieving appropriate levels of building density and mixed-use development, organising and improving transport flow and interconnections, public transport and non-motorised transportation options.
- Provide an integrated system of green spaces and other natural infrastructure, which should protect the city from adverse weather conditions, mitigate the urban heat island effect and provide spaces for natural habitat and human recreation.
- Develop integrated energy infrastructure for renewable sources of energy, district heat-cooling-electricity systems and waste-to-energy systems.
- Deliver comprehensive programmes for rehabilitation and regeneration of problematic areas (such as former industrial sites) and to ensure better standards for energy efficiency in the built environment.
- Encourage and support eco-towns or sustainable settlements, for which explicit definitions and codes of practices can be established.
- Address climate change vulnerabilities and opportunities in the concrete context of the city.
- Ensure that the advancement towards climate neutrality is based on principles of social inclusion and socio-spatial integration, by preventing social segregation and mitigating social imbalances between neighbourhoods.

Strengthening urban resilience

In order to be "future-proof", urban resilience is a general quality needed by a city's social, economic and natural systems. With regard to climate and energy, it may be understood as a product of successful policies for achieving adaptive capacities in cities, to a level that enables them to withstand both climate challenges and the challenges of post-carbon transformation, with no or minimal losses to their functionality and well-being. As solutions designed for the climate of the past may no longer be relevant, all major capital investment decisions should be subject to a climate robustness test. It is also important that each city undertakes a climate risk assessment to investigate the exposure of the city to climate, energy and environmental risks. Social impacts assessment can identify vulnerable groups and locations and outline physical and social protection measures. As the city's overall vulnerability is ultimately determined by the quality of its socio-economic infrastructure, resilience should be purposefully and progressively 'accumulated' by improving the quality of both social well-being and the physical stock.

The following part summarizes the urban sectors and visions presented in this report:

Urban energy infrastructure

Decreasing energy demands through end-use savings and efficiency measures alleviates the need to generate as much energy as would otherwise have been necessary. It also moderates the carbon footprint. Even with efficiency measures, demand for energy will always be present and a growing population and economic development will put further pressures on demand. It is, therefore, necessary to reduce the carbon intensity of the remaining energy supply and to decouple future growth from growing carbon emissions, by decreasing the relative share of fossil fuels in energy use. This report outlines measures that will help realise the following vision:

Vision for a climate neutral urban energy infrastructure: In a climate neutral city, energy is supplied from low-carbon sources and, as much as possible, distributed renewable sources (wind; solar; geothermal; biomass; small hydro; etc), waste and combined heat and power. The generating facilities include both free-standing power generators and on-site micro-generation. District heating and cooling systems are serviced by combined cooling, heating and power generation (tri-generation) based on renewables. Utilities effectively deliver renewable energy to consumers and redistribute energy generated by micro-generation. Energy grids are modernized, supply-friendly and demand-based (each consumer takes no more energy than needed). Energy tariffs, utility regulation, incentive packages and taxes, encourage investments in efficient services, while social policies and targeted support prevent energy poverty and social imbalances. The total net annual energy balance of the city is zero or positive, so that the city may send extra electricity to the regional grids.

Residential and service buildings

The buildings sector is one of the priority areas in relation to climate neutrality. First, residential, commercial and public buildings account for a substantial share of energy demand and emissions – 33 per cent of the total final consumption in the UNECE region and almost 40 per cent of CO_2 emissions from combustion. Second, buildings are among the most valuable and longest-lasting physical capital, with a high degree of inertia. Third, as an essential element of both the built environment and the organisation of social life more generally, buildings represent a key focus for adaptation to changing climate and any resilience strategies. Fortunately, adaptation and mitigation with respect to buildings clearly intersect – as improving energy efficiency is their common denominator.

Vision for climate neutral buildings: In the climate neutral city, buildings are retrofitted to become as energy-efficient, healthy and environmentally-friendly as possible; new buildings are required to be built to 'net-zero' or 'plus-energy' standards.

The requirements are based on the full life-cycle assessment, so that the construction materials and end-of-service disposal or re-use are taken into account. The construction and real estate industries operate in a framework of strong incentives to deliver zero-energy solutions. Buildings are serviced by a well-developed maintenance industry. Planning and development control prevent sprawl and ensure socio-spatial integration, by precluding social segregation and social imbalances. Buildings in vulnerable areas are monitored and if necessary, protection measures are undertaken.

Low carbon mobility

In the UNECE region, more than 30 per cent of final energy is consumed in transport, mostly road transport. This accounts for a large portion of GHG emissions, most of which are directly from fuel combustion by car engines. The UNECE region is responsible for about 60 per cent of global CO_2 emissions in the transportation sector. At the city scale, short-distance travel is most relevant and is discussed in this report.

Vision for a climate neutral urban mobility: The climate neutral city represents an integrated mix of living, working, shopping, entertainment, recreation and green areas. The urban space has a comprehensive network of bicycle routes and bicycle facilities. Cycling and walking infrastructure is safe and convenient, including for children, the elderly and those with reduced mobility. Public transport is attractive and affordable; priority in road infrastructure is given to rapid public transit. Certain zones in the city are reserved for pedestrians or only open to public transport and electric cars. The remaining road traffic is well organised and congestion-free, while differentiated congestion charges, park and ride facilities and limited parking ensure disincentives for use of private cars in would-be congested areas. The city has a comprehensive and easily available refuelling infrastructure and service centres for alternative-fuel vehicles. Commuting into the city is easy on public transport – efficient transit (railway, metro) connects the city with other centres.

Green spaces and water systems

The system of urban green and blue (water) spaces serves as the ecological framework for environmental and economic sustainability and social well-being. It is also an essential part of local climate management strategies, because urban forestry and habitat restoration are among the simple and low cost ways for carbon sequestration and for urban air quality management. Urban green infrastructure is also a key measure for responding to the urban heat island effect through evaporative cooling and shading to create cooler microclimates. Water management is another element to be considered in urban climate-proofing, as it mitigates the risks of flooding, droughts and heat waves.

Vision for a climate neutral urban green infrastructure: Green spaces in a climate neutral city represent a considerable proportion of land use, whilst being integrated in the compact city design. The green infrastructure is organised as an uninterrupted network of green corridors and includes a variety of different elements, such as forested parks, smaller parks, grassland, water areas and wetlands. Measures are carried out for increasing the greening of the city, including through regulations for installing green roofs and converting brown field sites into green areas. The green infrastructure also acts as a natural water management system, which mitigates the risks of floods, droughts and heat waves. The urban engineering infrastructure for water management is reconciled with the natural ecosystem hydrological relationships.

Waste management

Waste is the product at the end of its lifecycle. The continual production of waste consumes resources and energy. Waste landfills are among the most significant emitters of methane and, when burned, waste is also responsible for carbon emissions. Waste disposal places a heavy load on urban infrastructure and requires land and energy consumption for the construction and operation of waste disposal infrastructure. Waste can also amplify negative local climate impacts, e.g. by blocking drainage and causing flooding.

Vision for climate neutral urban waste management: In a climate neutral city, policies are implemented to minimize waste and to promote recycling. Requirements exist for product design (including the design of buildings) to reduce environmental impacts and waste. Residents and urban industries are encouraged to sort and recycle their garbage. Waste management is integrated with water and energy management, where remaining waste is treated as a valuable feedstock for energy generation. Overall, good city infrastructure for recycling, waste-to-compost and waste-to-energy reduces related GHG emissions.

City Roadmap to climate neutrality

Based on the findings of this report, a City Roadmap for Climate Neutrality has been developed, which includes:

a. *Establishing an overall organisational framework*; and

b. *Identifying priority sectors for action*.

These are presented in the concluding chapter of this Report.

PART I

New Challenges For Cities

1. Introduction

The urgency of the climate and energy agenda for cities is increasingly gaining relevance in international policy. Cities are now widely acknowledged as strategic vehicles for addressing today's challenges of climate change. Strategies developed at and for the urban-level to tackle climate change, improve energy efficiency, and ensure green growth are essential for building local and global sustainability. This is evidenced by a recent surge in reports from major international organisations which consider cities as both a means and a target for climate actions (UNEP SBCI, 2009; OECD, 2010; World Bank, 2010a; Bose, 2010; UN-Habitat, 2011). This recognition is, to no small degree, relevant to the UNECE region where cities are the key to the organisation of social and economic activities.

The purpose of this *Climate Neutral Cities* report is to provide policy practitioners, planners and other professionals with a synthesis, in the context of the UNECE region, of responses which are being undertaken to mitigate the energy intensity and carbon footprint of cities, to reduce their vulnerabilities to climatic conditions, and to advance overall their social, economic and environmental sustainability. Hopefully, the study will serve as a reference and advocacy guide for formulating relevant policies at the international, national and municipal level. Starting by making the case for climate neutrality, the study specifies a range of programmatic measures for a progressive transformation towards low energy, low carbon, highly resilient and ultimately, climate neutral cities. These measures will have broader multiplication effects, allowing the UNECE cities to address many of their social, environmental and developmental challenges.

The report is organised in four Parts and twelve Chapters.

In Part I, following this Introduction, Chapter 2 reviews the importance of cities for climate change policies, with a focus on the UNECE region.

Part II outlines institutional and cross-sectoral territorial mechanisms that underpin mitigation and adaptation strategies for cities. More specifically, it outlines the role of international and national policies (Chapter 1), policies of city governments (Chapter 2), urban planning and building control (Chapter 3) and urban resilience policies (Chapter 4).

Part III provides more targeted considerations for relevant individual sectors of the urban economy, including energy infrastructure (Chapter 1), buildings and housing sectors (Chapter 2), transport and mobility (Chapter 3), green spaces and water systems (Chapter 4) and waste management (Chapter 5). The discussions are illustrated by some examples from across the UNECE region. Policy recommendations provided in these chapters are then used in Part IV, which outlines the 'City Roadmap for Climate Neutrality', with specific actions to be implemented in the UNECE region at the city level.

2. Climate change, cities and policy agendas

One of the most pressing problems of the present century is to respond to the challenges generated by climate change, without compromising the principles of sustainable development (including the social, economic and environmental dimensions). This should involve, *inter alia*, limiting greenhouse gas (GHG) emissions and coping with the remaining unavoidable effects of climate change in order to minimize negative impacts on people's welfare, infrastructure and natural ecosystems (Box 1).

Energy consumption in cities - According to estimates, cities are responsible for 75 per cent of global energy consumption and 80 per cent of greenhouse gas emissions (GHG). GHG emissions from commercial and residential buildings are closely associated with emissions from electricity use, space heating and cooling. In Russia, the residential sector is the second largest energy end-consumer after manufacturing. © Valery Markov/Fotolia

There are many implications here for cities. Cities are both important generators of GHG emissions and end-users of goods and services, the production of which involves emissions elsewhere (Satterthwaite, 2011). For the most part, these emissions result from the combustion of fossil fuels as the main source of energy and the main source of

GHG (Figure 1). Cities use energy for heating, cooling, lighting and for the operation of machines and appliances. Cities also consume energy embedded in the manufacturing of consumer goods, foodstuff and building materials. Another principal GHG, relevant for urban-level policies, is methane, which is emitted from solid waste decomposition, wastewater treatment, food production, land use change and energy conversion. Cities are involved in combating climate change through policies such as improved energy efficiency, a reduced use of fossil fuel and sustainable methods of waste utilisation and recycling.

Meanwhile, urban communities themselves are also vulnerable to climate change. Urban areas concentrate people and infrastructure and are often in hazard-prone areas. They experience some of the largest impacts from both gradual climatic change and abrupt weather occurrences. It is the poorer and the most disadvantaged who usually suffer most. Cities must therefore embrace socially-oriented policies for improving resilience and preparedness to cope with the negative environmental impacts.

Box 1. Climate change

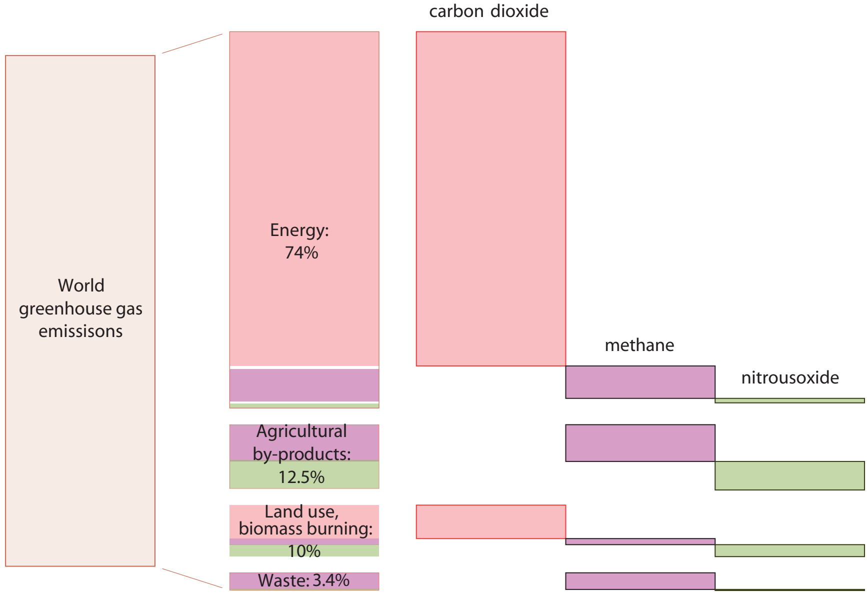
Accelerated climate change is believed to be a result of human activities that change the balance of GHGs in the atmosphere. The associated GHGs include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), ozone (O3) and chlorofluorocarbon (CFC), as well as some gases of minor presence, known as F-gases: sulphur hexafluoride (SF_6), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs). CO_2 is the largest individual contributor to the greenhouse effect (Figure 1). Although the levels of CO_2 in the atmosphere have varied enormously in the Earth's geological past, the natural cycle of CO_2 has remained stable for a few recent millennia. Human activities disturb this balance by releasing CO_2 captured in natural 'carbon sinks' such as fossil fuels and green biomass. The burning of fossil fuels and the reduction of forests, grasslands and peatlands due to the impact of human activities, have resulted in an increase of the concentration of CO_2 in the atmosphere by almost one-third, since the dawn of industrialisation in the 18th century. In the same period, the presence of methane in the atmosphere has more than doubled.

As a result of these interferences, the past century has seen an underlying rise in average temperatures, followed by changes in other climatic parameters, such as precipitation, wind and weather patterns – cumulatively known as 'climate change'. As average global temperatures rise, the climatic system responds with an increased frequency of abnormalities, leading to intensified heat waves, cold waves, droughts, storms, floods, rising ocean level, and, melting permafrost and ice caps. If the trend continues, the consequences will involve large human and economic losses and limitations on economic development.

The reduction in GHG emissions is a key mechanism to slowdown climate change; such practice is known as *mitigation*. However, even if all man-made carbon emissions were to cease within this century, it would still not be possible to return to pre climate change atmospheric temperatures for at least a millennium (Solomon et al., 2008). Given this irreversibility, certain *adaptation* measures are inevitable in order to adjust to the new climate. Adaptation to climate change refers to actions to reduce the vulnerability of social and ecological systems, or individuals to the adverse impacts of anticipated climate change.

Source: based on IPCC, 2007.

Figure 1. Breakdown of world GHG emission by cause and by gas



Source: MacKay, 2009, p. 15, based on 2000 data (the most recently available data).

