PART I

Chapter 1

Urbanisation, Economic Growth and Climate Change

This chapter analyses the relationship between cities and climate change and shows that it is not cities, nor urbanisation per se*, that contribute to greenhouse gas emissions, but rather the way in which people move around the city, the sprawling growth patterns they adopt, the way in which people use energy at home and how buildings are heated and cooled that make cities the great consumers of energy and polluters that they are. Cities' emissions can thus vary greatly depending on lifestyles, spatial form, public transport availability and the sources of their energy.*

Key points

Cities are major contributors of CO_2 emissions

- Roughly half of the world's population lives in urban areas, and cities consume a great majority – between 60 to 80% – of energy production worldwide and account for a roughly equivalent share of global CO_2 emissions. Greenhouse gas (GHG) emissions in OECD cities are increasingly driven less by industrial activities and more by the energy services required for lighting, heating and cooling, electronics use, and transport mobility.
- Growing urbanisation will lead to a significant increase in energy use and CO_2 emissions, particularly in non-OECD countries in Asia and Africa where urban energy use is shifting from CO_2-neutral energy sources, such as biomass and waste, to CO_2-intensive energy sources.

How cities grow and operate matters for energy demand and thus for greenhouse gas emissions

- Energy use and related CO_2 emissions are driven by how much energy is required to light, heat and cool buildings as well as to operate home appliances and office equipment, by how electricity is generated and by the energy used to move around the city and its peripheral areas.
- Urban density and spatial organisation are key factors that influence energy consumption, especially in the transportation and building sectors. Rapid urbanisation over the last half-century has been accompanied by urban sprawl, with urban land area doubling in the OECD and growing by a factor of five in the rest of the world. The expansion of built-up areas through suburbanisation is still growing in most OECD metropolitan areas.
- Increasing spatial density of urban development could significantly reduce energy use in urban areas and CO_2 emissions. Lower energy consumption is correlated with higher urban density.

Energy sources and technology choices also matter

- The greenhouse gas emissions impact of energy consumption depends not just on how much is consumed, but also on the energy source, and the mode of power production.
- Technology also matters: urban areas relying on inefficient or wasteful energy technologies contribute more greenhouse gas emissions than those that consume the same amount from more energy efficient sources.

There is an increasing recognition of cities and urban regions' role as key engines of economic growth, job creation and innovation – as well as their role as the major contributors to global warming. Higher concentrations of population are generally linked with higher energy use, which is one of the main drivers of greenhouse gas (GHG) emissions, particularly carbon dioxide (CO_2) emissions. This worldwide trend will only be reinforced as growing urbanisation – particularly in non-OECD countries – results in increased overall energy demand, and therefore increased GHG emissions. However, cities present great opportunities for reducing countries' contributions to climate change. In OECD countries, where urbanisation is already well advanced, the main drivers of GHG emissions are energy consumption patterns, including how people move around metropolitan regions and the amount of energy they consume for daily home and work activities. Urban density and spatial organisation are key factors that influence energy consumption, especially in the transportation and building sectors. This chapter discusses the relationships between urbanisation, economic concentration, energy use and GHG emissions in OECD countries and provides the main rationale for taking action at the urban scale: urban structure and form do matter for climate change.

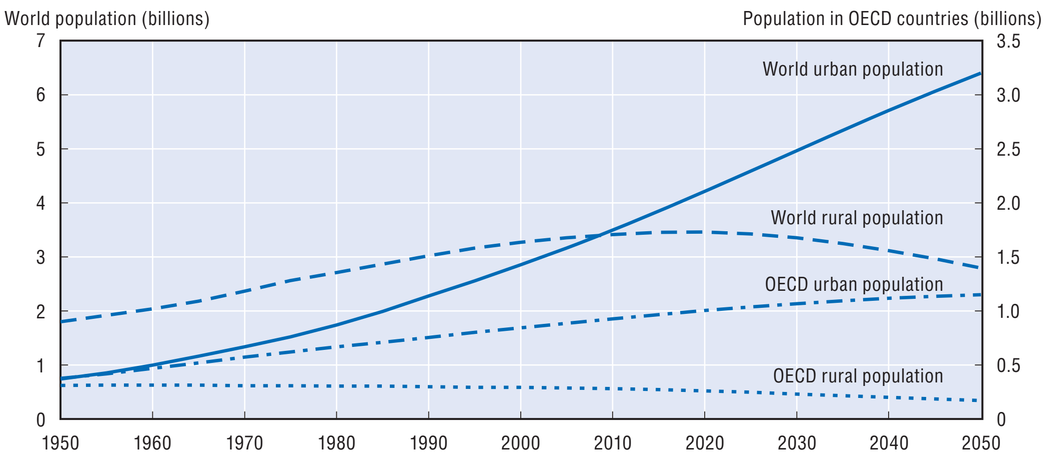
The worldwide urbanisation process

Urbanisation is a global phenomenon and is expected to continue for decades to come (OECD, 2006; UN, 2008). According to the United Nations, roughly half of the world's population lives in urban areas,[1] and this share is increasing over time, projected to reach 60% by 2030 (Figure 1.1). However, although urbanisation growth within the OECD is still ongoing, most of the urban population growth up to 2030 will occur in developing countries (Figure 1.2). Developing countries are projected to have urban growth rates roughly double those of OECD countries in the 2005-30 timeframe (UN, 2008). China, for instance, which is already the largest urban nation in the world, will see its current urban population rising from 600 to 900 million by 2030. As of 2015, the newly added urban population will be larger than the total population of many OECD countries, such as Germany, Japan, Mexico and France (Kamal-Chaoui in OECD, 2008a). Though the pace of urban growth will be highest in smaller towns and cities in countries in Africa and Asia, the proportion of the world's population living in so-called megacities, or urban centres with more than 10 million people, is also predicted to rise to 12% in 2025, from about 9% today, and the number of megacities will rise from 19 to 27 (UN, 2008).

World urbanisation trends are now catching up with the transformations that have already taken place in OECD countries over the last century. OECD countries have already experienced urbanisation: by 1950, urban populations in the OECD were greater than rural

Figure 1.1. **Urban and rural population in the world and the OECD**

Absolute population numbers



Source: Own calculations based on data from the *UN Population Database* (2009).

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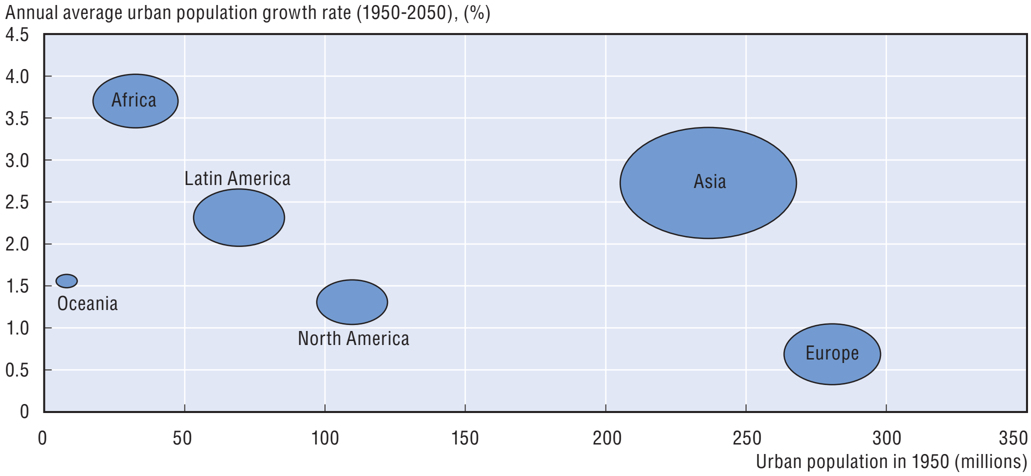
Figure 1.2. **Trends in urbanisation by continent**

Urban population and growth (1950-2050)



Notes: Urban areas are defined according to the *UN Population Database* which takes into account each country's own definition of urban. Bubble size depicts population size in 2010.

Source: Own calculations based on *UN Population Database* (2009).

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populations (Figure 1.1). That same milestone occurred in the global urban population in 2006. In many ways, OECD countries have been coping for more than half a century with the challenges brought about by an increasing urban population. If global urbanisation in the first half of the 20th century took place predominantly in European cities, population size has made Asia the continent with the highest urban population in the world today (Figure 1.2). Africa is also experiencing significant transformations, as it is home to some of the fastest-growing cities. The UN forecasts a decline in rural population after 2020, while among OECD countries the rural population has shrunk throughout the second half of the 20th century. The UN expects urban population to grow steadily both worldwide and in OECD countries (albeit at a slower pace). By 2050, 70% of the world's population – and 86% of the population in OECD countries – will live in urban areas.

There is no agreed-upon definition of an urban area; therefore a number of methods exist to analyse trends in urban areas. In this report, three units of analysis referring to urban areas are used:

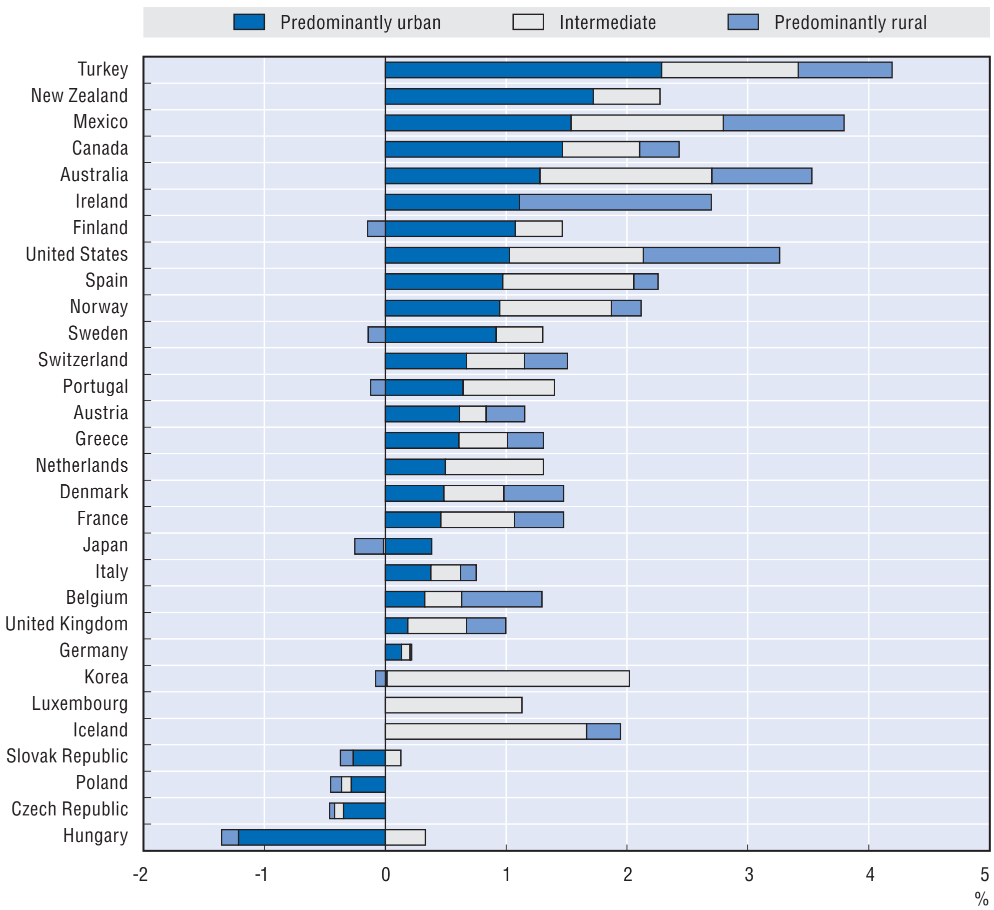
- **Urban areas.** These refer to urban areas as they are defined by the national authorities of each country. Data are often made readily available by national statistical institutes based on a single-county or municipality-level unit of analysis. However, often these urban areas are too small or too large to account for cities. This definition is used in particular when referring to UN data.
- **Predominantly urban areas.** These are defined using the OECD regional typology and employed throughout this report. They are regions where the population living in high-density areas (150 inhabitants per km^2) represents at least half of the population in that region. Although predominantly urban areas are also based on administrative areas, they are larger than a single municipality. The OECD has been able to produce comparisons across regions and countries using predominantly urban areas, but they remain too large for medium-sized cities in some cases and too small for metropolitan areas.

