Senate Department
for Urban Development
and the Environment

Berlin

Climate Protection

Climate-Neutral Berlin 2050

Results of a Feasibility Study

Contents

Greetings

Cities, home to more than 50 percent of the world's population, are both a driver of climate change and at the same time most vulnerable to its effects. Hence, more and more cities are searching for ways to provide a local contribution against climate change.

Berlin is one of them and wants to be a role model for other cities. In the past years and decades, the German capital has done a lot for the protection of the climate and has also achieved considerable results. However, more measures are necessary. This is the reason why the Senate of Berlin has set the goal of becoming a climate-neutral city by 2050 through a more renewable energy supply, "smart" infrastructures and, above all, with the help of a responsible urban society.

Berlin is to become a city in which climate protection includes dedicated resource and environmental protection, leading to better and healthier living conditions for Berliners.

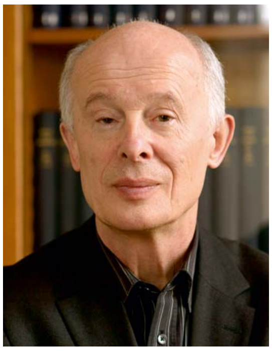
My administration commissioned a scientific consortium led by the Potsdam Institute for Climate Impact Research to investigate if and how the set goals can be reached.

With the participation of the wider expert community, the "Climate-Neutral Berlin 2050 Feasibility Study" has been completed and its main results are presented here.

It is my hope that this brochure can help to increase interest, understanding and commitment for climate protection in and for Berlin.

Michael Müller

Senator for Urban Development and the Environment



It depends on Berlin. If the German capital decides to reduce its emissions of greenhouse gases, it will make its necessary contribution to limiting the rise of the global mean temperature to no more than two degrees Celsius. This goal should help to prevent the worst risks of unlimited climate change – otherwise the world faces the threats of devastating weather extremes and rising sea levels. In Germany, we will be confronted with unprecedented heat waves in cities and floods like those recently seen on the Elbe and Danube rivers. Metropolitan cities like New York and Amsterdam are already making their climate protection contribution. But for Berlin it is about more.

Due to its unique experiment with the energy turnaround ("Energiewende"), people from around the world are observing Germany and – not for the first time in history – its capital city. Our country is, whether successful or not, a global model for the transition from a fossil-nuclear to an efficient-renewable economic strategy. But without the biggest city in Germany, such a change cannot credibly be achieved. And likewise, Berlin cannot become climate-neutral without the German "Energiewende" – in the winter, for instance, the city needs wind energy from Brandenburg.

As a result, Berlin cannot achieve the transition alone; it needs the reconstruction of the system with more power lines and storage capacities. But Berlin could become a pioneer – a pioneer of climate protection, of new technologies, of sustainable urban development. Then Berliners will have every reason to be proud.

Prof. Dr Hans Joachim Schellnhuber

Director of the Potsdam Institute for Climate Impact Research (PIK)

1. Introduction

In the face of advancing climate change and the specific concern for, as well as responsibility of big cities, the governing coalition of Berlin has decided to develop the necessary steps to become a climate-neutral city by 2050. With this decision, Berlin is reacting, like many other international metropolitan cities, not only to the dangers of climate change, but also to the expected increases in the price of fossil fuels. At the same time, the transformation process presents an opportunity for Berlin to become a highly modern city with a power supply based on renewable energy sources.
The Senate Department for Urban Development and the Environment commissioned the Potsdam Institute for Climate Impact Research (PIK) to lead a consortium of research institutes, as well as consultancy and planning offices (see last page of brochure) to appraise the feasibility of climate neutrality for Berlin and to identify ways of achieving this goal.
The feasibility study "Climate-Neutral Berlin 2050" was finished at the beginning of 2014. The next step will be for the Senate Department for Urban Development and the Environment to evaluate the study's results and recommendations. This brochure offers an overview of the key findings and conclusions of the feasibility study.

The Challenge of Climate Change: Cities Count

Global climate change is already happening, with noticeable consequences for many regions in the world. Over the past years, Berlin has also experienced heat waves and extreme weather events, which can be expected to intensify in the future.

To fight anthropogenic climate change, greenhouse gas emissions have to be reduced significantly. Cities in particular play a major role here. While they cover only 3 % of the total land surface of the earth, cities already hold more than 50 % of the world's population – an increasing trend. On a global scale, 70 % of all greenhouse gas emissions are caused by cities. Emissions from big cities exceed those of some states: the total annual CO_2 emissions of New York City (54 million tonnes) approximately correspond to those of Bangladesh,

What does Climate Neutrality Mean?

A city can be regarded as 'climate-neutral' if its greenhouse gas emissions can keep global warming below the dangerous threshold of 2°C – assuming a world population of 9 billion people by 2050, each endowed with the same per-capita emission rights of 2 metric tonnes of CO_2 equivalents (life-cycle based). Berlin's greenhouse gas emissions consist mainly of CO_2 (98 %). Given these conditions, Berlin could become climate-neutral if total urban carbon dioxide emissions can be limited to 4.4 million tonnes by 2050 - a reduction of about 85 % compared to 1990 levels. However, absorption capacities of greenhouse gases by the biosphere ('sinks'), as well as emissions embodied in products and infrastructure should also be considered. While current CO_2 statistics often ignore these, the target value of 4.4 million t CO_2 accounts for them.

London's (40m t) are almost equal to those of Ireland, and even Potsdam's emissions (around 860,000 t) match those of Sierra Leone in Africa. Berlin's CO_2 emissions (21.3m t in 2010) equal those of Croatia, Jordan or the Dominican Republic.

Berlin Acts

These figures alone show that if cities employ active climate policies, it will have a global impact. Many cities around the world have taken on this responsibility and have started to act. New York, for instance, aims to reduce its emissions by 30 % as outlined in its planning document "A Greener, Greater New York". Other cities are even more ambitious: by 2025 Amsterdam wants to reduce by 40 %, Rotterdam by 50 %, and Copenhagen even by 100 %.

And Berlin? Berlin has already achieved some success in climate policy. The energy-related CO_2 emissions have been reduced from almost 30m t in 1990 to 21.3m t in 2010 – a decline of 27 %. Since 2011, Berlin's climate politics have taken on a new challenge. The aim of becoming a climate-neutral city by 2050 presents an ambitious goal and simultaneously opens up long-term planning horizons for all the actors involved. With the city development concept (StEK) 2030, the Senate has defined its city development goals in a participative procedure. The topics environment and climate (including adaptation to climate change, see the city development plan [StEP] climate) play a crucial role here. Furthermore, Berlin aims to replace the energy saving law (Energiespargesetz) of 1990 with a law promoting the implementation of the energy turnaround and climate protection ("Gesetz zur Umsetzung der Energiewende und zur Förderung des Klimaschutzes in Berlin"). This new law will reflect the changing European and national energy- and climate-policy conditions as well as Berlin's particular circumstances and potentials. Berlin can become an active shaper and role model for the energy turnaround by helping to ensure the long-term security and affordability of the energy supply, exploiting technological opportunities and, last but not least, by reducing the city's CO_2 footprint to a sustainable level.

Goals and Approach of the Feasibility Study

The feasibility study addresses the following core questions: Can Berlin become climate-neutral by 2050? If so, how can this goal be achieved? What are the potential areas for significant reduction of CO_2 emissions in the city? Are the relevant technological and societal prerequisites available?

To answer these questions, an interdisciplinary approach was chosen. It can be characterised by four key elements (cf. Fig. 1):

Orientation Towards Fields of Action

The following five fields of action have been identified: energy supply, buildings and urban development, economy, private households/consumption, and traffic. The primary goal was to establish a feasible and politically relevant categorisation of Berlin's urban system, which then was analysed in an interdisciplinary manner.

Re-Worked Accounting Schemes

The sectors of the official energy and CO_2 accounting scheme of Berlin were re-calculated, based on the five fields of action defined by the feasibility study. The building sector was separated on the basis of a self-developed, complex buildings model of the city. The 'industry' and 'trade/services' sectors were merged in order to form the field of action 'economy'.

Stakeholder Involvement

The makers of the feasibility study kept up a constant and intensive dialogue with important experts and decision makers from all five fields of action. Their input was gathered at two major stakeholders' conferences, ten subject-specific workshops, and many individual interviews.

Thinking in Options

In order to assess the possible future development options of the energy system and the CO_2 emissions, two alternative scenarios per field of action were developed – again in close exchange with stakeholders. In each field, both scenarios reach the climate neutrality goal, but they do so through different measures. These scenarios were then combined into two alternative overall scenarios for Berlin.

This approach reflects the fact that it is impossible to impose climate neutrality onto the city. Instead, it has to emerge from a broad dialogue between stakeholders from science, politics, administration, the economy, and civil society in a 'co-production' effort. Hence, the study focuses on the basic aspects of feasibility of a climate-neutral Berlin – and ways to achieve it. Detailed plans for the coming years require further concept studies, which will be carried out subsequently, as has already been announced by the Senate Department.

Source references for this brochure can be found in the main text of the feasibility study.

