08.06 Solar-Energy Surface Potentials (Edition 2008)

Overview

Full knowledge of the long-term potentials of solar-energy utilization in a metropolitan area increases the possibility for taking energy-efficient construction and the use of renewable energies into account in urban planning, both in new project planning and in urban rehabilitation. To support this important **climate-protection goal**, an assessment in the context of an examination of the Berlin building stock was carried out with regard to the fundamental suitability of buildings for the installation of solar-technology systems (Solarer Rahmenplan Berlin) (“Berlin Solar Framework Plan,” *available only in German*).

The results of research project "Leitbilder und Potenziale eines solaren Städtebaus" (“Models and Potentials of Solar Urban Development,” avail. only in Ger), presented by the contractor Ecofys in 2004 were the basis for this work. This project categorized the entire building stock of the Federal Republic of Germany by so-called **urban-space types**.

This typology is based on three aspects:

- the break-down of the municipal building stock into urban spaces, depending on the history of their development
- the demarcation of the urban spaces according to particularly favorable or unfavorable technical and structural prerequisites for passive and active solar-energy use
- the recognizable changes in use and modernization requirement within the next approx. two decades, from which the possibilities of influencing urban planning and urban renewal on structural and technical changes will become apparent.

Urban spaces with similar structural and technical conditions, and similar urban-development histories, can be assigned comparable solar potentials.

In this context, the "**potential urban solar-energy surfaces**" are defined as the "solar potential." The urban solar-energy surface potential takes as its point of departure such a technical aspect as the identification of suitable areas in the building shell, and includes additional urban-development aspects, such as architectural heritage/ preservation of historical monuments, and technical/economic aspects, for the ascertainment of the potential.

The following criteria yield the urban solar-energy surface potential (listed in order of significance):

- All areas – façades and roofs – facing south ± 45 degrees can potentially be used. Moreover, a shade-analysis procedure is used to select those surfaces which are exposed to sunlight at 12:00 noon on December 21st.
- All areas are examined according to urban-development criteria and possibilities for realization. The result is that façades in particular prove to be less suitable for active solar energy systems.
- Sufficient window area should be available for passive solar-energy use. Gains in passive solar use are not only the most favorable form solar-energy use, but also increase residential quality by providing good sunlight exposure.
- Sufficient and suitable areas should be available for solar-thermal heat production, both for warm-water supply and as a support for home heating.
- Suitable areas for photovoltaic power generation should be available.
- Basically, in cases of competition for space, solar-thermal energy should receive priority over PV. Notwithstanding, photovoltaic facilities should get the “better” surfaces, because solar-thermal production reacts less sensitively to shading than does photovoltaics.

Solar-quality figures are established for each urban-space type on the basis of the surface potential ascertained. They show the relationship between the gross roof or façade surfaces ascertained on the one hand, and their proportions utilizable for solar systems on the other. For example, a solar-quality figure of 1.0 means that the entire area of a roof can be used for solar technology; a quality value of 0.0 on the other hand means that there is no room at all on the roof or façade for solar systems. The façades of inner-city apartment blocks often have such values, due to the strong shading effects. The highest quality figures are assigned to roof areas on planned trade and service locations. A listing of all quality figures is shown in Table 2.

In sum, the present "solar-energy surface potential" examination ascertained a **long-term potential contribution from solar-thermal energy of about 12%** to the heat supply of Berlin. This is a perspective for 2050, which also takes into account the reduction in heating requirements for buildings due to renewal cycles. As **the long-term practicable contribution of photovoltaics to the Berlin power supply, a share of about 9% was** ascertained.

Statistical Base

The drafting of an overview of the potential of roof and façade areas suitable for solar systems means the incorporation of various parameters, including first and foremost:

- The specific topographical, meteorological and structural features of the city
- The typology of the twenty nationally relevant urban-space types with varying solar potentials
- Solar-quality figures usable as planning code numbers and for potential ascertainment; and
- Energy-relevant solution models, i.e. optimized combinations of heating-requirement reductions and environmentally friendly heating supply, for each urban-space types.

With regard to the existing meteorological situation, **Berlin has a relatively sunshine-rich climate**. The city has its location in the North German Plain to thank for its largely continental climate. The result is that the Berlin Tempelhof station of the German Meteorological Service records an average of about 1670 hours of annual sunshine, according to a multi-year data, and is thus in seventy-second place among the approx. 430 stations nationwide (online information of the German Meteorological Service DWD).