- **Metropolitan areas (functional areas).** These refer to commuting areas as defined in the *OECD Metropolitan Database*, which takes into account population density, net commuting rates and type of region. These are typically large cities comprised of a number of administrative and adjacent areas where economic relations are intense. Metropolitan areas are typically defined as concentrations of population and economic activity that constitute functional economic areas covering a large number of authorities (OECD, 2006).

In the OECD, urbanisation is on the increase in almost every country. Taking into account predominantly urban areas in the OECD as defined by the OECD regional typology,[2] today more than 53% of the total population is living in urban areas; this number rises to almost 83% if we include intermediate regions,[3] less densely populated areas characterised by systems of medium-sized cities. Over 1995-2005, population growth in OECD countries has been more dynamic in predominantly urban areas and intermediate areas than in predominantly rural areas. Only two countries (Belgium and Ireland) show stronger demographic expansion in predominantly rural areas (Figure 1.3). What is more,

Figure 1.3. **Population growth in OECD regions**

Annual population growth rates by type of region (1995-2005)



Notes: In some cases like Korea, intermediate regions' growth can be accounted by for growth in cities of a smaller size in wider areas that are considered to be intermediate. For instance Gyeonggi-do is an intermediate region that surrounds the Seoul area almost entirely; given that there has been considerable business growth outside the administrative area of Seoul after the deconcentration policy, it is possible that part of that growth has gone to Seoul's suburbs located in Gyeonggi-do.

Source: Own calculations based on data from the *OECD Regional Database*.

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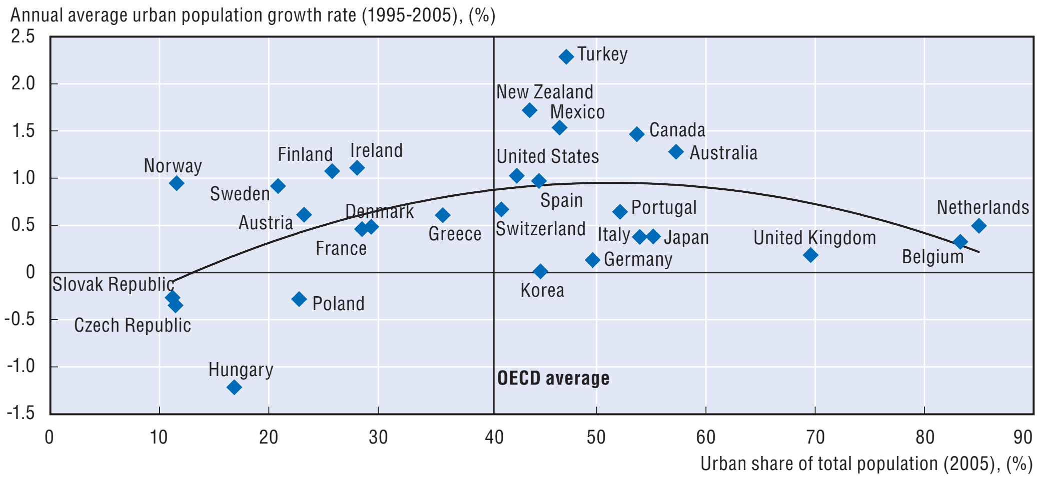
with a few exceptions in Eastern European countries, all OECD member countries have had positive urbanisation growth rates between 1995 and 2005. If predominantly urban areas are taken into account, all countries with urbanisation shares higher than the OECD average are becoming increasingly urbanised (Figure 1.4, see quadrant 1 located above right). As a result, the OECD population is becoming increasingly concentrated in a few places (Figures 1.5, 1.6 and 1.7).

Over 70% of people in the OECD who live in predominantly urban areas are in areas of more than 1.5 million people. In fact, urban populations locate increasingly according to city size. Thus, the share of total urban population living in smaller cities (between

Figure 1.4. **Urbanisation in OECD countries**

Urbanisation levels and growth according to predominantly urban areas (1995-2005)



Notes: Urban share of total population by country refers to population in predominantly urban regions as a proportion of total population. Iceland and Luxemburg were not included in the sample as the *OECD Regional Database* identifies no predominantly urban regions in those countries.

Source: Own calculations based on data from the *OECD Regional Database*.

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Figure 1.5. **Urban concentration in Europe**

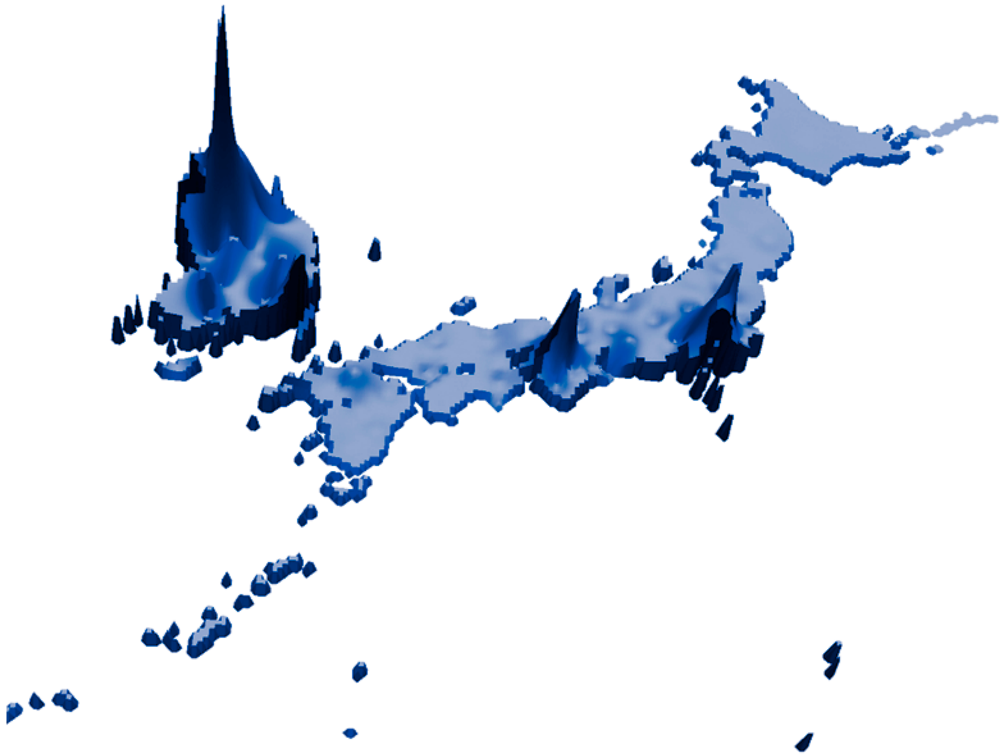
Population density at TL3 level (inhabitants per km^2) in European countries (2005)

Note: OECD regions are classified at two levels: Territorial Level 2 (TL2) and Territorial Level 3 (TL3).

Source: Own calculations based on data from the *OECD Regional Database*.

Figure 1.6. **Urban concentration in Asian OECD countries**

Population density at TL3 level (inhabitants per km^2) in Japan and Korea (2005)



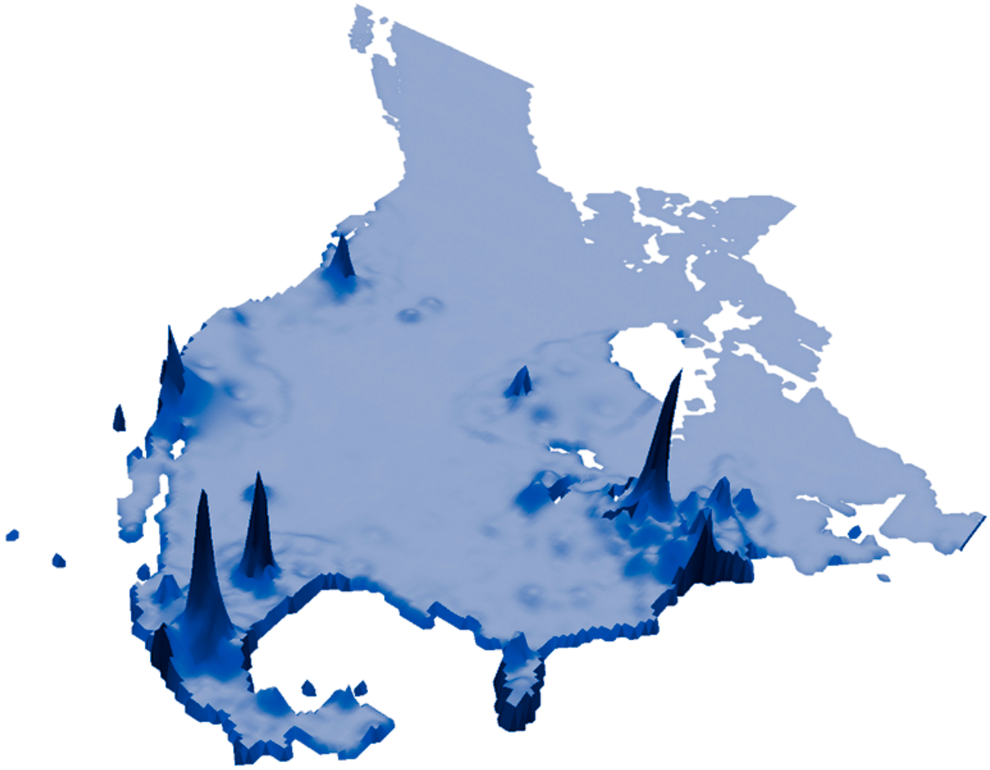
Note: OECD regions are classified at two levels: Territorial Level 2 (TL2) and Territorial Level 3 (TL3).