Stakeholders' workshop, 30.10.2013, Plenary session

Opening of the first stakeholders' workshop (15.4.2013) by L. Stock, head of the Special Department for Climate Protection and Energy (right) and Dr F. Reusswig (project leader, left)

Prof. Dr B. Hirschl (deputy project leader) presents the scenarios (30.10.2013)

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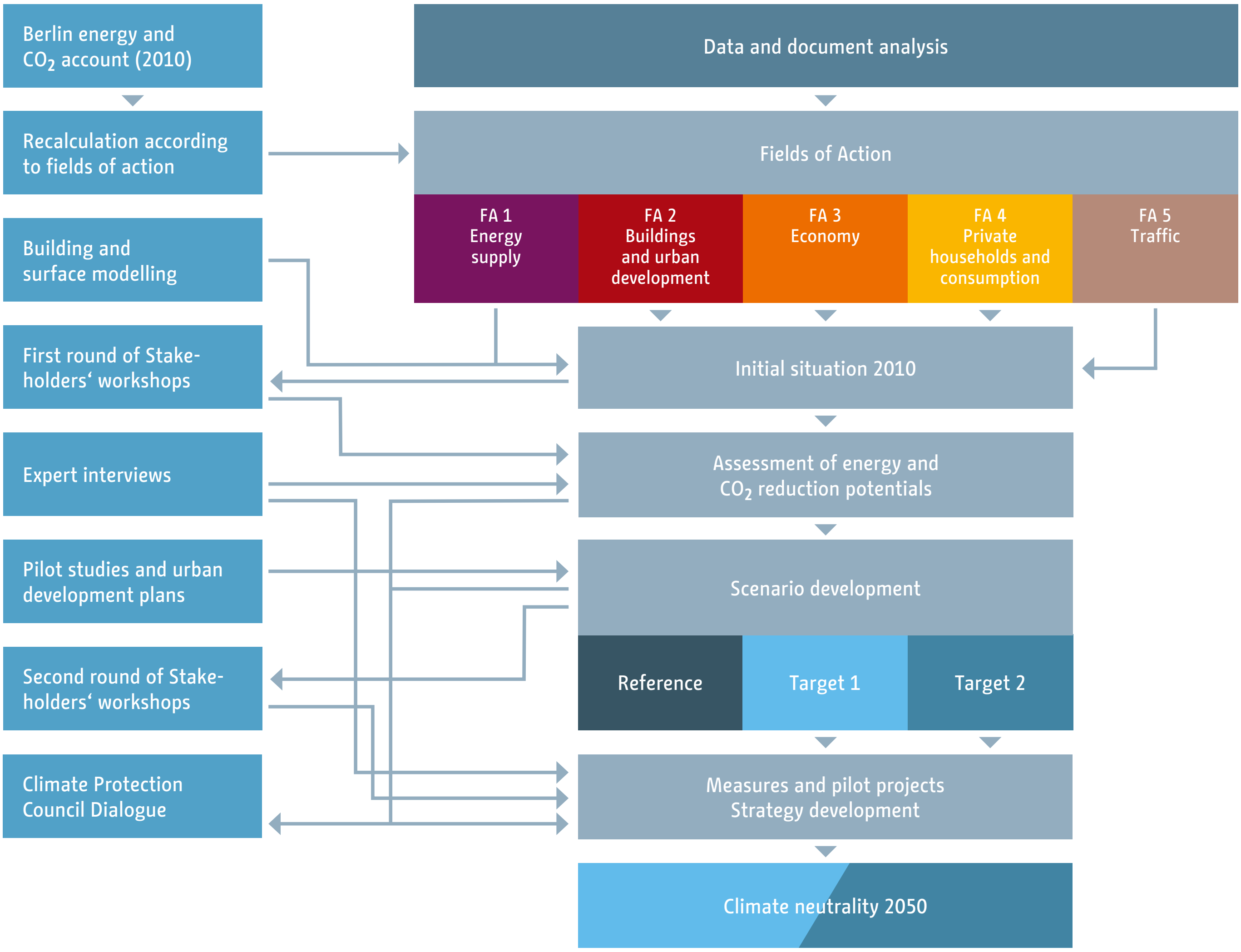
Procedure of the Feasibility Study



Panel discussion at the stakeholders' workshop (30.10.2013) with Prof. Dr M. Schreurs (Berlin Free University), S. Rehberg (BBU), Prof. Dr J. Twele (Reiner Lemoine Institute, Berlin) (from left)

Panel member Dr P. Graichen (Agora Energiewende) (30.10.2013) (left)

Prof. Dr C. Becker (standing) at the experts' workshop 'Buildings and urban development' on 15.4.2013

2. Initial Situation and Reduction Potentials

Berlin, capital city of the Federal Republic of Germany, is, with 3.375 million inhabitants, its largest city. The state of Berlin covers 887.7 km² and the population density is 3,875 persons per km², the second largest of Germany's major cities after Munich. Berlin lies slightly below the German city average with its gross domestic product of around 30,000 euros per capita. In the last several years, Berlin has become more and more attractive, which can be seen by its population increase as well as its rising economic output.

In spite of its recent growth, Berlin has managed to reduce its CO_2 emissions (according to consumption-based accounting) from 29.3m t in 1990 to 21.3m t in 2010 – a decrease of 27 % (cf. Fig. 2). However, the dynamics of the emission reduction has experienced a noticeable drop, from -1.7 % per year (1990-2005) to -0.4 % per year (2006-2010). The recommendations of the feasibility study (compare section 4) aim to reduce Berlin's annual emissions to 4.4m t by 2050 – this corresponds to an average annual reduction of 2 %.

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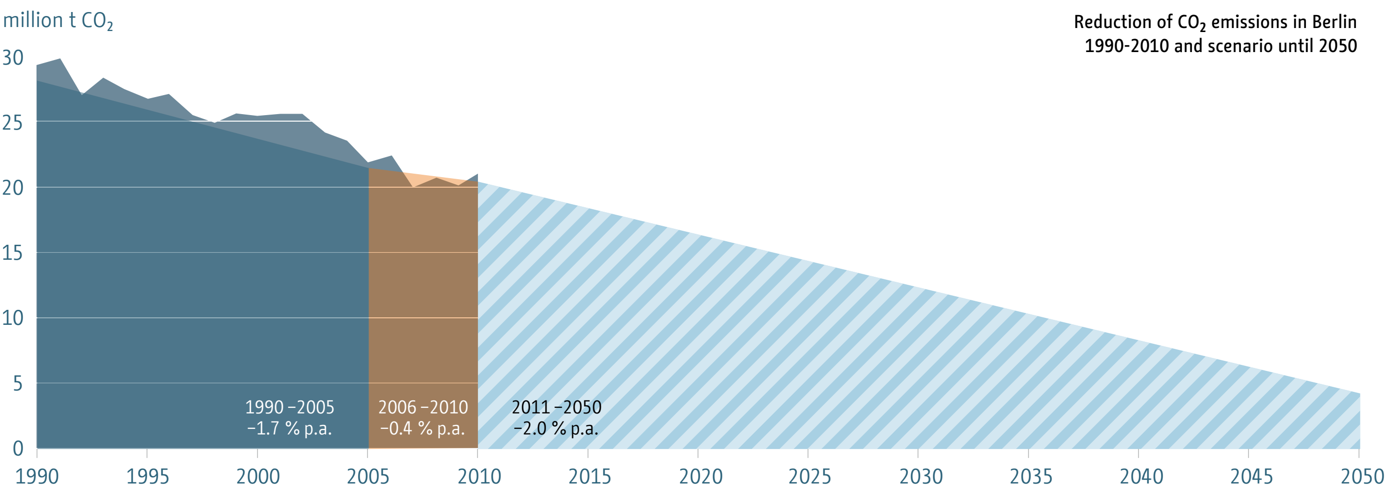
Reduction of CO_2 emissions in Berlin 1990-2010 and scenario until 2050



2010 was chosen as the base year of the feasibility study due to the availability of energy and CO_2 accounts taken from the Statistical Bureau of Berlin-Brandenburg. To begin with, a recalculation of the statistical data was carried out, in order to identify the contribution of the various fields of action of the study. As a result, the CO_2 emissions of the four energy-consuming sectors have been calculated (cf. Fig. 3).

The numbers reveal that CO_2 reduction strategies for Berlin's housing sector are very important – it accounts for almost half of the city's emissions. Nevertheless, the traffic and economy fields of action also play an important role. Private households account for about 9 % of Berlin's energy-related emissions – this does not include emissions for the production of goods abroad, consumed in Berlin. In the following, the reduction potential of the five fields of action will be looked at in more detail.

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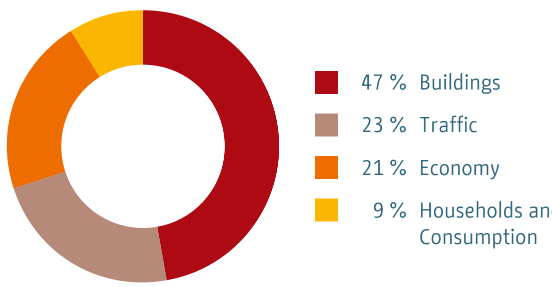
CO_2 emissions in Berlin by fields of action 2010 (our calculations)



Energy Supply

Berlin has not only managed to reduce its CO_2 emissions, but also its primary energy consumption: from 356,208 terajoule (TJ) in 1990 to 306,372 TJ in 2010. Of this, a significant percentage is still generated from fossil fuels like coal, oil and natural gas (cf. Fig. 4). In 2010, only 3 % of the primary energy consumption (9.8 TJ) and around 1 % of the supplied final energy was derived from renewable energy sources, mainly from biomass, but also from solar energy and one wind turbine. However, the renewable energy sector has been very dynamic in recent years (Fig. 5), a development that needs acceleration in order to reach the climate neutrality goal.