The basis for this work was the break-down of the entire building stock of the Federal Republic of Germany into twenty so-called urban-space types according to the criteria mentioned above (cf. Table 1).

Table 1:	**Nationally-defined urban-space types, with various potentials for use of solar energy**
Urban-space type	**Typological description**
1	Old city centers (pre-industrial city center, some with later accretions)
2	Inner-city blocks, often peripheral to city center (imperial and inter-war-era buildings with mixed use)
3	Imperial and inter-war-era trade and industrial complexes, largely with commercial use
4	Pre-war functional building complexes and public facilities
5	Factory and co-operative housing estates (uniformly planned imperial and inter-war-era buildings)
6	Single-family-home areas, villas, housing for government officials (imperial and inter-war-era loosely-structured housing)
7	Reconstruction blocks of ‘50s and ‘60s (on the old city ground plan, densely built)
8	Social-housing areas of the ‘50s (linear ground plan)
9	Social-housing areas of the ‘60s
10	Multi-storey housing of the ‘70s
11	East German-style multi-storey housing
12	Single-family-home areas (residential areas of the ‘50s, ‘60s and ‘70s)
13	Functional building complexes and public facilities of the ‘50s, ‘60s and ‘70s
14	Trade and industrial areas of the ‘50s, ‘60s and ‘70s
15	Multi-storey buildings of the ‘80s
16	Single-family-home areas of the ‘80s
17	Trade and industrial areas of the ‘80s
18	Functional building complexes and public facilities of the ‘80s
19	Shopping centers of the ‘80s
20	Leisure facilities of the ‘80s

Tab.1: Nationally-defined urban-space types, with various potentials for use of solar energy

Urban spaces with similar structural and technical conditions and similar urban development histories can also be assigned comparable solar potentials, so that local focal points for the use of solar technology become apparent.

Examples of individual reference urban spaces of these urban-space types in Berlin are shown in a documentation by the contractor Ecofys, which is available for download (Berlin Urban-Space Type Catalogue, reference areas with photos and tables as a PDF document /2.5 MB). Figure 1 shows an example from this documentation.

Reference urban space in Berlin;

Place:	*Bornitzstraße, Lichtenberg.*
Year of construction:	*1959 (Mercury)*
Storeys:	*III-V*
Density	*0.8*
Roof form:	*Saddleback roof*
Proportion in Berlin	*6.2*

Unusual features:

Modernizations were carried out primarily only at high-demand sites, frequently involving combination of apartments; maintenance backlog at low-demand sites; in many cases, change in ownership in cases of housing-company properties; partitioning into condos rare

Solar-quality figures:

Quality figure, roof	0.11
Quality figure, façade	0.00

Figure 1: Example from the urban-space type catalogue Berlin (here: Urban-Space Type 7 - Social housing estates of the '50s)

However, since there is no comprehensive information available about the distribution and location of these urban-space types in Berlin, it was necessary to adapt the data to the specific Berlin situation. For this purpose, a number of different information sources were consulted which had the major purpose of assigning the lot, or **section types** of the City and Environment Information System (ISU) to the urban-space types. The extensive results to this mapping process of land use in Berlin have been published under Map 06.07 Urban Structure (2007 Edition).

The additional **data bases** used are:

- Block Map 1: 5000 (ISU 5) Dec. 31, 2003,
- Orthophotos 2004, SenStadt, Div. III,
- Maps of building age, by borough, SenStadt, as of 1988,
- Public list of monuments in Berlin (Berlin Monument List) (Official Bulletin for Berlin, 51st year, No. 29, June 14, 2001, SenInneres (Senate Department of the Interior).
- SenStadt, Environmental Atlas, Maps 08.01 Building Heating Supply Areas and 08.02 Predominant Heating Types (2005 Editions)
- Map "Areas with Overall Urban Change Potential," SenStadt IA1, as of the end of 2005
- Single topical maps of the application FIS Broker, SenStadt, accessed August 2005 - March 2006.

Methodology

The central work step for the assessment of the Berlin building stock involved the **comparison of the typology** of the twenty urban-space types with various solar urban potentials, with the section types of the land-use maps of the Berlin City and Environment Information System (ISU). The goal was to check the specific delimitation criteria of the urban-space types for commonality with the the ISU section types. These criteria include:

- Building age
- Building use
- Shape, orientation and design of roofs and façades
- Value in terms of architectural culture (protection of historical monuments), and
- Urban density.

