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Federal Institute for Research on Building, Urban Affairs and Spatial Development

within the Federal Office for Building and Regional Planning

BBSR-Analysen KOMPAKT 01/2023

India, Germany and Europe

A Spatial Perspective at SDG 7 on Affordable and Clean Energy

Responding to crucial challenges in spatial and urban development, the United Nations agreed upon the 2030 Agenda, the Sustainable Development Goals (SDGs) and the New Urban Agenda. This publication checks the progress made in implementing the SDGs against the New Urban Agenda and vice versa. In order to understand the spatial patterns, a national and supranational spatial perspective is taken on some of the SDGs. Given the relevance of affordable and clean energy for balanced urban and rural societies, SDG 7 covers, amongst others:

- Renewable energy access and share
- Energy intensity
- Installed renewable energy

by

Dr. André Müller, Antonia Milbert,
Volker Schmidt-Seiwert, Regine Binot, Lukas Kiel

Prof. Dr. Debolina Kundu, Dr. Tania Debnath,
Dr. Swastika Chakravorty, Dr. Gautam Kumar Das

Photo: Schafgans DGPh

Joint foreword

Dear Reader,

The Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR) and the National Institute of Urban Affairs (NIUA) cooperate since 2018 in research activities. This cooperation is part of the urbanization partnership closed between the respective ministries in India and Germany in 2012. The joint research focuses on guiding documents and agreements of the United Nations for a modern urban development in both countries. Amongst these agreement are the 2030 Agenda and its Sustainable Development Goals (SDGs) as well as the New Urban Agenda.

A compact settlement structure, an efficient use of resources, mobility in cities and regions as well as healthy living conditions for all are key messages linked to the agreements of the United Nations. These agreements guide us all in planning, designing, financing, developing and governing our communities in order to accommodate to sustainable development.

BBSR and NIUA analysed together in a comparable manner already some of the Sustainable Development Goals: Good Health and Well-Being (SDG 3), Quality Education (SDG 4), Gender Equality (SDG 5), Decent Work and Economic Growth (SDG 8) as well as Sustainable Cities and Communities (SDG 11). This publication focuses on Affordable and Clean Energy (SDG 7). The authors paid particular attention to the cartographic visualisation of the analysed phenomena – as a picture is worth a thousand words.

We wish you a stimulating reading.

Dr. Markus Eltges
Director of the Federal Institute for Research on Building, Urban Affairs and Spatial Development

Hitesh Vaidya
Director of the National Institute of Urban Affairs

Photo: NIUA

Introduction

BBSR and NIUA continue with this publication on SDG 7 in India, Germany and Europe their efforts in identifying and applying a comparable approach to reporting on urban and rural development. The publication describes the findings in texts and maps in the same way as it discusses similarities and dissimilarities from national and supranational perspectives – all within the limits of available and comparable data sources.

The United Nations set a global policy framework for urban and rural development with the 2030 Agenda and the Sustainable Development Goals (SDGs) in 2015 and the New Urban Agenda in 2016. Their revised World Urbanization Prospect (UN DESA 2018) and subsequent ad hoc revisions provide updated estimates and projections for all countries of the world as well as their major agglomerations.

In addition, states, cities and communities, India and Germany amongst them, consider the 2030 Agenda and the SDGs as guiding political framework. India has initiated a respective national dialogue. Germany entered in late 2021 a new government term. The SDGs and their relevance as guiding principle are explicitly mentioned in the coalition agreement of the governing parties.

Reporting on the implementation of the SDGs is carried out every year with presentations at the High-Level Political Forum. Reporting on the implementation of the New Urban Agenda starts in 2022. UN HABITAT, the housing and settlement programme of the United Nations, is expected to provide evidence-based and data-oriented reports – so called Quadrennial Reports – every four years. Member States of the United Nations are invited to report with so-called Voluntary National Reviews on the national, sub-national and particularly local implementation. Some countries, amongst them Germany in close cooperation with a group of representative cities and communities, have already handed over their National Reports (BBSR 2021). Communities are invited to contribute to this process with so-called Voluntary Local Reviews. BBSR also supports this with its expertise.

As cross-references between the 2030 Agenda and the New Urban Agenda are evident, the SDGs and their underlying indicators constitute the analytical pattern of the publication. Considering the availability of data sources at national and supranational level, it covers with regard to SDG 7 most of the following selected sub-goals (the figures in brackets refer to the numbering of the Global Indicator Framework adopted by the General Assembly of the United Nations):

- Proportion of population with access to electricity (SDG 7.1.1)
- Proportion of population with primary reliance on clean fuels and technology (SDG 7.1.2)
  - Households using clean fuels for cooking purposes (a)
  - Per capita generation of renewable electricity (b)
  - Installation of off-grid/decentralised renewable energy systems and devices (c)
- Renewable energy share in total energy consumption (SDG 7.2.1)
- Energy intensity measured in terms of primary energy and Gross Domestic Product (GDP)/State Domestic Product (SDP) (SDG 7.3.1)
- Global financial flows to developing countries in support of clean energy research and development as well as renewable energy production, including hybrid systems (SDG 7.a.1) Global financial flows to developed countries in support of clean energy research and development as well as renewable energy production, including hybrid systems (SDG 7.a.2)
- Installed renewable energy generating capacity in developing countries (SDG 7.b.1)
- Installed renewable energy generating capacity in developed countries (SDG 7.b.2)

While data availability determines the analysis, national or even supranational programmes support respective development paths and changes. Given the cross-cutting nature of most of the SDGs as well as the different constitutional settings of India and Germany, this part of the introduction mentions crucial aspects in that respect. European aspects are referenced in the respective chapters. For further information on the difference in use between Gross Domestic Product (GDP) and State Domestic Product (SDP) please refer to BBSR-Analysen KOMPAKT Volume 05/2022.

Due to a lack of spatially relevant and available data, goal SDG 7.a.1 on global financial flows to developing countries with regard to clean and renewable energy research and production and goal SDG 7.a.2 on respective global financial flows to developed countries cannot be not covered by this analysis. Considering Germany and Europe, this holds also true for SDG 7.1.2.c on the installation ratio of off-grid/decentralised renewable energy systems and devices, because proxys would only be doable thus not illustrating the entire spatial picture.

Considering SDG 7.1.1 and SDG 7.1.2.a, the situation in Germany and Europe looks like the following:

The Energy Industry Act (Energiewirtschaftsgesetz – EnWG) secures the access to energy in Germany. Energy suppliers are obliged by law to connect and supply end consumers in the country to the electricity and gas grid. SDG 7.1.1 is therefore fulfilled with regard to all households in Germany. Given the war against Ukraine and the war-related energy crisis, the EnWG was last amended in July 2022. Amending the act would also allow the diversification of the energy supply as well as the acceleration of expanding renewable energy generation and their related infrastructure. In order to ensure the security of energy supply even in a period of turmoil, “trusted institutions shall administer companies running critical infrastructure in the same way as the expropriation – as ultima ration – is possible” (Deutscher Bundestag 2022). Furthermore, regulatory interventions in the electricity and gas market are a possible tool in the event of energy price inflation.

Moreover, all households in Germany receive the same energy mix, fed in the nationwide grid. Data and information related to the renewable energy generation capacity normally refers to SDG 7.2.1.b and not, as in this particular set of maps, to SDG 7.2.1a (see Figures 3). A rising number of local authorities utilises its local capacities in order to implement the energy transition (in German: Energiewende) (cf. AEE n. d.; see also Conclusion).

A note on the present energy crisis in Europe

Crude oil and natural gas running short because of Russia’s war of aggression against Ukraine has led to a noticeable increase in energy prices, resulting in a high inflation rate with considerable consequences for consumers, the economy as well as regional labour markets in Germany and Europe (cf. Nierhaus/Wollmershäuser 2022; Projektgruppe Gemeinschaftsdiagnose 2022; IAB 2022). Apart from handling the challenges related to the present energy crisis, economy and society in Germany should speed up the ongoing decarbonisation (Sachverständigenrat 2022: 210) – an asking in line with SDG 7 (Affordable and Clean Energy). However, this publication does not offer a detailed analysis of the correlation between the present energy crises and SDG 7. It rather scrutinises the targets and indicators related to SDG 7 of the United Nations with regard to their international compatibility and subnational differentiation.