Source: Own calculations based on data from the *OECD Regional Database*.

100 000 and 500 000 people) is lower than the population living in any other type of city, and smaller cities also grow more slowly (0.4% annually on average). Medium-sized cities (between 500 000 and 1 million people) grow faster than smaller cities but more slowly than larger cities (Figure 1.8).

Trends among metropolitan regions in the OECD show similar results. In some cases, a single metropolitan region accounts for nearly half of the national population. Seoul, Randstad and Copenhagen represent between 44 and 48% of their respective national populations. With a few exceptions, namely Berlin, Manchester, Cleveland, Birmingham, Budapest and Pittsburgh, metropolitan areas in the OECD have experienced an increase in population between 1995 and 2005 (Figure 1.9). On average, OECD metropolitan areas have been growing at an annual pace of almost 1% since 1995, but cities such as Phoenix, Atlanta and Toronto have observed growth rates several times the average and in many others such as Ankara, Miami, Guadalajara and Washington, metropolitan population expansion has grown at least twice as fast as the average. Madrid, Seoul, Sydney and Mexico City also have experience above-average population increases.

Figure 1.7. **Urban concentration in North America**
Population density at TL3 level (inhabitants per km^2, 2005)



Note: OECD regions are classified at two levels: Territorial Level 2 (TL2) and Territorial Level 3 (TL3).
Source: Own calculations based on the *OECD Regional Database*.

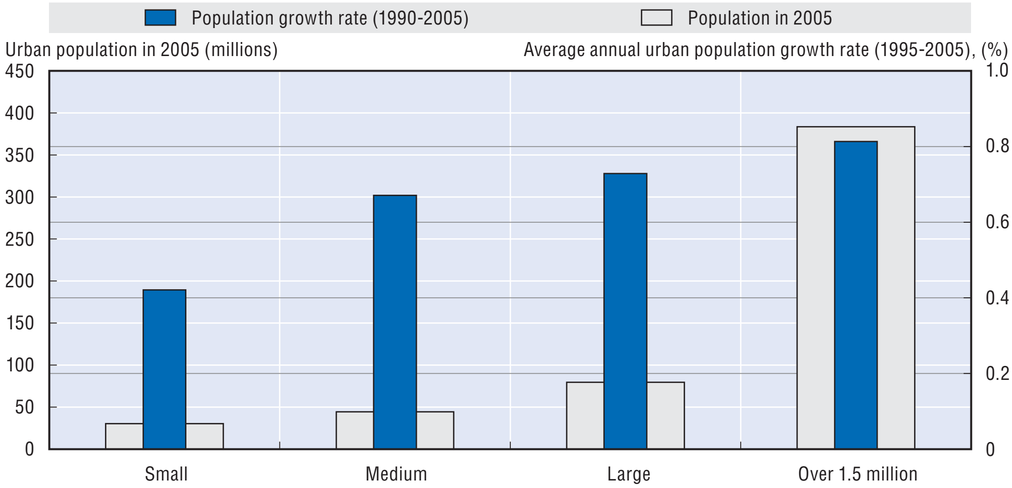
Cities and economic concentration

Urban areas are home not only to concentrations of people, but also to economic density and productivity. This is often the reason for a pooled labour market that increases the possibility of skills-matching between workers and firms. Firms also agglomerate, seeking to reduce risks of contract defaulting, as they have access to a wider set of skills and can establish linkages with suppliers and buyers. Cities are also often where knowledge spillovers take place, benefiting not only the city but also the wider regional area. Thus, in approximately half of OECD countries, more than 40% of the national GDP is produced in less than 10% of all regions, which account for a small share of the country's total surface and a high share of the country's population (OECD, 2009a).

Urbanisation is part of the development process and is generally associated with higher income and productivity levels. In OECD countries, higher urban population shares are associated in most cases with higher per capita GDP than their national average (Figure 1.10). In part, such higher per capita GDP can be attributed to metropolitan areas. In many OECD countries, one single metropolitan area produces one-third (*e.g.* Oslo, Auckland, Prague, Tokyo, Stockholm, London, Paris) to one-half (*e.g.* Budapest, Seoul, Copenhagen, Dublin, Helsinki, Brussels) of the national GDP (Figure 1.11). Thanks to the benefits of agglomeration economies, most OECD metropolitan regions with more than 1.5 million inhabitants feature a higher GDP per capita, a higher labour productivity and

Figure 1.8. **Urbanisation and city size**

Urban population and growth according to population size of predominantly urban areas (1995-2005)



Notes: This analysis was carried out using only predominantly urban areas. Small cities are predominantly urban areas with populations between 100 000 and 500 000 people. Medium-sized cities are predominantly urban areas with populations between 500 000 and 1 million people. Large cities are predominantly urban areas with populations between 1 and 1.5 million people.

Source: Own calculations based on the *OECD Regional Database*.

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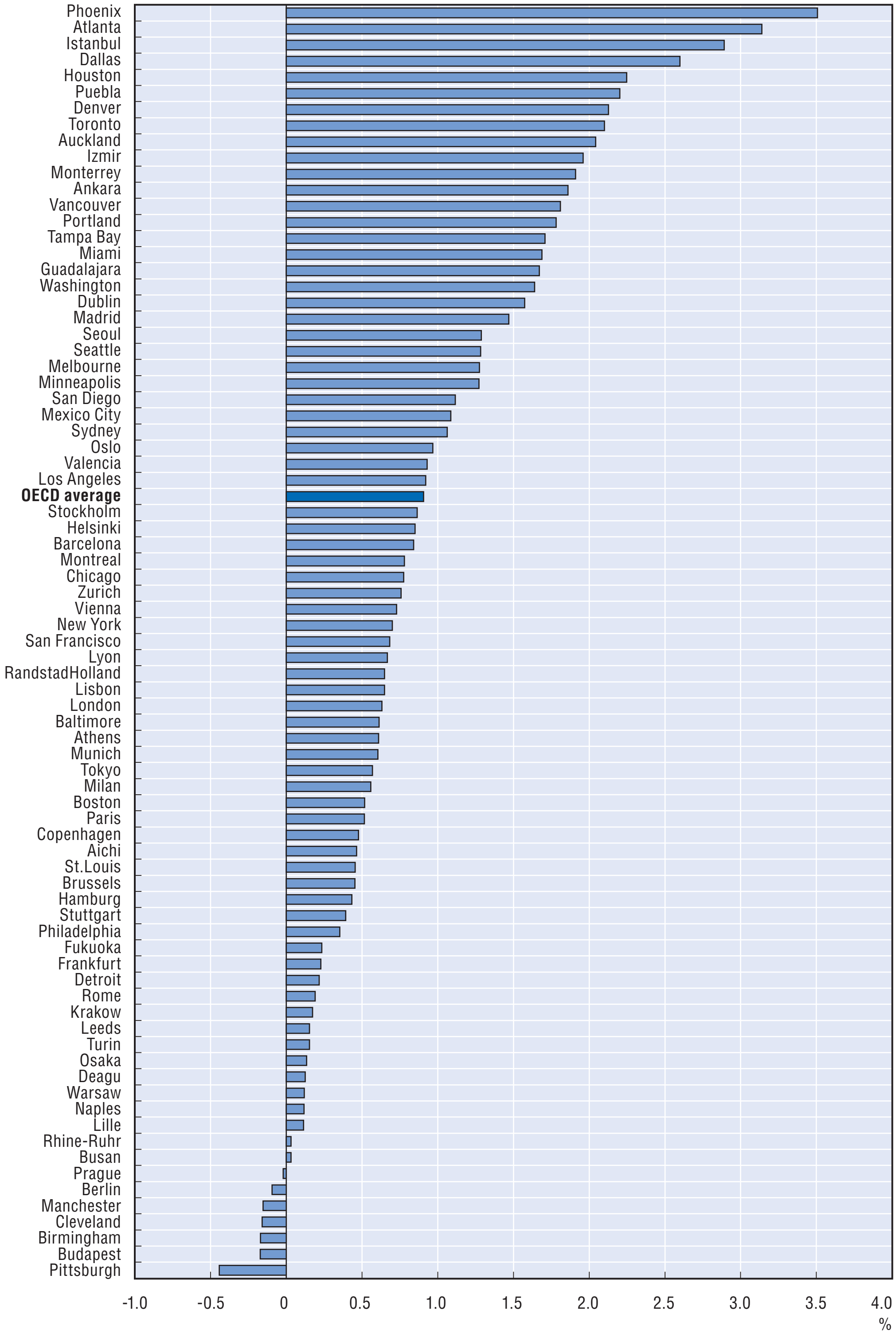
higher employment levels than their national average. Disaggregating GDP into four main factors reveals that, for the most part, higher income in metropolitan areas can be attributed to higher labour productivity levels (Figure 1.11).

However, the effect of labour productivity can be nuanced – or aggravated – by demographic or labour-market factors. In particular, the size of the pooled labour market (working-age population as a proportion of total population) and the way in which labour markets function (depicted for instance by employment rates) are important factors in determining how GDP in metropolitan areas diverges from the national level. Their effect is such that most metropolitan areas are probably held back by labour market-productivity relationships. The highest GDP levels relative to national GDP can be found in metropolitan regions, such as Warsaw, Monterrey, Washington DC and Paris, due to a great extent to labour productivity. Metropolitan regions, however, can also be held back by poorer performance – when compared to the national level – in labour market indicators such as participation rates. The size of the labour market is thus a relevant factor in determining agglomeration and performance of metropolitan regions. At the other end of the ranking, metropolitan regions with below-national-average GDP levels, such as Daegu, Naples or Berlin, are lagging behind precisely due to lingering productivity, participation and employment rates, and are only marginally helped by demographics (Figure 1.11). However, mid-ranking metropolitan regions, such as Chicago, Hamburg or Puebla, are mostly being held back by the size of the labour market.

Trends in urbanisation and population concentration are closely linked with concentration of economic activities and production (OECD, 2009b). Concentration of population in predominantly urban regions has also produced economic agglomeration. For instance, in Europe, economic activity concentrates around population centres (Figure 1.12). In Japan and Korea, economic density is evident in Osaka, Seoul and Tokyo

Figure 1.9. **Population growth in OECD metropolitan areas**

Average annual growth rates (1995-2005)



Note: The period of growth in the case of Auckland is 1996-2005.