With the aid of high-resolution and geo-referenced aerial photography, an urban-space type was assigned to the ISU section type for every built-up area. For this purpose, the twenty nationally-defined urban-space types were reduced to the seventeen types relevant for Berlin. The result was the creation of an **urban-space type/ section type assignment table**, which however, in many cases required the multiple assignment of a section type to the appropriate urban-space type (cf. Table 2).

The characteristics significant for the determination of solar-power-surface potentials, particularly the available roof and façade surfaces, could in most cases be adequately ascertained from aerial photography. This was also the method used for the specific determination of urban-space types for which there was multiple assignment to ISU section types, according to the Table.

Table 2: Assignment of similar section types to urban-space type with various solar-quality figures

ECOFYS urban-space type		**ISU section type**	**Solar-quality figure**	
Urban-space types, predominantly residential use			**Roof**	**Façade**
(1) Inner-city blocks, imperial and inter-war era	(1)	Closed rear courts	**0.07**	**0**
	(2)	Rear courts		
	(3)	Decorative and garden courts		
	(4)	Rehabilitation by de-coring		
	(5)	Preservation-oriented rehabilitation		
	(6)	Shed-courts		
	(38)	Mixed area II with dense construction – partial		
(4) Factory & cooperative estates, imperial and inter-war era	(10)	Large courts and row buildings of the '20s and '30s	**0.03**	**0**
	(72)	(in East Berlin, only large courts)		
(5) Pre-war single-family home, villa & government-official housing areas	(21)	Row buildings of the '20s (only East Berlin)	**0.03**	**0**
	(25)	Village		
	(22)	Gardens and semi-private green yards		
	(23)	Row gardens – partial		
	(26)	Gardens – partial		
(6) Reconstruction of '50s and '60s (closed style)	(7)	Open housing estates – partial	**0.19**	**0**
(7) Social-housing estates of the '50s	(8)	Unplanned reconstruction – partial	**0.11**	**0**
	(11)	Row buildings of the '50s – partial		
(8) Social-housing estates of the '60s	(8)	Unplanned reconstruction – partial	**0.08**	**0**
	(9)	High-rise, large estates – partial		
	(11)	Row buildings of the '50s – partial		
(9) Multi-storey housing of the '70s	(9)	High-rise, large estates – partial	**0.15**	**0.15**
(10) Concrete-plate housing (NBL)	(71)	Concrete-plate housing of '80s and '90s	**0.15**	**0.05**
11) Single-family home areas of '50s, '60s and '70s	(22)	Row gardens – partial	**0.05**	**0.02**
	(23)	Gardens – partial		
	(26)	Open housing estates – partial		
	(33)	Mixed area II with low buildings – partial		
(14) Multi-storey housing since the '80s	(25)	Gardens and semi-private green yards	**0.08**	**0.04**
	(73)	Compact, > = 4 storey housing of the '90s		
(15) Single-family home areas since the '80s	(74)	Residential construction of the '90s (row houses, single-family and duplex houses)	**0.05**	**0.03**
	(22)	Loose construction, < 4 storeys		
	(23)	Row gardens – partial		
Urban-space types with predominantly commercial, service, and industrial use				
(2) Pre-war commercial and industrial areas	(31)	Commercial district with dense construction	**0.25**	**0**
	(29)	Core area – partial		
	(30)	Commercial area with low buildings – partial		
	(92)	Railyards, without tracks – partial		
(3) Pre-war community services and special use	(12)	Old building school (pre-1945)	**0.03**	**0**
	(14)	Schools – partial		
	(41)	Security and order – partial		
	(42)	Postal – partial		