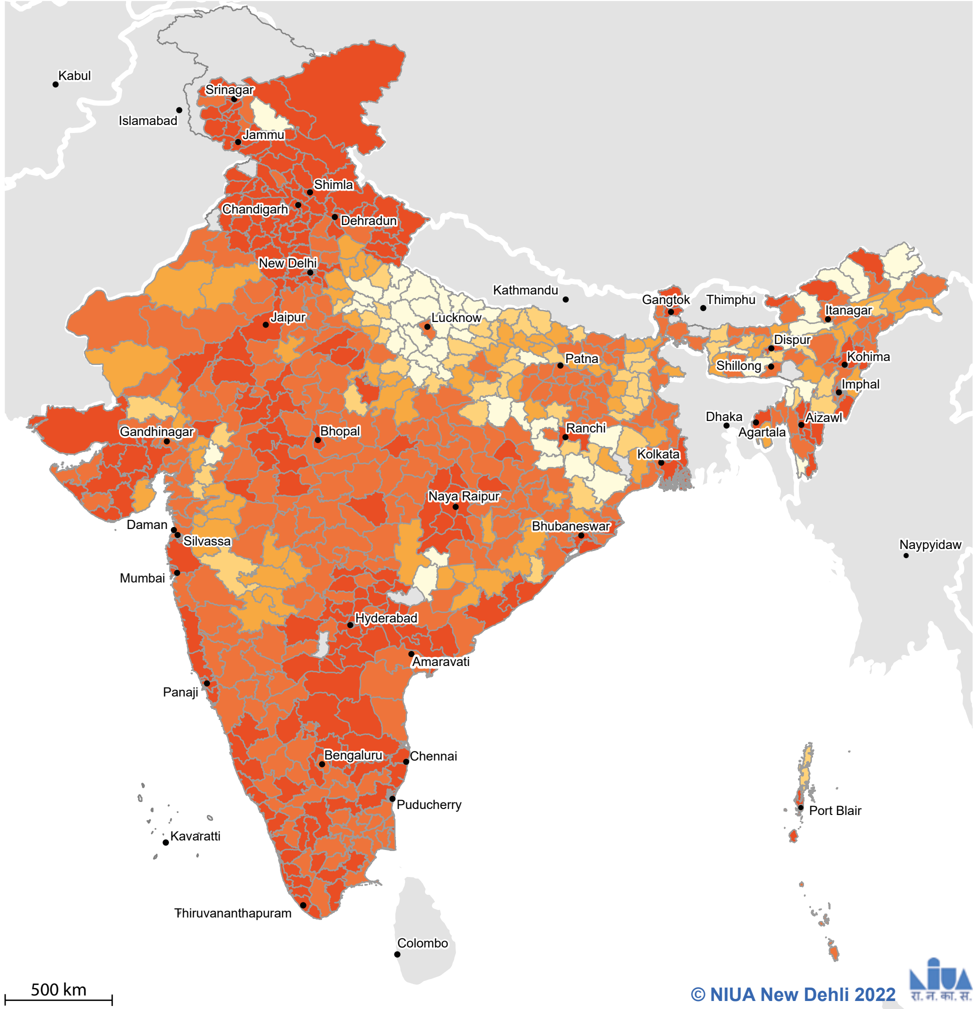
Access to electricity

India has made substantial progress in terms of access to electricity for domestic use. As per the National Family Health Survey 4 (NFHS-4) (2015–2016) and 5 (NFHS-5) (2019–2021) India has seen a steady rise in the percentage of households with access to electricity, from 88.2 % in 2015–2016 to 96.5 % in 2019–2021. Goa is the state showing the highest percentage of households with a hundred per cent coverage of access to electricity in 2019–2021, followed by Punjab (99.6 %), Haryana (99.5 %) and Kerala (99.5 %). On the other side of the spectrum, Uttar Pradesh ranks last amongst the 28 states of India.

Out of 28 states, 7 – namely Arunachal Pradesh, Assam, Bihar, Jharkhand, Meghalaya, Odisha and Uttar Pradesh – are below the national average of providing electricity facilities to households. Among the union territories, Delhi shows with 99.9 % the highest household access share amongst the union territories while Andaman & Nicobar Islands shows the lowest (97.4 %). In each of the 8 union territories there are more households with access to electricity than nationwide.

Out of the 707 districts included in the NFHS-5, being spread across 28 states and 8 union territories, 488 districts show a larger share of households with electricity facilities than the national average and 291 a smaller share. The districts with a hundred per cent coverage of access to electricity are noted in 18 districts spread across Delhi, Goa, Haryana, Himachal Pradesh, Jammu & Kashmir, Kerala, Madhya Pradesh, Mizoram, Punjab and Telangana. The majority of the districts in Haryana, Jammu & Kashmir, Ladakh and Punjab have an almost universal access to electricity at their disposal (99 % and above). In 13 districts throughout all states, less than 80 % of all households have access to electric power – with Sitapur in Uttar Pradesh showing the lowest percentage value. Around 20 districts in central Uttar Pradesh are home to households with less than 90 % access to electricity. All districts of the union territories – except 2 districts – show a higher share of households being able to access electricity than the national average.

Figure 1.A **Proportion of population (households) with access to electricity in India**



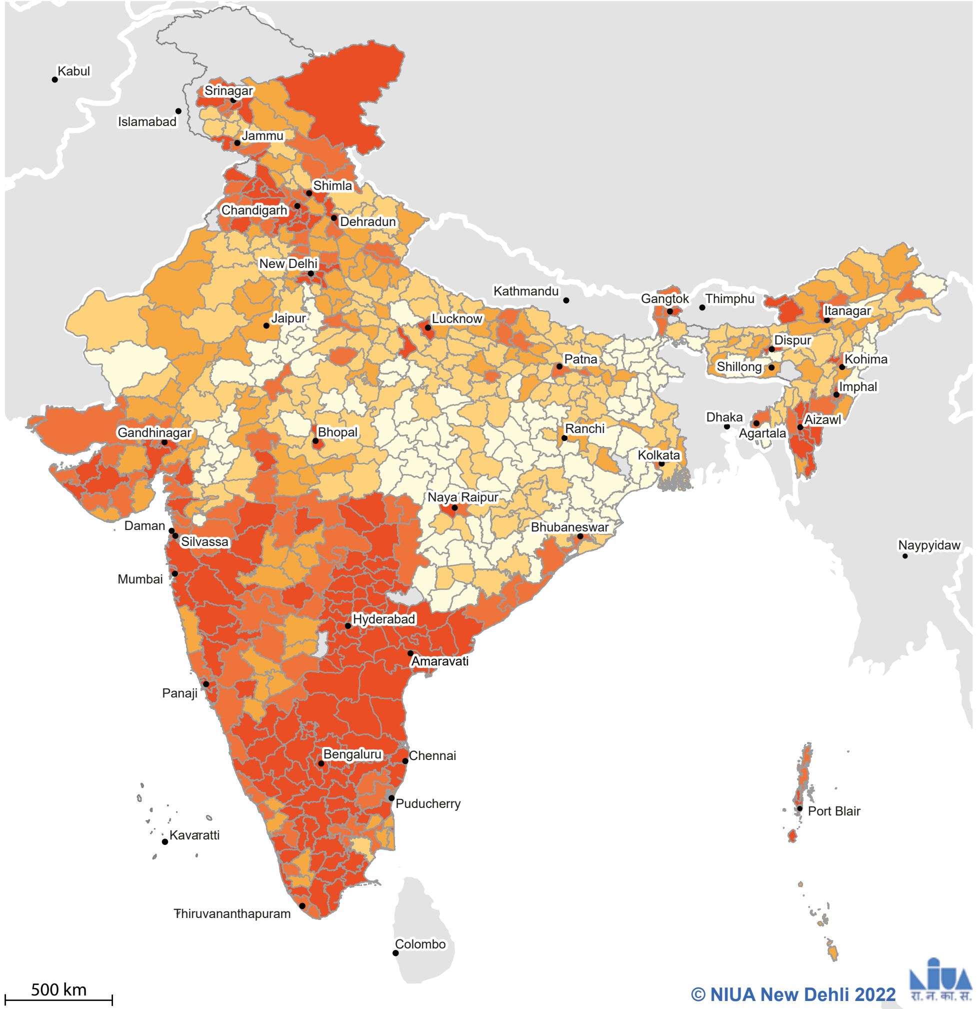
Share of households with access to electricity in %, 2019–2021

- up to below 90
- 90 up to below 94
- 94 up to below 96
- 96 up to below 99
- 99 and more
- no data

Data source: National Family Health Survey 5, 2019–2021
Geometric basis: ESRI data & maps, districts, states, union territories
Author: NIUA Team

Disclaimer: The information on this map has been created with the highest degree of accuracy possible. However, NIUA cannot be held responsible for errors, omissions or positional accuracy. The depiction of boundaries is not authoritative.

Figure 2.A **Proportion of population with primary reliance on clean fuels and technology in India**



Share of households using clean cooking fuel in %, 2019–2021

- up to below 30
- 30 up to below 45
- 45 up to below 60
- 60 up to below 75
- 75 and more
- no data

Data source: National Family Health Survey 5, 2019–2021
Geometric basis: ESRI data & maps, districts, states, union territories
Author: NIUA Team

Disclaimer: The information on this map has been created with the highest degree of accuracy possible. However, NIUA cannot be held responsible for errors, omissions or positional accuracy. The depiction of boundaries is not authoritative.

Clean cooking fuels cover in India piped gas, Liquefied Petroleum Gas (LPG) / canned gas and electricity, as these types of fuels do not cause indoor pollution. They are of central significance for India with regard to SDG 7. NFHS-4 (2015–2016) and NFHS-5 (2019–2021) also provide information on households and their access to different types of cooking fuels. As per NFHS-4 and NFHS-5, there is in India a rise in households using clean cooking fuels, from 43.8 % in 2015–2016 to 58.3 % in 2019–2021. However, the number of households using clean energy varies significantly between the states. Taking them as examples, Goa (96.5 %), Telangana (91.7 %) and Mizoram (83.6 %) are those states out of 28 with the highest shares of respective households, whereas Chhattisgarh (32.7 %), Meghalaya (32.2 %) and Jharkhand (31.6 %) are the ones with the lowest shares.