Both sides of climate policy – mitigation (locally reducing the causes of the climate change) and adaptation (addressing the local negative impacts of climate change) – are integral parts of a comprehensive urban strategy for *climate neutrality*. A strategy for climate neutrality suggests that:

a. Cities aim to achieve net zero emissions of GHG by reducing such emissions as much as possible and developing trade-off mechanisms to offset the remaining unavoidable emissions; and

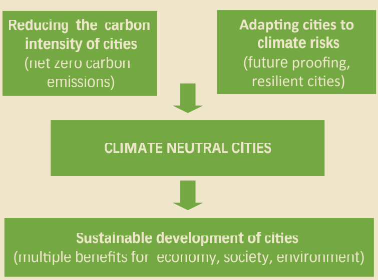
b. Cities aim to become climate-proof, or resilient to the negative impacts of the changing climate, by improving their adaptive capacities (Box 2).

Climate neutrality is not only a goal for cities to seek; it is also a pathway to that goal – a process of purposeful and progressive transformation towards low energy, low carbon, highly resilient and ultimately climate neutral urban economies and societies. Climate neutrality presupposes a change from fragmented sectoral-based interventions to an interrelated matrix of comprehensive actions integrated at an urban scale.

While climate neutrality is a strategy to be 'climate-smart', it is also a means to address other environmental, economic and social challenges. In fact, reducing energy use and associated GHG emissions are 'no-regret-policies' because they make a major contribution to urban sustainability with multiple co-benefits. Certainly, policies such as 'compact city' (or 'smart growth' as it is commonly called in North America), transport planning, increased green spaces and improved energy efficiency are all elements of urban sustainability that predate the international quest for climate neutrality. The need to reduce GHG emissions only strengthens their importance. Climate neutrality is, furthermore, a great opportunity to promote national and local economic competitiveness, to enhance energy security, to improve quality of life and to tackle poverty. Benefits from climate neutral cities certainly represent a 'multi-win' situation, with positive effects felt from the global community as a whole, to national economies, to cities and down to individual citizens who will enjoy an improved living standard, better health and more employment opportunities. The pursuit of these co-benefits is crucial for generating sufficient support among different stakeholders to climate neutral policies.

Box 2. Mitigation and adaptation as two sides of an integral urban response

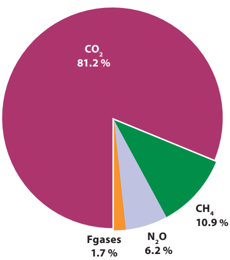
Mitigation and adaptation have traditionally been considered as distinct sets of policies. The distinction, however, dissolves at the urban scale, since both the reduction of energy use (important for mitigation) and the reduction of climate vulnerability (important for adaptation) are at the centre of local concerns. Indeed, many urban practices demonstrate interdependencies and synergies between adaptation and mitigation and, with other measures to be implemented regardless of the climate change concerns. For example, insulating housing helps reduce energy demand (mitigation) and to give property and inhabitants better protection from weather extremes (adaptation). As another example, large cities represent 'heat islands' because they are significantly warmer than the surrounding areas. Heat islands have negative impacts on human health and biodiversity. Measures to mitigate the local heat islands effect, such as tree planting, vegetated roofs, cool roofing, cool paving, and, reduction of heat losses from buildings and infrastructure, also reduce emissions (mitigation) and prepare cities for amplified heat waves (adaptation). There are, however, examples of adaptation measures which hinder mitigation, such as traditional air conditioning, which may help tackle heat waves, but increases energy demands. The challenge is to reduce contradictory relationships as much as possible and to build upon complementarity. The concept of climate neutrality, as shown below, assists with such a synergetic approach:



The UNECE region is undoubtedly a major stakeholder in international climate and energy policies. It has a stronger economic position relative to the other UN regional commissions. For comparison, it has less than a fifth of the world's population, but is responsible for approximately 60 per cent of the world's GDP, 45 per cent of energy consumption and 40 per cent of GHG net emissions[1] (Figure 2). There is also of course, much variation between individual UNECE countries, for instance, in the intensity of GHG emissions. This is, for example, demonstrated in Figure 3 by a per capita measure of CO_2 emission from fuel combustion (which, as already discussed, is a predominant source of total CO_2 emissions). Although there may be some doubt as to what extent such data are reliable (especially for the lower tail), this variation does visibly exist, due to varied levels of development, differing structures of national economy and differing mixes of energy supply. Since countries at a high risk of exposure, or those potentially most vulnerable to the impacts of climate change, are not necessarily those with the higher emissions, there is certainly a particular responsibility for climate actions placed on the latter – and in the global context, on the UNECE region as a whole as a more affluent region.

The UNECE region is also characterised by very high levels of urbanisation. For the year 2010, more than 73 per cent of its residents are estimated to be 'urban residents' and by mid-century this proportion may reach 85 per cent (Figure 4). The most rapidly urbanising countries in the next decades will be those which today have lower rates of urbanisation; urban areas are already the powerhouses of national economic development in such countries. Therefore, all cities in the UNECE region bear a responsibility for reducing the carbon intensity of their economies, while at the same time improving the resilience of the whole region.

Figure 2. Estimates for GHG emissions in UNECE region compared to the world in 2005

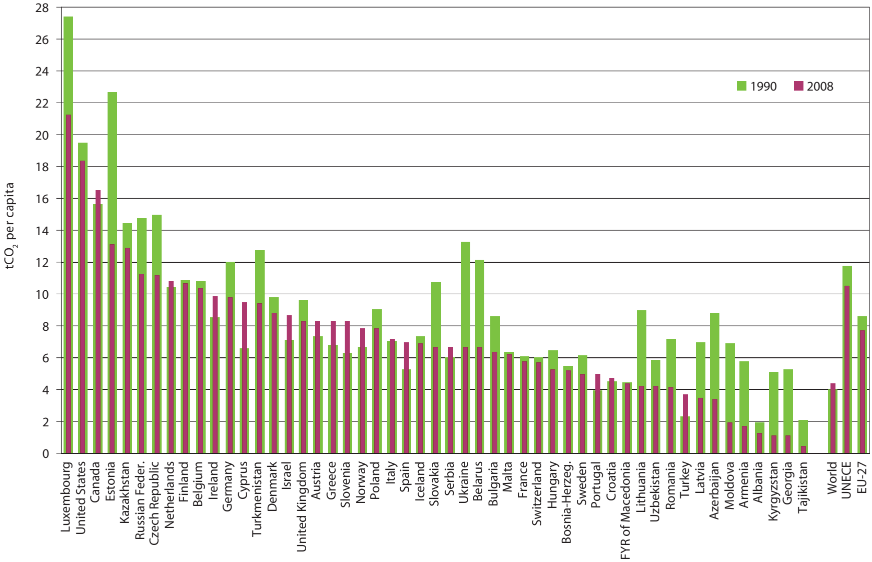


Gas	UNECE GtCO$_2$e	UNECE % total	World GtCO$_2$e	World % total
CO_2	13.81	81.2	33.89	76.8
CH_4	1.86	10.9	6.41	14.5
N_2O	1.05	6.2	3.29	7.4
HFCs	0.21	1.2	0.38	0.9
PFCs	0.05	0.3	0.11	0.2
SF_6	0.03	0.2	0.06	0.1
Total	17.00	100.0	44.13	100.0

Notes: (a) Includes land use change and international bunkers, (b) Estimates for GHG emissions are subject to considerable variations due to a lack of reliable data.
Source: Based on World Resource Institute, 2011

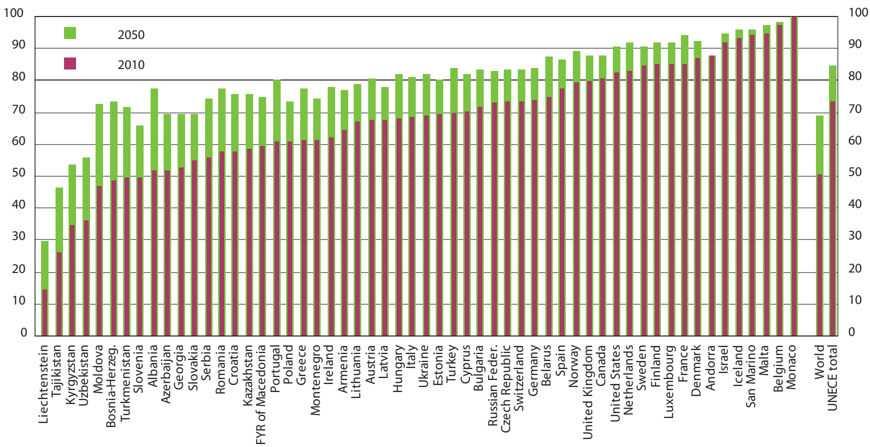
[1] Taking land use change and forestry into account.

Figure 3. CO_2 emissions per capita in 1990 and 2008



Notes: CO_2 emissions from fuel combustion only.
Source: Based on IEA, 2010a

Figure 4. Percentage of population residing in urban areas: UN forecast for 2010 and 2050



Note: The definition of 'urban areas' may vary between countries.
Source: Based on database of UN DESA, 2010

UNECE cities (like cities in many other regions) already possess good institutional prerequisites for addressing such a responsibility, such as designated administrations and spatial planning instruments. There are indeed many successful examples of cities effectively constructing and delivering integrated territorial policies for climate neutrality. However even in those cities that are considered to be advanced in their climate change policies, the existing situation leaves much room for improvement. Yet others may not have sufficient political will, information or resources to follow the leaders. Many urban areas are divided into multiple municipal jurisdictions with fragmented territorial responsibilities. This creates barriers to cooperation, in particular when developing the infrastructure across jurisdictions. Furthermore, ageing and badly maintained physical stock and energy-inefficient practices in countries with economies in transition, coupled with limited awareness and capacities, represent a serious barrier in terms of both resilience and mitigation. Overall, the very diversity of the experiences in the UNECE region represents an opportunity for mutual learning, capacity building, advocacy and the diffusion of innovative practices.

PART II

Governance And Institutions

1. International and national policies

At the international scale, regulatory regimes for climate neutral cities are linked mainly to the architecture of global climate governance shaped by the United Nations, including the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC) (Box 3). The reductions of energy consumption and emissions in urban areas constitute important measures to comply with the Protocol. As the commitment period of the Kyoto Protocol expires in 2012, there are international negotiations underway on a regime to succeed it. It is apparent that countries will have to commit themselves to ambitious reductions in GHG within a post-Kyoto agreement. The urgent need of a decisive response to climate change is also part of the United Nations Millennium Development Goals (MDG) - more specifically of Goal 7 'Ensure environmental sustainability' and Target 7A, which calls to 'integrate the principles of sustainable development into country policies and programmes and reverse the loss of environmental resources'. Measures for climate neutrality are also relevant to other MDG, including those related to poverty reduction, improved employment opportunities, improved living conditions, and access to new technologies.

Box 3. The first global agreements for climate protection

The 1992 Earth Summit in Rio de Janeiro led to the establishment of the first global treaty for implementing climate policy, namely the United Nations Framework Convention on Climate Change (UNFCCC). Its goal is to 'achieve a stabilization of GHG concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interferences with the climate system'. UNFCCC was the driving force behind the Kyoto Protocol – a binding agreement linked to UNFCCC. The Protocol was adopted in 1997 and came into force in 2005. It sets binding targets for industrialized countries listed in its Annex B, aiming to reduce their GHG emissions compared with 1990 levels, to an average of 5 per cent (averaged over the five-year period 2008-2012). Of the 38 countries in the Protocol's Annex B, 35 are the UNECE Member States (the others being Australia, New Zealand and Japan). The exact target for each country was based on its historic emissions and capacities to change, so that the targets have ranged from -8 per cent for each of the EU-15 countries and the European Union as a whole, to 0 per cent for Russia and Ukraine and up to +10 per cent for Iceland. The countries must have met their targets primarily through national measures. The Kyoto protocol also established three market-based mechanisms as additional means of compliance, including Emission Trading, the Clean Development Mechanism and Joint Implementation.

UNECE has taken a number of initiatives relevant to completing the MDG, including in the field of climate change in the urban environment. Several framework documents are particularly noteworthy. UNECE has recently adopted the *Action Plan for Energy-efficient Housing in the UNECE Region*. It develops a comprehensive programme of work for a transformation towards a low energy and ultimately carbon-neutral buildings/ housing sector (see Chapter 8). Also, the *Transport, Health and Environment Pan-European Programme* (THE PEP) was adopted in 2002 as a joint programme of UNECE and the World Health Organisation (WHO). THE PEP considers how to decrease the impact of transport on health and the environment and to reduce transport-related GHG emission. Proposed measures include the development of clean and efficient public transport, improving the coordination between spatial and transport planning, providing infrastructure for walking and cycling, and improving energy-efficient and clean transport modes (see also Chapter 9).

Examples of relevant policy developments and regulations at the international level are also evident from international unions within the UNECE region, such as at the European Union (EU) level. Most importantly, in 2009, the EU adopted an integrated package of energy and climate policy, which includes the following commitments, to be reached by 2020 (known as 20-20-20):

- 20 per cent cut in GHG emissions by 2020 as compared to the 1990 levels;
- 20 per cent share of renewable energy of total energy consumption to be reached by 2020; and,
- 20 per cent cut in energy consumption of projected 2020 levels through improved efficiency.

At the national level, governments have their own strategies and laws, which are translated into regional and local policies. In addition to regulatory instruments, a number of financial, educational and voluntary instruments can be found. However, the workability of the national initiatives varies considerably. In many countries energy efficiency and climate strategies remain to be implemented, or are limited in scope. Meanwhile, national governments are key to creating enabling policies for the local territorial level, including in cities.

Effective government policies for climate neutrality involve not only a sectoral focus, but also cross-sectoral and local territorial approaches, for which it is necessary to integrate territorial policies and climate policies. The following instruments can generally be used by national governments to facilitate the transition towards climate-smart cities:

a. Sectoral and cross-sectoral instruments:

- *Regulation:* legislation, performance standards, regulations for utilities and the public sector, national action plans.
- *Financial and fiscal incentives:* grants, subsidies, taxes, social/welfare assistance.

- *New markets promotion:* the establishment and promotion of a carbon market, green markets, energy efficiency services.
- *Strategic programmes:* research and development, strategic initiatives for the public sector.
- *Advocacy and capacity-building:* educational programmes, technical assistance, information facilitation, awareness-raising.

b. Territorial instruments:

- Observing the national policies and targets via territorial agencies.
- National spatial planning and building regimes.
- Inter-spatial fiscal redistribution regimes.
- Area-based investment programmes: infrastructural and environmental programmes, special programmes for vulnerable areas.
- Awards to 'champion' regional and city governments in relevant competitions.

2. City and regional governments

As a number of sectors important for GHG emissions are located in the urban area, city governments play a crucial role in influencing the transformation of those sectors; they are also the key to local adaptation measures because of their physical and constitutional proximity to the local context and to the residents. Sub-national and local governments can execute their authority in regulatory and planning functions, local charges, procurement procedures and direct management of public property. They not only translate national policy and resources into implementing policies 'on the ground', but also present themselves as an important vehicle for innovation in climate policy and practice. Indeed, even in the absence of dedicated regulations at the national level, city governments are eager to take actions for their own responses to global warming. As demonstrated by Table 1, there are examples of cities in the UNECE region that have committed themselves to more ambitious reduction targets than those set by their respective national authorities. Some cities even target climate neutrality, thus bringing this goal closer to reality (for further examples, see also: C40, 2011).

Key factors for effective climate policy development and implementation in cities are collective public awareness and individual political leadership. Because the combination of these factors varies between different areas, there may be a large spectrum of responses among cities even within the same sub-national jurisdiction or in the smaller countries (e.g. for the case of Sweden, see Langlais, 2009). Even those local governments that do demonstrate proactive strategies often face a lack of legal mandate from national governments to implement advanced measures (OECD, 2010).