	(43) Administration – partial (44) Commercial district with dense construction (45) Core area – partial (46) Commercial area with low buildings – partial (49) Railyards, without tracks – partial (60) Old building school (pre-1945)		
(12) Community services and special use, ‘50s, ‘60s and ‘70s	(13) Schools – partial (14) Security and order – partial (41) Postal – partial (42) Administration – partial (43) University and research – partial (44) Culture – partial (45) Hospitals – partial (46) Churches – partial (49) Community services, general – partial (60) New schools (post-1945) – partial	**0.11**	**0.02**
(13) Commercial and industrial areas, ‘50s, ‘60s and ‘70s	(30) Schools – partial (32) Security and order – partial	**0.1**	**0.03**
(16) Commercial and industrial areas since the ‘80s	(30) Postal – partial (32) Administration – partial (33) University and research – partial	**0.22**	**0.12**
(17) Offices, services & community services since the ‘80s	(13) Culture – partial (14) Hospitals – partial (29) Churches – partial (41) Community services, general – partial (42) Commercial area with low buildings – partial (43) Supply and disposal areas – partial (44) Commercial district with low buildings – partial (45) Supply and disposal areas – partial (46) Mixed area II with low buildings – partial (49) New schools (post-1945) – partial (60) Schools – partial	**0.22**	**0.13**

Table 2: Assignment of similar section types of urban-space type with different solar quality figures

The list of the seventeen urban-space types of building stock relevant for Berlin has been supplemented by four additional categories for **planned construction projects** (Urban-Space Types 18 -21). However, the areas delimited accordingly on the map should only be seen as indications, since the respective projects were at different stages of planning, and their further development was not foreseeable. Generally, the advantage of projects is their possibility of tying strategies for the use of solar or other regenerative energies into the planning process at an early stage, which may greatly increase their possibilities of realization.

In order to take the district-heating-supplied areas in Berlin into account, the Map 08.01 Building Heating Supply Areas (2005 Edition) was consulted. The purpose was to include an additional criterion particularly for the conclusive evaluation of Berlin’s overall potential contribution in solar-thermal energy and photovoltaics, respectively, to the future energy supply of the city. If a construction area is already provided with district heating, this approach will permit summertime heating and cooling requirements to be met by this system. In these cases, roof and façade areas suitable for the active solar technology should be considered primarily as potential solar-power sources.

Map Description

As long-term possible contributions of solar systems to the energy supply of Berlin, the following values were ascertained by the investigation:

- **solar-thermal energy for heat supply: 12%** (cf. Table 3)

- **photovoltaics for power supply: 9%.**

This is the perspective for 2050.

Neither the inner-city housing blocks typical of Berlin nor the functional buildings of the post-war period, nor the commercial districts built during the ‘80s are ideal for the current mobilization of areas for solar utilization, since solutions can at present be realized here economically only with some difficulty.

Figure 2 shows comparison of the distribution of surfaces available for solar-energy utilization by urban-space type. Berlin had around 3,390,000 inhabitants in 2005. The total potential urban solar-energy surface on roofs is 10.40 sq.m. per inhabitant, and 3.38 sq.m. per inhabitant on façades, for a total of 13.78 sq.m. per inhabitant in Berlin. The single-family homes of the post-war period (Urban-Space Type 11) have the greatest potential, with a urban solar-energy surface potential (roofs and façades) of 6,480,000 sq.m. in the capital. In terms of solar-urban roof-surface potential, the Post-War Commercial and Industrial Areas (Urban-Space Types 13, 16, 20), the Housing Estates of ‘50s and ‘70s (Urban-Space Types 7 and 9) and Functional Buildings the ‘50s, ‘60s and ‘70s (Urban-Space Type 12) stand out.