The CO_2 reduction potential of the Berlin energy supply lies in various areas:

- Emission-intensive energy carriers such as coal and oil need to be rapidly removed from the conversion sector and heat supply.
- Natural gas as a less emission-intensive energy carrier can fill the resulting gaps to a large extent, but it must also be made less CO_2-intensive through increasing the share of renewable gas by feeding-in renewable gas from excess renewable electricity or from biological origins.
- The share of combined heat and power generation (CHP) can still be increased, while pure electricity production without heat extraction should be reduced. Grid-bound thermal power (e.g. district heating) continues to be important for the city. Decentralised sub-networks, however, will have to complement it more and more. The increasing 'intelligence' of the energy system as a whole, including its networks, makes an ever more efficient interconnection of the various energy markets, from consumers to producers ('smart city'), possible.
- Solar energy offers the most promising potential of all the renewable portfolio, fitting well with the urban load curve and the urban distribution network. Berlin's 320,000 residential houses – not only the roofs, but also the facades – offer a space-efficient basis for a massive roll-out of photovoltaics as well as solar heating systems. Studies find that Berlin can generate 300 times the amount of solar energy it produced in 2010.
- With biomass, Berlin needs to utilise its own potential systematically, but sustainably. Biomass imports are possible, but they must satisfy strict sustainability criteria. Due to the global scarcity of biomass, imports can hardly deliver a significant contribution to Berlin's energy demand.

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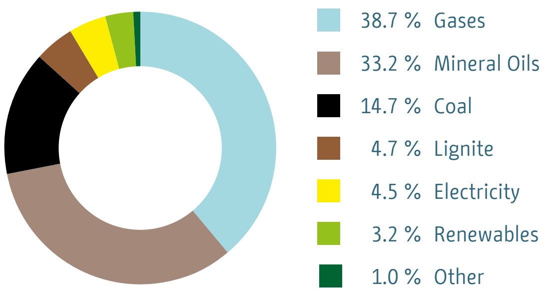
Composition of Berlin's primary energy consumption by energy carriers in 2010



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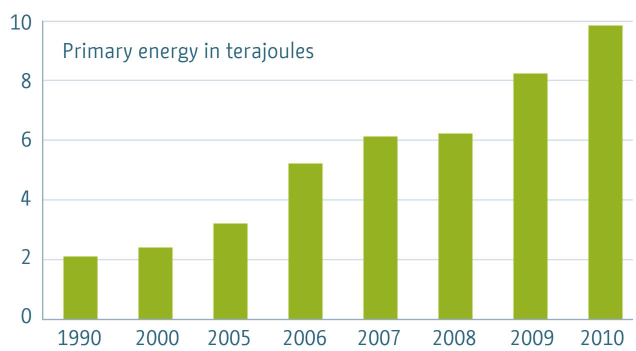
Increase of renewable energy (primary energy consumption) in Berlin 2000-2010



Buildings and Urban Development

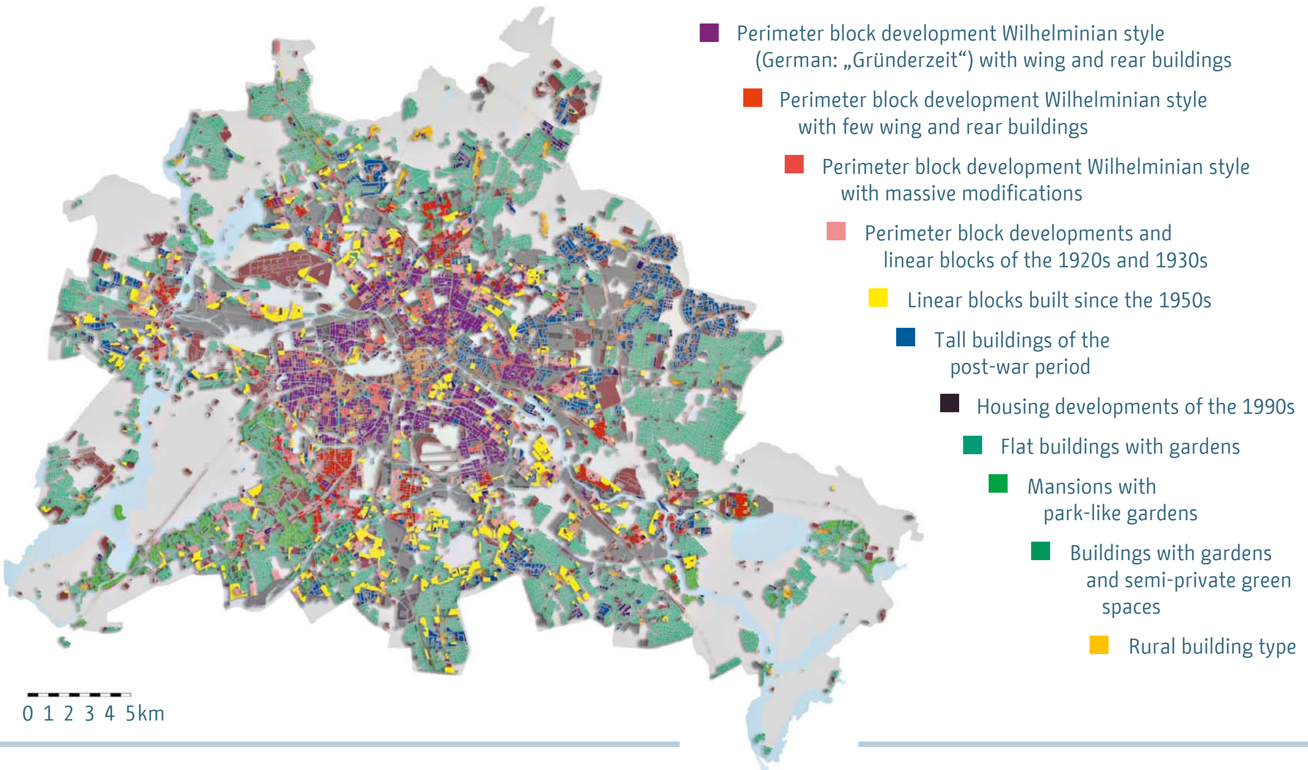
Berlin's high share of green and open spaces (about 44 % of the urban area) is an important asset of the city – not only for the quality of life, but also for adapting to to rising urban temperatures due to climate change. In addition, Berlin commands an architecturally significant heritage with vast amounts of monuments and Wilhelminian-style houses. In 2011, 320,000 residential buildings were counted, containing 1.9 million residential units. Of these, 86 % are rented apartments, and only 14 % are freehold households. Almost 90 % of Berlin's dwellings are in multifamily houses, while single- or two-family houses account for only 10 %. 9.6 % of the buildings are protected as listed monuments. Fig. 6 shows the various urban structure types predominantly used for housing purposes in Berlin.

There are different ways to reduce the CO_2 emissions of Berlin's building stock:

- Due to population growth (by 2050, Berlin expects about 250,000 additional inhabitants) there will be substantial construction activities. This increase in housing demand can be satisfied in a climate-friendly way through redensification and high energetic standards for new buildings (e.g. passive or PlusEnergy standard houses).
- In Berlin, around 1 % of the housing stock gets energetically renovated (facade, basement, roof, windows etc.) per year. This renovation rate must be increased, starting by energetically improving the unrenovated housing stock and continuing up to 2050 by further improving the energy efficiency of houses that have been renovated at least once in the past already.
- Long-distance heating currently covers around 30 % of the building heat supply. Areas of sufficient urban density offer a reduction potential by replacing coal- and oil-based heating systems with grid-bound CHP-generated heating. In less dense areas it makes sense to develop local heating network systems. Overall, the share of renewable energies supplying heat needs to increase, while the heat demand of buildings needs to decrease (by better insulation and feedback control systems, for instance).

6

Distribution of urban structure types across the Berlin city area



A new buildings model was developed by the consortium of the feasibility study in order to estimate the specific share of total emissions held by Berlin's building sector (residential and non-residential buildings), as well as to identify potentials for reduction. It is based on building-specific data taken from the automated cadastral map (Automatisierte Liegenschaftskarte), a 3-D model of building envelopes, and block-specific data from the 2011 census relating to the buildings' energy supply. Based on this model, the feasibility study calculates that heating demand could be lowered by 78 % from 150 PJ (2010) to 33 PJ in 2050. Section 3 (scenarios) outlines to what degree and by which means this reduction potential can be exploited under realistic circumstances.

Economy

Currently, in Berlin's economic structure, the 'commerce, trade and services' (CTS) sector, with about 90 % of added value and employment, clearly dominates the industry sector. Tourism and the creative industries are among the branches with growing importance (cf. Fig. 7). The final energy consumption of Berlin's economy (around 40,000 TJ in 2010, excluding industrial and commercial buildings) is split between the CTS sector with a share of 80 %, and industry with 20 %. There are many energy-saving potentials for end energy demand in the Berlin economy:

- An improved use of information and communication technology (ICT) offers saving potentials for the CTS sector of 40-80 %, and for the manufacturing industries of 5-40 %.
- In the area of mechanical energy, there is a reduction potential in the CTS sector of 30-50 %, and in manufacturing 10-50 %.
- Process energy can be reduced in the CTS sector by 0-40 %, and in manufacturing by 20-40 %.

Overall, a total of 20-50 % of final energy demand in Berlin's economy can be eliminated by 2050. In conjunction with the increased generation and use of renewable energies, CO_2 saving potential could reach up to 90 %.