Source: Own calculations based on data from the *OECD Metropolitan Database*.

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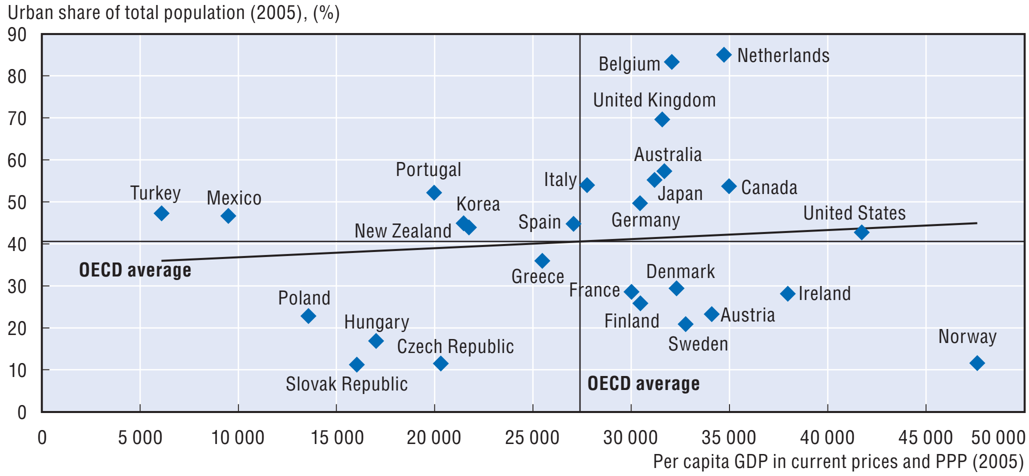
Figure 1.10. **Urbanisation and income**

Urban share of total population and per capita GDP in OECD countries



Notes: Urban share of total population by country refers to population in predominantly urban regions as a proportion of total population. Iceland and Luxemburg were not included in the sample as the *OECD Regional Database* does not identify predominantly urban regions in those countries. Switzerland was not included as GDP figures at sub-national level in that country are not available. Mexico's per capita GDP data refer to 2004; New Zealand's per capita GDP data refer to 2003; Turkey's per capita GDP data refer to 2001.

Source: Own calculations based on data from the *OECD Regional Database*.

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(Figure 1.13). Such agglomeration effects are fuelled by higher wages that can be paid due to higher productivity levels that in turn attract more workers so that centripetal forces are set in motion.

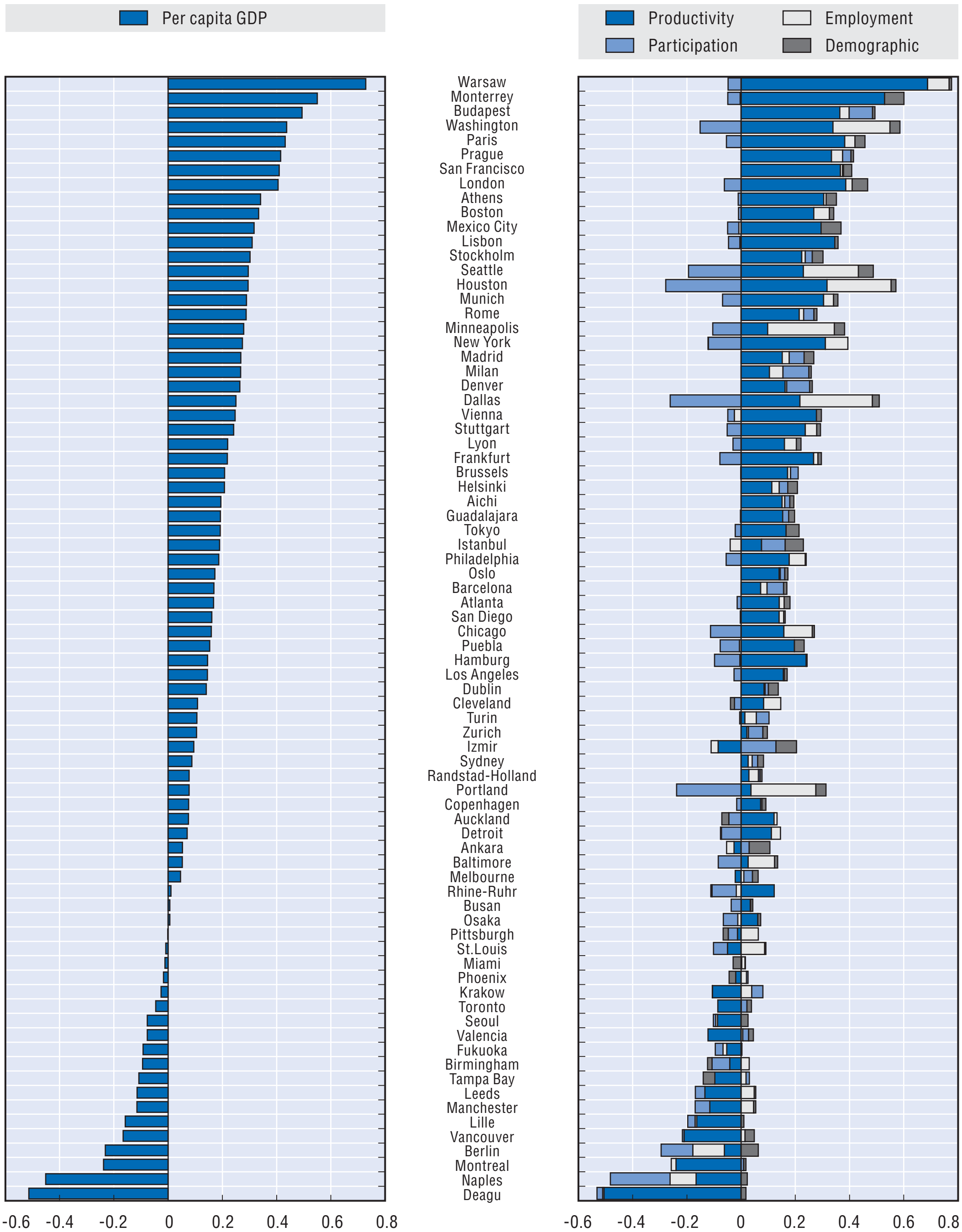
However, the benefits associated with economies of agglomeration are not unlimited. Cities can reach a point where they no longer provide external economies and become less competitive (OECD, 2009b). One of the main explanations of such mixed outcomes is linked with the existence of negative externalities, including congestion and other environmental costs such as high carbon-intensities and/or high vulnerability to climate change (these can be thought of as centrifugal forces). Negative externalities associated with large concentrations in urban areas raise the question of whether the costs borne by society as a whole are becoming unsustainable. As externalities, these negative attributes are not internalised by firms and households, and may only show up as direct costs in the long term. They include, for instance, high transportation costs (*i.e.* congested streets) and loss of productivity due long commuting times, higher health costs, higher carbon emissions and environmental degradation. Taking into account the costs and the benefits of agglomeration, it has been argued that urban concentration may entail a "privatisation of benefits and socialisation of costs" (OECD, 2009a).

Economic growth, energy use and greenhouse gas emissions

Cities use a significant proportion of the world's energy demand. Cities worldwide account for an increasingly large proportion of global energy use and CO_2 emissions. Although detailed harmonised data are not available at the urban scale, a recent IEA analysis estimates that 60-80% of world energy use currently emanates from cities (IEA, 2008a). This can be attributed, in part, to changes occurring in urban areas in emerging and developing countries, including increased economic activity. As countries urbanise, they tend to shift from

Figure 1.11. **Factors determining per capita GDP differentials**

Labour productivity, employment and participation rates, demographic factors among OECD metropolitan regions with respect to their national average (2005)



Notes: Per capita GDP can be disaggregated into four components: productivity, employment, participation and demographic. The demographic component represents the size of the pooled labour market of each metropolitan region compared to the national average. Labour market pool is calculated as the proportion of the working-age population over the total population. Australia, Germany and US data refer to 2004; New Zealand data refer to 2003; Switzerland data refer to 2002; Turkey and Mexico data refer to 2000.

Source: OECD Metropolitan Database (2009).

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Figure 1.12. **Economic concentration in Europe**

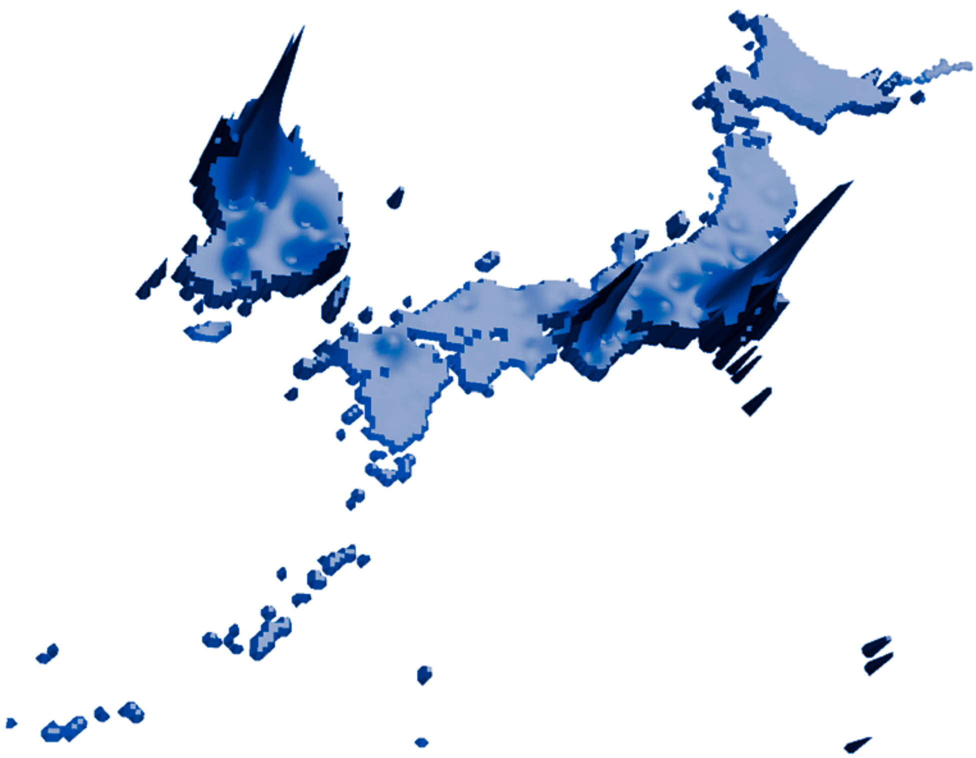
Economic density at TL3 level (GDP per km^2, 2005)

Note: OECD regions are classified at two levels: Territorial Level 2 (TL2) and Territorial Level 3 (TL3).