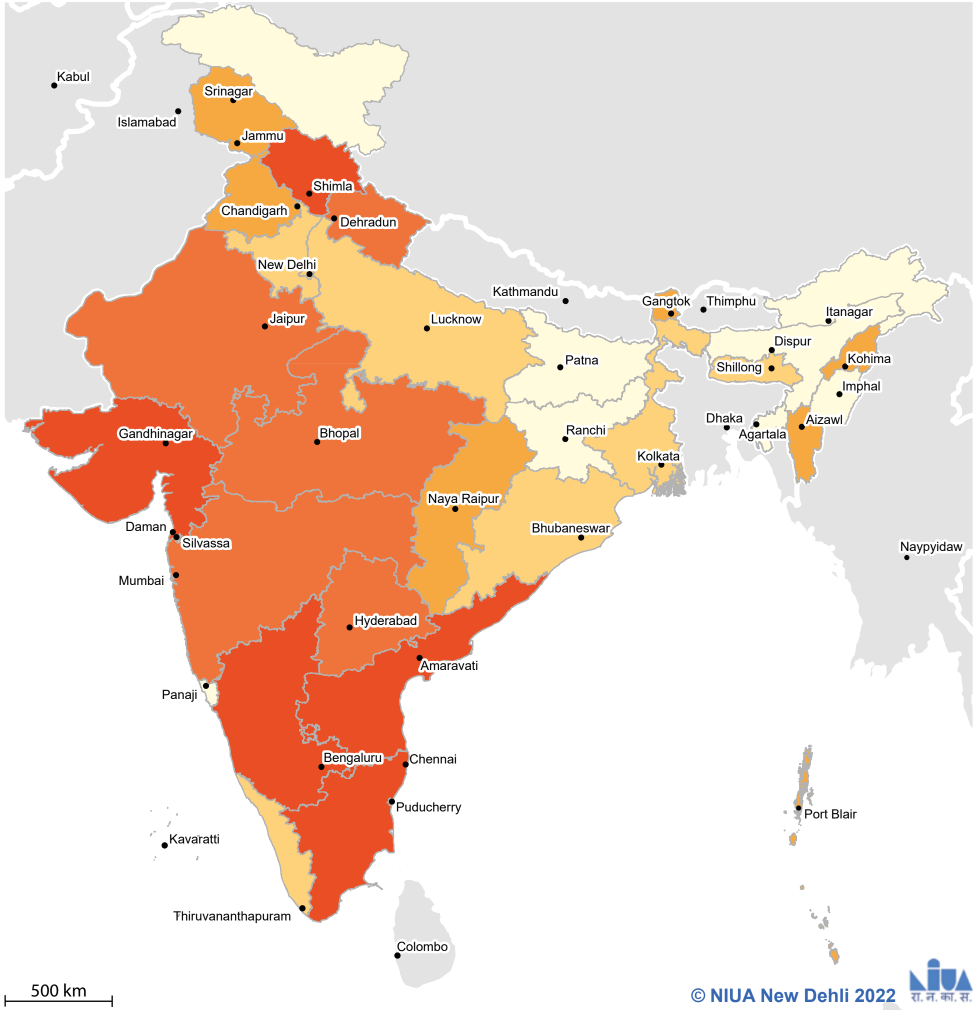
The performance of households in India using clean fuels was unsatisfactory in 2019–2021, given the target set by SDG 7. Only 50 % of all 28 states perform better than at national average. In contrast, all 8 union territories show figures of households using clean fuels for cooking purposes that are above the national average. Amongst the union territories, it is Delhi that experiences with 98.9 % the highest and Lakshadweep with 58.8 % the lowest share of households using clean cooking fuels. In states, such as Andhra Pradesh, Karnataka, Kerala, Maharashtra, Manipur, Punjab, Sikkim and Tamil Nadu, the shares of such households lie between 70 % and 86 %. In states, like Arunachal Pradesh, Gujarat, Haryana, Himachal Pradesh and Uttarakhand, the shares vary between 50 % and below 70 %. In 7 states, i.e. Assam, Madhya Pradesh, Nagaland, Rajasthan, Tripura, Uttar Pradesh and West Bengal, the range lies between 40 % and below 50 %.

Similar to the situation on state level, there are also significant variations across the districts of the country in households using cooking fuels. Out of all 707 districts as part of the National Family Health Survey 5 (NFHS-5) (2019–2021), 257 districts of all 28 states and 35 districts of all 8 union territories lie above the national average in the use of clean fuels for cooking purposes by households. Amongst all districts of all states, Hyderabad in Telangana holds the first rank with 99.3 %, whereas the last rank is taken by West Khasi Hills in Meghalaya, where only 8.6 % of all households use clean fuels for cooking purposes. Amongst the districts of all union territories, the span ranges from 34.6 % in Reasi in Jammu & Kashmir to around 100 % in Shahdara and North West in Delhi. Amongst all 707 districts, in only 61 districts 90 % of the households use clean cooking fuels. Less than 50 % of all households do so in 352 districts.

As a signatory country of the Paris Agreement, India committed itself to increase the generation of its electricity power from non-fossil fuels. In that respect, the country undertakes various large-scale sustainable power projects and promote green energies. It has focused so far on solar, wind and hydro. It is worth noticing that India increased its capacity of generating electricity from various non-renewable energy sources between 2014 and 2021 by 250 % (cf. Government of India 2022a). India generated in 2020 a total of 144 Terawatt hours (TWh) electricity power from renewable energy sources. In terms of per capita energy generation from various renewable energy sources, the country produced that very year 107.4 Gigawatt hours (GWh) of renewables per one million people.

However, the per capita generation of renewable energy varies widely across the states of India. Only 9 states, i.e. Andhra Pradesh, Gujarat, Himachal Pradesh, Karnataka, Maharashtra, Rajasthan, Tamil Nadu, Telangana and Uttarakhand, lie above the national average of renewable energy generation per one million people. They are the major contributors to the renewable energy sector. The per capita generation of electricity from various renewable energy sources is the highest in Karnataka (392.2 GWh per one million people), followed by Himachal Pradesh (295.6 GWh), Tamil Nadu (287.9 GWh), Gujarat (279.7 GWh), Andhra Pradesh (267.4 GWh), Rajasthan (188.1 GWh) and Telangana (183.3 GWh per one million people). Most states in the South of India may rely on a large solar energy potential – a topic yet to be explored in its urban and spatial relevance.

Figure 3.A **Per capita generation of renewable electricity in India**



Annual generation of renewable electricity in GWh per 1 million inhabitants, 2019–2021

- up to below 10
- 10 up to below 30
- 30 up to below 100
- 100 up to below 200
- 200 and more
- no data

Data source: National Family Health Survey 5, 2019–2021
Geometric basis: ESRI data & maps, districts, states, union territories
Author: NIUA Team

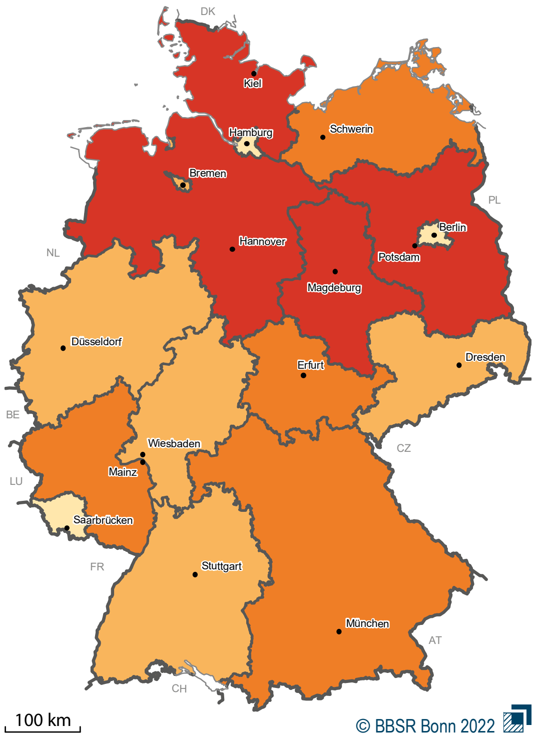
Disclaimer: The information on this map has been created with the highest degree of accuracy possible. However, NIUA cannot be held responsible for errors, omissions or positional accuracy. The depiction of boundaries is not authoritative.

The Renewable Energy Law (EEG – Erneuerbare-Energien-Gesetz) came into force in 2000, building upon its predecessor, the Electricity Feed Act of 1991 (StrEG – Stromeinspeisungsgesetz). Grid operators are thus obliged to give priority to feeding in energy from renewable sources. Based on numerous amendments to the EEG, the expansion targets have been raised continuously – from 65 % by 2030 in 2017 to 100 % by 2050 as the latest one.

The national average of renewable electricity generation is 2,740 GWh per one million inhabitants. The Länder in the northern part of Germany generate the most of renewable electricity per capita, deriving mainly from wind power. In those of the southern part of the country electricity generation from photovoltaic dominates. The city states of Germany – Berlin, Bremen and Hamburg – produce relatively small amounts of electricity, on the one hand. On the other hand, North Rhine-Westphalia, Saarland and Saxony still generate a lot of electricity from conventional, non-renewable sources. Data and information on the generation of electricity on the municipal and county level are not available.

With the amount of renewable energy generated, Germany belongs to the group of main producers of renewable electricity per capita in Europe. Only the Nordic and Alpine Countries, where hydropower and geothermal power determine the generation of renewables, surpass in fact Germany. Iceland and Norway are with 52,520 and 28,231 GWh per one million inhabitants respectively of produced renewable electricity per one million inhabitants at the one end of the spectrum, Malta and Hungary with 460 and 354 GWh respectively at the other end.

Figure 3.B **Per capita generation of renewable electricity in Germany**

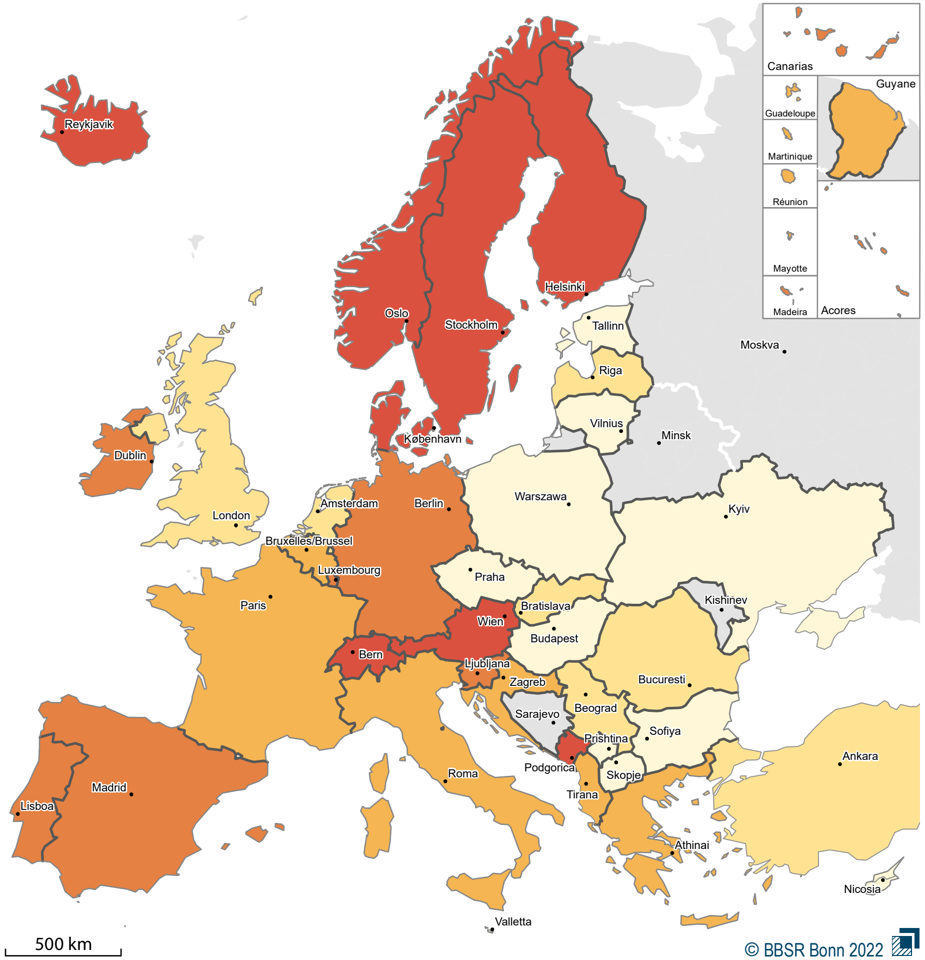


Generation of renewable electricity in GWh per 1 million inhabitants, 2019

- up to below 1,000
- 1,000 up to below 2,000
- 2,000 up to below 5,000
- 5,000 and more