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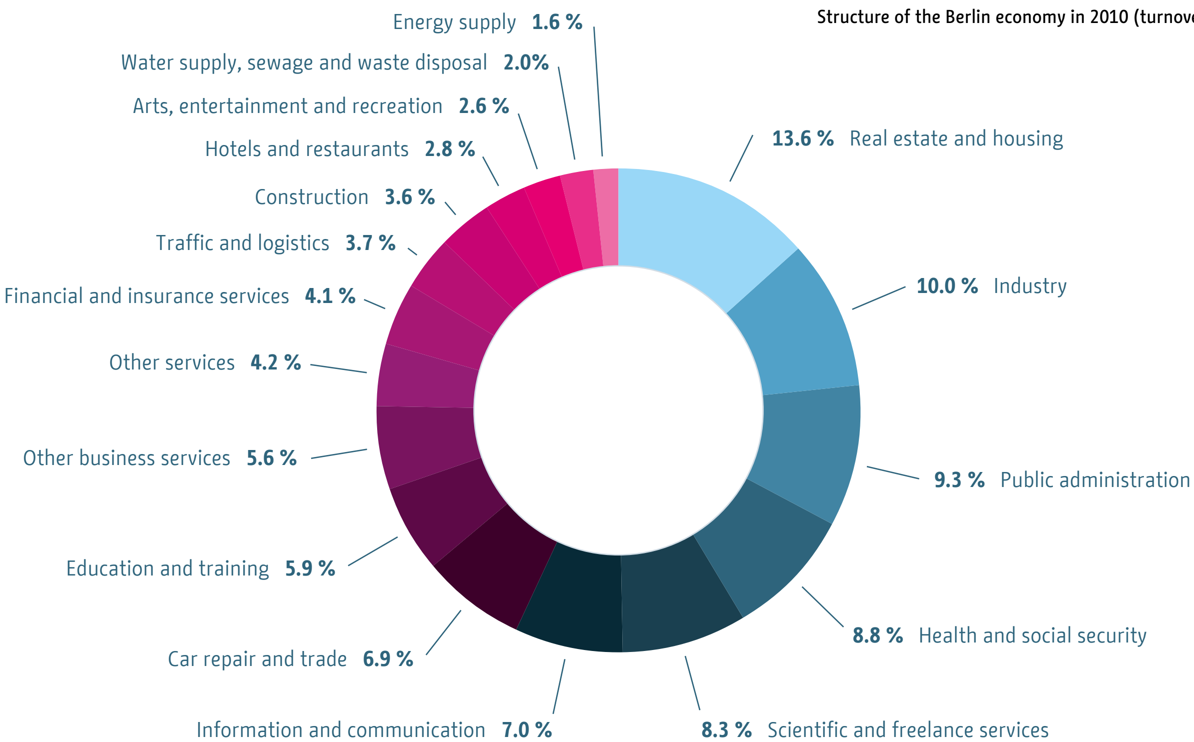
Structure of the Berlin economy in 2010 (turnover shares)



Private Households and Consumption

In 2010, there were about 2 million private households, of which 54 % were single-person households. This is a peak value compared to other German and international cities. The ongoing trend towards smaller household sizes has an increasing effect on energy consumption because, among other things, each small household requires its own basic set of equipment.

In the year 2010, Berlin's households consumed 12,221 TJ (about 3.4 billion kWh) of electricity and 69 TJ (around 19.2 million kWh) of natural gas for cooking purposes. Heating and hot water generation were accounted for in the 'Buildings' field of action.

The most important strategies for reducing the energy consumption of private households focus on household size, supply with electric equipment, equipment efficiency, and concrete user behaviour.

The reduction potential of the household size factor can be positively influenced if the ongoing trend to more living space per capita can be stopped or at least slowed down by new forms of living together or through apartment exchange initiatives. In addition, the current portfolio of household equipment displays large proportions of older, less efficient appliances, which should be replaced by new, more efficient equipment to induce a significant saving potential (cf. Fig. 8).

In addition, energy saving behaviour on the part of private households can reduce overall consumption, for example by the use of connector strips that avoid stand-by losses of inactive machines. Furthermore, consumers can relieve adverse climate effects by buying more regional and seasonal products, by taking eco labels (e.g. Blauer Engel, bio labels) into consideration, by throwing away less food, or by reducing meat consumption. These actions would not only benefit the environment, but also promote public health.

The feasibility study assumes that all these measures taken together–equipment exchanges plus behaviour adaptation–can sum up to a total saving potential of 50 % of final energy consumption (6,110 TJ) by 2050. A crucial relevant aspect is the development of the general electricity factor (Generalfaktor Strom), which describes the average emissions of electricity generation in Germany: on the basis of expected long-term improvements of the general electricity factor, CO_2 emission savings will be 75-93 % compared to 2010–depending on the energy mix of the German electricity supply.

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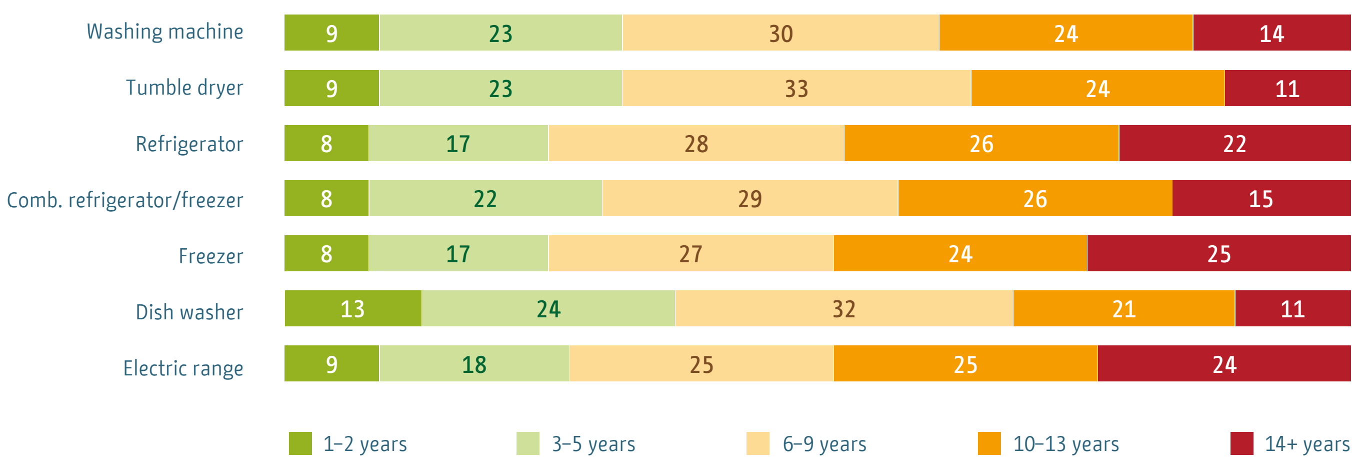
Age structure of large electric devices in private households



Traffic

The traffic sector was responsible for roughly 23 % of all emissions in Berlin in 2010, with around 4.8 million tonnes of CO_2. Recently, these traffic-caused CO_2 emissions have been decreasing slightly, after a significant rise in the 1990s, but they have had a constant share of total emissions since 2000. Road traffic dominates the emissions by far (Fig. 9).

In 2010, Berlin counted around 1.29 million registered vehicles, of which 1.1 million were cars that ran mainly on petrol or diesel. Currently, alternative motors do not play a significant role, but they have developed dynamically in the past few years. Since 2010, the number of vehicles with liquid gas motors has increased from around 9,000 to 14,000 in 2013, while the number of hybrid vehicles doubled between 2009 and 2013 to approximately 4,300 in Berlin. The number of electric vehicles has increased manifold during that time, so that Berlin can be seen as a nationwide showcase of electric mobility. In addition, both cycling and walking have experienced a positive development. In Berlin, car ownership is less common than in many other places in Germany. Younger generations in particular need mobility, but can survive without owning a car. Another asset of Berlin is its very good system of public transport – even by international standards.

The various reduction potentials for Berlin's traffic relate to the ongoing trends–the three strategies 'avoid, divert, improve' indicate the direction.

- A significant amount of traffic can be successfully avoided if future urban development is consequently oriented towards the Leitbild of a 'city of short distances'. Berlin's polycentric city structure is a very good starting point for this. Furthermore, newly developed urban logistics concepts offer ways of avoiding the transportation of goods.
- In the future, traffic can further be diverted from motorised individual traffic to less emitting, or even non-emitting, environmentally friendly means of transportation (local public transport, cycling and walking). Due to Berlin's urban and population structures, the sharing systems and interlinked transportation modes required for this are economically interesting as well.
- The energy efficiency of motorised propulsion systems must be further improved. The ongoing de-carbonisation of traffic can be further advanced by utilising hydrogen, electric traction current, and methanol (for air traffic), as long as renewable energies are used in the production of these power sources. This latter measure would significantly lower the CO_2 impact of flying.

Overall, by 2050 the transportation sector has a theoretical saving potential of up to 60 % for final energy consumption and up to 90 % for CO_2 emissions.

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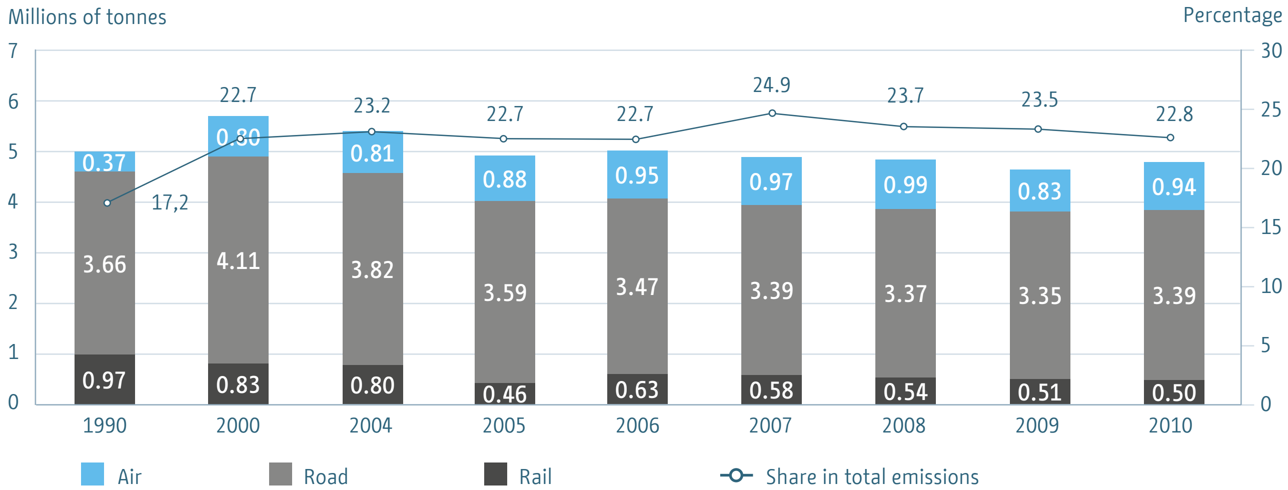
Development of the CO_2 emissions of the Berlin traffic sector 1990-2010



3. Scenarios for a Climate-Neutral Berlin: Thinking in Options

In order to obtain a view of Berlin's future in 2050, diverse scenarios were developed and described qualitatively and quantitatively. Scenarios are not forecasts, but conditional futures, i.e. they reveal how a system can develop given certain conditions and what relevant alternative outcomes may occur. In this case, the question was to find out what needs to be changed in order to achieve climate neutrality by 2050 and how this goal concretely relates to the defined fields of action. The development of the scenarios used in the Feasibility Study is based on the analysis of Berlin's initial situation, on literature-based appraisals of technical reduction potentials of the relevant key factors in each field of action, and on many interviews with experts and several stakeholders' workshops.