Table 1. Examples of GHG emission-reduction plans for UNECE cities

City, Country	Base year (CO_2e)	Reduction target, year (CO_2e)	Principal document, year adopted	Hyperlinks
Copenhagen, Denmark	2005 (2.5 Mt)	20%, 2015 (2.0 Mt) carbon neutral, 2025 (1.15 Mt are offset)	Copenhagen Climate Plan, 2009	http://bit.ly/gdN7a8
Stockholm, Sweden	1990 (3.7 Mt or 5.4 t per capita)	37%, 2015 (2.3 Mt or 3.0 t per capita), carbon neutral, 2050	Stockholm action plan for climate and energy 2010–2020	http://international.stockholm.se/Stockholm-by-theme/A-sustainable-city
Hamburg, Germany	1990 (20 Mt)	30%, 2012 (14 Mt) 40%, 2020 (12 Mt) 80%, 2050 (4 Mt)	Hamburg Climate Action Policy, 2007 (revision 2009/2010)	http://bit.ly/H9zfkE
London, UK	1990 (45 Mt)	22%, 2015 (35 Mt) 38%, 2020 (28 Mt) 60%, 2025 (18 Mt)	The Mayor's draft Climate Change Mitigation and Energy Strategy, 2010 (proposed)	http://bit.ly/GTsQ95
Rotterdam, Netherlands	1990 (24 Mt)	50%, 2025 (12 Mt)	Rotterdam Climate Initiative, 2007	http://bit.ly/A5pC5
Vancouver, Canada	1990 (2.9 Mt)	6%, 2012 33%, 2020 80%, 2050	A Community Climate Change Action Plan for the City of Vancouver, 2005; Vancouver's Climate Leadership, 2009	http://vancouver.ca/sustainability/climate_protection.htm
Chicago, USA	1990 (32.3 Mt)	25%, 2020 (24.2 Mt) 80%, 2050 (6.5 Mt)	Chicago Climate Action Plan, 2008	www.chicagoclimateaction.org
Paris, France	2004	30%: City, 2020 25%: Region, 2020	The Paris Climate Protection Plan, 2007	http://bit.ly/HbLVp8
Madrid, Spain	2004 (15 Mt)	20%, 2020 (12 Mt) 50%, 2050 (7.5 Mt)	City of Madrid Plan for the Sustainable Use of Energy and Climate Change Prevention, 2008	http://bit.ly/Ha73Ld

Note: Mt = million (metric) tonnes per year, CO_2e = GHG emissions in equivalent CO_2; hyperlinks are accessed in March 2012.

This may include, for example, limited regulatory and fiscal authority and lack of control over energy utilities or over strategic transportation development. In their strategies, local governments often go beyond their legislated capacity, which raises concerns over their effective implementation. The national governments need to delegate sufficient enabling capacities (such as taxation and revenue generation authority) and regulatory mandates to local governments in order to actively involve them in building a coordinated response to global warming. A strong collaboration between central and local governments should be based not only on the transfer of regulatory powers and budget capabilities, but also on the transfer of knowledge and best practice.

Also important is cooperation between neighbouring municipalities, because many initiatives cross the borders of individual administrative jurisdictions (e.g. infrastructural projects or public transport). Particularly, larger metropolitan areas are often divided into a fragmented matrix of municipalities. Here, the role of regional (sub-national) administrations as coordinating, enabling and funding bodies cannot be overstated (Wheeler, 2009). They can facilitate cross-border cooperation and overcome the potential fragmentation of local efforts. An effective instrument for infrastructural projects is regional spatial planning, which may be administered by regional governments. They can facilitate cross-border cooperation between different municipalities and overcome the potential fragmentation of local efforts. Cities which have a 'regional' administrative mandate, which is often the case for larger cities, are more capable in facilitating larger projects and territorial cohesion (OECD, 2010).

It is not necessary, however, that city governments form only 'local' or 'regional' institutions. They can also create 'horizontal' national and international networks or associations which complement the 'vertical' regimes of governance (Box 4). Such inter-urban associations provide a platform for sharing knowledge and for mutual support. Climate protection measures advocated by these associations are often expressed in agreements. An example is the 2007 *World Mayors and Local Governments Climate Protection Agreement*, which calls for a reduction in GHG emissions by 60 per cent from 1990 levels worldwide by 2050 and, in industrialized countries nationally, by 80 per cent from 1990 levels. It also declares a number of commitments for the signatories themselves, although without specific measurable targets. Similar 'horizontal' agreements exist at the national level, as illustrated by the 2005 *US Mayors Climate Protection Agreement* coordinated by the United States Conference of Mayors, to which more than a thousand mayors have become signatories. Under the Agreement, cities commit themselves to meet or beat the Kyoto Protocol targets (7 per cent reduction from 1990 levels for the US) in their own communities through actions ranging from anti-sprawl land use policies and urban forest restoration projects, to public information campaigns and advocating state and federal GHG reduction policies and programmes.

Box 4. International city networks for climate protection

A number of international urban networks have been prominent in the field of climate protection, including:

- ICLEI - Local Governments for Sustainability
- World Mayors Council on Climate Change (WMCCC)
- C40 Climate Leadership
- United Cities and Local Government (UCLG)

In 2008, UNEP launched a Climate Neutral Network (CN Net), which is a web-based project at an early stage of development, seeking to bring together the small but growing wave of nations, local authorities and companies who are pledging to significantly reduce emissions *en route* to zero emission economies, communities and businesses. The key objective of CN Net is to facilitate information exchange amongst stakeholders in cities and local administrations.

Apart from cooperation between cities and between different administrations, city governments should seek a broader participation of stakeholders and the involvement of the population in climate-related decision-making processes. This is to inform, and to be informed by, the local community's knowledge about climate challenges (including information about existing impacts on residents) and to share the ownership of new strategies with a larger group of stakeholders, thus ensuring their more successful implementation. Such participation and cooperation can also bring-in missing technical expertise. For example, universities obviously represent an intellectual resource at the local level that can, on the one hand, support city governments in developing energy-related and carbon reduction policies and strategies and, on the other hand, play a key role in building knowledge on climate-smart practices through changes in curriculum and teaching methods (World Bank, 2010b).

Local responses to climate change are often circumscribed by the fiscal capacities of municipalities or regions. Even if substantial achievements can be reached with moderate cost, systematic and comprehensive climate policies *are* capital intensive. City governments need to identify sustainable sources of income for these policies. Local fiscal and payment regimes may themselves play a stimulating role to encourage or discourage certain activities, projects or lifestyles and these may have serious implications for climate neutrality. Some examples are public transport fees, parking fees, congestion charges, property taxes and development charges. Financial resources can also be sought from the private sector; public-private partnerships may be established in order to share risk and raise private finance for infrastructure and energy efficiency projects. In their turn, national governments must ensure adequate resource mobilization for the local and regional governments, because it is at the national level that different forms of taxes can be institutionalized more comprehensively and effectively. Certain possibilities exist for cities in the use of the Clean Development Mechanism and the Joint

Implementation Mechanism under the Kyoto Protocol, for projects that reduce cities' carbon emissions.

3. Spatial planning and building control

Today, spatial planning in its various manifestations – regional and urban planning, land use zoning – finds itself right at the heart of adaptation and mitigation measures. Indeed, urban layout, public transit provision and integrated district heat-electricity systems are some of the planning considerations that have long been acknowledged as among the principal instruments to reduce urban energy intensity (e.g. Owens, 1986). Planning is also instrumental in identifying risk-prone zones and in providing spatial strategies to safeguard urban infrastructure. What is no less important is that planning decisions on land use and urban layout have impacts lasting for decades and even centuries. Particular land use and infrastructural patterns create circles of 'path dependence', when future investments are predetermined by existing infrastructure, which may lock economies into particular lifestyles and patterns. Spatial planning is important to prevent being locked into high-carbon or hazard-prone conditions that would be expensive or impossible to alter later (World Bank, 2010b).

Spatial planning is relevant for all sectors of the urban economy (some of which are considered in the following chapters) and is principal for the integration of different sectors and urban systems into a consolidated spatial strategy (Rydin, 2010). It is often the case, however, that links between territorial plans and climate policies are weak. This is because climate policies are often focused on particular economic sectors and may disregard spatial relations between and within urban sectors, as well as the importance of how urban space is organised (OECD, 2010). A purposeful integration of planning with policies for climate-smart growth is needed.

Spatial planning as an institution of public policy does not, however, need to be reformed if it is already well established and if it follows the UNECE guidelines (UNECE, 2008); but planners have to embrace new energy-conscious and climate-conscious priorities and practices, and probably need to acquire new skills and know-how. On the other hand, where planning as a public institution is weak, the attention to climate change and growing national commitments to carbon reductions present an opportunity to develop a good planning system, as one of the key institutional responses to this new international agenda.

Solar Settlements with plus-energy houses - These houses are part of the "Solar Siedlung", a 50 plus-energy building settlement of Vauban district in Freiburg, Germany. Over the year, these plus-energy houses produce more energy through renewable energy than they consume due to their low-energy construction design. The inhabitants of this district are particularly environmental conscious: every third resident has chosen to live car-free. © rsester/Fotolia

The potential of urban planning is today realised in the design of new low carbon or even zero-carbon cities, or urban districts worldwide. Some prominent examples of new low carbon communities include: Masdar City, currently being built in Abu Dhabi as a zero-carbon, zero-waste, car-free municipality for 50,000 residents, which will become the world's first climate neutral city, Dongtan in China being planned as a low carbon city to accommodate 0.5 million people, the Western Harbour (Västra Hamnen) district of Malmö being turned from a brown field area into an environmentally-friendly town based on 100 per cent renewable energy. Smaller scale examples are BedZED – or Beddington Zero-Energy Development – consisting of 99 homes, which is the first zero-energy, low-impact, car-discouraging residential community in the United Kingdom (UK) and Etten-Leur, with 43 houses is a similar zero-energy housing demonstration project in the Netherlands. While there are encouraging examples, it is even more important to act in existing urban districts, where there is a large potential for paving a more sustainable future through climate-smart urban planning. Indeed, most of those UNECE cities that embrace policies for carbon reduction (see Table 1) make proactive use of the instruments of planning (see also Joss, 2010 for a list of 79 recently planned "eco-towns" worldwide).

Green Homes in Malmö - Västra Hamnen in Malmö, Sweden, turned from being an industrial area into a green residential district. It provides a good example of how modern architecture, latest building technology and sustainability aspects can be merged. The estimated energy consumption is 105 kWh per square meter per year, thus making the residential area consume half the energy of other residential areas of Malmö. Renewable energy is used in form of solar and wind power and heat extraction. All the energy consumed in this district is produced locally. © crimson/Fotolia

More specifically, the planning practice needs to address a number of important concerns for reducing cities' energy and carbon intensities and adapting them to the new climate. These are:

- Limit urban sprawl and car-dependency by ensuring appropriate levels of building density and mixed-use developments, organising and improving transport flows, public transport and non-motorised transportation options. As mentioned above, regional spatial plans can help to integrate local initiatives and coordinate infrastructure projects (see Part III Chapter 3).
- Provide an integrated system of green spaces and other natural infrastructure, which should protect the city from adverse weather conditions, mitigate the urban heat island effect, reduce the need for engineered systems, and provide spaces for natural habitats and human recreation (see Part III Chapter 4).
- Develop integrated infrastructure for renewable sources of energy, district heat-cooling-electricity systems and waste-to-energy (see Part III Chapter 1).

- Deliver comprehensive programmes for rehabilitation and regeneration of certain problematic areas (e.g. derelict, former industrial land) and to ensure better standards for energy efficiency in the built environment (see Part III Chapter 2).
- Encourage and support eco-towns or sustainable settlements, for which explicit definitions and codes of practices can be established.
- Translate the assessments of climate change vulnerabilities and opportunities into the concrete geographical context of the given city.
- Ensure that the advancement towards climate neutrality goes alongside social inclusion and socio-spatial integration, by preventing social segregation and mitigating social imbalances between neighbourhoods.

Building control is a powerful tool to complement planning. Contrary to spatial planning itself, which may be opposed by some political ideologies as 'excessive' public interference (resulting in the scope therefore being limited in certain regions), building control is more easily accepted as a regulatory regime (this has been the case for the United States and some post-socialist countries – see Cullingworth and Caves, 2009, Golubchikov, 2004, Stanilov, 2007). Building control may also ensure the presence of planning targets in the actual construction practices, including in the private sector. Legal provisions can be established such as those, for example, which require that building permits are only issued for projects that are optimized spatially to reduce energy demand, including density and transport considerations, taking advantage of natural heating, cooling, lighting and shading potentials, and, that incorporate building materials and other means for reducing urban heat island effects (e.g. cool walls, roofs and paving, increasing green areas). Moreover, urban development projects should be subject to a holistic assessment with regard to their environmental standards, which means that the full lifecycles of buildings (all stages from manufacturing of construction materials to demolition and recycling of the materials) are optimized in order to reduce the overall carbon footprint. Projects with certain levels of energy efficiency should be given a fast track application process for planning permits so as to increase incentives.

4. Strengthening urban resilience

One impact of climate change: more frequent and severe floods - During the month of May in 2010, heavy rains caused flooding in Europe. The flood hit Poland, Czech Republic, Hungary, Slovakia, Serbia and Austria (see picture above). In Poland, 23,000 people had to be evacuated. © Gina Sanders/Fotolia

Climate-smart cities are not only cities that are 'climate friendly', but also cities that are exposed only to a 'friendly climate', that is, that are protected from climate change's negative effects. The latter represents a serious challenge in itself, as the effects of climate change are already being recorded worldwide. Depending on their location, cities are increasingly exposed to intensified heat waves (e.g. the record-breaking heat waves in some regions of the world in 2003 and 2010), droughts, wildfires, storms surges and floods, as well as to rising sea levels (in coastal areas), melting permafrost (in northern areas), and, other climate-induced geomorphological hazards. These manifestations may involve significant cost to human health, to physical capital and to natural habitats, leading to further public and private costs associated with aid, rehabilitation, resettlement, or conflict resolution (for details see IPCC, 2007a).

Key aspects in mitigating the present and future negative impacts are improved adaptation and resilience (e.g. Nelson et al., 2007). Resilience is usually defined as the 'ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organisation, and, the capacity to adapt to stress and change' (IPCC, 2007b, p.86). So, on the one hand, there are external changes, rapid or slow, which expose cities to new situations, to disturbances and even shocks. On the other hand, there are internal capabilities and capacities of urban systems to withstand these changes, to minimize negative impacts and to maximize benefits. Urban resilience with regard to climate can then be understood as a product of successful policies, whereby the adaptive capacities of cities (as human and technical systems) are able to withstand climate challenges with no or minimal losses to their functionality and well-being.

Yet, the notion of urban resilience is not restricted to climate adaptation; it can be extended to the capabilities of cities to cope with other challenges, hazards and shocks – both of natural origin (e.g. earthquakes, tsunamis) and socially-produced (e.g. economic downturn, terrorism). In other words, urban resilience is a general quality of the city's social, economic and natural systems to be sufficiently 'future-proof'. It is noteworthy that reducing reliance on carbon-intensive energy consumption allows urban economies to accommodate better the effects of energy price fluctuations, of the extinction of hydrocarbon resources and, importantly, of policies and demands increasingly set by international and national governments for 'low carbon transitions' (Newman et al., 2009; Bulkeley et al., 2010).