Source: Own calculations based on data from the *OECD Regional Database*.

Figure 1.13. **Economic concentration in Japan and Korea**

Economic density at TL3 level (GDP per km^2, 2005)



Note: OECD regions are classified at two levels: Territorial Level 2 (TL2) and Territorial Level 3 (TL3).

Source: Own calculations based on data from the *OECD Regional Database*.

CO_2-neutral energy sources (biomass and waste) to CO_2-intensive energy sources, leading to an increasing proportion of CO_2 emissions from cities (Jollands in OECD, 2008a). Cities (including towns) currently use over two-thirds of the world's energy, an estimated 7 900 Mtoe in 2006, even though they only account for approximately 50% of the world's population.

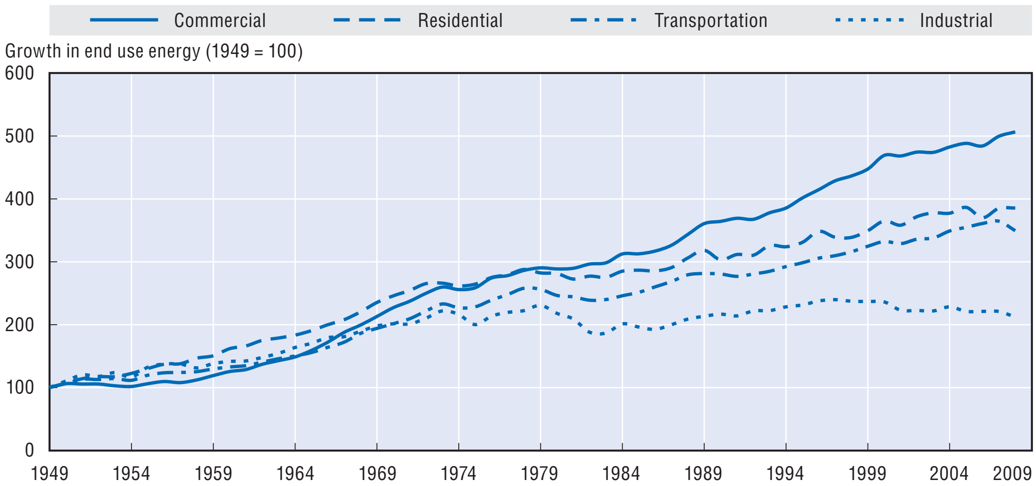
Projections indicate that cities are likely to increase their share in the total world energy consumption. By 2030, cities are expected to account for more than 60% of the world's population and 73% of the world's energy use, or more than 12 400 Mtoe in energy (IEA, 2008a). Of the global energy use projected by 2030, 81% is expected to come from non-OECD countries. US cities will likely account for 87% of US energy consumption in 2030, compared with 80% in 2006. Urban areas in the European Union will likely account for 75% of EU energy consumption, up from 69% in 2006. Cities in Australia could experience an increase from 78% to 80% of national energy consumption during the 2006 to 2030 period, and Chinese cities could account for 83% of national energy consumption compared with 80% today (IEA, 2007).

Cities contribute to climate change in three main ways: through direct emissions of GHGs that occur within city boundaries; through the GHG emissions that originate outside of city boundaries but are embodied in civil infrastructure and urban energy consumption; and through city-induced changes to the earth's atmospheric chemistry and surface albedo.

- **Direct GHG emissions** include carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) emissions from energy conversion, CH_4 emissions from the landfill decomposition of municipal solid waste, CH_4 and N_2O from anaerobic decomposition and nitrification-denitrification of nitrogen during wastewater treatment, CO_2 emissions from waste incineration, fluorocarbon (HFC, PFC) and sulfur hexafluoride (SF_6) emissions from refrigerants, semiconductor manufacturing and insulators, and CO_2 and N_2O emissions from rural-urban land conversion.
- **Embodied GHG emissions** include GHG emissions embedded in the energy required to produce the concrete, steel, glass, and other materials used in civil infrastructure, the CH_4 and N_2O emissions used to provide the food consumed by urban residents, and the CO_2, CH_4 and N_2O emissions from rural power plants and refineries that generate energy for urban consumption.
- **Changes to atmospheric chemistry and surface albedo** include the direct and indirect GHGs that result from changes in atmospheric composition and surface reflectivity. For instance, the IPCC estimates that tropospheric ozone (O_3), a secondary pollutant commonly found in cities, is the third most important GHG behind CO_2 and CH_4 (IPCC, 2007). Carbon monoxide (CO), an indirect GHG produced predominantly from mobile sources in cities,[4] lengthens the atmospheric residence time of CH_4.

Although cities' impact on the earth's climate is diverse and complex, GHG emissions from direct energy use increasingly account for the bulk of cities' climate impact in OECD countries. In other words, GHG emissions in OECD cities are increasingly driven by the energy services required for lighting, heating and cooling, appliance use, electronics use, and mobility. Industrial energy use and GHG emissions (including GHG emissions embodied in building materials) appear to have become less significant. In the US, for instance, industry's share of total energy use fell from a peak of 48.4% in 1955 to a low of 31.4% in 2008,[5] and growth in industrial energy use has essentially remained flat since the late 1970s (Figure 1.14). The importance of energy use as a source of GHG emissions is more obvious; fossil fuel energy systems accounted for an estimated 85% of US GHG emissions in 2007 (EPA, 2009).[6, 7]

Figure 1.14. **US energy consumption by sector (1949-2008)**



Source: OECD, based on US Energy Information Administration (2009), "Energy Consumption by Sector", *Annual Energy Review* 2008, Report No. DOE/EIA-0384, *www.eia.doe.gov/emeu/aer/consump.html*.

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There are three main categories of final urban energy use: electricity, thermal energy, and transportation energy. These three forms of energy are not exclusive (Table 1.1). Electricity is used to a limited extent for water and space heating, and to a lesser but increasing extent for transportation. Oil, predominantly used as a feedstock for transportation fuels, is also used sparingly for electricity generation and heating. For the purpose of matching goals with appropriate strategies, it is important to keep these different types of uses in mind. Energy efficiency that reduces electricity demand, for instance, does not directly reduce exposure to oil price volatility because so little oil is used to generate electricity. The intensity of energy demand at certain periods, known as peak demand, may also be stronger in cities, which in theory could reduce opportunities to make use of renewable energies. However, in practice, this is not a significant obstacle to renewable energy production because of new technologies that can manage loads.

Table 1.1. **Categories of urban energy use**

Type	Main energy sources (% total)	Main use
Electricity	Coal (41%), nuclear (27%), natural gas (17%), oil (5%).[1]	Lights, appliances, electronics, industrial motors.
Thermal energy	Natural gas, oil, electricity (n.a.).[2]	Space heating, water heating, cooking, industrial process heat.
Transportation energy	Oil (97%).[3]	Vehicles, transit systems (mobility).

1. Percentages are for all OECD countries.
2. Thermal energy sources are difficult to isolate, but natural gas is typically the dominant source of space and water heating in OECD countries. In the US, for instance, natural gas accounted for 76% of residential and commercial primary energy consumption in 2008, most of which was for space and water heating.
3. Percentage is based on US data .There are no recent estimates for the composition of transportation energy use for OECD countries; we use the US as a proxy here, and argue that this percentage is representative of typical OECD countries.

Source: Percentages for electricity energy sources are from IEA (2007), *Key World Energy Statistics*, OECD, Paris. US sectoral data are from EIA website, "Energy Consumption by Sector", online at: *www.eia.doe.gov/emeu/aer/consump.html*.

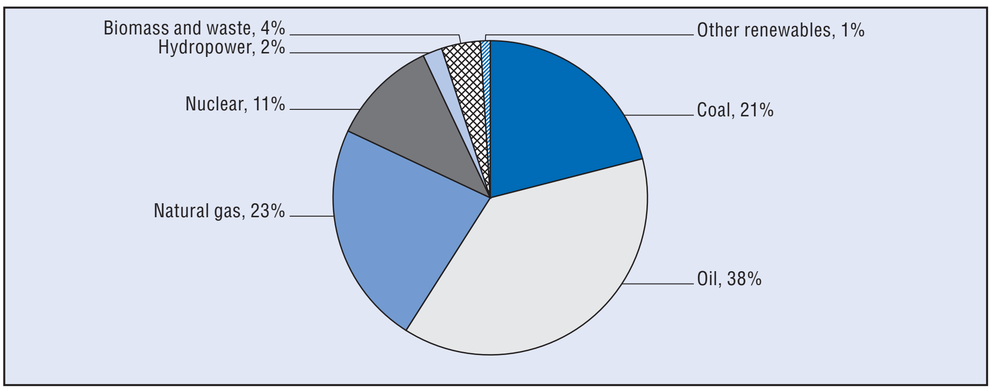
Many cities have undertaken inventories of their GHG emissions, but comparisons among cities are difficult. There is currently no single protocol ranking for assessing urban areas' per capita GHG or CO_2 emissions, making comparisons across cities impossible. Cities have taken different approaches in defining what sectors to include, in establishing the geographic boundaries of the area included, and have aggregated data in different ways. Additional urban GHG inventory differences include:

- different definitions of the urban area (*i.e.* by the larger metropolitan region, by city limits, or by another unit);
- choice of inventory years presented;
- inventory scope (*i.e.* whether or not more than city-owned operations are reported, and whether indirect emissions are included); and
- methodological issues.

Comparable GHG inventories and indicators at city-scale would be valuable because they would allow cities to manage emissions in their urban areas and enable national and international policy makers to properly target and assist city authorities to act (Chapter 10).

Energy consumption is often used as an indicator of GHG emissions generally, and CO_2 emissions in particular, but the relationship is not direct. Energy consumed in cities, be it in the form of electricity, oil or gas heat, or fuel, is produced from a variety sources, each with a different climate footprint (Figure 1.15). Some sources, such as hydropower, nuclear, solar, and wind energies produce no or minimal GHG emissions. Fossil fuel sources – coal, oil, and natural gas – do contribute to GHG emissions, but to different degrees; for example, coal contributes more GHG emissions in the power sector than natural gas (IEA, 2009). The efficiency of energy production is another determinant of the degree to which energy consumption contributes to GHG emission. Some energy is always lost between production and end use, but the amount lost (often dependent on infrastructure quality) varies greatly depending on the efficiency of production and quality of transmission infrastructure. Urban areas relying on inefficient or wasteful energy sources contribute more GHG emissions then than those that consume the same amount from more efficient sources. OECD countries face a challenge in moving to low-emissions urban energy production. In 2005, fossil fuels accounted for 83% of primary energy use in

Figure 1.15. **Total energy consumption in OECD countries (2007)**



Source: IEA (2009), Energy Statistics Division historical data, © OECD/IEA, Paris.