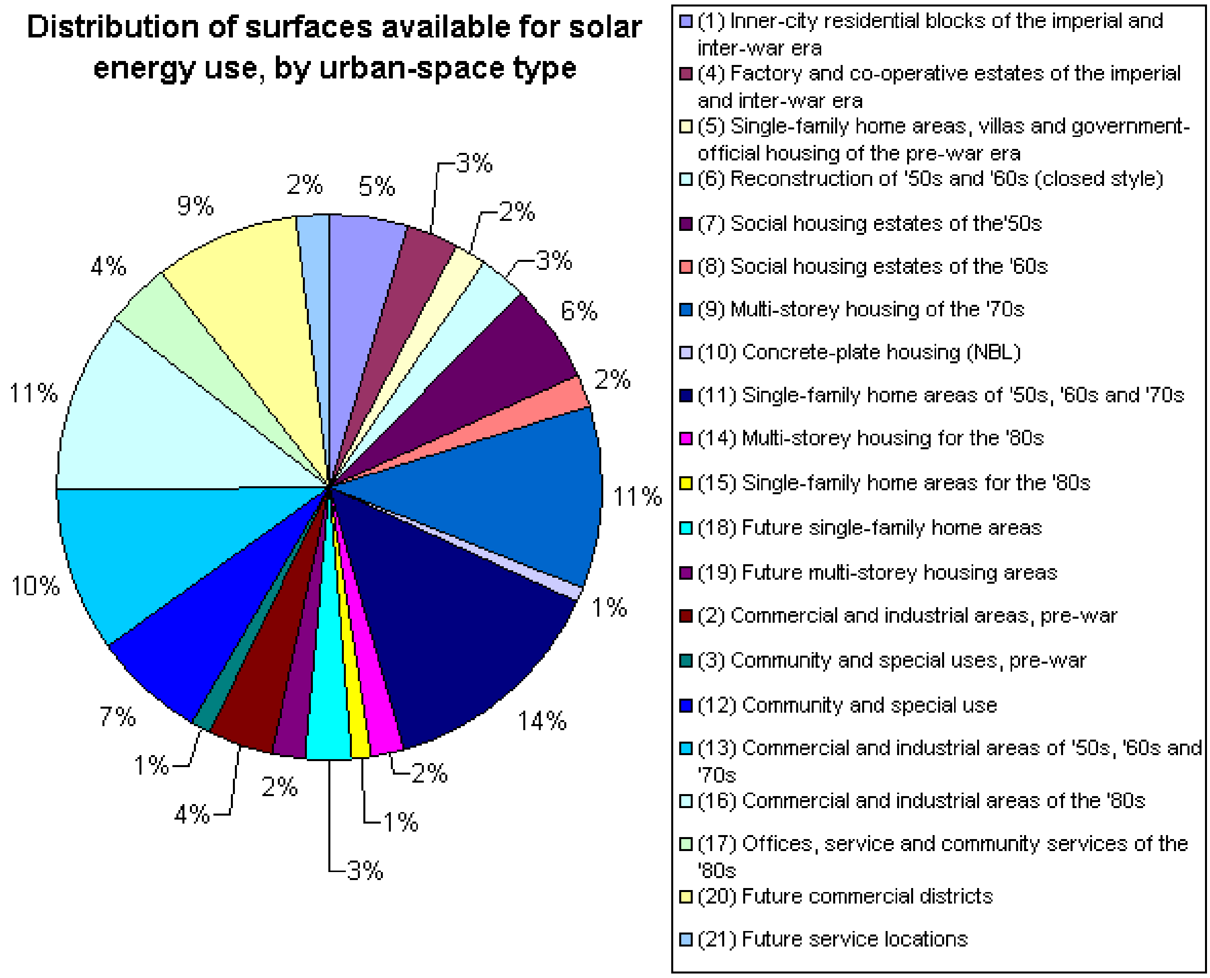

Figure. 2: Distribution of surfaces available for solar energy use, by urban-space type

The main thrust of further more intensive investigations for the concretization of possible potentials for the installation of solar-technology systems will be toward for the following urban-space types:

- Social housing of the ‘50s, row buildings
- Multi-storey housing of the ‘70s
- Single-family home areas of the ‘50s, ‘60s and ‘70s; and

- Commercial and industrial area of ‘50s, ‘60s and ‘70s.

Moreover, there are particularly favorable possibilities for including solar-energy goals in all projects on construction sites. Here, the investigation will focus primarily on future single-family home and multi-storey housing areas, and also on large-scale service areas.

Table 3 shows a summary of long-term potential contribution of solar-thermal energy to the heat supply in Berlin, by urban-space type.

Table 3: Long-term use potential of solar-thermal energy in Berlin, by urban-space type