In relation to both climate and energy, there are a number of organisational measures for improving urban resilience. Each city has to undertake a climate risk assessment (which may be part of a city's evidence-based profile for climate and energy) to investigate the exposure of the city to climate, energy and environmental risks. Such an undertaking does not need to be based on sophisticated climate modelling, but rather on the analysis, against a matrix of possible vulnerability scenarios, of existing physical and social patterns for the city. For example, social impacts assessment can identify vulnerable groups and locations and can outline physical and social protection measures. Geographic Information Systems (GIS) may facilitate the identification and visualisation of vulnerable locations, such as those exposed to heat waves, floods or storms, or those which contain energy-inefficient buildings, disadvantaged neighbourhoods or key social facilities, which may be in a risk category (such as hospitals, retirement houses, or schools). The results of this assessment can inform the action plan for climate neutrality and for the implementation of the suggested preparedness and prevention measures for specific areas or groups. An essential organisational element is also the setting-up of systems for surveillance, early warning and contingency plans in the city.

Haze caused by wildfires - A heat wave during the summer months of 2010 in Russia caused the worst wildfires in decades and up to 5,000 people were claimed dead. In a range of merely a couple of weeks, temperature records for the time of the year were hit on several occasions. Above, a group of tourists is trying to distinguish St Basil's Cathedral through the thick, acrid haze caused by the wildfires around the capital. © Apro/Fotolia

Consequently, all major capital investments should be subject to a climate robustness test and incorporate future-proof design. Previous solutions designed for the climate of the past may no longer be relevant under new uncertainties. To overcome the inherent uncertainties of climate change, major new investment solutions should incorporate flexibility, diversification and redundancy. The *2010 World Development Report* (World Bank, 2010b) highlights a number of important principles for such strategies:

a. 'No-regrets' actions that would provide benefits irrespective of climate change (such as energy and water efficiency);

b. Reversible and flexible options to keep the possibility of wrong decisions as low as possible (e.g. restrictive urban planning for coastal areas can be relaxed, whereas forced retreats from such areas due to flooding or increased protection can be very costly);

c. Safety margins or redundancy (e.g. paying the marginal additional costs of building a higher bridge, or extending safety nets to vulnerable groups);

d. Long-term planning based on scenario analysis and an assessment of alternative urban development strategies under a range of possible future scenarios; and

e. Participatory design and implementation based on local knowledge about existing vulnerability and fostering ownership of the strategy by its beneficiaries.

Whilst the anticipation of the external (natural or economic) shocks is vital for prioritizing certain fields or directions and for arranging operational responses, the city's overall vulnerability is ultimately determined by its physical shape and the quality of its socio-economic infrastructure. Factors which leave cities badly exposed are a dilapidated and inefficient capital stock: buildings built in the absence or in violation of construction regulations, poorly maintained urban engineering systems, under-developed public services, social inequality, and, polarization and deprivation. It is not possible to make cities resilient overnight; rather, resilience is purposefully and progressively 'accumulated' by improving the quality of both the social well-being and the physical stock, while incorporating into all capital investment decisions the relevant principles and considerations, as described in this report. As Newman et al. (2009, p. 7) note, "In a resilient city every step of development and redevelopment of the city will make it more sustainable: it will reduce its ecological footprint (consumption of land, water, materials and energy, especially the oil so critical to their economies, and the output of waste and emissions) while simultaneously improving the quality of life (environment, health, housing, employment, community) so that it can fit better within the capacities of local, regional, and global ecosystems."

PART III

Actions For Priority Sectors

The following gives an overview and guidelines for the individual priority sectors of the urban economy with regard to climate neutral cities.[2] Two elements are discussed for each sector:

- *Relevance to the climate neutral agenda*: Why is this particular sector important for urban mitigation and adaptation? What is its existing status in relation to climate neutrality? Why should the sector be prioritized above other concerns and necessities in the corresponding policy agenda?
- *Strategies and actions for the transformation towards climate neutrality*: What functional and operational performance does the sector need to demonstrate in a resilient, energy-efficient and climate-friendly city? What general policy options exist and what specific actions need to be taken in line with transforming the city towards greater levels of climate neutrality?

1. Urban energy infrastructure

The carbon footprint of a city is directly related to the amount of fossil-based energies the city consumes. It can be reduced by decreasing end-use energy demands through introducing saving and efficiency measures. But even with such measures, some demand for energy will always be present and a growing population and economic development is expected to bring further pressure. It is therefore necessary to reduce the carbon intensity of the remaining energy supply and to decouple future growth from growing carbon emissions by decreasing the relative share of fossil fuels (Table 2).

Those UNECE cities and regions that take climate-action measures seriously set targets to increase renewable sources in their energy supply. Hydroelectricity, wind, solar photovoltaic, solar thermal, geothermal, tide and wave are all renewable types of energy that do not involve direct GHG emissions (although indirect emissions come from building the power installations).

[2] The industrial sector, while also important for climate policies, is not considered among the sectors in this Part. Firstly, this sector is regulated by policies that are historically more developed than for the other sectors; while, secondly, within the majority of the UNECE cities, industrial emissions have been stable or even decreasing over past decades. Nevertheless, the location and nature of the given manufacturing enterprise and its emission profile should be given due consideration in the planning and permit process, and should be properly addressed by other relevant measures outlined elsewhere in this study.

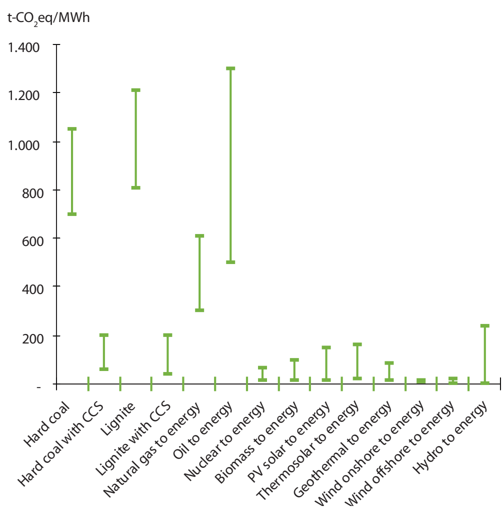
Biomass (wood, biofuels, waste) can also be a carbon-neutral source of energy if the burned biomass is renewed in a sustainable way. However, if biomass is harvested faster than its annual re-growth, net CO_2 emissions will be positive due to a loss of biomass stock (reported in inventories as land-use change and deforestation).

Figure 5 demonstrates the span of carbon content per unit of energy (emission factors) for different technologies based on a life-cycle analysis.

Table 2. Energy balance and corresponding policies directed at climate neutrality

Energy Balance Formulas (International Energy Agency)	Urban-Level Policies
SUPPLY Production + Imports - Exports = Total Primary Energy Supply	**REDUCE CO_2 IN SUPPLY** Decarbonising energy supply (e.g. renewable micro-generation, fuel switch)
TRANSFORMATION Total Primary Energy Supply - Energy transformation - Losses - Energy Industry Own Use = Total Final Consumption	**REDUCE LOSSES IN TRANFORMATION** Efficiency of transformation and distribution (e.g. co-generation, improving efficiency of networks)
CONSUMPTION Total Final Consumption = Industry + Transport + Buildings + Agriculture/Forestry + Fishing + Others + Non-Energy Use	**REDUCE ENERGY DEMAND** User efficiency and demand management (e.g. improving building energy performance, reducing the need for motor vehicle use)

Figure 5. Life-cycle assessment of emissions of different electricity-generation technologies



Source: European Environment Agency (EEA, 2010b).
Note: CCS = carbon capture and storage.

Some UNECE member States have improved their carbon-intensity profile during the last two decades by increasingly using a greater share of fuels with smaller carbon content and technologies with smaller emission factors and by generating a larger proportion of electricity and heat from non-fossil fuels (Figure 6). According to 2008 data from the International Energy Agency (IEA), in Iceland, for example, 83 per cent of total primary energy supply (TPES) was hydropower and geothermal power. Combined, these two types of power met all the country's electricity needs (hydropower: 75 per cent; geothermal: 25 per cent). Geothermal power accounted for 94 per cent of the country's heat production.

A very high proportion of hydropower in electricity is also found in Albania, Georgia, Kyrgyzstan, Norway and Tajikistan; and a somewhat high proportion in Austria, Canada, Latvia, Sweden and Switzerland. A few countries use nuclear power extensively, which is low carbon. Armenia, Sweden and Switzerland combine hydropower and nuclear power to produce much of their electricity.

The percentage of electricity produced domestically from nuclear power in 2008 was, for France 76 per cent, Lithuania 71 per cent, Slovakia 58 per cent and Belgium 54 per cent. However, the use of nuclear power involves a debate on health and safety associated with the risk imposed by the nuclear fusion and radioactive materials (as recently demonstrated by the Fukushima nuclear plant accident in Japan in 2011), as well as with the risk of proliferation. In the United States, no new nuclear stations have been ordered since the late 1970s, although a number of new plants are expected to be built by 2020. Furthermore, nuclear energy is based on uranium as raw material, which is finite and not renewable.

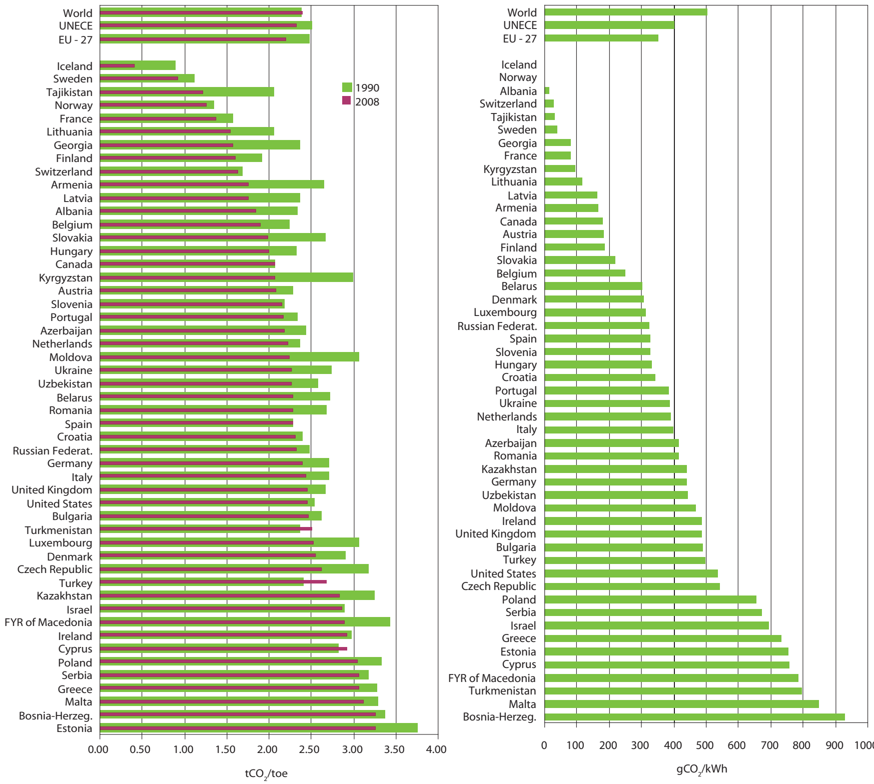
Because of the cost and impact, the deployment of large-scale renewable and nuclear installations is only possible through capital-intensive and state-regulated activities. Meanwhile, the call for low-carbon energy offers opportunities to shift from large, vertically integrated energy industries to decentralized neighbourhood-scale energy generation[3], which can be sufficient to cover all local needs. Increasing use of decentralized energy is also a way to reduce energy transmission losses, since energy systems are more efficient when power lines to consumers are as direct as possible and the number of transformation steps minimized.

It is of course the city and regional levels that can play a key role in decentralized energy. Even when the city government does not own and operate power-generating facilities (although it sometimes does), it can use a number of levers to promote local green energy infrastructure.

[3] Decentralised energy is also known as on-site generation, dispersed generation, embedded generation, decentralized generation, or distributed energy.

For example, it can purchase renewable energy for city operations, identify strategic sites where renewable and low carbon energy sources could be located, provide planning incentives and development land, permit the construction of efficient and clean power installations only, and require new developments to connect to district heating systems.

Figure 6. Carbon intensity of energy generation: CO_2 emissions per TPES (total primary energy supply) in 1990/2008 (left) and CO_2 emissions from electricity and heat per energy generated in 2008 (right)



Source: Author's calculation based on IEA, 2010a.

Note: CO_2 emissions from fuel combustion only; TPES = total primary energy supply (see Table 2).

The following options, which are considered in the rest of this chapter, should be implemented for city-scale decentralized renewable and low carbon power supply:

a. Switching to lower-carbon technologies and promoting district heating and cooling systems with co-generation and tri-generation;

b. Installing renewable power installations, e.g. wind turbines, solar farms, energy from biomass and waste plants;

c. Promoting on-site micro-generation of heat and electricity in the building sector;

d. Developing smart grid and efficient municipal energy services.

Improving efficiency, promoting co-generation and district heating

A large amount of energy is lost through the conversion from primary fuels into consumable energies — both during their distribution and through power consumption by the energy generating industry itself. These losses account for the considerable differences in energy balances between primary energy supply and final energy consumption (see Table 2 - as reported by the International Energy Agency, or between gross inland consumption and final consumption, as reported by Eurostat).

In the UNECE region as a whole, 32 per cent of primary energy is used in transformation before the energy is available for consumption. Similarly, in the EU, 30 per cent is used. Improving transformation efficiency helps not only to decrease this gap and save primary fuels but also to avoid many of the corresponding emissions.

The European Environment Agency estimates that the EU average transformation efficiency for conventional power plants was 47.8 per cent in 2007. Increasing this average efficiency to just 50 per cent, with the same fuel-mix, would save about 62 Mt of CO_2e a year — compared with the 5,039 Mt of overall GHG emissions in the EU in 2007.

If levels of efficiency were further increased to 75 per cent, 10 per cent of EU GHG emissions could be avoided (EEA, 2010a). To put this in perspective, 75 per cent of transformation efficiency is typically demonstrated by Combined Heat and Power (CHP) plants, which integrate the production of power (electricity) and thermal heat in one single process. This arrangement is also known as co-generation. Such plants can utilize waste heat from electricity generation and offer this heat for space heating and hot water supply, or, alternatively, capture waste heat from industrial process and convert it into useful electricity and heat.

It is also important to consider the energy mix used in power generation. Increasing the share of gas in the energy supply has been promoted in many UNECE cities; indeed, natural gas contains 40-50 per cent less carbon than coal and 25-30 per cent less carbon than oil, only marginal quantities of sulphur and is more energy-rich and efficient. Power stations with modern gas turbines can achieve 60-65 per cent of conversion efficiency, but more remarkably, the most modern city-based gas-fired CHP can reach efficiencies of more than 90 per cent at the point of end use (due to lower losses from transmission, fewer condensation losses in boilers and the close proximity to the consumers).

A considerable amount of primary energy and carbon emissions can therefore be saved by large-scale deployment of modern CHP plants. Co-generation can be used for both industrial and non-industrial purposes and also at the micro (household) scale.

But it is most advantageous if connected to district heating (also known as community heating) and deployed on a city scale or a neighbourhood scale. As well as satisfying local needs in heat, hot water and power, CHP plants can also provide cooling, by chilled water — this is known as tri-generation or as combined cooling, heat and power.

CHP plants have therefore become an essential element for advanced district heating and cooling (DHC) networks. Although district heating and CHP can function independently of each other, DHC with CHP are today one of the most proven, efficient and cheapest available technologies to reduce emissions and save energy in cities.

District heating

District heating in particular should be considered for deployment in areas of high population densities with continuous demand - which means, effectively, most cities in the UNECE region. However, there are examples of countries where even low-density areas are supplied by district heating. The countries with significant shares of low-density single-family houses connected to district heating in 2003 were: Iceland (85 per cent), Denmark (48 per cent), Finland (13 per cent) and Sweden (10 per cent) (Nilsson et al., 2008).