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OECD countries. Renewable energy, alternatively, accounted for less than 5%. The shares of oil and natural gas in total primary energy consumption in OECD countries also illustrate the importance of thermal and transportation energy in OECD countries.

The impact of energy consumption on GHG emissions depends not just on the amount consumed, but also on the GHG intensity, or GHG emissions factor, of all the activities involved in processing and producing it. When total life-cycle emissions, such as resulting from the extraction, processing, and transporting of fossil fuels, were taken into account in an inventory of 10 large cities,[8] the intensity of GHG emissions was 7-24% greater than that for end-use activities only (including energy production and air and sea activities outside of city boundaries) (Table 1.2). For example, Cape Town's per capita electricity consumption is lower than that of Geneva, but the GHG intensity of its electricity supply is significantly higher, due to South Africa's use of coal for 92% of its electricity generation and Geneva's reliance on hydropower. Thus, an important distinction must be made between urban inventories that capture emissions from city energy consumption and those that capture total life-cycle emissions associated with a city's energy supply (Kennedy *et al*., 2009).

Table 1.2. **Total GHG emissions, including end-use, life cycle, and within city measures, for ten world cities**

	Emissions within city[1]	Emissions from end-use activities[1, 2]	End-use emissions including life-cycle emissions for fuels[1, 2, 3]
Bangkok	4.8	10.7	Not determined
Barcelona	2.4	4.2	4.6
Cape Town	Not determined	11.6	Not determined
Denver	Not determined	21.5	24.3
Geneva	7.4	7.8	8.7
London	Not determined	9.6	10.5
Los Angeles	Not determined	13	15.5
New York City	Not determined	10.5	12.2
Prague	4.3	9.4	10.1
Toronto	8.2	11.6	14.4

1. Figures indicate global warming potential, expressed in carbon dioxide equivalents (t eq CO_2) per capita.
2. Includes activities occurring outside city boundaries (*e.g.* from power generation, air and marine activities).
3. Includes upstream emissions such as those caused by the extraction, processing, and transporting of fossil fuels.

Source: Kennedy, Christopher *et al.* (2009), "Greenhouse Gas Emissions from Global Cities", *Environmental Science and Technology*, Vol. 43, No. 19, American Chemical Society, Washington, US, pp. 7297-7302.

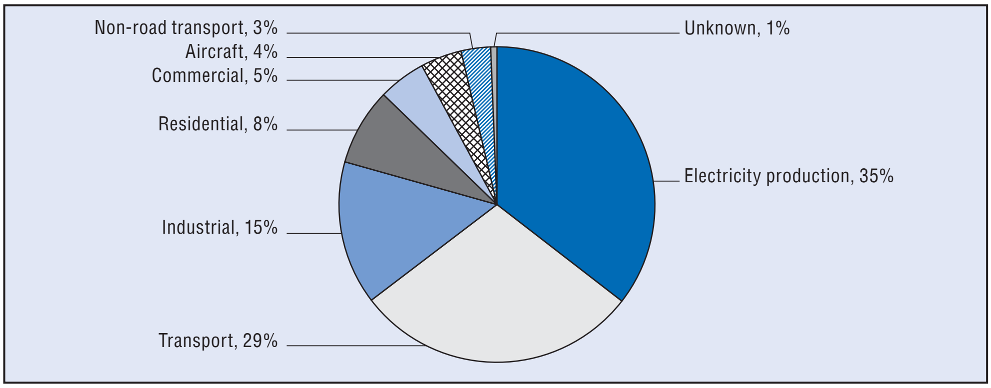
StatLink http://dx.doi.org/10.1787/888932342639

The urban form matters – the impact of sprawl

Energy use, and thus carbon emissions, are chiefly driven by how electricity is produced, the uses of such energy in households and the way in which people move around the city. Roughly two-thirds of all emissions in the United States come from electricity and road transport activities in urban and intermediate regions, with an additional one-quarter produced by industrial and residential uses (Figure 1.16). Predominantly urban regions home to the largest cities and intermediate regions that contain medium-sized cities are responsible for more than half of those emissions. They are also likely to be responsible for some emissions in rural areas, as consumers of electricity produced in rural regions. Therefore, policies that induce households to use energy more efficiently, including through building codes and policies that favour reduced commuting journeys and public transportation (*e.g.* spatial densification and congestion charges), might be useful in stimulating changes in the amount of carbon emissions.

Figure 1.16. **Carbon emissions in US cities**

Produced in predominantly urban areas by type of activity (2002)



Source: Own calculations based on data from the Vulcan Project (2009). The Vulcan Project is a NASA/DOE-funded effort under the North American Carbon Program (NACP) to quantify North American fossil fuel carbon dioxide (CO_2) emissions at space and time scales much finer than has been achieved in the past.

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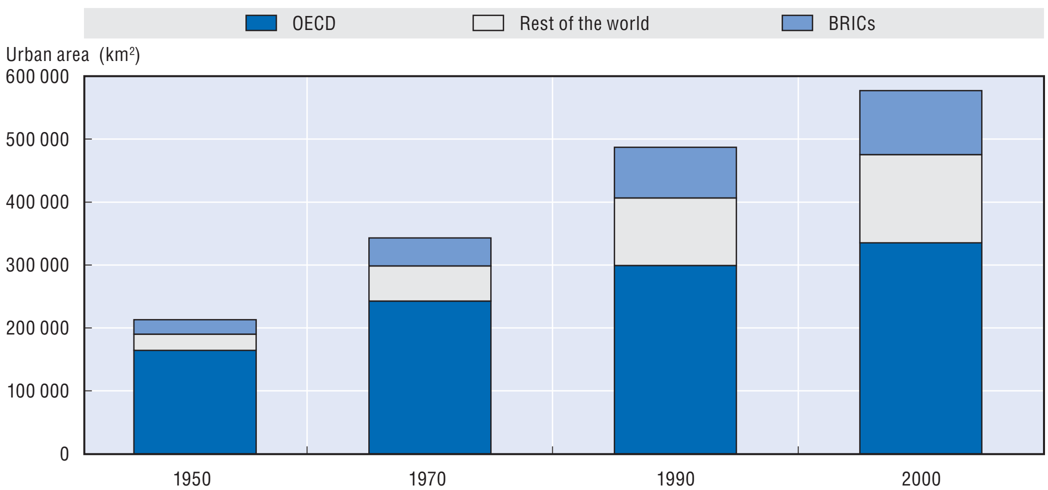
The form of urbanisation matters for energy demand and thus for GHG emissions. Population growth in OECD metropolitan areas has meant an expansion of developed areas through suburbanisation. Suburbanisation and urban sprawl has been important in the OECD, but has recently been more so for the rest of the world. Urban land area in the OECD has doubled in the second half of last century, but has experienced a fivefold increase over the same period in the rest of the world (Figure 1.17). In fact, in the vast majority of OECD metropolitan regions, the suburban belt grows faster than the core (Figure 1.18). In only 15% out of 78 metropolitan regions in the OECD, the core has seen population expansion increase faster than the suburbs. In a number of these cases, the core has benefited from both favourable economic conditions (*i.e.* lower land prices at the core) and/or intended policies in order to regain population at the core. For example, in Copenhagen, inner-city

Figure 1.17. **Urban sprawl**

Trends in urban land expansion in the world and the OECD



Note: BRIC countries refers to Brazil, Russian Federation, India and China.

Source: OECD (2008), *Environmental Outlook to 2030*, OECD, Paris.

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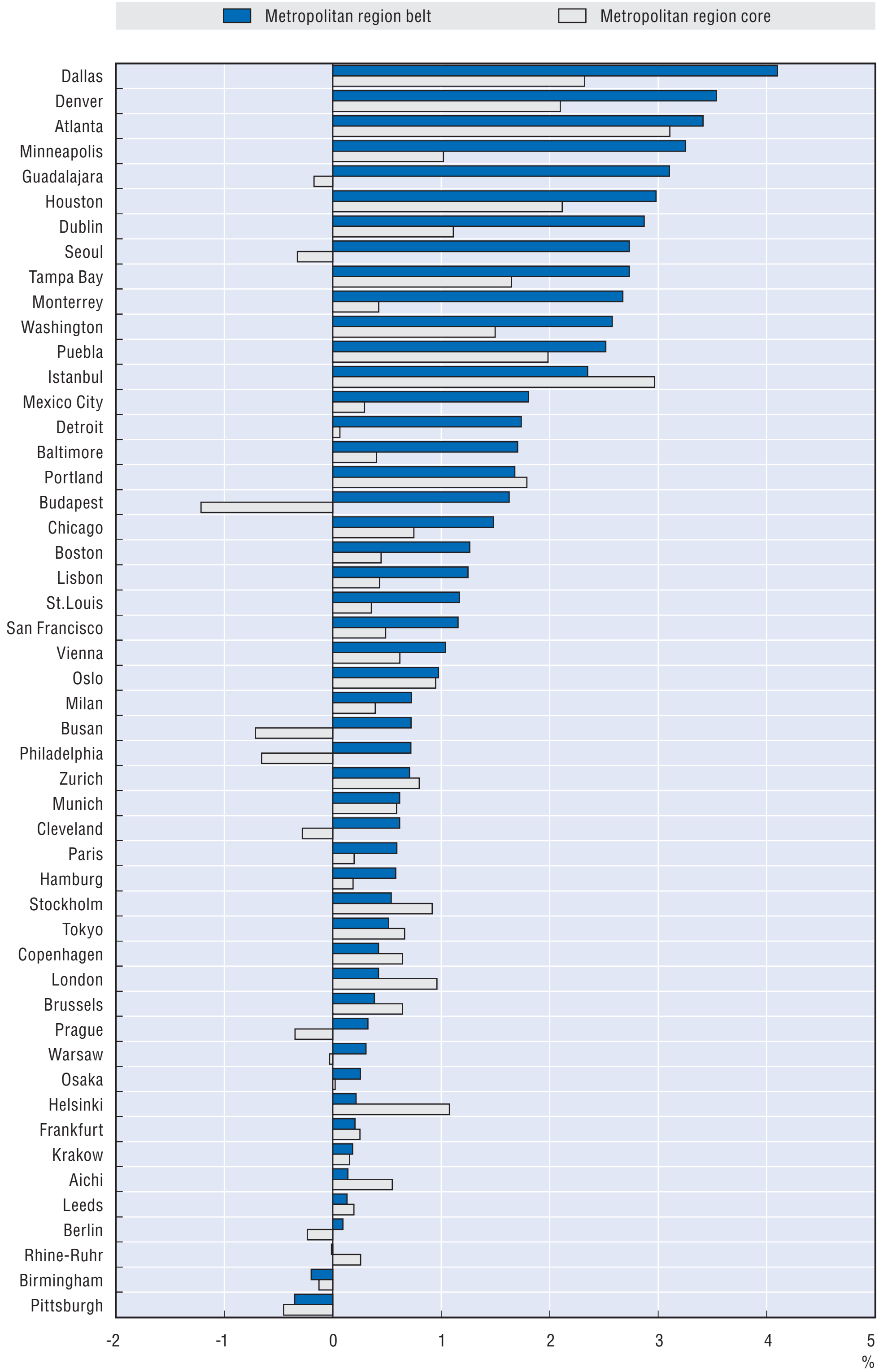
Figure 1.18. **Suburbanisation in OECD metropolitan regions**

Population growth in metropolitan region's core and belt compared (1995-2005)



Note: For US metropolitan regions, core-base counties were used to identify metropolitan statistical areas' cores.