The Reference Scenario

A reference scenario usually serves the purpose of providing a contrast to the target scenarios; this helps to estimate the effects of additional climate protection measures. This reference commonly corresponds to a 'business-as-usual' (BAU)-scenario. In contrast to this, the feasibility study reference scenario already assumes that additional measures for climate protection will be taken in Berlin. More precisely, the reference scenario assumes that beside the steps already implemented today, all the plans and projects of city development already decided on today (e.g. StEP Verkehr, StEP Klima) will be implemented consistently.

The Two Target Scenarios: Alternative Ways to Climate Neutrality

While some important parameters were not varied between the two scenarios because they were external to the system (such as energy prices, economic growth, and population), various parameters internal to the system were identified and contrastively opposed to generate the two target scenarios. These include:

- values, attitudes, and consumption patterns;
- technological progress and diffusion;
- the degree of centrality/de-centrality of the economy, infrastructure, and urban development;
- the weighting of the contribution made by energy carrier substitution and energy savings.

The variation of key parameters was carried out with the requirement of achieving a significant total reduction of CO_2 emissions as a result: plausible degrees of variance and combinations of the key factors in the fields of action were set in such a way as to achieve, wherever possible, a total reduction of 85 %. This goal was achieved in two ways, leading to two different scenarios for Berlin. The summary table on the following page compares the specific characteristics of some of the key elements of the scenarios.

The two target scenarios can be described with their key attributes as 'the centralised, efficient city' (target scenario 1), and the 'decentralised, cross-linked city' (target scenario 2). The 'centrality versus decentrality' aspect proved appropriate for characterising the resulting systems, especially for the energy supply, urban development, economy and traffic fields of action. As far as private households, urban development, and traffic are concerned, the varying weighting of efficiency and behaviour (sufficiency) and the degree of cross-linkage also played an important role. As a result, both scenarios provide wide space for action, since for many key factors the future situation might be located 'in the middle'.

The results show that both target scenarios will achieve the goal of climate neutrality for Berlin, but the reference scenario will not, although it reduces Berlin's CO_2 emissions of 1990 by two thirds and those of 2010 by half (cf. Fig. 10).

Target Scenario 1
The Centralised, Efficient City

Energy
- More CHP for electricity and district heating
- Strong PV roll-out
- Power-to-heat: 20 % central; less decentral

Urban Development & Buildings
- Moderate redensification
- Focus: inner city
- Open space maintenance
- Moderate refurbishment
- Constant living space per capita

Economy
- Big corporations dominate
- Strong individual companies

Private Households
- Focus on technological efficiency (rebound)
- Smaller household sizes
- Eco-consumption mainly in leading social milieus

Traffic
- Private car still dominant, but no fossil fuels
- Slight increase in multi-modality (e.g. sharing concepts)
- Air travel: fossil share higher, more restrictions

Target Scenario 2
The Decentralised, Cross-Linked City

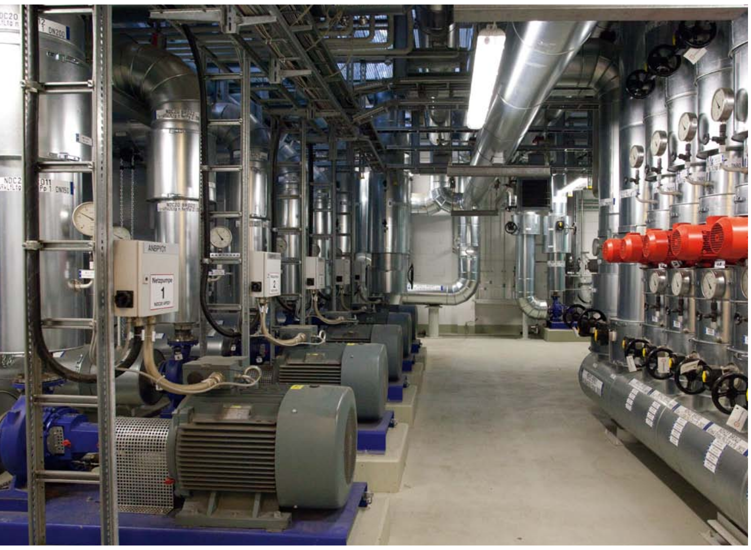
Energy
- Less CHP for electricity and district heating, more decentralised local heat networks
- Massive PV roll-out
- Power-to-heat: 20 % central; more decentral

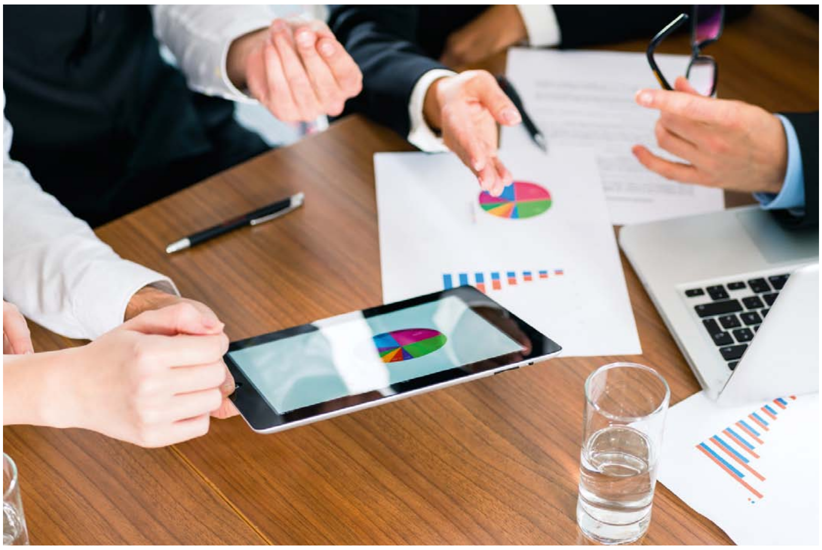
Urban Development & Buildings
- High redensification
- Focus: city-wide
- Open space quality campaign
- Thorough refurbishment
- Slightly less living space per capita

Economy
- SMEs dominate
- Strong corporate networks

Private Households
- Technological and behavioural efficiency (no rebound)
- Larger household sizes
- Eco-consumption widespread in society

Traffic
- Private car less important, no fossil fuels
- Strong increase in multi-modality (sharing concepts very common)
- Air travel: fossil share lower, less restrictions





Many facets of Berlin today will become more important in the future, e.g. Combined-Heat-and-Power generation, energy efficiency networks in trade and industry, multi-modality in the traffic sector and renewable energy systems.

Berlin can thus achieve its climate neutrality goal in at least two ways. The transformation of the energy system plays a central role. Combined heat and power generation, which is already important today, will become even more crucial. Grid-bound heating will continue to play an important role in Berlin; the density of attached households will have to increase in order to prevent the already declining heating turnover (10-30 % depending on the scenario) from falling any further. Power-to-heat will become significant in the grid-bound heating market with an electricity consumption of 7 to 9 PJ/a, while at the same time a higher level of heat storage will be required.

As far as renewable energies are concerned, solar energy, especially photovoltaics, will play a key role in Berlin's future. It can be installed on the roofs and facades of buildings, the city distribution network can take on large