DHC should be designed as a flexible system. Apart from CHP, DHC networks can be supplied from a variety of other sources, including geothermal and solar heating stations, fuel cells, biomass, surplus heat from industries and energy from waste facilities (see Part III Chapter 5). The ability to integrate diverse energy sources may provide for a flexible platform to reduce dependency on a single source of supply and introduce competition into the supply chain.

Similarly, the CHP plants themselves can work on different fuel mixes. A challenge for climate neutral policies is to drive the whole energy infrastructure of district heating and CHP towards renewable supply; and the anticipation of such a move should be integrated into the planning for new installations. For example, such "future-proofing" has been a priority for London authorities trying to keep open future possibilities for easy replacement or refuelling of new-build gas-powered CHP with renewable fuel or hydrogen (Jones, 2009).

Across the UNECE region, the potential for developing both CHP and DHC is still great. As for co-generation, only a few countries such as Denmark, Finland, Russia, Latvia and Netherlands have successfully expanded the use of CHP to between 30-50 per cent of their total power generation (IEA, 2009). Many UNECE countries now provide incentives for CHP and require it to be incorporated into city planning.

As for district heating, its penetration is similarly low in most Western European and North American cities, but rather high in Northern Europe and countries with economies in transition. Iceland, Finland, Denmark, Sweden and Austria can boast advanced and efficient forms of district heating. Except for Sweden, district heating in these countries uses CHP systems intensively. In many former socialist countries, district heating systems are also well developed and often based on CHP.

Countries with economies in transition which have a significant share of district heating in the residential heating market are: Russian Federation, Latvia, Ukraine, Poland, Belarus, Lithuania, Czech Republic, Slovakia, Romania and Estonia. In the first three, more than 60 per cent of households are connected to district heating (IEA, 2004). A problem for these countries, however, is that district heating has not been properly maintained since the fall of the State socialist systems and requires modernization (see Box 5). This represents a huge opportunity for energy efficiency businesses.

However, it may turn out to be for the worst, judging from the experience of some cities in the United States where a lack of proper maintenance of privately owned heat distribution network has historically paralyzed progress towards district heating. The development of systems with potentially high efficiency gains requires long-term commitments, public-private partnerships and other institutional efforts, including by municipalities.

Box 5. Modernizing district heating in Eastern Europe and former Soviet countries

Cities in many UNECE countries with economies in transition have inherited well-established district heating systems which represent excellent institutional preconditions for creating sustainable cities. However, due to a lack of proper maintenance and modernization since the collapse of state socialism, this "success story" has somewhat depreciated.

The heat distribution grids of such systems have commonly deteriorated, sometimes to the extent that 40 per cent or more of heat energy is lost when transmitted through the pipelines. But even if pipes are upgraded and thermal leakages are minimized, the overall design of these systems is typically sub-optimal, as it is often based on a constant (rather than variable) water flow regime and lacks automated demand-based regulation systems.

It is estimated that 15-30 per cent of heat energy used in apartments and service buildings supplied by district heating can be saved by installing simple on-site automatic stations for regulating the volumes of heat taken from the district system by an apartment building. However, if measures are implemented on individual buildings rather than on the overall network, the total impact still remains small.

Some cities in Eastern Europe have therefore undertaken more complex modernisation of their district heat networks. Measures may involve the installation of additional transfer sub-stations equipped with modern demand-driven automatic management (such as based on variable speed pumps which adjust to changes in the system's pressure); if necessary, the rearrangement of heat flows within apartment buildings is also provided.

Combined with information and communication technology (ICT), the operation of any part of the whole system can be remotely supervised and adjusted in real time. The modernized systems are more reliable, allow for multiple suppliers and involve considerable energy savings.

Sources: UNDP Kazakhstan, 2010; IEA, 2004.

Distributed power and micro-generation

Apart from co-generation, cities can promote other forms of renewable energy supply, such as city-scale or neighbourhood-scale power installations and even smaller (building-scale) micro-generation. Again, different sources of renewable energy can be used — geothermal, wind, solar, ocean, biomass, landfill gas and waste-to-energy. The small power generators can be linked to the common electricity grid and district heating or, alternatively, supply electricity and heat directly to the consumer (such as stand-alone renewable power operating at distribution voltage level).

Feed-in tariffs

A boost for the development of the different types of distributed generation and co-generation comes from the so-called feed-in tariffs. Regional or national electricity network providers are obliged to buy electricity generated from independent renewable producers such as individuals or companies.

The prices are paid for by kilowatt-hour of electricity used, at government-controlled rates, known as feed-in tariff. The rates are typically based on the cost of renewable energy generation plus a reasonable profit and are therefore differentiated by the type of energy and the amount produced. Feed-in tariffs are combined with guaranteed non-discriminatory grid access and long-term contracts for the electricity produced.

All of this is to encourage the development of renewable sources and to help reduce the renewable energy costs to the so-called grid parity, or average electricity prices. Indeed, certain forms of renewable electricity may already be cheaper than the grid electricity — for example, providing locally generated electricity in remote areas may be cheaper than building new distribution lines; the cost of landfill gas in many urban areas is already lower than that of the grid electricity. In the UNECE region, feed-in tariffs (or some form of them) have been introduced in the majority of EU member States, in Israel (for solar photo voltaic), Switzerland, Turkey, Ukraine and in some parts of the USA and Canada (UNEP SBCI, 2009, p.35), although some of them have scaled back the extent of the tariffs due to the economic downturn.

Not all renewable systems suit local conditions. For example, the availability of wind and solar insulation can limit the effectiveness of related generators. In determining sites for renewable plants, city planners should consider the suitability of the site with regard to the local conditions:

- access for fuel deliveries
- local grid proximity and capacity
- impacts on the power streams in the common grid
- any potential impact on adaptation to climate change.

Spatial planning can be used to evaluate needs and capacities.

An environmental impact assessment should also be undertaken if the renewable energy generation could adversely affect the landscapes and ecosystem. For example, flooding risk and changes in water levels may result from small hydropower plants, the incineration of municipal waste or biomass may generate harmful air pollution, and wind turbines can cause noise and visual pollution.

Local communities may sometimes oppose certain plans for renewable power installations. But including these communities in the decision-making and planning can help to find an optimum solution that addresses their concerns and leads to more effective deployment of new plants.

Generally, local communities are more open to change if they are involved as stakeholders. In the United Kingdom, for example, installing onshore wind turbines is perceived to be difficult because of local residents' persistent objections, but this becomes more acceptable if the community shares the benefits. Some regions have developed special protocols attached to building approval for wind farms, which require that a percentage of money for each unit of energy generated be paid into the local community funds.

Micro-generation

Micro-generation, or on-site renewable energy generation in the buildings sector — both by commercial buildings and dwellings — should be promoted alongside renewable generation. In a climate neutral city, networked micro-generation might even be sufficient to cover all local electricity and heat demand, given that the final energy consumption is reduced through improving end-use efficiency.

Micro-generation can include different types of heat pumps, small CHP plants, solar PV and thermal collectors, wood-pellet stoves, small wind turbines and other renewable technologies. For example, as part of its Climate Action Policy for 2007-2012, the German city of Hamburg is carrying out measures for deploying solar roofs. About 150,000 roofs are to be examined to determine their potential for generating energy, including by using a laser scanner flight programme, which measures both direct and diffuse solar radiation potential of roofs in the city (Germany, 2009).

In the absence of feed-in tariffs, an initial large-scale deployment of electricity micro-generation may be restricted by the lack of access to the grid, because storing electricity on-site in batteries is costly. The reluctance of energy utilities to provide such possibilities for micro-generation is an issue for some countries of the former Soviet Union. Capabilities should be provided for bi-directional electricity flows, allowing on-site generation from renewable sources to be transmitted to the grid.

As the share of distributed generation increases dramatically, there is also a need to modernize the electricity grid itself so it can better handle variable supply and demand. The so-called "smart grid", which integrates electricity networks with digital technology, can intelligently handle the loads and respond in real time to the actions of the many generators and consumers connected to it. This is particularly relevant because, unlike other forms of generation, distributed energy does not have a stable energy output, as it often depends on rapidly changeable external conditions, such as wind velocity or solar radiation intensity.

One of the new management concepts for smart grids is a "virtual power system" or "virtual power plant". This consists of many dispersed power sources combined in cyberspace as a unit, comparable to a large power station. The virtual plants are treated in the same way as traditional plants from an energy trading and coordination perspective. A virtual power plant can contain a mixture of different generators; a well-chosen mix can offset the inherent unreliability of individual generators.

Overall, energy utility distribution should be maintained and updated to high technological standards. There are also other responsibilities, which municipalities should bear as a result of the transformation towards energy efficiency, such as, for instance, providing efficient municipal energy services (including street lighting), developing infrastructure for electric cars, collecting used low energy bulbs containing mercury, and other measures corresponding to specific urban sectors, as discussed in subsequent chapters.

2. Residential and service buildings

The buildings sector refers to the residential, public and commercial sectors that use buildings for carrying out their activities and functions. It involves not only the building industry, but also all the activities that use the existing buildings.

The buildings sector is one of the priority energy end-use areas in relation to climate neutrality:

- Residential, commercial and public buildings account for a large share of energy demand and emissions — e.g. 33 per cent of the total final consumption in the UNECE region and almost 40 per cent of CO_2 emissions from combustion (Figure 7).
- Buildings are among the most valuable and longest-lasting physical capital, with a high degree of inertia. Any measures taken or not taken today will leave a substantial legacy for many decades to come.
- As an essential element of both the built environment and of the organisation of social life more generally, buildings represent a key focus for the adaptation

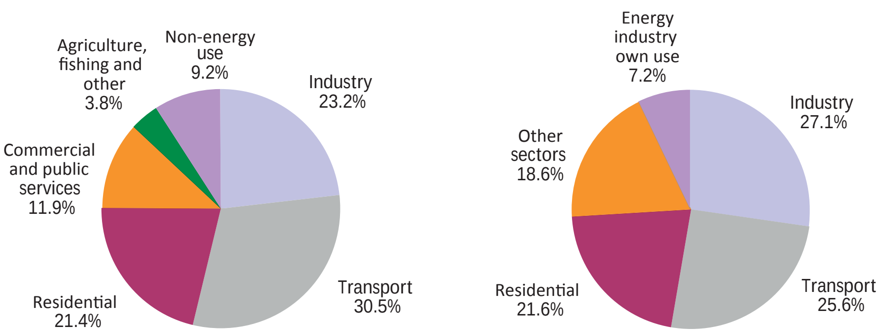
to a changing climate and for any resilience strategies. Fortunately, adaptation and mitigation with respect to buildings clearly intersect – as improving energy efficiency can be considered as their common denominator. Improved physical conditions and insulation of the building stock not only decreases energy demand in the sector, but also make buildings more climate-proof.

The building sector consumes energy in various ways, including in manufacturing building materials, in construction, reconstruction, recycling and in the day-to-day running of the building. The latter accounts for 80-90 per cent of total energy use during the lifetime of a building. Much of the energy is used by the residential sector; more specifically, an average of 20-30 per cent of total final consumption across the UNECE member States (Figure 8). It is spent on space and water heating, as well as on cooling, lighting, appliances and cooking (Figure 9).

Main sources of energy in the UNECE region buildings sector

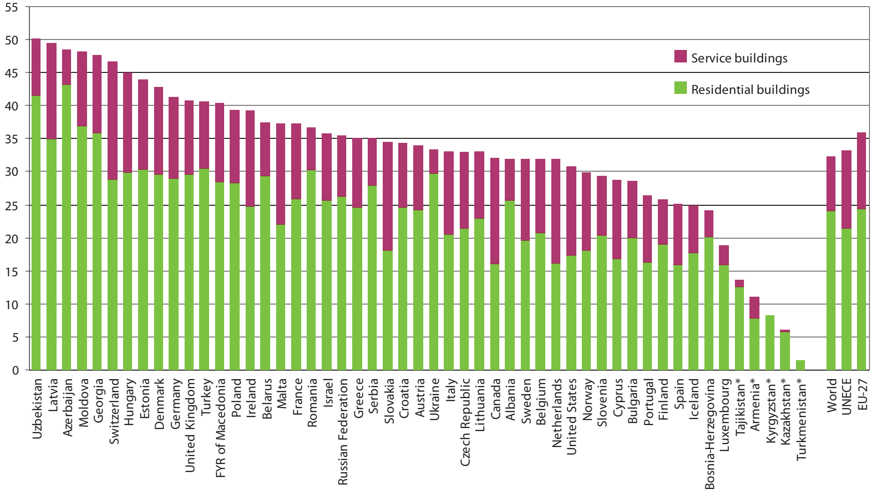
The corresponding GHG emissions (mostly CO_2) have diverse forms. In the UNECE member States, the main sources of energy in the building sector are electricity, district heat and natural gas. This means both direct CO_2 emissions via the on-site combustion of fossil fuel for heating and indirect (upstream) emissions via demand for electricity and district heat — so, as Figure 7 indicates, the direct and indirect emissions from the residential sector in the UNECE region are 21.6 per cent of total CO_2 emissions.

Figure 7. Total final energy consumption by consuming sectors (left) and energy-related CO_2 emissions with electricity and heat allocated to consuming sectors (right) in UNECE member States in 2008



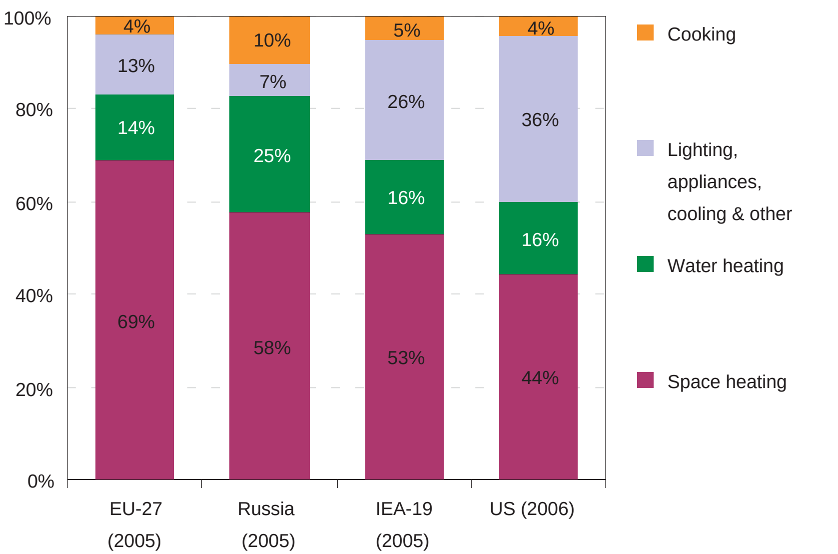
Source: Author's calculation based on IEA, 2010b, 2010c (energy); IEA, 2010a (emissions).
Note: CO_2 emissions from fuel combustion only. 'Non-energy use' includes fuels not-for-energy feedstock (e.g. in petrochemical industry). 'Energy industry own use' includes emissions from own use of energy in energy-producing industries. 'Other sectors' include commercial and public services, agriculture, fishing and other. 'Transport' excludes international marine bunkers and international aviation bunkers.

Figure 8. Energy used in the buildings sector (service and residential) as percentage of total final consumption, 2008



Note: For countries marked with (*) only limited or electricity data exist for the building sector.
Source: Author's calculation based on IEA, 2010b, 2010c.

Figure 9. Household energy consumption by end-use in different UNECE regions



Source: Based on, respectively, Odyssee, 2008; Bashmakov, 2009; IEA, 2008[4]; DOE, 2008.