Data source: Spatial Monitoring System of the BBSR
Data origin: Environmental-economic accounts of the Länder
Geometric basis: VG5000 (Länder), 31.12.2020 © GeoBasis-DE/BKG
Author: A. Milbert

Figure 3.C **Per capita generation of renewable electricity in Europe**



Annual generation of renewable electricity in GWh per 1 million inhabitants, 2020

- up to below 1,000
- 1,000 up to below 1,600
- 1,600 up to below 2,200
- 2,200 up to below 2,800
- 2,800 and more
- no data

Data source: Spatial Monitoring for Europe
Data origin: Eurostat
Geometric basis: GfK GeoMarketing, NUTS 0 regions
Author: L. Kiel

Installed off-grid/decentralised renewable energy systems

The transition to clean energy production constitutes a great economic opportunity. Due to its geography, India is particularly well placed to become a global leader in utilising renewable energy to meeting its energy demands while accelerating its economic growth. India's energy transition needs to benefits its citizens; well-designed policies and programmes may limit the potential trade-offs between affordability, security and sustainability.

In addition to signing the Paris Agreement, India committed itself to move towards zero emissions by 2070 and meet approximately half of its energy requirement by using renewable energy sources. Given the size of its population and its rapidly growing economy, it may be assumed that the country's demand for energy would increase at a respective high rate.

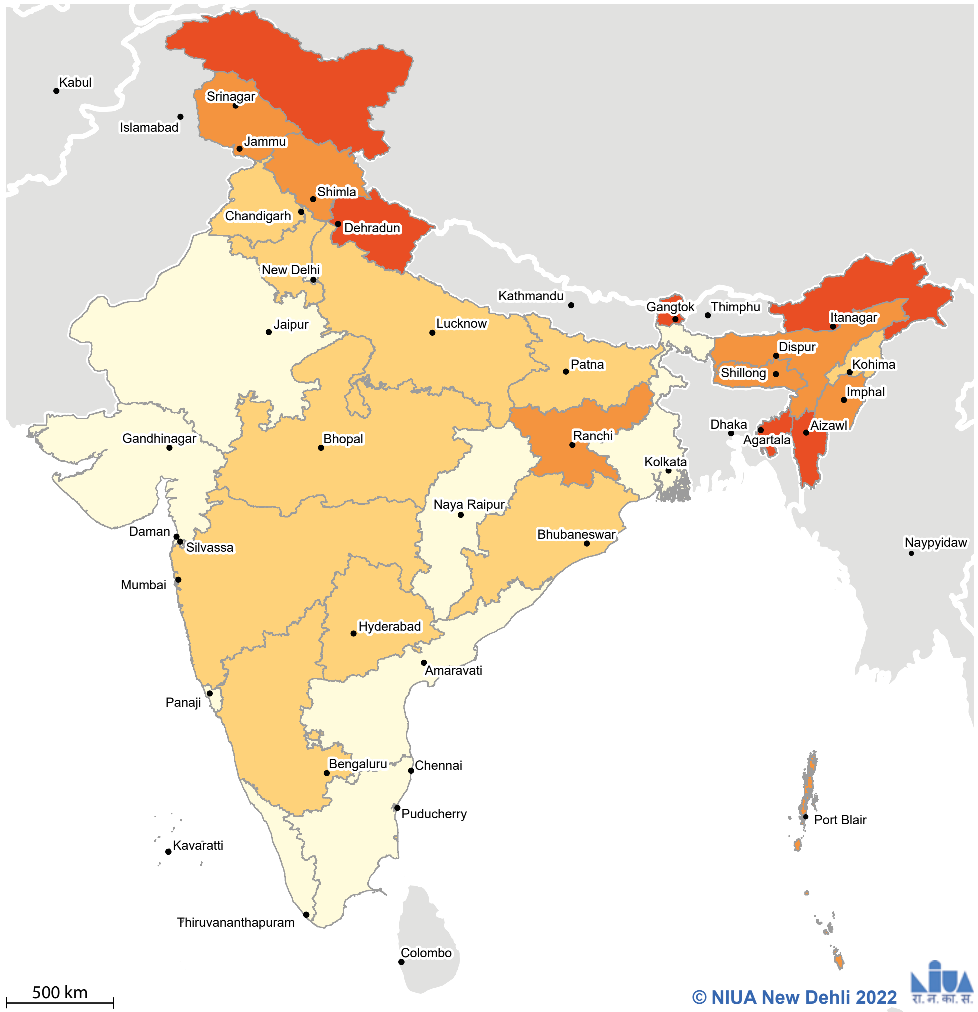
India's energy mix has experienced a shift from more conventional energy sources to renewable ones. Despite some serious downfalls, the installed capacity of renewable energy systems, excluding hydropower, grew at a rate of 8.5 % in 2021 compared to 2020. Thermal power increased only at a rate of 1.8 % that very year.

The United Nations Economic and Social Commission for Asia and the Pacific (UN ESCAP) defines a decentralised energy system by locating energy producing facilities closer to the respective energy consumers (UN ESCAP 2012). A decentralised energy system allows a more optimal use of renewables in the same way as it combines better heat and power generation, reduces the use of fossil fuels and increase eco-efficiency. Due to declining installation costs and an increasing performance, off-grid/decentralised renewable energy systems could become an important growth market for deploying renewables in the future – particularly in developing countries (cf. IRENA 2013). Kumar Chaurasiya, Warudkar and Ahmed (2019) extensively screened the country's potential of wind power. Deshmukh, Wu, Callaway and Phadke (2019) deal with geospatially relevant issues of wind power.

Considering off-grid/decentralised renewable energy systems, India shows a steady growth over longer time periods. According to estimates carried out by the Ministry of Statistics and Programme Implementation of the Government of India, the installation of solar-based Street Lightening Systems (SLSs) experienced a growth rate of 16 % in 2022 and the one of Solar Photovoltaic Plants (SPVs) registered a growth rate of 12 % (Government of India 2022b).

However, large inter-state variations exist. Whereas in some states in Northeast India,

Figure 4.A **Installation of off-grid/decentralised renewable energy systems and devices in India**



Number of installed off-grid/decentralised renewable energy systems and devices per 1,000 inhabitants, 2020

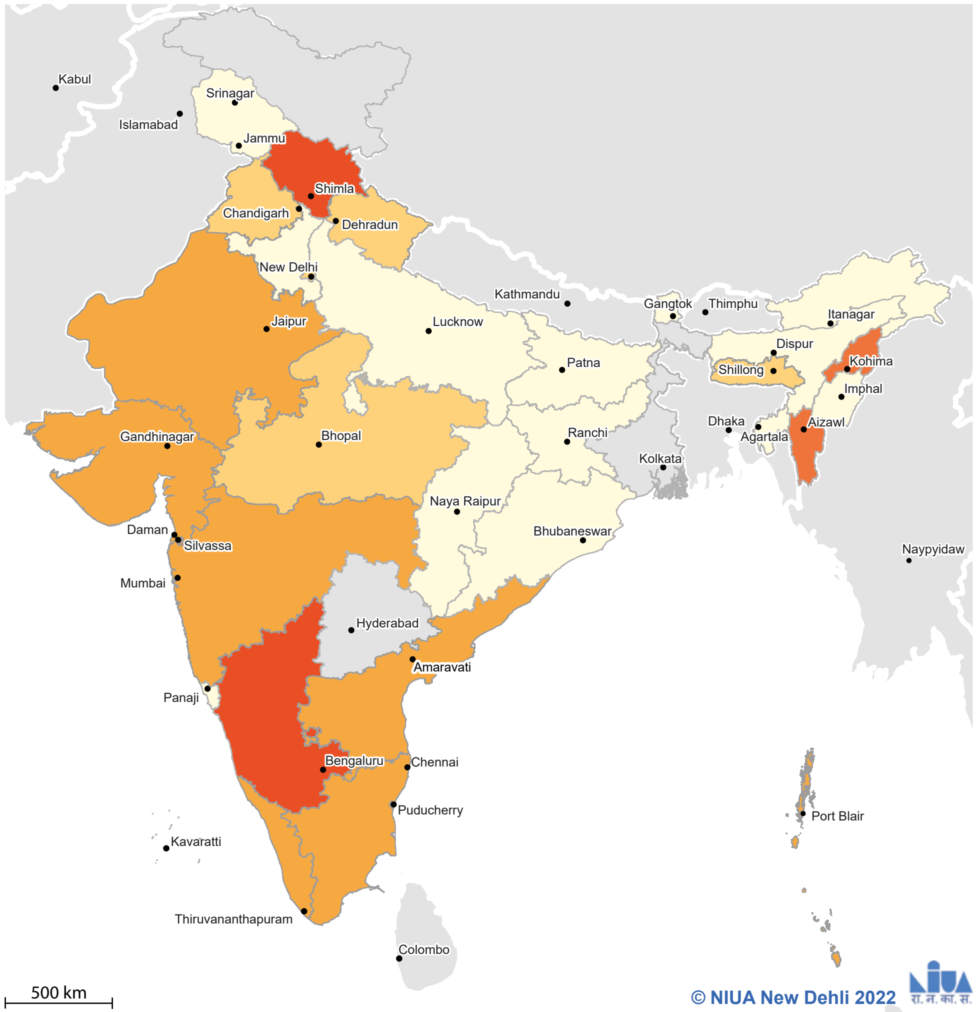
- up to below 8
- 8 up to below 16
- 16 up to below 32
- 32 and more
- no data

Data source: Energy Statistics India 2020
Ministry of New and Renewable Energy
Ministry of Health and Family Welfare
Geometric basis: ESRI data & maps, districts, states, union territories
Author: NIUA Team

Disclaimer: The information on this map has been created with the highest degree of accuracy possible. However, NIUA cannot be held responsible for errors, omissions or positional accuracy. The depiction of boundaries is not authoritative.