ECOFYS urban-space type	Usable surface area, in 1000 sq.m.	Usable surface area, w/o district heat, in 1,000 sq.m.	Potential solar coverage		Annual solar yield in MWh	Total long-term heat require-ment, in MWh/a	Share of total potential, in %
Urban-space types with a predominantly residential use			in %	in MWh /sq.m.			
(1) Inner-city blocks, imperial and inter-war period	52,248	37,851	0	0	0	3,500,616	0
(4) Factory and co-operative estates, imperial and inter-war period	9,823	6,145	15	10,05	61,753	658,114	9
(5) Single-family home areas, villas and government-officials’ housing, pre-war period	9,016	7,955	32	27,84	221,470	784,409	28
(6) Reconstruction of ‘50s and ‘60s (closed style)	9,552	5,303	26	22,62	119,943	831,024	14
(7) Social housing estates of the ‘50s	14,551	7,853	45	30,15	236,780	974,930	24
(8) Social housing estates of the ‘60	6,064	2,059	50	33,5	68,968	406,301	17
(9) Multi-storey housing of the ‘70s	17,925	2,774	0	0	0	10,210,699	0
(10) Concrete-plate housing (NBL)	3,070	565	0	0	0	175,001	0
(11) Single-family home areas of ‘50s, ‘60s and ‘70s	34,710	28,619	45	30,15	862,870	2,325,545	37
(14) Multi-storey housing since ‘80s	9,855	7,417	15	8,55	63,413	561,735	11
(15) Single-family home areas since the ‘80s	2,983	2,357	16,5	11,06	26,055	199,869	13
(18) Future single-family home areas	5,430	4,585	43	24,51	112,369	309,519	36
(19) Future Multi-storey housing areas	5,603	5,422	41	19,27	104,477	263,353	40
Urban-space types with predominantly commercial service and industrial use							
(2) Pre-war commercial and industrial areas	5,593	2,817	0	0	0	307,601	0
(3) Pre-war community and special use	13,016	5,942	1	0,75	4,457	976,219	0
(12) Community and special use, ‘50s, ‘60s and ‘70s	15,743	5,679	1	0,75	4,259	1,180,710	0
(13) Commercial and industrial areas, ‘50s, ‘60s and ‘70s	21,581	12,856	0	0	0	1,402,791	0
(16) Commercial and industrial areas since the ‘80s	6,506	4,048	0	0	0	357,848	0
(17) Offices, services and community services since the ‘80s	5,176	1,309	0	0	0	284,695	0

(20) Future commercial areas	**11,429**	**11,023**	**0**	**0**	**0**	**514,296**	**0**
(21) Future service locations	**2,763**	**2,616**	**11**	**4,95**	**12,949**	**124,335**	**10**
TOTAL	***262,638***	***165,195***	***-***	***-***	***1,899,764***	***17,160,612***	***12***

Tab. 3: Long-term use potential of solar-thermal energy in Berlin, by urban-space type

The Significance of the Solar-Energy Surface Potential for Berlin's Climate-Protection Goals

The results of the investigation of solar-energy surface potentials also indirectly permits inferences regarding CO_2 reduction potentials via solar-energy use. The potential for solar power production comes to 1,093,720 MWh/yr. Complete exploitation of the solar-power potential ascertained would mean a **CO_2, saving of approx. 732,792 tons annually**. That would be equal to almost 8.5 percent of the CO_2 emissions of approx. 8,665,780 tons caused in 2000 by the entire Berlin power consumption of 12,934,000 MWh.

Although the calculated reduction of 8.5 percent is based on a comparison referenced to today's power-plant stock in Germany, its efficiency and its structure of power-generating facilities, it is nonetheless clear that solar energy could make a considerable contribution to CO_2 reduction.

The level of potential CO_2 savings through the use of solar-thermal systems depends on the CO_2 emissions factors of the fuels replaced by solar energy. If natural gas is assumed to be the main fuel, the equivalent CO_2 value of a heat quantity of one kilowatt hour produced with natural gas amounts to 310 grams. The total potential for solar-thermal heat production of 17,160,612 MWh thus enables a CO_2 savings of approx. 5,319,790 tons per year.

In order to fully exploit both the photovoltaic and the solar-thermal energy potential of much of the building stock suitable, in terms of the orientation of roofs and façades, for solar utilization, the structural and technical prerequisites for the installation of solar systems must first be created. This can only be accomplished in the context of necessary redevelopment measures oriented towards the replacement cycles of the components.

In order to fully exploit the solar-thermal potential, additional prerequisites are necessary. The heating systems must be compatible with solar-thermal systems, and placement areas must be available for the hot-water tanks. The efficiency of solar-thermal energy is maximized when it is used to provide home heating, in connection with reduced heating requirements for buildings, and with large-area heating systems.

In order to achieve the long-term climate-protection goal of 80% CO_2 reduction by 2050, the potentials of both solar-thermal energy and photovoltaics will have to be realized, combined, moreover, with high-quality energy rehabilitation and energy-efficient new buildings.

Berlin has the advantage that large portions of its building stock have already been modernized over the past two decades, either in urban-renewal areas, in publicly subsidized housing areas, or in concrete-plate housing estates.

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