[4] IEA-19: Australia, Austria, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, Republic of Korea, Netherlands, New Zealand, Norway, Spain, Sweden, Switzerland, United Kingdom, United States.

Energy savings in buildings may be achieved through appropriate technological solutions, from the simple to the more advanced such as plus-energy buildings — which not only produce renewable energy for all their own energy needs but also deliver energy to the common energy grid, since they use less energy than they produce. Even less-sophisticated retrofitting projects in the UNECE region are cost-effective, typically demonstrate 40-60 per cent and in some cases even up to 90 per cent of energy reduction (if a retrofit meeting passive building standards is applied, see below).

Despite the large potential, investment in energy-efficient buildings across the UNECE region is not yet optimal, thus contributing to the so-called "energy efficiency gap" between the actual use of energy and the optimal use demonstrated by existing cost-effective methods and technology (see Jaffe and Stavins, 1994; IEA, 2007).

The "5-in" model

One can conceptualise the key elements for improved energy efficiency as five simple keywords — or a "5-in" model (UNECE, 2009):

investment

information

innovation

incentives

initiative.

In practice, there are a number of barriers to this model, as summarized in Table 3. The most common challenges include:

- Fragmentation of the technological chain involved in the design, production and maintenance of housing.
- The conservative construction industry.
- Large number of individual buildings with obviously fragmented ownership structure.
- Low priority for energy issues compared to other necessities for households and other economic agents.

Other common obstacles include a lack of sufficient investment capacities, uncertainty and risk of such investments, organisational barriers and a lack of information.

Retrofitting the Empire State Skyscraper - Buildings currently account for approximately a third of the world's final energy use (Figure 8). Retrofitting a standard building can realize energy saving that could reduce the adverse effect on the environment. Simple measures as insulating windows and caulking leaks in facades can have great impact on the energy efficiency. The retrofitting of 80-year old The Empire State Building in New York reduced the energy use by nearly 40 per cent. © Beboy/Fotolia

Thus, to progress towards energy-efficient buildings and housing we will need not only technological solutions but also a comprehensive institutional system for putting these solutions in place. UNECE is working on creating such institutional conditions. One instrument it has developed is the *Action Plan for Energy-efficient Housing*, which provides a complex of interrelated policy measures specifically for the housing sector (Box 6).

Table 3. Typical barriers to energy efficiency in the buildings sector

'5-in': keywords for energy efficiency	Barriers for improved energy efficiency in buildings
Incentives	Low priority for energy efficiency Energy price subsidies Split incentives or principal-agent problem (e.g. owners vs. tenants) Poor enforcement of standards, corruption
Information	Information asymmetries Lack of awareness Lack of knowledge and expertise
Initiative	Lack of management or leadership Fragmentation of the buildings sector Poor coordination and communications Political, organisational and structural barriers
Innovation	Path dependence in decision-making Technological lock-ins Market barriers for efficient technology Technological backwardness, territorial inequalities Lack of affordable technologies, loss of traditions
Investment	Short-term investment horizons Uncertainties, risk Lack of financial capacities, limited affordability High 'transaction costs', high upfront costs Opportunity costs barrier

Box 6. UNECE Action Plan for Energy-efficient Housing

The *Action Plan for Energy-efficient Housing* was developed by the UNECE Committee on Housing and Land Management to offer an integrated and comprehensive policy package to guide UNECE member States in this field. It was formally adopted at the Seventy-First Session of the Committee in 2010.

The *Action Plan* lists a range of measures aimed at removing barriers to energy efficiency and at progressively moving towards a low energy and ultimately carbon-neutral housing sector. As schematically shown below, it outlines three policy areas for action, focused on (i) governance frameworks, (ii) technological development and (iii) access to and affordability of energy efficiency.

Each of the policy areas consists of four key goals, which are further broken down into detailed targets and then actions to be taken with respect to those targets. Each goal is also underpinned by a vision of what is expected to be achieved through the realisation of this goal by the year 2020.

The implementation of the Action Plan will allow UNECE Member States to fully realise the potential of their housing sector with regard to energy efficiency. The *Action Plan* will at the same time address the problems of affordability and accessibility to both housing and energy services and will integrate sectoral policies for energy and housing with spatial strategies for sustainable development.

Source: UNECE, 2011

On the basis of the *Action Plan* (UNECE, 2011) and other studies provided by the UNECE Committee on Housing and Land Management (UNECE, 2009), the rest of this chapter considers in more detail the following key policy areas for the building sector, available at the urban level:

a. Energy efficiency technology and performance standards;

b. Property management and maintenance;

c. Energy pricing for the buildings sector;

d. Public services and municipal housing.

Energy efficiency technology and performance standards

Many instruments are being deployed across the world with varying degrees of success for overcoming the barriers described above and for reducing energy and carbon emissions in the building and housing sectors (e.g. Urge-Vorsatz et al., 2007; IEA-AFD, 2008; UNEP SBCI, 2009).

Evidence suggests that updated and mandatory energy-efficiency standards in buildings are among the most effective instruments for increasing energy efficiency (e.g. Geller et al., 2006). The mandatory standards may refer to the various elements of a building: a building's thermal design (e.g. thermal capacity, insulation, passive heating, thermal bridges), indoor climatic conditions and air quality, the systems for heating, hot water, ventilation, cooling, lighting, and the design, positioning and orientation of the building.

Mandatory building codes can be drawn up at the national or local levels, and, in any case, cities should have the power to make their own standards more stringent than the national ones. The mandatory codes must also be reviewed regularly so that minimal requirements are raised to the new levels, are cost-effective and promote the use of feasible, energy-saving technology. Many countries set new energy performance standards years before their actual implementation, to give the building industry time to prepare for new regulation. This mechanism, known as dynamic building codes, reduces the costs of the change and mitigates the opposition from the building industry (Laustsen, 2008).

Many countries already require low energy buildings as performance standards for all new-builds. Energy consumption for heating of such buildings is typically less than 50 kWh per m^2/year, as compared with 150 to 200 kWh/m^2 in normal housing. Comfortable room temperature is assured through highly efficient components, such as high levels of insulation of walls, roofs and windows, heat recovery from recycled air and the use of internal sources of heat (including existing household appliances and human heat). The design of buildings may be required to fit a specific location and to use passive lighting, active shading, and energy-efficient appliances and lighting. Energy for electricity, the cooling system or hot water can come from conventional sources or from autonomous micro-generation.

Passive Housing - In passive houses, the use of alternative energy sources such as solar panels can reduce - or even replace - conventional heating with fossil fuels. Using energy saving window blinds can reduce heat exchange up to 28 per cent. This amount varies depending on the geographic location of the house, amount of sun hours and altitude. © Joe Gough /Fotolia

The "passive house"

Some of the popular housing developments include so-called "passive houses". The passive house standard was originally defined in 1988. The first passive house was built in Darmstadt, Germany, in 1990 (Passivhaus Institut, 2011). Passive housing is mostly defined for colder European climatic conditions, where it reduces heating energy consumption to at least 15 kWh per m^2/year, or by up to 90 per cent as compared to normal housing and by 60 per cent compared to the low energy building definitions. They may even be entirely independent of off-site energy supplies and have lower operating costs than more conventional buildings. In Austria, Germany, Switzerland and the Scandinavian countries, such buildings have already been popular for a number of years. The cost of constructing them in these countries with relevant experience has been found to be only marginally higher (in the range of 10 per cent) that that of non-passive housing.

The building codes for the new-builds in many countries are already approaching the passive house standards, and even these standards are considered not stringent enough. Countries in the EU are preparing themselves for the so-called nearly zero-energy buildings to become the minimum standard from 2020 as required by the 2010 update of the EU Energy Performance in Buildings Directive (EU, 2010).

While there is so far no common definition for zero-energy buildings or homes, a few subtypes for such buildings can be identified (Laustsen, 2008):

- *Zero-net energy buildings* deliver as much energy to the supply grids over a year as they use from the grids.
- *Zero-carbon buildings* do not use energy that entails CO_2 emissions, or they balance or offset the fossil fuel they use by producing enough CO_2-free energy on-site.
- *Zero stand-alone buildings* do not require connection to the grid other than as a back-up. Stand-alone buildings have the capacity to store energy for night-time or winter use.
- *Plus-energy buildings* deliver more energy to the supply systems than they use. Over a year, these buildings produce more energy than they consume.

Appropriate targets and measures should ensure an increasing penetration of passive, zero-energy and zero-carbon buildings in preparation for the eventual requirement for all new homes to be based on zero-energy technology.

It is not only new-builds that should be considered for inclusion in energy performance standards. As the new-builds actually amount to only 1-3 per cent of the overall building stock in any given year, it will take many decades before buildings constructed according to the new standards will constitute the majority of the building stock. It is therefore necessary to ensure that energy efficiency standards exist for the refurbishment and retrofitting of existing buildings.

A more radical approach is the introduction of energy performance standards for all existing buildings. Such standards may initially be used in a pilot phase (e.g. for subsidies or renovation priorities) but after a transition period should be made mandatory for all existing buildings. In this way, the latter would be retrofitted if they do not match such standards or, otherwise, considered unsuitable for occupation (subject to local conditions, the designated function and the age of the building).

Indoor air quality

These measures, both for new-build and retrofit must take account indoor climate conditions and avoid possible negative effects such as inadequate ventilation or the need for excessive use of air conditioning. As a rule of thumb, indoor air quality should prevail over energy considerations, as an airtight building, without adequate ventilation, may damage the health of occupants and workers even more than poor insulation. Buildings codes and other instruments (including energy certificates) should include indoor air quality alongside energy performance indicators.

The post-occupancy monitoring of energy consumption, air quality and the general satisfaction of the users should in theory be a major concern for architects and builders, although in practice the absence of regulation leads to mass reproduction of poor-quality solutions, which do not in any way stand up to their "green building" promise (Roaf et al., 2009).

Buildings as complete systems

Building should be considered as complete systems. Their overall performance during their full lifecycle, in terms of their emissions, is due not only to their direct energy consumption but also to energy used in their construction and demolition. Use of energy in concrete and steel manufacturing, extraction of raw materials and transportation of construction materials, for instance, contribute to the carbon footprint of a building.

Often, buildings that are allegedly "low energy" are built without due consideration of these 'other' forms of energy consumption. For instance, over their lifecycle, their carbon footprint can actually be larger than that of buildings with a lower operational energy efficiency but built in a sustainable way and using local materials with low embedded energy. The choice of materials and their transportation should be major considerations for both construction and refurbishment.

There must be a certain degree of flexibility for local municipalities to set their own standards (e.g. to make regulations more stringent than minimal national requirements). Building codes should nevertheless also be adjusted to take into account the general level of economic prosperity of a particular country. Stringent and universal building codes may be unfeasible for smaller developers and individual self-builders in less prosperous countries, thus pushing them into informal practices. It may be advisable to have differentiated requirements depending on the size of the given project and the developer's status. Building codes should also be supported by other instruments, including subsidies to lower-income groups to help them to acquire energy efficiency technologies.

Mechanisms to enforce and control the implementation of the mandatory codes are a crucial element in this system. This is where cities, through effective building control and compliance monitoring, can apply the power of enforcement with greatest effect, even when the building codes are regulated at the national level.

Property management and maintenance

Another area for action by policymakers is to integrate energy performance standards within property maintenance. Improving and professionalizing property management is an institutional prerequisite that is important in all UNECE member States. However, it represents a particular challenge for the former socialist countries, where the housing sector, in particular, is often characterized by a large proportion of multi-apartment buildings on the one hand, and limited self-management skills and capacities of the residents on the other.

One specific aspect is to speed up rent and home-ownership legislation. There must be mandatory provisions for setting-up collective coordinating bodies such as homeowners' associations, for which legal obligations for maintenance should be established (UNECE, 2003). These bodies should be required to manage their maintenance funds for use in financing energy efficiency projects, as part of maintenance activities and to serve as collateral for loans.

Homeowner associations should also have recourse to specific enforcement provisions against owners who are not willing to take part in essential maintenance schemes or are otherwise unable to fulfil their obligations. At the same time, support schemes for low-income households should be provided (e.g. income-related subsidies for refurbishments) to improve their energy efficiency, including for residents in condominiums that are undergoing refurbishments according to the homeowner association's decision.

Energy pricing for the buildings sector

One of the elements in the energy efficiency incentive system is the organisation of energy pricing and billing. Companies and households attach greater value to energy efficiency if they experience a certain budgetary burden from their energy use. Importantly, the threshold of cost-effective energy efficiency investment increases as energy prices rise. It is therefore vital to establish an adequate pricing system and also to eliminate fixed-cost payment systems for energy (electricity, heat, gas and hot water).

However, there are at least two preconditions to be met (Wollschlaeger, 2007):

- Firstly, energy payments must be directly linked with actual energy use and the users must be informed of this through energy bills and energy metering. Metering system installation should therefore precede energy price reform.
- Secondly, pricing according to use is only sensible if users are able to control their use of energy. For example, if users cannot control how much heat they use because it is supplied by a district heating provider and if radiators do not have thermostats, then there will naturally be no effect.

It is often incorrectly assumed that deregulated energy prices are sufficient to stimulate energy efficiency. However, such measures are not sufficient and need to be understood as only one element of the integrated package of efficiency policy. And energy pricing needs to take into account the socio-economic context.

In many countries with economies in transition (such as in the Caucasus region), monetary 'incentives' introduced in the 1990s often lead to a non-payment crisis for services such as district heating, hot water, gas and even electricity, as the impoverished population could not afford to pay full prices. This in turn resulted in disconnection, infrastructural degradation, increased levels of 'dirty' energy use by households as a cheaper alternative (such as coal, kerosene) and — while possibly lessening loads on electricity or gas distribution grids — have resulted in a deterioration of both living conditions and the environment.

To mitigate the market mechanism, a number of measures should be taken alongside energy price reforms. Criteria may be developed in terms of the percentage of household income that is spent on total energy use before it is considered to be in fuel/energy poverty (e.g. in the UK it is 10 per cent). For those in energy poverty, targeted subsidies should be provided. Ideally assistance should improve the housing energy performance of such households, so that less energy is consumed to achieve the required minimum levels of comfort (Boardman, 1991).

More universal (non-targeted) measures may include differentiated tariff systems such as block tariffs, which make energy affordable for lower-income families, yet encourage conservation. Under such systems, households are charged progressively by the unit of energy used, depending on energy-use bands or thresholds. Currently, however, exactly the opposite is often true, as users are charged less per unit of energy, the more energy they consume or buy. To be effective, the tariff difference for a next energy-use band should be set at a sufficiently higher level. In addition, the use of smart metering and differentiated tariffs, based on the time of day and the season, may help improve energy efficiency by making households aware of the cost of the energy they use and by giving them incentives to spread their energy use more evenly throughout the day.

Specific requirements and incentives should also be imposed on the suppliers of energy who service households, commercial, public and industrial buildings. These measures commonly include regulatory and financial instruments for utility demand-side management. One example is the White Certificates, increasingly used in the EU (a tradable permit attached to the obligations of energy producers, suppliers or distributors, to undertake energy efficiency measures). Other measures may include, for example, obliging energy providers to spend extra income received from the higher energy-use bands exclusively for end-user energy efficiency. In any case, it is important to decouple a utility's profits from its gross sales, so that instead, the profits increase with energy conservation successes. Such an approach is behind California's energy conservation programme, the wider adoption of which has become a condition for US states to receive federal energy-efficiency grants from the 2009 fiscal stimulus (see World Bank, 2010b).