Figure 5.A

Renewable energy share in total energy generation in India



Share of Wh of renewable electricity in the total electricity generation in %, 2020

- up to below 4
- 4 up to below 10
- 10 up to below 20
- 20 up to below 30
- 30 and more
- no data

Data source: India Energy Dashboard 2020, NITI Aayog
Geometric basis: ESRI data & maps, districts, states, union territories
Author: NIUA Team

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like Arunachal Pradesh and Mizoram, where 117 and 112 such systems have been installed per one thousand people so far, in other states and union territories, like Chhattisgarh, Delhi and West Bengal, below 5 such systems are in place. The higher number of off-grid/decentralised renewable energy systems installed in the northeastern states refers mainly to SPVs, such as street lights, home light systems, solar lanterns and power plants. Largest states, like Gujarat, Kerala and Rajasthan, still show very low numbers of off-grid/decentralised renewable energy systems installed per one thousand people.

As a signatory country of the Paris Agreement, India committed itself to generate 50 % of its total electricity consumed from non-fossil fuels as its Intended Nationally Determined Contribution by 2030. The India Energy Dashboards provided by NITI Aayog (2020) compile energy statistics from various sources in the country. Although this sub-goal of SDG 7 is about energy consumption, the figure refers to generation data, due to the unavailability of respective data for the entire country. In 2020, 73.9 % of the total electricity generation were based on coal. Along with a share in large-scale hydro (9.6 %), natural gas (4.8 %) and nuclear power (2.9 %), only 8.8 % derived from renewable energy sources, including solar, wind, biomass, waste and small-scale hydro (cf. NITI Aayog 2020).

The share of renewable energy sources in generating electricity varies widely across all states and union territories. 15 states and union territories have generated so far a larger portion of their electricity from renewable sources. It is worth noticing that Lakshadweep hits the 100 % mark of electricity generation based on renewables. Daman & Diu (97.8 %) and Chandigarh (88.7 %) follow in this row of union territories. Considering all states, the highest share can be found in Himachal Pradesh (41.5 %), Karnataka (36.2 %), Nagaland (28.6 %) and Mizoram (21.8 %). Rajasthan generates 17.4 % of its total electricity from renewable sources.

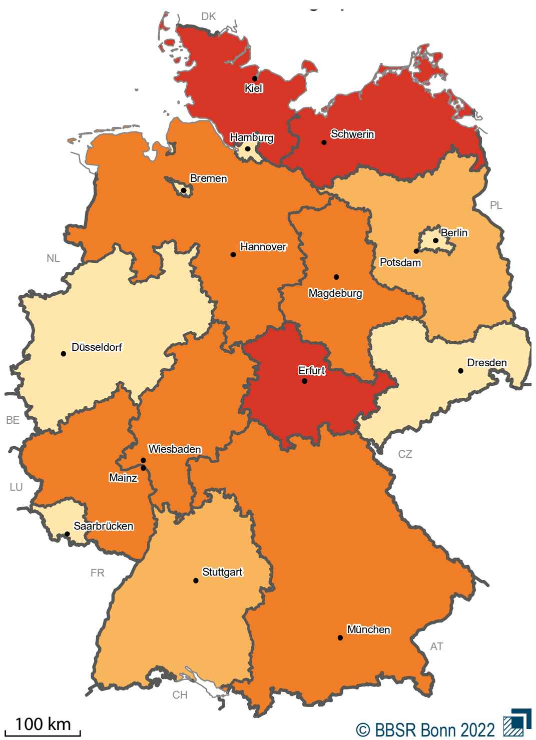
On the other side of the spectrum are Goa, Arunachal Pradesh, Jharkhand, Sikkim, Tripura, Chhattisgarh, Bihar, Odisha and Manipur (0 % up to maximum 1.1 %) – all shares negligible with regard to generating electricity from renewables. All those states, except for Bihar, may rely on a large hydropower potential. An exploration of this alternative energy potential seems appropriate.

Almost 20 % of the total energy consumption in Germany in 2021 derives from renewable energy. Households use the largest part of their energy demand for heating purposes, of which around 16 % are renewables-based. In contrast to that, the share of renewables in electricity consumption is 41 % and in electricity generation 51 %, thus surpassing the non-renewables (cf. BDEW 2022).

In those Länder with a higher share of electricity generation deriving from renewable energy, the electricity consumption is also linked on a higher proportion of renewables. Here again, the Länder in the northern part of Germany are the leading ones in energy transition. In Mecklenburg-West Pomerania, for instance, 80 % of the electricity generated derived already in 2019 from renewables and around 42 % with regard to the consumption of energy (cf. Statistical Offices of the Federal Level and the Länder; own estimations; see Figure 5.B).

Directly comparing the situation in India, Germany and Europe and thus showing regional differences is also possible based on data and information related to renewable electricity generation.

Figure 5.B **Renewable energy share in total energy generation in Germany**

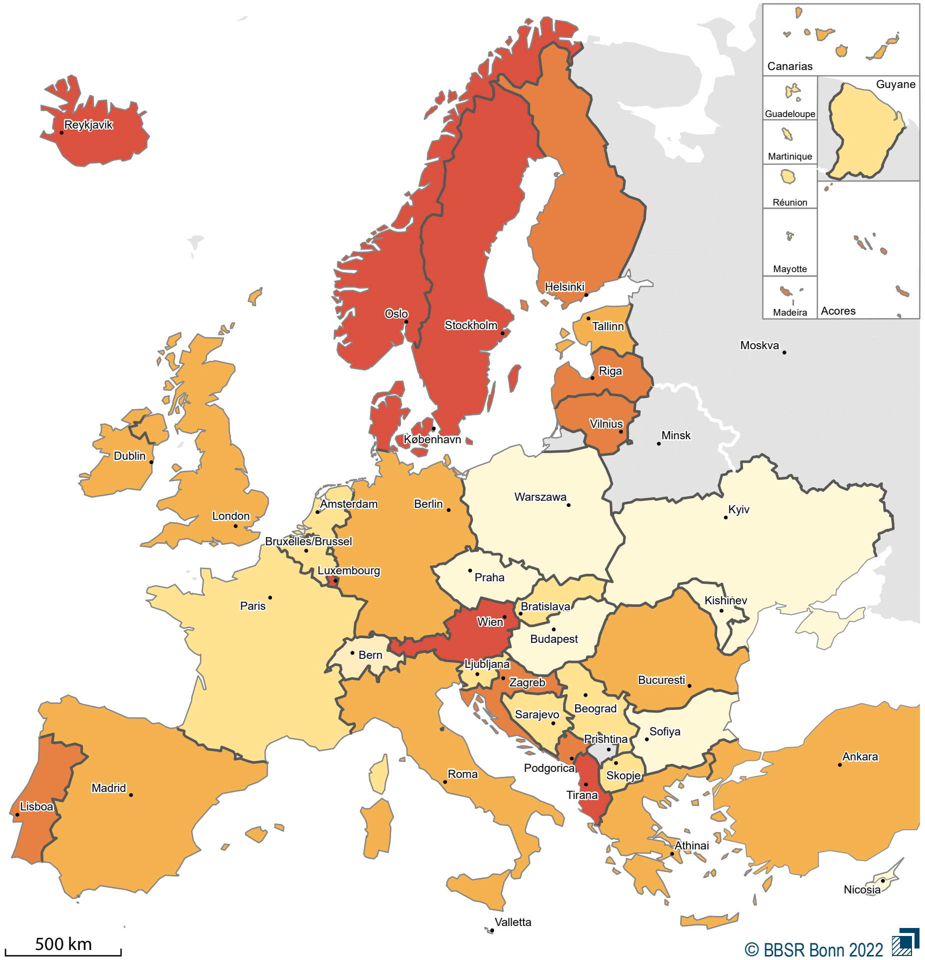


Share of the generated renewable electricity in the total generated electricity in %, 2019

- up to below 20
- 20 up to below 40
- 40 up to below 60
- 60 and more

Data source: Spatial Monitoring System of the BBSR
Data origin: Environmental-economic accounts of the Länder
Geometric basis: VG5000 (Länder), 31.12.2020 © GeoBasis-DE/BKG
Author: A. Milbert

Figure 5.C **Renewable energy share in total energy generation in Europe**



Share of the renewable energy sources in the electricity generation in %, 2020

- up to below 20
- 20 up to below 35
- 35 up to below 50
- 50 up to below 65
- 65 and more
- no data

Data source: Spatial Monitoring for Europe
Data origin: Eurostat
Geometric basis: GfK GeoMarketing, NUTS 0 regions
Author: L. Kiel

39 % of the generated electricity in Europe derives from renewable sources. Leading countries with up to 99 % in Iceland are the Nordic Countries and – as an Alpine States – Austria, mainly relying on hydropower. Spain and Germany rank with 45 % each (based on data reported by EUROSTAT in 2020) above average, whereas the Netherlands and Belgium are placed with 27 % each well below average as France with 24 % does.

Germany takes up with a share of 20 % renewables in the total energy consumption a place below the EU27 average of 23 %. Considering only the electricity consumption, the average share of renewables in the 27 EU Member States sums up to 37 %. In that respect, Austria and Sweden head the list with 78 % and 74 % respectively. Hungary and Malta are with 12 % and 9 % respectively at the end of the spectrum.