Source: Own calculations based on data from the *OECD Metropolitan Regional Database.*

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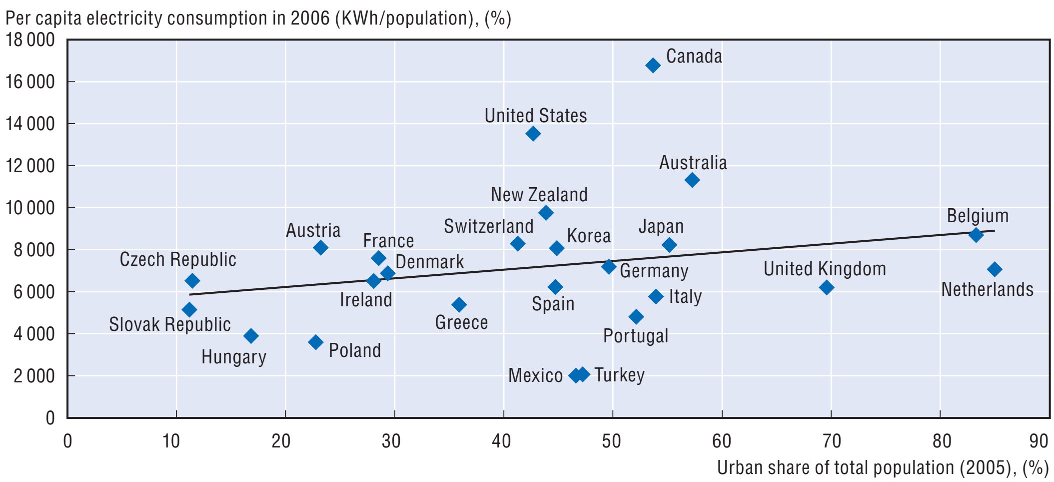
neighbourhoods have been improved through the 1997 *Kvarterloft* programme that promoted citizen and private-sector participation and the Urban Renewal Act of 1998. Both initiatives promoted quality of life in urban areas through densification, regeneration, and traffic and environmental planning (OECD, 2009c). In other cases, such as Tokyo, the process of gentrification coincided with a fall in housing prices in the urban core after the housing bubble burst in the early 1990s (An, 2008).

Increasing density could significantly reduce consumption of electricity in urban areas. Where increased urbanisation (estimated in terms of predominantly urban areas) has led not only to demographic and economic agglomeration, but also to higher levels of electricity demand, densification tends to decrease electricity demand. In general, the more urbanised a country becomes, the higher the demand for electricity (Figure 1.19). However, not all urban areas demand electricity in the same way and lifestyles in different cities can make a big difference. As density increases in urban areas, per capita electricity demand decreases (Figure 1.20). For instance, Japan's urban areas are around five times denser than Canada's, and the consumption of electricity per person in the former is around 40% that of the latter. If we take countries in the same geographical context with similar heating needs such as Denmark and Finland, the proportions are quite similar. Denmark's urban areas are denser than Finland's by a factor of four, and people there only consume around 40% of the electricity consumed by the Finns.

Not surprisingly, density emerges as a crucial element to reduce carbon emissions. Urbanisation greatly increases carbon emissions (Figure 1.21) Germany has almost twice the urban population of France, and German cities have twice the pollution levels as those in France. However, not all urban areas pollute equally. As density increases, CO_2 emissions from transport go down (Figure 1.22). Austria's urban areas are more than four times denser

Figure 1.19. **Urbanisation and electricity consumption**

Urban population shares and electricity consumption

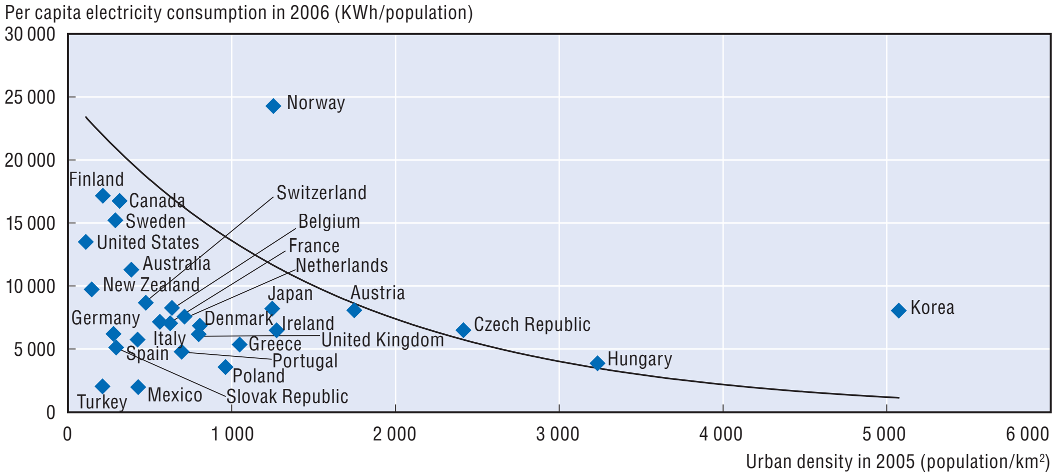


Notes: Urban shares were calculated on the basis of predominantly urban areas. Finland, Norway and Sweden were taken out of the sample since they were considered to be an outlier. Iceland and Luxemburg were not included in the sample as the *OECD Regional Database* identifies no predominantly urban areas in those countries.

Source: Own calculations based on data from the *OECD Regional Database* and IEA (2009), *Energy Balances in OECD Countries*, © OECD/IEA, Paris, p. 183.

StatLink http://dx.doi.org/10.1787/888932342221

Figure 1.20. **Urban density and electricity consumption**



Notes: Urban density is calculated on the basis of predominantly urban areas. Iceland and Luxemburg were not included in the sample as the *OECD Regional Database* identifies no predominantly urban regions in those countries.

Source: Own calculations based on data from the *OECD Regional Database* and IEA (2009), *Energy Balances in OECD Countries*, © OECD/IEA, Paris, p. 183.

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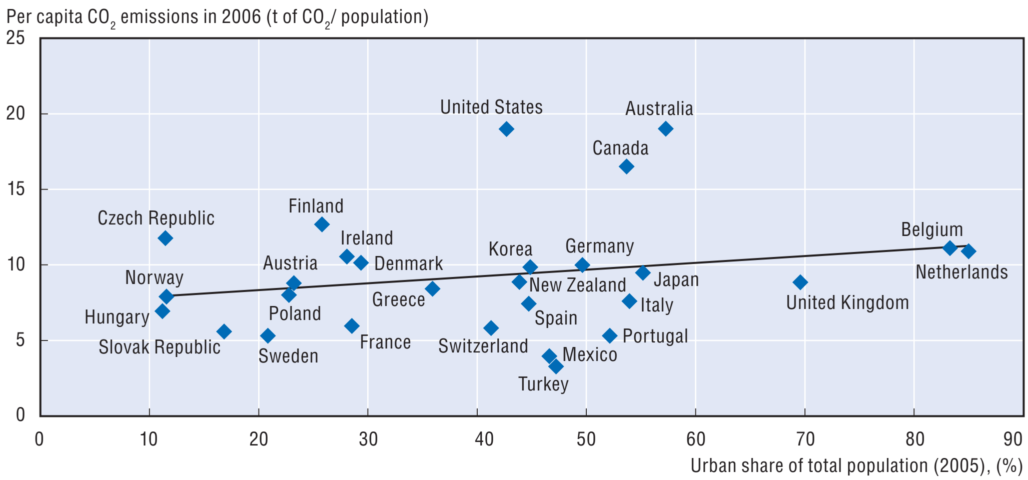
Figure 1.21. **Urbanisation and carbon emissions**

Urban population shares and CO_2 emissions



Notes: Urban shares were calculated on the basis of predominantly urban areas. Finland, Norway and Sweden were taken out of the sample as they were considered outliers. Iceland and Luxemburg were not included in the sample as the *OECD Regional Database* identifies no predominantly urban regions in those countries.

Source: Own calculations based on data from the *OECD Regional Database* and IEA (2008), *CO_2 Emissions from Fuel Combustion*, © OECD/IEA, Paris, pp. 37 and 49.

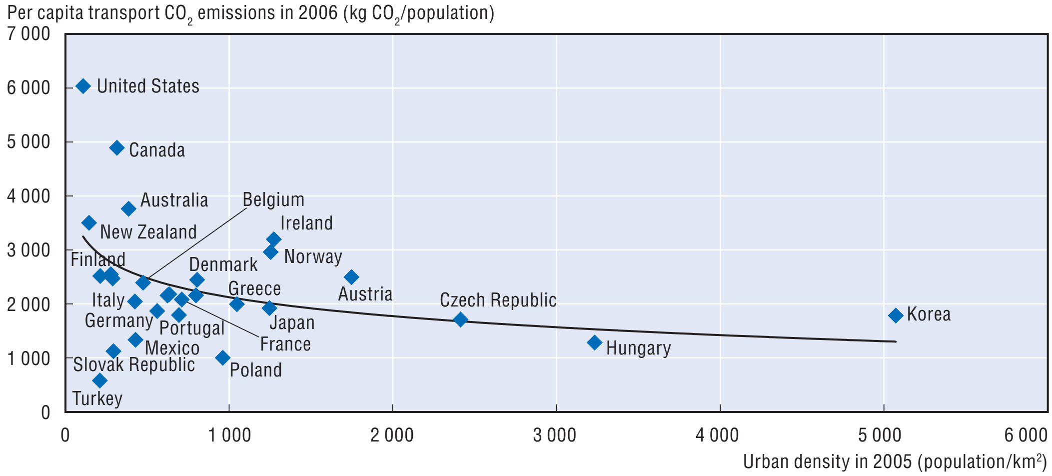
StatLink http://dx.doi.org/10.1787/888932342259

than Australia's, and generate only 60% of the amount of CO_2 emissions per capita that Australia's urban areas generate. Therefore, while urbanisation levels might bring about an expansion in carbon emissions, these are reduced with higher density (Figure 1.23).