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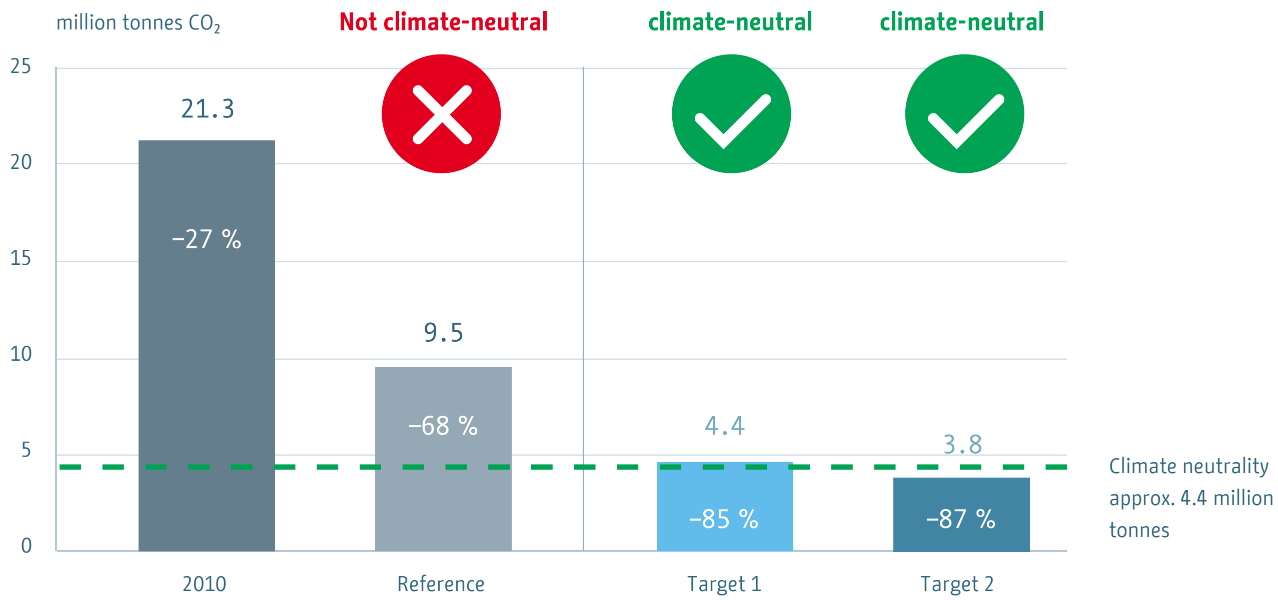
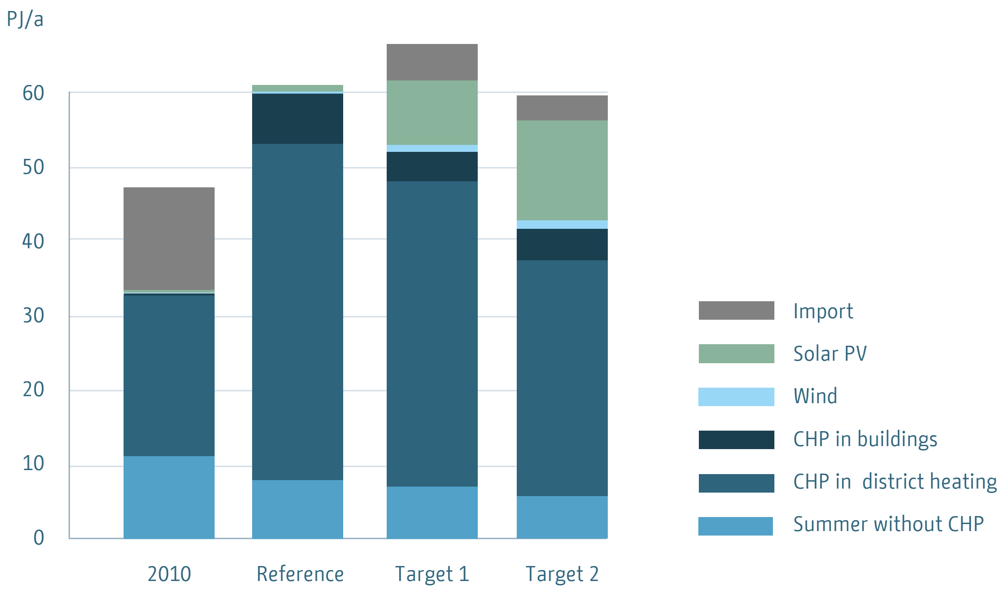
CO_2 emissions from final energy consumption according to consumption-based accounting in 2010, in the reference scenario and in the two target scenarios (reduction in % compared to 1990).



amounts of solar electricity and the production costs are already significantly lower than electricity prices for private households and business enterprises are today. In both target scenarios, photovoltaics is able to cover between 9 and 13 PJ/a, corresponding to the current yearly electricity demand of between 800,000 and 1.2 million two-person households (cf. Fig. 11). This rising electricity demand in Berlin relates to the assumption that this energy form will be used more and more for transportation purposes – either for more private cars or more shared cars, depending on the scenario. In any case, by 2050 Berlin's vehicle stock will produce significantly less emissions and make less noise.

11

Electricity supply, Source: Our illustration

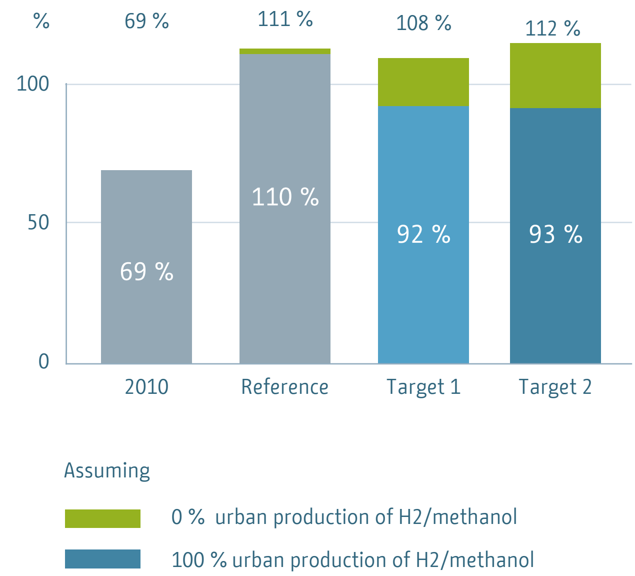


City–Hinterland Relationships: Berlin as a Potential Exporter of Electricity

Berlin will increase its total electricity production – and simultaneously decrease its import needs. This will change the image of the big city as an 'energy sink' significantly: in terms of energy accounting, Berlin can practically even out its electricity balance. If the new, system-relevant big consumers such as those from the power-to-gas/methanol technology sector (up to 9 PJ/a) were located outside Berlin, Berlin could even export an appreciable amount of electricity. However, the scenarios assume that it makes more economical and infrastructural sense to locate this production predominantly in Berlin. From a seasonal perspective, Berlin will export most of its electricity in the summer, when it produces large amounts of solar energy. In the winter, the city will need wind energy – from Brandenburg, for example – to complement its own CHP-generated power. Thus, the result pleads the case for a new division of tasks with Berlin's periphery: a high solar and cogeneration-based production of electricity will help reduce the area required for energy generation – in Berlin, but also in Brandenburg, where, at least from a Berlin perspective, lignite power plants might no longer be necessary.

12

Degree of power self-sufficiency
Source: Our illustration



Overall, the energy source mix will move towards natural gas, which will cover around three quarters of total primary energy consumption in 2050. As far as final energy consumption is concerned, nearly one third will be used for district heating and one third as electricity. This considerable increase in the energy consumption share of district heating is a relative one, since total heat demand will drop significantly by 2050. For electricity, the feasibility study assumes an increase in demand due to numerous new electricity-powered applications. However, this rise can be covered by local production. The proportion of renewable energies will not be entirely in line with the goals of the German Federal Government. However, with a share of up to 40 % in district heating, up to around 50 % in electricity production, and up to 60 % in the heating of buildings, the largest German city will achieve a respectable result. It is in Berlin's best interest that the expansion goals for renewable energies be reached at the federal level.

4. Strategies and Measures For a Climate-Neutral Berlin

Climate neutrality is still a thing of the distant future. However, this goal must be focused on today already and taken as a guide for action in order not to miss the target in the end. For this reason, the feasibility study attempts to offer guidelines for how to get on the path towards climate neutrality beginning today. For these guidelines, projects and measures were sought that are equally applicable in both scenarios, so as to maintain the freedom to choose the appropriate path for Berlin for a little longer. Beside the criterion of CO_2 saving (effectiveness), the public visibility of these proposed measures played an important role. Projects with high visibility were described as key projects in the study. They will be complemented by a number of further measures, so that taken together the goal of climate neutrality can be achieved.

Overall, it is important that climate neutrality should be seen as a priority in Berlin's politics and society. Further, the state of Berlin needs to support the federal climate protection goals and create the right conditions for its own measures. The feasibility study suggests new and complementing mechanisms for financing: an energy efficiency fund, a rent deposit fund, and crowdfunding for concrete projects.

Energy Supply

The measures suggested for the 'Energy supply' field of action aim for central reduction potentials: on the one hand, the reduction of energy consumption by increasing energy efficiency, on the other the increased use of forms of energy production which are low in emissions.

- A central key project is the 'Solar Capital Berlin' master plan. This plan combines a number of measures to reduce constraints, bundle local competencies, and provide specific 'solar-urban incentives'.
- Another key project aims to develop a Berlin water purification plant so that it uses and stores electricity intelligently.
- Berlin needs an intelligent network of different technologies and infrastructures and the installation of innovative production components (power-to-heat, virtual power plants, heat storage).
- Building Berlin's climate-neutral energy system requires the knowledge, the commitment and also the capital of as many people as possible. The feasibility study recommends the stronger economical and procedural inclusion of Berlin's citizens.

Buildings and Urban Development

In 2010, the building sector contributed 47 % of Berlin's CO_2 emissions. It therefore bears a strong responsibility in achieving the goal of climate neutrality. A number of important determining factors must be considered:

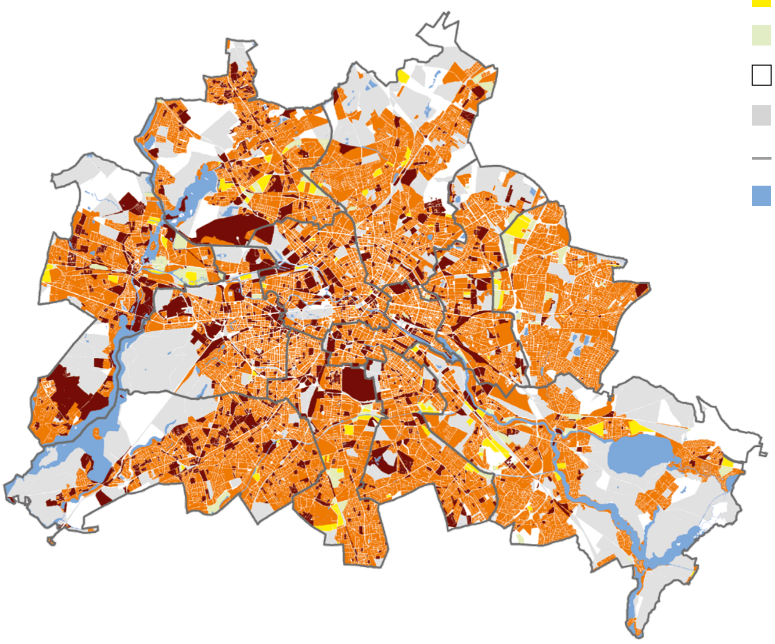
1. Rent prices in Berlin have risen significantly in recent years, partly due to allocatable renovation costs. On the other hand, lower income households with poorly isolated housing in particular face the threat of energy poverty if energy prices continue to rise in the future.
2. A large proportion of Berlin's housing was modernised in the years following reunification. This modernisation often included measures of energy efficiency. However, this mainly affected the stock of large housing corporations, while the scattered private property still shows modernisation deficits. By 2050, Berlin needs a graduated refurbishment roadmap.
3. At the same time, the scope of action increases if whole districts, instead of single buildings, are taken as targets. For this, the refurbishment and energy supply of buildings must be approached and judged in an integrative fashion.