Energy intensity

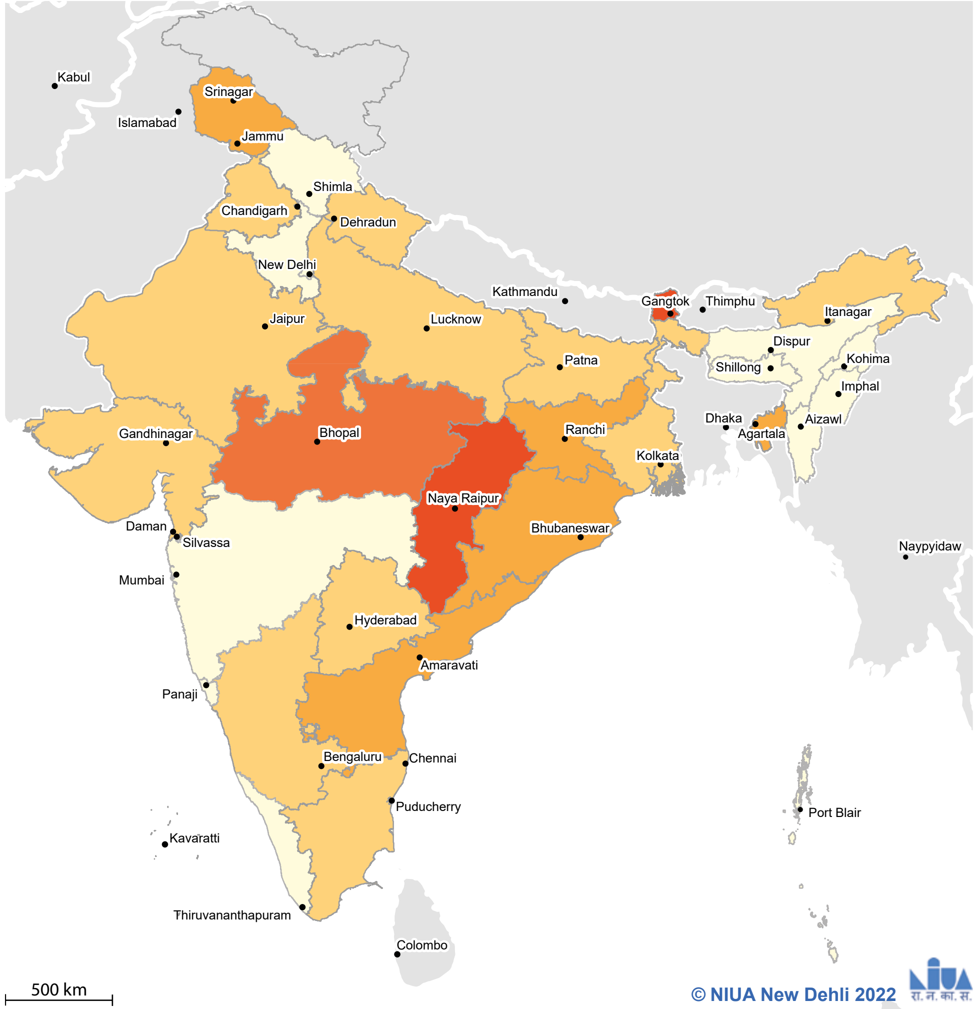
In India, energy generation per unit of the country's State Domestic Product (SDP) may only be estimated, due to the unavailability of respective data on district level. While high levels of generating energy indicate high prices or costs of transforming energy to SDP, low levels indicate reduced prices or costs. A low energy level thus represents a proxy for improving the efficiency in energy use.

8.1 GWh of electricity are generated on average in India per SDP unit. 13 states, i.e. Andhra Pradesh, Arunachal Pradesh, Chhattisgarh, Gujarat, Jammu & Kashmir, Jharkhand, Madhya Pradesh, Odisha, Rajasthan, Sikkim, Tripura, Uttar Pradesh and West Bengal, generate more electricity per SDP unit than the national average.

Chhattisgarh produces with 48.9 GWh the highest amount of GWh per SDP unit. States, such as Assam and Mizoram, only generate 1 GWh; others, like Delhi, Kerala, Nagaland and Manipur, produce between 1 and 2 GWh. The span lies in Haryana, Himachal Pradesh, Meghalaya and Maharashtra between 3 and 5 GWh, in Bihar, Karnataka, Punjab, Tamil Nadu, Telangana and Uttarakhand between 5 and 8 GWh. Arunachal Pradesh, Gujarat, Rajasthan, Uttar Pradesh and West Bengal generate more GWh than the national average, although their figures clearly do not exceed the mark of 10 GWh. Those states above this mark and between 10 and 21 GWh are Andhra Pradesh, Jammu & Kashmir, Jharkhand, Madhya Pradesh, Odisha and Tripura.

Figure 6.A

Energy intensity in India



Gross annual electricity generation in GWh per unit of State Domestic Product (SIP, in Euro), 2020

- up to below 5
- 5 up to below 10
- 10 up to below 15
- 15 up to below 20
- 20 and more
- no data

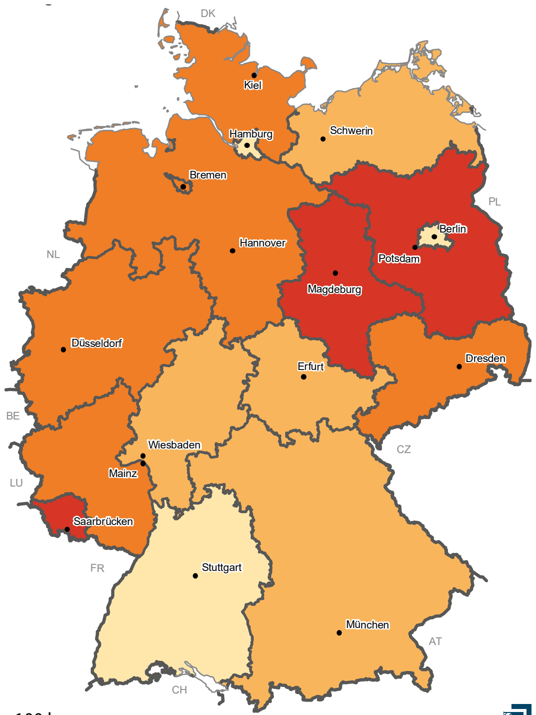
Data source: India Energy Daschboard 2020, NITI Aayog
Geometric basis: ESRI data & maps, districts, states, union territories
Author: NIUA Team

Disclaimer: The information on this map has been created with the highest degree of accuracy possible. However, NIUA cannot be held responsible for errors, omissions or positional accuracy. The depiction of boundaries is not authoritative.

The environmental economic accounts apply energy productivity, i.e. the Gross Domestic Product (GDP) generated per unit of primary energy used (cf. Destatis n. d.). The term 'energy intensity' as central notion of SDG 7.3.1 reverses this ratio and quantifies the use of energy per unit of GDP generated (in Germany additionally referring to 1 million Euro). This implies that the less energy is applied to generate wealth, the more sustainable a regional economy is.

Households account for 29 % of energy consumption, industry and transport for almost 28 % each and trade, commerce and services for about 15 %. The differences becoming obvious in energy intensity are primarily related to the very large regional discrepancies of the GDP, particularly generated between West and East Germany. The respective reasons in the eastern part of Germany are the lack of large companies and company headquarters there, a lower proportion of industrial companies and (as a result) company-oriented services as well as lower average salaries in many sectors. The discrepancies might also be explained by the different industrial structures in the Länder, i.e. the spatial distribution of energy-intensive industries such as mining, quarrying, metal processing and chemical product manufacturing (cf. BMWi 2020).

Figure 6.B **Energy intensity in Germany**

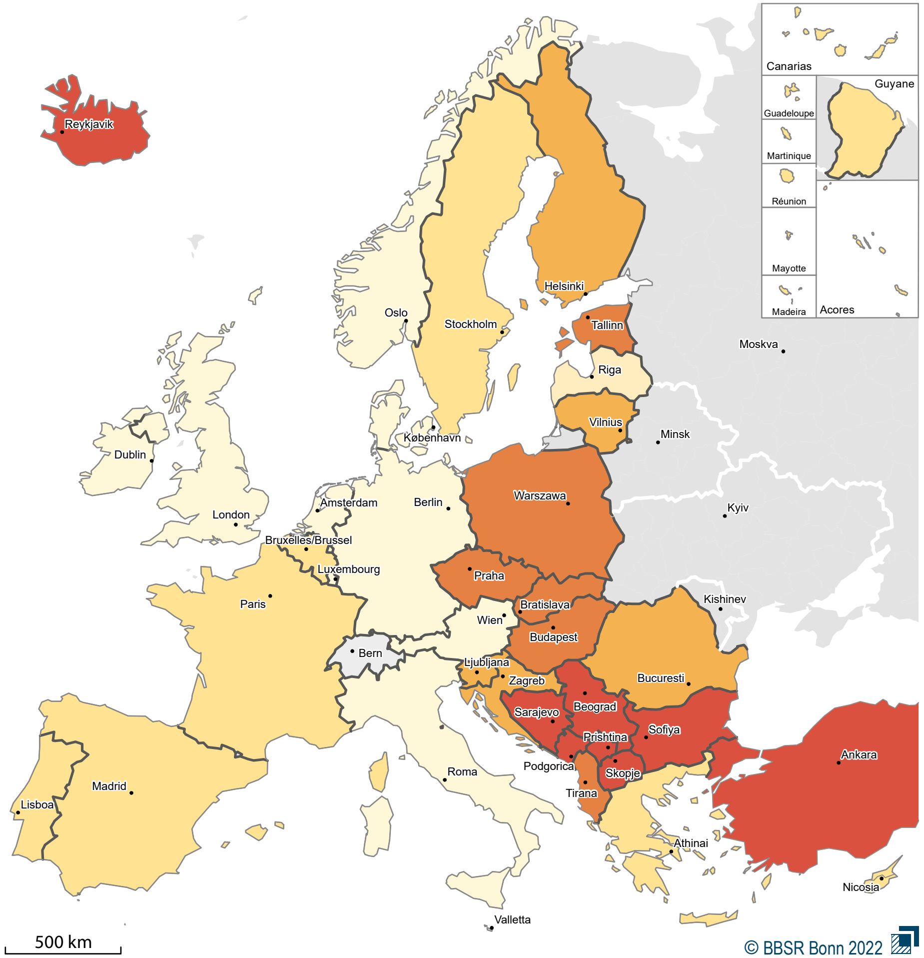


Consumption of primary energy GWh per 1 million Euro of Gross Domestic Product (GDP), 2019