Public services and municipal housing

A municipal government usually has a number of properties under its control, such as government buildings, schools, hospitals, sport and cultural facilities, streets and public spaces. Investing in the improved energy efficiency of these places constitutes an important policy package at the local level. The government may also use public procurement for direct stimulation of the large-scale deployment of efficiency technology.

Green light for LED traffic lights - LED bulbs are semiconductor diodes, which produce light with less energy than conventional light bulbs. In London, 300 intersections will be upgraded with 3,000 new LED traffic lights by 2013. When accomplished, LED technology will represent around seven per cent of all London traffic signals. The estimated reduction of carbon emissions is around 470 tons per year. A LED bulb lasts approximately 10 times longer than a standard bulb and will use around 60 per cent less energy than the traffic lights currently used in London. © anweber/Fotolia

Separate efficiency polices should target the public/social housing sector, which presents particular opportunities from an institutional point of view. Public housing in some countries (e.g. in the United Kingdom) already delivers better standards of energy efficiency than the average private home. Among other advantages, this helps to tackle fuel poverty, as households pay lower prices for the energy bills. There should be special programmes of retrofitting existing public stock and stricter requirements for better energy efficiency performance for new homes.

As the organisation of public housing varies considerably across the UNECE region, different combinations of financial and legal measures can be provided, depending on the context. It is a significant asset for energy efficiency policies if the city can provide incentives for improving social housing or if it has a large public housing stock under its control. Such is the case for Vienna. Long known as "Red Vienna" for its strong social commitments, the city is now using the well-developed public facilities to re-invent itself as "Green Vienna" (Box 7).

Box 7. From "Red Vienna" to "Green Vienna": the role of housing

Vienna is one of Austria's nine autonomous provinces. It has its own housing policy, including subsidies, renewal programmes and housing allowances. The City Administration is also the largest landlord in Vienna (with 220,000 housing units), followed by a number of limited-profit housing associations, so that the major part of housing in the city is under public control. This facilitates energy efficiency measures with respect to both new housing construction and housing refurbishment.

All new housing projects that wish to receive public subsidies (recently, 7,000 apartments annually) have to pass a competitive selection process, one of the criteria of which is energy performance. As a result, most new housing estates in Vienna have much better thermal performance than the requirements of the Building Code. While the law requires the maximum of 38 kWh/m^2/year for heating, most new housing estates achieve 20–25 kWh/m^2/year. There is an increasing number of passive buildings that use less than 15 kWh/m^2/year.

The energy efficiency policy in Vienna goes beyond the mere thermal insulation of the exterior walls to provide also, for example, naturally lit staircases, switch-off wall sockets, environmentally friendly construction methods, greening of the roofs and also good connections to infrastructure and public transport.

The main challenge, however, is believed to be with the existing building stock, including some 170,000 apartments still in need of thermal improvements. A special regional programme provides subsidies for the refurbishment of 10,000 public dwellings per year, reducing the heating energy consumption from the average of 120–200 kWh to around 50 Wh. The subsidy covers one third of the refurbishment costs, while the rest is covered by a rent increase. This increase is, however, normally not higher than the saving on energy cost achieved by the refurbishment.

The City Administration believes that such a policy achieves several goals at once: (a) climate protection, (b) reduced energy costs to households and better social cohesion, (c) reduced energy imports and strengthening of the national economy and (d) the creation of new local jobs. This was also why the Austrian Government, as part of its economic stimulus, approved further thermal improvement programmes in the buildings sector nationally.

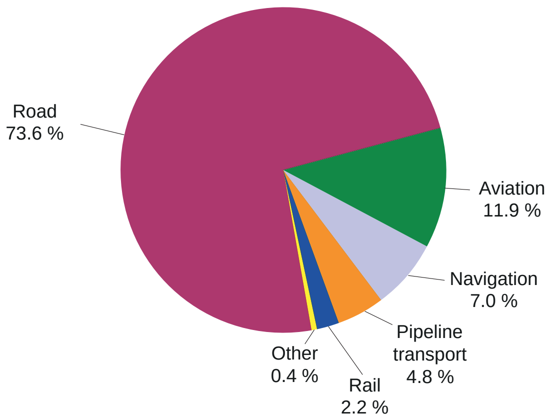
Source: Förster, 2009

On the other hand, in some countries with economies in transition, private housing now comprises as much as 80–90 per cent of the total housing stock, while remaining public/non-privatized homes may be scattered among privatized flats in multi-family buildings (e.g. this is the situation in the Russian Federation, among other countries). While such a structure promotes socio-spatial mix, it also challenges the government's ability to find proper organisational solutions for improving the performance of such a stock.

3. Urban form and low carbon mobility

In the UNECE region, over 30 per cent of energy is consumed in transport (Figure 7), mostly road transport (Figure 10). This is consequently responsible for a large portion of GHG emissions. Most of the emissions come directly from fuel combustion from car engines. The UNECE region accounts for about 60 per cent of global CO_2 emissions in the transport sector. Relative to other sectors, transport has been less effective in terms of reducing its GHG emissions and its relative contribution has been increasing.

Figure 10. Energy use in the transport sector by type of transport in UNECE in 2008



Source: Author's calculation based on IEA, 2010c, 2010b.
Note: Including international marine and aviation bunkers.

Yet recently, different types of transport show different dynamics of change, including: short-distance, long-distance and freight. It is the short-distance travel that is most relevant at the city scale and will be considered in this chapter. While in the more economically affluent UNECE countries short-distance travel has remained stable or slowly growing, in the former socialist countries the rise of car ownership and decline of public transport has been growing particularly rapidly.

The following are the three elements that cities should consider when transforming city transport towards carbon neutrality, all of which require multi-stakeholder and multidimensional efforts:

- Reduce average travel distances through land-use planning and sprawl control.
- Reduce the intensity of the use of motorised transport through public transport and transportation demand management.
- Promote cleaner and more efficient technologies in transport.

This chapter will review these policies.

Average distances for travel and urban forms

The first element relies heavily on the interface between urban planning and transport. Since the overall GHG emissions from transport depend on the distance travelled, urban planning policies should aim at reducing the average distance.

Increasing densities (up to certain levels), preventing sprawls and improving accessibility and proximity via polycentricity and mixed-use developments are all typical strategies for reducing the average distance for travel. Such policies certainly pre-date the international attention to global warming, so that we already have accumulated knowledge and experience in this area.

Higher densities decrease both car journey length and the number of journeys travelled by cars and are, in principle, a good strategy. However, at a certain level of density, negative environmental, energy, climate and socio-physiological impacts start to outweigh the gains.

Denser urban areas also amplify the negative effects of climate on cities — especially in areas with a high concentration of tall buildings (Roaf et al., 2009). There is no consensus on the optimal level of urban density, nor whether higher densities should always be encouraged. Moreover, key problems for intensified densities and a "compact city" are that many cities already differ from an optimal density and that the habits and aspirations of a considerable portion of the population are based on low-density models.

Mixed-use development

There is a broad consensus about the benefits of mixed-use development, i.e. which generally includes integrating housing, work, facilities and entertainment in close proximity so that both trip distances and car dependence are reduced. If introduced in lower density townscapes, it can stimulate urban polycentricity.

When considering new housing developments, planners should envisage them to be of a substantial size and to be located within or near to existing settlements, so that car-travel distance is minimized. The new housing should ideally be located near to public transport interchanges and corridors. However, constructing free-flowing strategic highway networks is likely to encourage the sprawl of development and strung-out communities (Banister and Anable, 2009).

Transportation demand management

As well as targeting average distances, public transport services need to be developed, non-motorised transportation stimulated, transport infrastructure improved and road congestion eased. The delivery of such policies, as with the previous element, is interrelated with the organisation of urban space and the planning of urban and transport infrastructure.

Many people believe that the ideas of sustainable development are seriously compromised by organising cities around private-car mobility. This is due not only to the emission of CO_2 and other environmental pollutants, but also to the disintegration of the city space and the diminishing room for other urban activities.

Congestions charge - A congestion charge was introduced in London in 2003. Heavy goods vehicles as well as private cars pay a daily fee for entering central parts of the city. Electric and hybrid cars are exempt since their carbon emissions are lower than the ones of petrol and diesel cars. Six months after the congestion charge was introduced, the traffic entering the zone during charging hours was reduced by 16 per cent. One year later, the number of bus passengers entering the zone during the morning peak hours had increased by 29,000. © c/ Fotolia

Urban public transport in the UNECE region's cities

The attractiveness of public transport is largely determined by whether or not it offers comprehensive services, security, reliability, speed and comfort at an affordable price. In many of the UNECE region's cities, public transport is insufficiently funded, resulting in poor service quality, inadequate capacities and a bad reputation. In others, it is limited in scope or too expensive for passengers and therefore not appealing as an alternative to the comfort of individual cars.

On the other hand, some cities in the region not only have excellent public transport services but even find it worthwhile to provide elements of free public transport to increase its attractiveness (Box 8). However, even simple organisational measures may be effective: for example, integrating the various urban transport systems into a single pro-consumer space — so that one ticket is valid on bus, boat, tram, train and metro — is relatively cheap and can have a great impact.

Non-motorised transportation and transport-demand management

Non-motorised transportation comprises mostly walking and cycling. Apart from the reduction of GHG, it contributes to individual fitness and improved public health, reduces traffic congestion, noise and pollution; and increases the attractiveness of cities.

Important options that encourage modal shifts and rationalize transport flows, also include: road pricing and car-parking policies, congestion pricing tolls, park and ride facilities, car-sharing and car clubs, and travel planning. A further important strategy would be to encourage remote forms of doing business and acquiring services (such as IT-based) to alleviate dependencies on traffic loads.

Box 8. Fare-free public transport?

To ease traffic congestion, some cities have experimented with fare-free municipal public transportation. A prominent example is Hasselt in Belgium, a city of 70,000 people that has offered a zero-fare bus service to its residents since 1997. The proponents argue that the benefits include not only reduced car traffic, but, as a consequence, also a reduced need for the construction of new roads and parking facilities; moreover, the city has attracted wider attention, boosting tourism.

In the United States, too, a number of cities such as Seattle (since 1973), Portland (since 1975), Pittsburgh (since 1985) and Salt Lake City (since 1985) operate limited downtown fare-free zones. Similarly, in Croatia, Zagreb introduced free public transport in its central zone in 2009; there are a number of public garages at the edge of this zone and the scheme is expected to alleviate bottlenecks in the city centre.

The critics of fare-free public transport say that it has to be cross-subsidized from other municipal expenditures and may limit municipal capacities to improve public transport. Free public transport also creates incentives to move from walking and cycling to public transport, and encourages people to travel more frequently than necessary.

However, even if not entirely free, public transport in many cities is commonly subsidized, making it more affordable and attractive. Some cities offer zero-fare public transport for certain social groups. These may include the elderly, as in Moscow and some other East European cities, but can also include groups such as tourists.

For example, since 2008, travellers arriving at Geneva airport have been offered free tickets for public transport and, if staying in a hotel, can receive a free Geneva Transport Card. Hamburg, in Germany, has recently organised car-free Sundays, known as the "Free for the climate" campaign, when public transport is free of charge in the whole metropolitan area and shops are also encouraged to open on those days.

Cleaner technologies for transport

The third element for the city transport transformation is technological change, including a change from fossil fuel to alternative fuel, and to more efficient and less polluting engines. Since the late 1970s, technological progress and regulation have improved the efficiency of the average new petrol car by 25 per cent. Improvements can also be found in exhaust-pipe emission standards (Banister and Anable, 2009).

A variety of alternative fuels are currently promoted, including biofuels, compressed and liquefied natural gas, electricity and hydrogen power. Hybrid vehicles can use several types of fuel — it is estimated that in the United Kingdom, the best hybrid vehicles emit less than 100g CO_2/km compared with the current total fleet average of around 165 gCO_2/km (Hickman et al., 2009). Many municipalities have changed their fleet to some of these cleaner technologies.

Plug-in hybrid and electric vehicles are currently seen as the basis for the carbon-free mobility of the future, if the electricity supply moves to renewable sources. These technologies are especially relevant for cities. Urban policies can assist by promoting the development of proper infrastructure for recharging electric cars, by introducing a special alleviated levy and permit regime for such vehicles and by equipping the municipal transport fleet with these technologies. The share of carbon-free mobility will be further boosted by the electrification of rail-based city transport and the provision of renewable energy for this.

Some cities are increasingly including the provision of electricity-powered aerial ropeways as a means of public transportation. These are believed to be one of the world's safest and most sustainable modes of transport, and can replace a considerable number of buses and cars (Urban World, 2010).

Biofuels (including bioethanol, biodiesel, or biogas) are already used intensively in some cities. Their use for motorised vehicles reduces the GHG emissions if the biomass for their production is renewable. Biofuels may also use waste as a feedstock and thus reduce emissions from landfills. Waste-to-energy technology can, for example, supply biogas, which can be compressed and used for fuelling cars (see Part III Chapter 5).

However, a potential danger of biofuels, if they are to be deployed rapidly, lies in the unsustainable conversion of forests, peatlands and grasslands into biofuels farms, as well as the depletion of local environmental resources such as soil and water. It may take many decades to compensate for the release of carbon due to the loss of the original ecosystems (Gibbs et al., 2008).

The possibilities of food shortages and food-price rises due to takeover of subsistence farmlands and incentives to switch farms from the production of food to biofuels are also chief concerns, especially in the context of the nearly 60 per cent of the world's population that is malnourished (Pimentel et al., 2009).

4. Green spaces and water systems

The system of urban green spaces serves as the ecological framework for environmental and economic sustainability and social well-being. This green infrastructure includes forests and parks, street trees, river corridors, watercourses, as well as urban agriculture and private gardens. It is an essential part of local-climate-management strategies, because urban forestry and habitat restoration are among the simple and low-cost ways for both carbon sequestration and urban air quality management. Increasing the amount and size of vegetation helps to reduce the amount of pollutants in the low atmosphere. Vegetation also removes carbon dioxide during photosynthesis and emits oxygen.

Green City - One quarter of Luxemburg's total surface is covered by green areas. Many green parks and valleys stretch through the city. According to the European Green City Index, Luxemburg is the 6th greenest city in Europe. © yarchyk/Fotolia

Urban green infrastructure is also a key measure in responding to the urban heat island effect. This is the high temperature anomaly in cities due to a changed surface albedo[5] and heat losses from the human-made infrastructure. This effect necessitates greater use of air conditioning, leads to heavier air-pollution, and amplifies heat-related illness and mortality.

Green spaces help to mitigate the effect through evaporative cooling and shading, creating cooler microclimates. Large urban parks are like "cool islands" within cities. These islands enhance local wind patterns in cities through the so-called "park breeze" effect. As urban areas warm-up faster than non-urban areas during the daytime, the warm air rises and causes a local low-pressure anomaly, so that winds blow from the non-urban high-pressure areas towards the urban low pressure areas. Green spaces of sufficient size within the city create a similar micro-circulation effect, so that a breeze from the parks cools the surrounding neighbourhoods (e.g. see Gartland, 2008).

The practice of using green infrastructure for climate adaptation and mitigation control includes traditional sustainability measures such as creating and protecting an inter-connected network of the major green spaces in a city and further greening of the urban environment to the largest possible extent.

[5] "The proportion of the incident light or radiation that is reflected by a surface". *Concise Oxford English Dictionary*, twelfth edition.

A well-integrated urban green network is needed, not only because an uninterrupted system provides the best option for protecting the local biodiversity, but also because such a system has greater resilience against adverse conditions. If this system is diversified further and includes different elements such as forested parks, grassland, water areas and wetlands, it will have even a larger resilience potential.

Water management is another important element for urban climate-proofing to mitigate the risks of flooding, drought and heat waves. It includes surface and groundwater systems, watercourse corridors and the engineering infrastructure to manage them. Water systems should be integrated with green infrastructure as much as possible and be planned on the basis of coherent ecosystem-hydrological relationships.