Both scenarios of the feasibility study take the necessity of differentiation into account. While Target scenario 2 aims to double the pace of refurbishment to a rate of 2 % per annum, Target scenario 1 assumes a more moderate increase of 1.5 %, which then needs to be balanced by further measures. The following projects and measures suggest ways to achieve the set goals regardless of the concrete refurbishment rate:

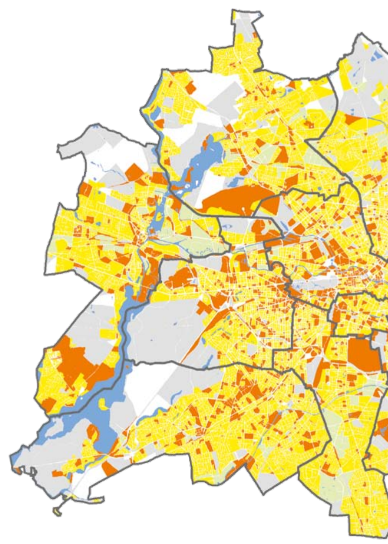
- Berlin needs to continue pursuing inner development and redensification in order to absorb the population growth expected up to 2050 efficiently within the city limits. This will require offering flexible and adapted use of residential space, decreasing the area requirement per person.
- At the same time, climate change adaptation measures need to be taken into consideration, which means keeping strategically important green and open spaces free and improving their quality (cf. StEP Klima – City Development Plan for the Climate).
- For the refurbishment of Berlin's housing stock for energy efficiency, it is important to bear in mind renova-

13

A: Specific final energy consumption by the building stock (excluding solar thermal and geothermal heating) in 2010



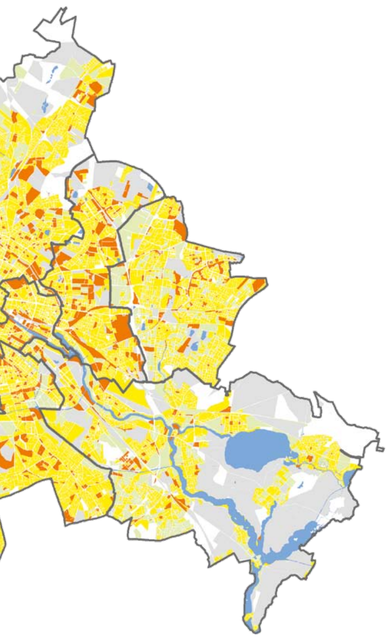
B: Specific final energy consumption by the building stock (excluding solar thermal and geothermal heating) according to Target Scenario 1



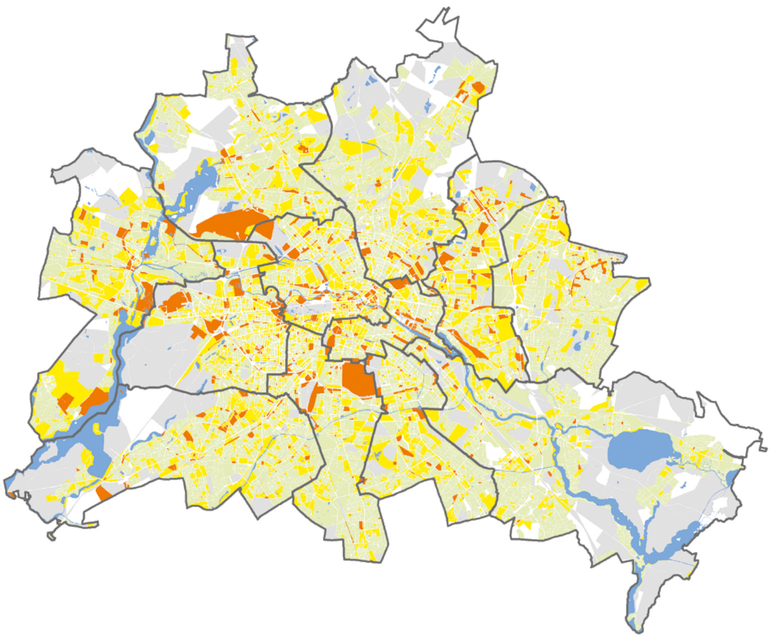
tion and modernisation cycles, to balance out renovation deficits and to find efficient holistic solutions in districts with manageable ownership structures (cf. the key project Climate neighbourhoods, or 'Klimakieze'). Special solutions can be considered for listed monuments.

- The considerable new construction of residential and commercial buildings which will take place in Berlin until 2050 must be carried out respecting exemplary standards as far as the building and its energy supply are concerned (cf. the key project Neutral Quarters, German: 'NeutralQuartiere').
- Urban land use planning should set fixed climate protection standards to a greater degree, and buildings owned by the state of Berlin should set a good example as far as heating demand and energy supply are concerned.

As a result of these considerations, Berlin will have built up a housing stock which is of good to very good quality from the point of view of energy efficiency by 2050 (cf. Figs. 13 A-C). The dwellings for the additional 250,000 inhabitants will be integrated in a space- and energy-efficient manner and Berlin's biggest asset – its green and open spaces – will add significantly to the city's quality of life and climate adaptation. Although the effects of measures related to the green and open spaces of Berlin cannot be captured statistically at the moment, they carry a high significance in terms of climate protection. For this reason, the study suggests further measures in this area, such as the continued transformation of Berlin's forests towards climate resilience and the restoration and maintenance of its peat lands in order to increase the sink capacity of greenhouse gases within the city.



C: Specific final energy consumption by the building stock (excluding solar thermal and geothermal heating) according to Target Scenario 2



Economy

Berlin's economy has considerable energy efficiency potentials waiting to be exploited (20-50 %), especially in its lighting system and in the information and communication technologies (ICT) of small and medium sized companies, but also in the areas of process energy, vehicle fleets and commercial buildings. Berlin's economy sector can also help to increase the generation and use of renewable energies. Target scenario 2, in particular, relies heavily on locally linked networks, which imply a greater reliance on decentralised solutions.

In order to exploit these reduction potentials, the following measures should be taken:

- The positive outcomes of the energy efficiency round table ('EnergieEffizienz-Tisch Berlin') show that further round tables on the topic 'Climate-neutral Berlin 2050' could be especially helpful to small and medium-sized enterprises (SMEs). The first instances of these round tables should be promoted and made visible as key projects.
- Previously established climate protection agreements for large companies should be carried on and adapted to the 2050 climate neutrality goal. The introduction of industry-specific benchmarks and the proliferation of business energy management systems, for SMEs as well as for larger businesses, are important measures to be taken.
- The model of energy-saving partnerships should be expanded further and additional contracting models should be tested and promoted systematically.
- For existing commercial zones, the feasibility study recommends creating and promoting integrated energy and climate protection concepts. The development of a zero-emissions industrial park could be a key project as a showcase for Berlin's climate-neutral economy.
- In addition, climate-neutral events and appropriate competitions can send strong signals, as would the introduction of a regional Berlin electricity brand, which could be achieved through a municipal energy supplier or a citizens' energy association.
- From a technical point of view, projects to increase commercial waste heat utilisation, projects in the area of renewable process energy and green ICT solutions should be supported and divulged.
- Finally, the exemplary role and diffusive effect of public procurement is of great relevance. The approximately 3 billion euros spent per year can have a great economic leverage effect. For this reason, the existing administrative regulations on public procurement and the environment should be revised to include criteria for climate neutrality, and the Berlin procurement system should become more centralised and hence more efficient.

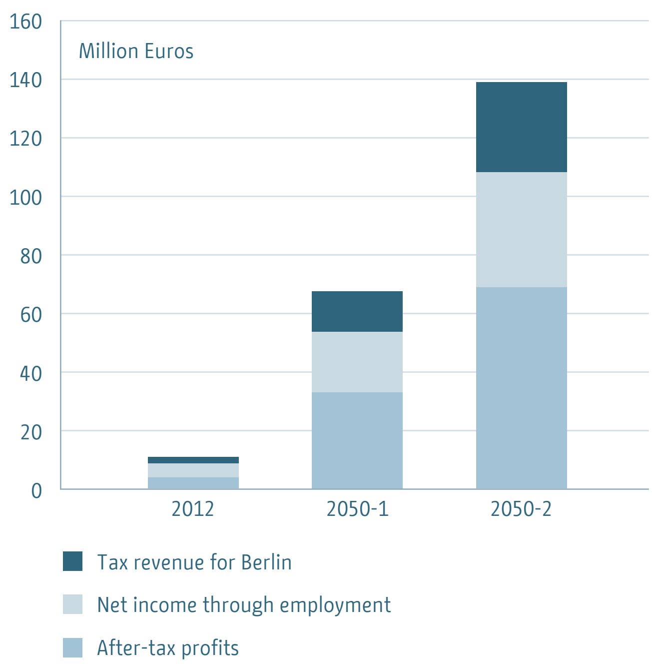
Regional Economical Effects

The transformation to a more decentralised energy supply based more heavily on renewable sources, the increase in energy efficiency and the many other new energy services involved in achieving climate neutrality will incur costs. However, public discussion tends to suppress the costs of the continuation of the current, fossil-based energy system. Furthermore, it is unrealistic to extrapolate today's cost relation between the fossil system and its renewable alternative into the future. Declining costs due to learning-curve effects of new technologies and the foreseeably rising costs of fossil energy sources will shift the current relationship in favour of renewable energies in the medium to long term. If the additional environmental costs – due to air pollution or climate consequences – are taken into account instead of ignored, as occurs frequently today, studies show that early and ambitious climate protection action pays off economically.