Lifestyles, in particular the way in which people commute, are also crucial in the generation of CO_2. As urban areas become denser and rely more on public transport, carbon emissions are reduced. Not surprisingly, among OECD member countries, North American countries produce 50% more CO_2 emissions than the Europeans; while European countries

Figure 1.22. **Urban density and carbon emissions in transport**

Per capita carbon emissions produced by transport activities and urban density

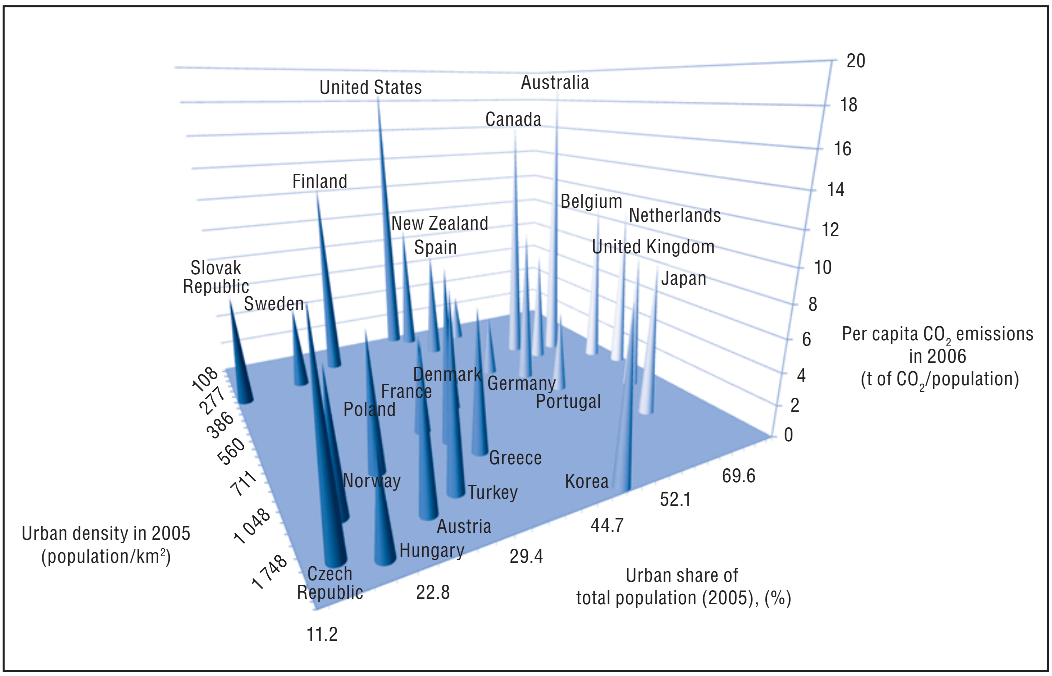


Notes: Urban density was calculated on the basis of predominantly urban areas. Iceland and Luxemburg were not included in the sample as the *OECD Regional Database* identifies no predominantly urban regions in those countries.

Source: Own calculations based on data from the *OECD Regional Database* and IEA (2008), *CO_2 Emissions from Fuel Combustion*, © OECD/IEA, Paris.

StatLink http://dx.doi.org/10.1787/888932342278

Figure 1.23. **Urbanisation, density and carbon emissions**



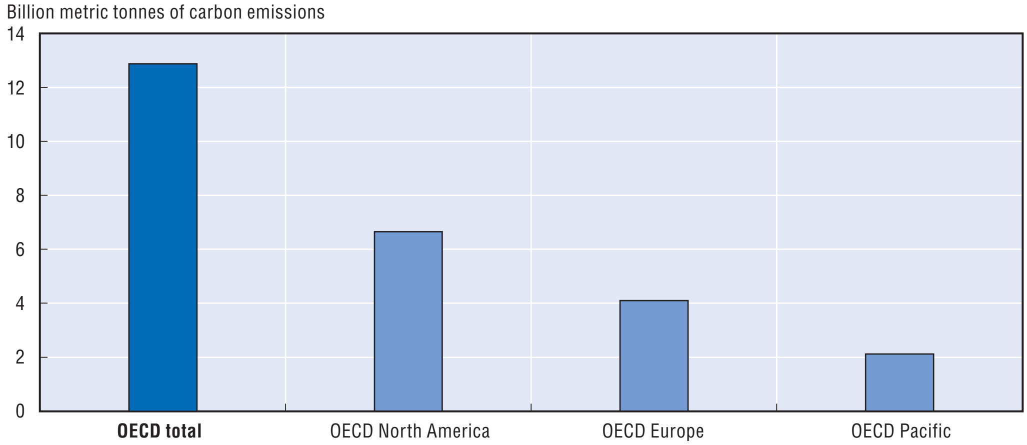
Notes: Urban density and urban share were calculated on the basis of predominantly urban areas. Iceland and Luxemburg were not included in the sample as the *OECD Regional Database* identifies no predominantly urban regions in those countries.

Source: Own calculations based on data from the *OECD Regional Database* and IEA (2008), *CO_2 Emissions from Fuel Combustion*, © OECD/IEA, Paris.

StatLink http://dx.doi.org/10.1787/888932342297

pollute twice as much as the Asian countries (Figure 1.24). Similarly, not all cities in the same country have the same lifestyles nor do they contribute to carbon emissions in the same way. Although the United States is the OECD country with the most flows of carbon emissions, internally cities like Los Angeles are noticeable for the concentration of CO_2 emissions (Figure 1.25). Even smaller cities like Houston produce much more CO_2 than New York – the largest city in the country. The Toronto region is one of the metropolitan regions in North America with the highest share of public transit (around 23% in 2006) only surpassed by New York. The public transit share of the Toronto region is comparable to those of many

Figure 1.24. **CO_2 emissions in the OECD**

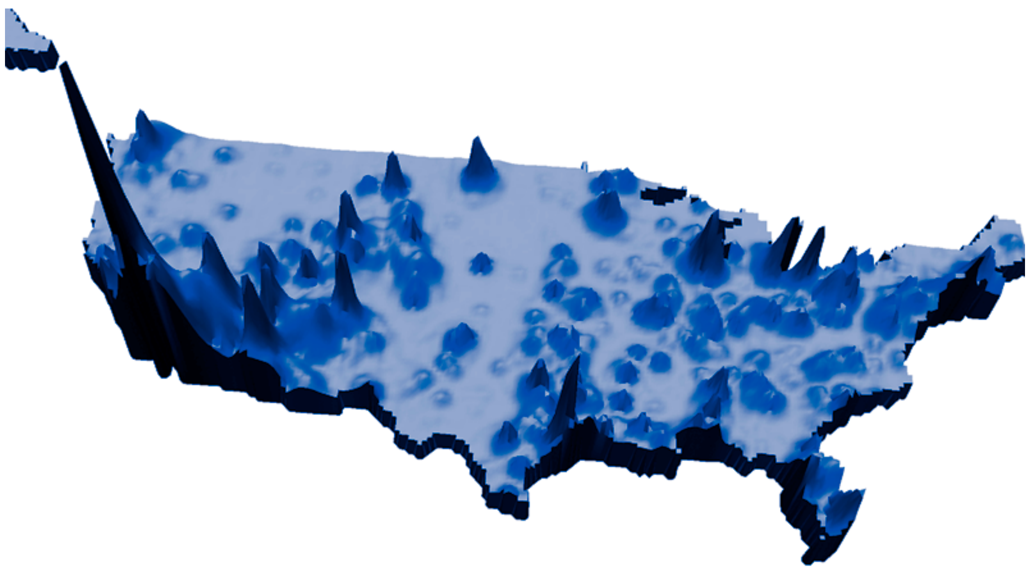


Source: IEA (2008), *2006 CO_2 Emissions at National Level*, *www.iea.org/Textbase/stats/index.asp*.

StatLink http://dx.doi.org/10.1787/888932342316

Figure 1.25. **Concentration of carbon emissions in the United States**

CO_2 emissions at county level (2002)



Source: Own calculations based on data from the Vulcan Project (2009) and the OECD typology of regions. The Vulcan Project is a NASA/DOE-funded effort under the North American Carbon Program (NACP) to quantify North American fossil fuel carbon dioxide (CO_2) emissions at space and time scales much finer than has been achieved in the past.

European metropolitan regions, such as London, Munich and Amsterdam, but falls well below public transit shares in Japanese cities like Tokyo. Despite the high use of public transit within the North American context, the Toronto region has one of the highest rates of car use among OECD metropolitan regions (71% in 2006) (OECD, 2009d). European metropolitan regions have been able to lower car use through a more extensive use of public transit, as well as development of other transportation modes including walking and cycling.

Notes

1. This refers to the population living in areas classified as urban according to the criteria used by each country (*UN Population Database*, 2009).
2. Throughout the document OECD definition of urban and rural refers to predominantly urban and predominantly rural regions. The former refers to regions in which the share of population living in rural local units is below 15%; the latter refers to regions in which the share of population living in rural local units is higher than 50%. In order to classify regions as predominantly urban or predominantly rural it is necessary to define local units within each region to their degree of rurality. A local unit is therefore rural if its density is lower than 150 inhabitants per km^2.
3. Intermediate regions are those with a share of population living in rural local units between 15% and 50%.
4. In the United States, for instance, the EPA reports that as much as 95% of the CO in typical cities comes from mobile sources. See *www.epa.gov/oms/invntory/overview/pollutants/carbonmon.htm*.
5. Energy Information Administration (EIA) website, "Energy Consumption by Sector". See *www.eia.doe.gov/emeu/aer/consump.html*.
6. This estimate was made by summing all emissions from coal, natural gas and petroleum extraction, distribution and conversion in the EPA's GHG emissions inventory.
7. The EPA GHG inventory includes CO_2, CH_4, N_2O, HFCs, PFCs and SF_6, but does not include gases whose radiative forcing properties are more uncertain, such as O_3. The IPCC estimates the radiative forcing of tropospheric O_3 at + 0.35 [–0.1, +0.3], which, at the high end would make tropospheric O_3 more important than CH_4 (IPCC, 2007). An increase in the importance of O_3 would not change the importance of energy systems; fossil fuel combustion accounts for about half of global NO_x emissions (Brasseur *et al.*, 2003), and NO_x is one of two precursors to tropospheric O_3 formation.
8. Bangkok, Barcelona, Cape Town, Denver, Geneva, London, Los Angeles, New York City, Prague and Toronto (Kennedy *et al.*, 2009).

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