For example, vegetation reduces surface water run-off, thus improving flood-control management. If the urban green system includes low-lying areas such as wetlands, stream corridors, ponds and ditches, it will regulate water levels and reduce the need to build expensive alternative infrastructure for piped drainage. And it will also decrease the risk of soil erosion. The engineering infrastructure will need to become more "intelligent" and be integrated with the urban ecosystem-hydrology relationships.

City aesthetics are enhanced by well-presented green space and water space, which can physically separate industrial and motorway land uses from the rest of the urban fabric. If green infrastructure is integrated with transport-management policies, it improves the attractiveness of cycling and walking.

Green landscapes also bring economic and social gains. For example, property values in cities tend to be higher if neighbourhoods include larger green spaces. Residents in such neighbourhoods are healthier because of the beneficial environmental effects and because of opportunities for outdoor recreation.

Cities, even with a high density, could increase their green areas by restoring brown field sites as parks and redeveloping closed landfills as green areas. Even small solutions deployed on a large scale can have a great impact. Some of the novel approaches (although with a long history behind them) include integrating vegetation into the design of individual buildings, such as greening roofs and walls, creating "pocket parks" and planting trees in courtyards.

Green roofs

Green roofs represent an effective additional mechanism for addressing the heat island effect and for "precipitation management". As such, they are increasingly being proposed as climate-change-adaptation measures.

They integrate the positive effects of vegetation cover directly into the buildings' design. They reduce the over-heating of buildings in summer and provide better thermal insulation in winter, thus improving the building's own energy performance in addition to the positive effects for the neighbourhood as a whole.

In North America and Central Europe, traditional rooftops can reach temperatures as high as 90 °C during the summer, but green roof temperatures stay below 50 °C. The difference in surface temperature between a green roof and an unplanted roof can be as much as 40 °C or more (Gartland, 2008).

A cooling roof is also beneficial for solar panels, as they currently work best at temperatures up to 25 °C and have reduced productivity at higher temperatures. Green roofs also intercept storm-water runoff and thus reduce the load on the building's drainage system, thereby extending its maintenance cycle. The life of the roofs can itself be extended, as they are better protected from rain. They can have different designs: from simple lawns to trees to rooftop farming. However, the instalment of green roofs needs to be done properly, including the installation of root barriers and waterproof membranes and to be regulated to reduce the risk of roof overload and accidents such as fires during a dry and hot period (see Box 9).

Within the 2009 Copenhagen Climate Plan, one element proposed was the establishment across the city of so-called "pocket parks", to create synergy between the built and green spaces. These small green spaces are expected to help cool the city on hot days and absorb rain on wet days, and, moreover, open up possibilities for leisure and sports activities. The pocket parks are designed to be of high landscaping and architectural merit; at least two new parks are expected to be created in Copenhagen each year (City of Copenhagen, 2009).

Box 9. Compulsory green roofs

Many cities in Austria, Germany and Switzerland, following the original experiences of Basel and Linz, have introduced either compulsory requirements for greening all flat roofs on new buildings or additional subsidies for such measures for existing roofs.

In Chicago, all government buildings must have a green roof. Toronto in Canada is the first city in North America to have a bylaw to require and govern the construction of green roofs on both public and private buildings (City of Toronto, 2010). The bylaw covers new residential, commercial and institutional development with a minimum gross floor space of 2,000 m^2 from January 2010 and all new industrial development from January 2011.

5. Waste management

Waste management involves the collection, transportation, processing and recycling of human-made waste materials from domestic, commercial and industrial users. Due to potential health, safety and environmental impact, waste management must be under stringent government control and be regulated by the different levels of government. Waste is relevant for city climate strategies for a number of reasons:

- Its decomposition in landfills is one of the most important contributors to the anthropogenic emissions of methane. If burned, waste is also responsible for carbon emissions.

- It places a heavy load on urban infrastructure and space and involves land-use change and energy consumption related to the construction and operation of this infrastructure.
- It can also amplify negative local climate impacts — for example, dumping of solid waste can clog drainage channels and cause local flooding.

Waste prevention, recycling, composting and energy recovery from waste are good environmental and climatic practices, helping to achieve sustainability and climate neutrality.

Coping with the challenge of waste requires proper management of the full lifecycle of products and materials; therefore, a zero-waste strategy is growing in popularity as one of the best practices. It not only encourages recycling of products but also aims at the restructuring of their design, production and distribution to prevent waste emerging in the first place. This is relevant, for example, in the buildings sector. Since this sector should minimize embedded energy in construction materials and building practices, it should also envisage efficient means for the 'recycling' of the building at the end of its life — i.e. efficient dismantling and the re-use of materials.

Recycling involves the use of waste as a resource for other products. Many materials can be recycled, including glass, paper, metal, plastic, textiles and electronics. Pre-sorted biodegradable waste (e.g. kitchen and garden waste, sewage sludge) may be used for composting (including in combination with biogas production (see below). However, urban waste recycling and composting requires effective municipal infrastructure for collecting these materials, and sorting and further processing them.

Other organic waste, if it is non-recyclable, can be used as a resource for energy generation, following the same technologies as for the production of biofuels from crops, but with less potential controversy. A number of technologies, which are discussed below, are already commercially popular. These include anaerobic digestion for biogas, incineration of waste, pyrolysis for syngas, biofuels, charcoal and extracting heat from wastewater.

Wet organic waste can be used for producing renewable biogas by applying a technology known as anaerobic digestion. The nature of this process is similar to the emission of methane from landfills, but instead of the gas escaping into the atmosphere it is used as an energy resource. Anaerobic digestion plants use natural bacteria in sealed vessels to break down biodegradable organic matter (such as food waste, human sewage, waste paper, grass, or animal dung) into methane and CO_2, leaving a nutrient-rich residue (digestate), which can be used as a fertiliser. The resulting bio-methane (biogas) is very similar to natural gas and, once purified and upgraded to the necessary specification, can be injected into the gas network or used as a car fuel.

Woody biomass or plastic, however, cannot be used for biogas. Non-recyclable solid waste, which is not suitable for biogas generation, can be incinerated to produce energy. Although waste incineration produces CO_2, the technology is considered to be cleaner and more efficient than relying on landfill as an alternative waste-management strategy (landfills not only emit GHGs, but also increase pressures on land use). It results in smaller CO_2 emissions per energy produced than when burning fossil fuels.

"Mass burn" energy-from-waste units can provide both heat and electricity and are most efficient when based on co-generation connected to district heating (as described in Chapter 7). The benefits of the system are that it requires no pre-treatment for solid wastes, reduces the volume of waste (sometimes by a factor of 10) and is commercially proven. However, the process has a poor public image, and due to the hazardous stack emissions which contain dioxins is opposed by environmental groups.

Indeed, incinerators require very strong environmental regulation and control measures for stack emissions and flue gas filtering, as well as for the safe disposal of hazardous residues from the stack emission control process. As a result of the EU Waste Incineration Directive of 2000, the facilities in the EU are considerably cleaner and safer today, but concerns over health and safety of incineration are still present in some other parts of the UNECE region.

A more environmentally friendly alternative to incineration is gasification and pyrolysis of waste, which can be used for any low-moisture content organic material, including plastic waste, tyres and wood. The best results from gasification and pyrolysis are obtained from uniform feedstock. Solid waste should be pre-sorted to remove most of the non-organic material and processed to homogenize the material. The organic material is heated with limited or no access to oxygen, often under pressure, to break it down into a range of products including syngas, charcoals and biofuels. The yield of products varies with temperature and oxygen. High temperature heating with some access to oxygen is known as gasification and produces primarily syngas — a mixture of carbon monoxide and hydrogen, which can then be combusted to produce electricity. Similar thermochemical decomposition of organic material in the absence of oxygen is known as pyrolysis, used for the production of char. Contrary to oxygen-fuelled combustion, pyrolysis does not produce CO_2 emissions; instead, the carbon becomes locked up in the resultant biochar.

Biochar is a fine-grained, highly porous charcoal. It can itself be burned to produce energy and to offset fossil-fuel use, and is also an effective fertilizer with a high potential for climate change mitigation. It helps soils retain nutrients and water, resulting in increased soil fertility. Moreover, when used as a fertilizer, the carbon in it resists degradation and can lock up carbon in soils for hundreds to thousands of years, providing a powerful tool for carbon sequestration if produced in a sustainable way and on an industrial scale (see Lehmann, 2007; Lehmann and Joseph, 2009).

Box 10. Integrated planning and waste management in Hammarby Sjöstad

Hammarby Sjöstad is a new residential district in Stockholm, where construction started in 1994 on the site of a former industrial area of wharfs and docks. When it is completed in 2017, it will comprise 11,000 apartments for 25,000 residents.

The overall goal for the district is to halve its major environmental impact compared to similar areas built in the early 1990s. This goal will be achieved by a holistic eco-planning process, called the Hammarby model, which integrates sustainable solutions for buildings, land use, transport, water, waste and energy.

Waste management is an important element of the model. Waste is either recycled or converted into renewable energy. It is separated by households and disposed of, depending on its type, into different building-based refuse chutes or residential block-based recycling rooms. Refuse chutes are linked to underground pipes that transport the waste by vacuum suction to a central collection station, thus avoiding the need for refuse collection vehicles to drive into the area.

Combustible waste is then burned to supply electricity and hot water. Advanced technology is used for wastewater treatment, which extracts heat from purified wastewater and biogas from sewage sludge. The post-extraction sludge is used as a fertilizer. Another goal is to reclaim 50 per cent of nitrogen and water and 95 per cent of phosphorus, from wastewater, to be used for local agriculture.

The main source of heating in Hammarby Sjöstad is district heating. In 2002, 34 per cent of district heat was generated from wastewater, 47 per cent from combustible household waste and 16 per cent from biofuels. In addition, when the heat is extracted from the warm wastewater, the remaining cold water can be used for district cooling. About 1,000 households use stoves, burn biogas derived from the district's sewage sludge; it is estimated that electricity consumption in the buildings concerned is lowered by 20 per cent. The recovered biogas is also used to fuel local public transport and cars.

Rainwater, storm water and snow-melt are treated locally and then drained into the Hammarby Sjö Lake and not to the usual wastewater treatment plant. Green roofs on many buildings are designed to reduce street rainwater drainage.

Source: Hammarby Sjöstad, 2011

Warm wastewater can be a source of heating. The thermal energy obtained in a sewer can be raised by heat pumps via heat exchangers to the specified temperature level. This process is combined with the other environmentally friendly methods for urban waste management in places such as Hammarby Sjöstad in Stockholm (Box 10). Unlike in most other countries, less than 20 per cent of household waste in Sweden is deposited as landfill.

PART IV

Post-Carbon Transitions

1. City Roadmap to climate neutrality

Having considered various technological and organisational measures in this report, a "City Roadmap for Climate Neutral Cities" is presented in this chapter. This Roadmap frames the actions for policy makers *at the city level*.

Based on the findings of this report, the Roadmap includes elements related to (a) the establishment of an overall organisational framework at the city level and to (b) a framework for action in priority sectors.

Establishing an overall organisational framework

1. Identify or set up a climate change/environmental policy unit to supervise and deliver policies and strategies at the city level, including by facilitating and coordinating interdepartmental links. Establish the necessary cooperation with relevant authorities at the national and regional level.

2. Facilitate multi-stakeholder partnerships for organisational action including with the private sector, developers, property owners, local/community governments and the public.

City profile and action plan for climate and energy

3. Develop and implement a city profile and action plan for climate and energy:

a. To serve as an "evidence baseline" for activities supporting climate neutrality, draft a city profile for climate and energy based on an inventory and analysis of the city's existing energy balance, climate footprint, vulnerabilities and opportunities. The profile can be supported by geographic information systems to identify priority areas for planning climate adaptation measures and energy efficiency actions, or to identify areas with better potential for renewable energy;

b. Based on the city profile, develop an integrated action plan for climate, energy and the environment, which should include: emission-reduction targets, climate change adaptation measures, support mechanisms for the most vulnerable groups, and time frames for the climate neutral transition. The plan should also include sectoral measures (as set out below) and should aim at creating synergies and integration between the different sectors.

c. Draw up procedures for continuous evaluation, reviewing and updating the action plans;

d. Mobilize financial resources at national and international levels for implementing the action plan, pilot projects and other climate neutral initiatives, including from public-private partnerships and the private sector;

e. Implement the action plan. Based on the plan, review public procurement practices and permission systems. Incorporate the plan into revised spatial planning.

6. Educate the public, professional associations, business and industry about climate change, energy efficiency, vulnerabilities and climate neutral solutions, establish advice centres and knowledge-sharing platforms. Address skills-development needs and provide capacity-building programmes for various groups and job markets.

7. Establish a system of climate monitoring, early warning and contingency measures at the city level.

8. Advertise the cities' climate neutral policies widely. Advocate to higher government levels the need for regulatory and administrative changes based on the local needs for delivering climate neutrality. Participate in inter-urban networks and cooperation activities at the national and international levels, for mutual learning and greater visibility.

9. Monitor and evaluate the implementation of the action plans and the city's climate neutral policies, including spatial planning. Consider any unintended effects, both positive and negative, and devise measures for preventing and mitigating any negative effects.

Identifying priority sectors for action

1. Assist in the development of green markets, green business start-ups and green jobs, support public and private R&D.

2. Increase the use of green energy. Stimulate distributed renewable energy generation, as well as intelligent city electric grids. Use energy-efficient technologies for city facilities. Develop district heating-cooling systems and tri-generation.

3. Stimulate and promote energy service companies, which will help finance and coordinate energy efficiency measures.

4. Use spatial planning, zoning and other instruments to reduce and prevent sprawl, stimulate mixed-use compact communities. Implement protection and resilience measures for vulnerable zones.

5. Promote walking and cycling by integrating these into all urban planning policies and infrastructure improvements. Develop good public transport. Provide disincentives for using cars. Install alternative fuel infrastructure, increase the fuel efficiency of municipal fleets by strategic purchases of alternative fuel vehicles.
6. Improve energy efficiency and the physical condition of buildings via the promotion of zero-energy building design, climate-proof development and low energy retrofitting. Strengthen the quality of property management and maintenance systems. Integrate energy efficiency into the city's housing programmes.
7. Preserve and expand green and open spaces, greenbelts. Promote tree planting and green roofs. Consider other measures to mitigate the urban heat island effect.
8. Increase recycling infrastructure in the city, install waste-to-energy technologies. Promote sustainable material cycles via design control.
9. Promote demonstration projects: set up "champion" projects in the public sector; award champions in the private sector. Promote pilot projects of different kinds and in different sectors to test the effectiveness and replicability of different solutions.
10. Designate areas as testing grounds for zero-carbon neighbourhood development and consider expanding them over time.

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Climate Neutral Cities

With about two thirds of the UNECE population living in urban areas, this is where the region's social, intellectual and economic life is concentrated. This report provides an overview of the importance of cities for energy reduction, climate protection and climate adaptation. It discusses the actions that cities in the UNECE region need to undertake in order to mitigate their energy intensity and carbon footprint, and to reduce their vulnerability to climate change and post-carbon energy transitions. Climate Neutral Cities presents targeted considerations for relevant urban sectors, such as energy, mobility, buildings, green space, waste and water, with the overall aim of advancing sustainable development and ensuring green growth. This report concludes with introducing a City Roadmap for Climate Neutrality, including milestones for actions in priority sectors and for the set-up of an organizational framework.

For further information on UNECE's work on urban areas, please visit our website:

www.unece.org/hlm/welcome

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