- up to below 0.8
- 0.8 up to below 1.2
- 1.2 up to below 1.6
- 1.6 and more

Data source: Spatial Monitoring System of the BBSR
Data origin: Environmental-economic accounts of the Länder
Geometric basis: VG5000 (Länder), 31.12.2020 © GeoBasis-DE/BKG
Author: A. Milbert

Figure 6.C **Energy intensity in Europe**



Consumption of primary energy in GWh per 1 million Euro of Gross Domestic Product (GDP), 2020 (UK: 2019)

- up to below 1.0
- 1.0 up to below 1.4
- 1.4 up to below 1.8
- 1.8 up to below 2.2
- 2.2 and more
- no data

Data source: Spatial Monitoring for Europe
Data origin: Eurostat
Geometric basis: GfK GeoMarketing, NUTS 0 regions
Author: L. Kiel

Analysing the ratio of the energy consumption related to the GDP in Europe spatially splits the continent almost into 3 parts: Countries in the East show the highest rates of energy consumption in relation to their economic output. The second split covers countries in the West, like France and Spain, and those in the North. Mid-European countries, like for example Germany but also Italy, Norway and the United Kingdom, shape the third split, due to their lowest ratio values.

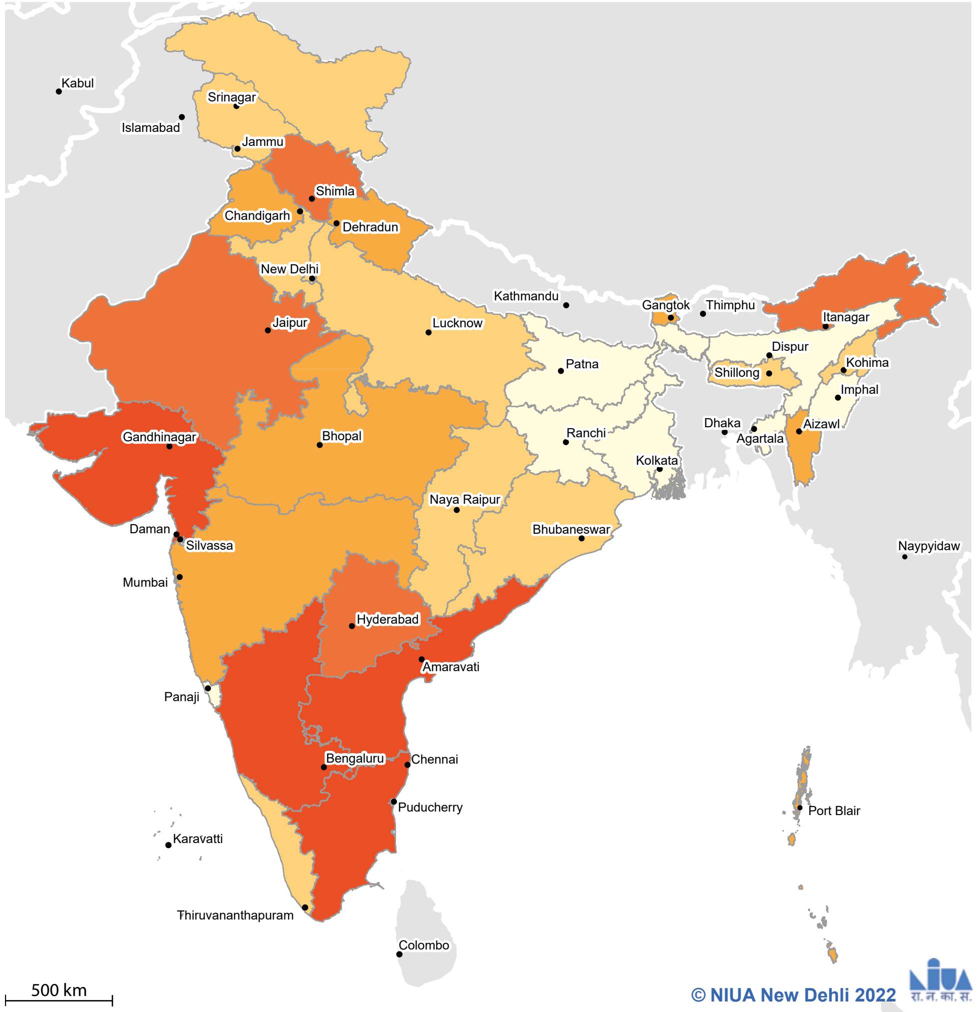
Installed renewable energy generating capacity

Give the population size of India with 1.3 billion people at present, its climate adaptation and mitigation ambitions will not only be transformational for the country but also for the entire planet. India has given a thrust of concerted actions to increase its capacity installed for generating renewable energy power. It remains to be seen to which extent its potential will finally be transformed into a real-life capacity. The ambitious target is set to achieve a capacity of 175 GWh of renewable energy by the end of 2022 and 500 GWh by 2030 (Government of India 2022b). This constitutes the world's largest expansion plan for renewable energy. The Ministry of Statistics and Programme Implementation of the Government of India provides respective data in an integrated manner at state level.

The geographical distribution of electricity generating capacity installed as per 2020 indicates that states in West India account for the largest share (35 %), followed by states in South India (28 %) and North India (25 %). States in the northern part of the country also show the largest share of generating hydro energy. Karnataka is home to the largest hydro energy capacity installed (3.59 GWh per 1 million inhabitants); considering other renewable energy sources the amount there sums up to 15.46 GWh. Karnataka also shows the largest capacity installed of grid-connected renewable posts (15.23 MWh), closely followed by Tamil Nadu (14.35 MWh) – in both cases mainly because of wind and solar power. In Andhra Pradesh, Gujarat, Himachal Pradesh, Rajasthan and Telangana the capacity installed crosses the 100 MWh mark. Amongst all states, Telangana registers with 9 % the highest annual growth rate of capacity installed.

Looking back at the last 8 years, India has witnessed the fastest growth rate in renewable energy capacity installed (including hydro power) amongst all large economies – 1.97 times in general and 18 times with regard to solar energy alone. Sustaining this growth rate and the efficient conversion from non-renewable energy sources to renewable ones and thus meeting the country's energy demands requires that some of the challenges are met: possibly rising commodity prices, tight markets, increasing energy security risks, prevailing consumption habits of households with regard to traditional fuels and the financial ailing of electricity distributing companies.

Figure 7.A **Installed renewable energy generating capacity in India**



Renewable energy installed capacity (in MWh) per 1 million inhabitants, 2020

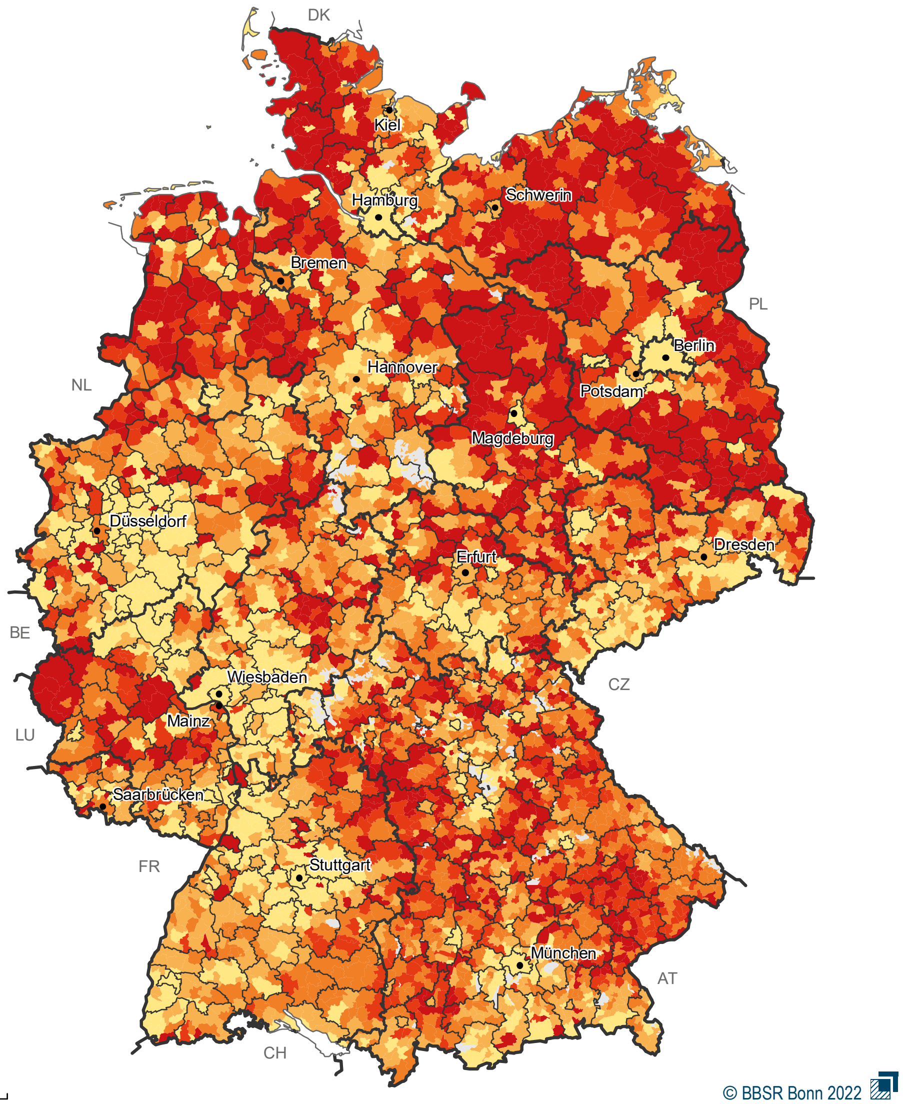
- up to below 10
- 10 up to below 20
- 20 up to below 80
- 80 up to below 140
- 140 and more
- no data

Data source: Energy Statistics India 2020
Ministry of New and Renewable Energy
Ministry of Health and Family Welfare (2020)
Geometric basis: ESRI data & maps, districts, states, union territories
Author: NIUA Team

Disclaimer: The information on this map has been created with the highest degree of accuracy possible. However, NIUA cannot be held responsible for errors, omissions or positional accuracy. The depiction of boundaries is not authoritative.