Especially for the regional economy, including that of the city of Berlin, a large number of benefits can be gained if the target scenarios are realised. In 2012, a total of 3.2 billion euros was paid by public authorities, trade and industry, and households for the import of fossil energy carriers to the city. Here is a significant potential available to a future Berlin economy based on local energy sources, energy producers and energy service providers – a potential which would also stimulate economic growth and employment in the city. Today, an estimated 260 million euros of profits from the supply of energy leave the city, in addition to significant external tax payments. Both could benefit Berlin in the future.

The feasibility study explored the effects of renewable energies on added value and employment in both target scenarios. Target scenario 2 in particular assumed that many companies and investors along the value-added chain were from Berlin – a local municipal utility company, many small citizens' energy plants, planners, managers, energy service providers, etc., with the result that not only the value-added and employment effects would be positive, but the degree of economic participation in the energy turnaround would increase significantly. Figure 14 shows the results for the value-added effects due to renewable energy expansion in Berlin, divided into the three components communal tax revenue, income through employment and company profits.

14



The results show that an increase in the renewable energy expansion figures can be accompanied by a similar increase in the value-added effects. Berlin can benefit from its goal of climate neutrality economically, as well. For this, however, it is necessary that the local economy be able to provide the required competencies, capacities and qualifications to carry out the planning, production and maintenance of the new facilities in Berlin. These general requirements must be fulfilled by the government together with the trade and industry sectors of the city.

Regional economy effects of renewable energy in Berlin in 2012 (left) and 2050 (both target scenarios, right)

Private Households and Consumption

According to the calculations of the Feasibility Study, private households are responsible for around 9 % of Berlin's CO_2 emissions (waste producer balances, excluding building heating and hot water). The so-called life-cycle emissions (also called gray energies) are not entirely taken into account; these can increase waste output up to twofold, depending on the product group. Today, many people already contemplate whether to buy strawberries in the winter (seasonality) or if an apple from Havelland in Berlin's immediate vicinity should not be preferred over one from New Zealand (regionality).

As important as it is to consume in a climate-friendly manner, it is very difficult to do so when essential product information is often missing. Consequently, every strategy that aims to promote climate-neutral consumption should take into consideration at least the following four points:

1. raise awareness, sensitise people;
2. remove barriers which are in the way of turning good intentions into action (by providing better information or better offers, for instance);
3. create motivation and incentives;
4. show that it is feasible and set good examples.

A key task is to take away peoples' feeling that they are making a 'sacrifice' with their eco- and climate-friendly behaviour; one that might even be ineffective, since they are alone in behaving this way. Instead, the positive collective effect of individual activity must be made more visible. In this sense, the following measures are recommended:

- A central initiative to kick off a strategy in support of climate neutrality which wishes to include society and its citizens must be sufficiently communicated and made visible. A number of key projects of this type are proposed, such as the 'Green Band of Energy', a piezoelectric light installation that feeds off pedestrians at such locations as Alexanderplatz, or a 'Green Club Initiative' targeted at younger groups.
- Active support by the Senate and boroughs for thoughtful and reduced consumption (through a Green Berlin savings card and the promotion of exchange markets and repair opportunities, for instance).
- A kind of scrapping premium ("Abwrackprämie") offered by commercial enterprises for inefficient old machines and equipment to increase energy efficiency in households.
- The creation of adjuvant conditions for climate-friendly activities and processes in neighbourhoods and society at large.
- An educational campaign for climate neutrality covering schools, universities and non-school related sectors.
- A more informative way of designing energy bills (with comparison values).

By 2050, Berlin's private households will be much more efficient and less CO_2-emitting than they are today. Specifically targeted measures of the Senate as well as federal trends such as the improvement of the general electricity factor will have significant impact.

Traffic

From the scenarios, it can be seen that existing planning concepts (such as StEP, bicycle and pedestrian strategies, and the integrated business traffic concept) and instruments (such as environment zones - 'Umweltzone') can have a significant impact on achieving climate neutrality by 2050. However, they will not suffice in order to reach the goal. That is why further measures are called for.

- For some time now, various alternative engines for road vehicles have been developed which reduce effects on the climate, the environment and noise pollution. A municipality does not have the capacity to develop such engines, but it can help to accelerate their diffusion by such measures as further developing environment zones into climate-neutral zones.
- Berlin offers very good conditions for further inter-linking transportation and energy systems. Widespread charging stations allow electric vehicles to draw energy from the network; they can even be used as attachable storage capacities if needed. Pilot projects in the city should support this development.
- Berlin also offers excellent conditions for making traffic in the city even more inter- and multimodal. Today's already well-developed combination of environmentally sound transport (pedestrian, bicycle, public transport) should integrate modern means of transportation such as bike- and car-sharing, as well as offering one-stop system solutions (and tickets).
- More train stations and stops of the public transportation system should be expanded to become hubs for intermodal mobility.
- In the future, Berlin will continue to be an attractive place to live and work, especially for young people. Moving to a new place can be seen as an opportunity to promote drastic changes in behavioural habits. A mobility advice service for new residents can actively promote climate-neutral mobility as a trademark of Berlin. Stronger business mobility management should accompany this initiative.

Berlin's transportation system already offers valuable starting points for a gradual buildup of climate-neutral mobility for the future. This potential should be exploited and developed further in a goal-orientated fashion.

5. Conclusions

The feasibility study shows that Berlin can become climate-neutral by 2050, meaning the city can reduce its CO_2 emissions by 85 % relative to 1990. And it can reach this goal in more than one way. Two different target scenarios showed that climate neutrality can be achieved by more central structures and efficient technologies, as well as by a higher proportion of decentralised structures and sufficiency. Through the usage of combined heat and power generation and solar energy, urban areas have excellent possibilities of generating enough energy not only to lose their status as energy sinks but also to achieve surpluses, helping to reduce space requirements for energy production in other places. District heating will remain important, but change its face. The use of decentralised and renewable heat supplies will be greatly expanded. While this will reduce the necessity to modernise buildings for energy efficiency, the energy status of Berlin's building stock will still have to improve compared to today. Even though total electricity consumption will increase with the evolving system – through electric mobility, power-to-heat and power-to-methanol, for example – Berlin's economy and its private households will achieve high efficiency and saving potentials. These new technologies, combined with virtual power plants and smart structures for the stability of the system, will benefit not only Berlin's energy system, but the supra-regional one as well. Ultimately, the climate-neutral transformation of the Berlin energy system will stimulate the growth of value-added activities and employment in the city. Berlin can achieve its climate neutrality goal if it implements a number of specific measures in the relevant fields of action supported by political and economical top-level decision-makers and, last but not least, through attractive, visible key projects to show all citizens the goal's advantages and appeal to the role of each individual.

Glossary

CO_2 – Carbon dioxide. The most relevant greenhouse gas contributing to global warming.

CO_2 equivalents (CO_2eq) – Other greenhouse gases (e.g. methanol [CH_4] or laughing gas [nitrous oxide, N_2O]) are recalculated to show their global warming potential in terms of CO_2.

Final energy – The remaining quantity of primary energy after conversion and transfer losses, which passes a connection (e.g. the house service connection) to a consumer (private households, trade and industry, transportation). After further conversion losses, final energy is available as useable energy for diverse applications (heating, cooling, transport, etc.)

General electricity factor – The quotient of the sum of the emissions of all electricity plants producing for domestic use and the sum of domestic final electricity consumption. Crucial base for the calculation of CO_2 waste producer balances with regards to electricity.

Combined heat and power generation (CHP) – The simultaneous production of heat and electricity through units of different sizes and designs, e.g. bigger heating plants or smaller block heating stations. This allows for higher useable final energy compared to separate heat and power generation.

Multimodality (multimodal mobility) – The use of different means of transportation according to their adequacy instead of fixation on one given transportation form. Multimodality requires technical and economical availability and further connectivity of the diverse means of transportation.

Power-to-gas (P2G) – The use of (temporary) excess electricity from renewable sources, by which initially hydrogen (H_2) is produced through electrolysis. By adding CO_2, this is then converted to methane (CH_4), which can be stored and distributed through the existing natural gas infrastructure. Methane can be used for transportation or for reconversion into electricity.

Power-to-heat (P2H) – The use of (temporary) excess electricity from renewable sources, by which electricity is used to produce heat and hot water directly. This can also be carried out with heat pumps. In either case, P2H technologies operate in combination with heat storage.

Primary energy – Energy that is available from the original energy sources, for example as fuel (e.g. coal or natural gas), but also from energy carriers such as the sun, wind or nuclear fuels.

Terajoule (TJ) – The basic unit of energy according to the International System of Units is 1 joule (also watt second), which corresponds roughly to the work done by one beat of a human heart. One TJ is 1012 joules, or 278 megawatt hours (MWh).

Waste producer balance – A measure of greenhouse gas emissions based on final energy consumption. Unlike the source balance, the waste producer balance ascribes emissions from conversion (e.g. heat or electricity production) to the final consumer according to the “polluter pays” principle.

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Team of Brochure Authors
Fritz Reusswig, Bernd Hirschl, Wiebke Lass

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