Figure 7.B

Installed renewable energy generating capacity in Germany



Renewable electricity installed capacity (in MWh) per 1 million inhabitants, 2022

- up to below 800
- 800 up to below 1,600
- 1,600 up to below 3,200
- 3,200 up to below 5,400
- 5,400 and more
- unincorporated and uninhabited areas

Data source: Spatial Monitoring System of the BBSR
Data origin: core energy market data register
Geometric basis: VG5000 (associations of municipalities), 31.12.2020 © GeoBasis-DE/BKG
Author: A. Milbert

More renewable energy has been installed so far per inhabitant in Germany in rural municipalities and smaller-sized towns of rural regions than in (large) urban environments. The potential of photovoltaic is not yet exploited in large cities – particularly on roofs of existing (old) buildings and planned (new) buildings (cf. Krippner 2019; Bergner/Siegel/Ewald 2021). The Renewable Energy Law 2023, coming into force on 1 January 2023, aims at easing this situation: consumers and civil energy associations shall be supported in installing photovoltaic panels on their rooftops in the same way as feeding in the grid the harvested solar electricity shall be paid at higher rates (cf. Bundesregierung 2022a).

Both, photovoltaic and wind power plants, can be installed on a larger scale in rural areas. Large offshore wind power plants exist in addition to onshore ones in the northern part of Germany. Besides, the topography of North Germany is more suitable for wind power than the mountain valleys and forests of its central and southern parts. It was in Bavaria first, where a distance regulation for wind turbines of at least 1000 metres away from any residential building was introduced in 2014, significantly curbing the enlargement of wind power (cf. Stede/May 2019). Other Länder, e.g. Saxony and Thuringia, followed the example of Bavaria and thus tightened their distance regulations.

The Federal Parliament of Germany thus passed the Wind on Land Act, which came into force on 1 February 2023 and obliges all Länder to reserve 1.7 % of their territory by 2027 for wind power and 2 % from 2032 onwards (Bundesregierung 2022b).

Conclusion

The joint publication is another milestone of the cooperation between BBSR and NIUA. Its underlying common understanding of analysing spatial structures as well as the collaboratively transcultural cooperation of both institutions show that the envisaged blueprint of joint spatial research in the area of urban and spatial development might be of added value for both, methodological approach and policy advice.

The joint analysis illustrates the spatial structures as defined by selected indicators of SDG 7 on Affordable and Clean Energy. It uses, in the large number of cases, the lowest common data level possible in India, Germany and Europe and develops also here a common visual language, partly with variations.

Some findings with regard to data availability and comparability may be revealed:

Considering the situation in India, a large number of government bodies are associated with the power sector in the country and entrusted with operational responsibilities to system operators at various levels. The Ministry of Power, the Central Electricity Authority and the Ministry of New and Renewable Energy are responsible for policy-making and planning.

Currently, the Electricity Act (2003) is the primary law regulating the electricity sector. 27 State Electricity Regulatory Commissions (SERCs) and the Central Electricity Regulatory Commission (CERCs) govern inter- and intra-state matters of generating, transmitting, trading and distributing power. One of the key roles attributed to the commissions is the approval of tariffs for the retail sale of electricity. SERCs exercise complete control over transmission, distribution and retail sale.

Spatially granular data at district level related to SDG 7 is only partially available in India. A large-scale sample survey, carried out in the framework of NFHS-5 (2019–2021), provides, in that respect, the latest data available at district level. It also provides data on city level on respective indicators, unfortunately for 8 cities only. Analysing the situation at city level thus remains challenging in the same way as overall data on the consumption of renewable energy at subnational level is hardly reliable. Energy Statistics, compiled by NITI Aayog, comprises data from various sources (All India Electricity and Energy Statistics), constituting the main available data banks at subnational level with reference to the respective states. Moreover, a dearth of spatially disaggregated data on generating renewable energy exists beyond state level – resulting in the biggest challenge of analysing in a spatial perspective the achievement of SDG 7.

The situation in Germany and Europe looks like the following: The Federal Network Agency for Electricity, Gas Telecommunication, Post and Railway (in German Bundesnetzagentur) is the highest regulatory authority in Germany with regard to so-called network markets. Founded in 1998, the agency is responsible for telecommunication networks and postal services and, since 2005, for the energy market (electricity and gas). The agency regulates the conditions applicable by electricity and gas suppliers to use the networks for the provision of their customers with energy. This includes the conclusion on fees guaranteeing fair consumer prices. The agency additionally monitors the transformation towards a sustainable energy supply. All electricity and gas suppliers, including micro-operators and private solar arrays, are thus obliged to report their installation to the agency. The respective data, gathered in the Core Energy Market Data Register (in German Marktstammdatenregister), is available free of charge for analytical purposes (cf. Bundesnetzagentur 2022). As far as installed capacities, differentiated by energy source, are concerned, this database provides a nationwide information basis, including georeferenced data on the respective operating location.

A supranational differentiation, with regard to energy and electricity generation and consumption, is only doable in Germany at the level of the Länder (NUTS 1). The reason is related to the fact that many different data sources have to be analysed in order to carry out energy balances (cf. Bayerisches Staatsministerium für Wirtschaft, Landesentwicklung und Energie 2022). Energy balances at the local level of municipalities may only be assembled on the basis of estimates (cf. Landeshauptstadt Düsseldorf 2018) or refer to buildings which the respective municipality owns (cf. Stadt Köln 2022).

Against this background may electricity generation be geographically located than electricity consumption. Indicators referring to consumption, yet being operationalised via electricity generation, would lead to misleading analytical findings. Energy intensity might serve as an example: If primary energy production is applied instead of consumption, imports of energy are not taken into account. Electricity consumption corresponds to more than 99 % of electricity production only in the case of renewable energy. Other energy sources, such as oil or black coal, are entirely imported (cf. UBA 2022).

SDG 7 uncovers, amongst all SDGs, the most dominant level differences between developed and developing countries as well as emerging economies. The energy generation and consumption differ significantly per capita or per unit of GDP or SDP. In Germany, every household can rely on a guaranteed access to energy in general and renewable energy in particular. The main characteristic of SDG 7.1.1 is thus narrowed down to the price. Energy poverty means being obliged to spend a disproportionate share of a household income on energy.

A note on the energy transition on the local level

Efforts of local authorities in the context of the energy transition cannot be illustrated comprehensively by data, due to non-existing comprehensive data banks, but by practices in most cases. Examples may refer herewith to self-sufficient communities and 'bioenergy communities' (cf. AEE n. d.). The first entirely self-sufficient community is Feldheim in Brandenburg (cf. Westermann-Gruppe n. d.). Amongst various labels, the one called 'bioenergy community' is awarded to municipalities covering at least 50 % of their electricity and heating needs with renewable energy (cf. LUBW n. d.).

The urban and spatial analysis started in 2019, continued between 2020 and 2022 and ends herewith in 2023, for the time being. This entire endeavour could not have been undertaken without the expertise of all authors involved. A sort description of their individual strengths characterises their respective inputs to this unique transcultural teamwork. Please find the persons (in alphabetic order) herewith:

Regine Binot, cartographer by education is a research assistant at BBSR.

Dr. Swastika Chakravorty, demographer by education is a research associate at NIUA.

Dr. Tania Debnath, social scientist by education specialised in labour economy is a post-doctoral fellow at NIUA.

Dr. Aparajita Ghatak, geographer by education specialised in GIS and remote sensing worked as a project manager at NIUA.

Dr. Biswajit Kar, social scientist by education specialised in the education sector worked as a post-doctoral fellow at NIUA.

Lukas Kiel, market and social research analyst by education is a research assistant at the BBSR.

Dr. Gautam Kumar Das, economist by education specialised in social inequality, labour economics, agriculture and rural development, is a researcher at NIUA.

Prof. Dr. Debolina Kundu, urban scientist by education is a professor and principal investigator at NIUA leading the scientific cooperation between NIUA and BBSR, coordinating projects with international agencies and chief-editing journals.

Rakesh Mishra, demographer by education specialised in econometrics worked as a researcher at NIUA.

Antonia Milbert, a horticultural engineer by training but a statistician by vocation focused in her research as principal investigator and senior adviser at the BBSR on indicator systems to monitor sustainable, gender-equal and equal regional living conditions as well as spatial typologies. From the beginning of 2023 onwards, she will be heading the division that monitors with the support of subjective and objective indicators the transformation of the lignite mining regions in Germany.

Dr. Biswajjit Mondal, geographer by education specialised in spatial analysis is a GIS expert at NIUA.

Dr. André Müller, an engineer and urban researcher and planner by education focuses as a principal investigator and senior adviser at the BBSR on the multi-level analysis of urban and spatial development in a national, European and global context, including place-sensitive financial instruments and purposeful projects.

Dr. Arvind Pandey, social scientist by education specialised in migration studies and social protection worked as a post-doctoral fellow at NIUA and now holds an assistant professorship at the School of Public Policy and Governance of the Tata Institute of Social Sciences.

Volker Schmidt-Seiwert, an applied geographer by education focused as principal investigator and senior adviser at the BBSR on European spatial monitoring, including GIS-based and statistical regional analysis, as well as the cartographic representation and visualisation of spatial structures and development. He retired at the end of 2022.

Dr. Krishna Surjya Das, economist by education specialised in labour studies worked as a researcher at NIUA.

NIUA wishes to acknowledge (also in alphabetic order) the contributions of

Aksheyta Gupta, geographer by education specialised in GIS worked as GIS expert at NIUA.

Nelson Mandela S, economist by education specialised in labour studies worked as a research fellow at NIUA.

Pragya Sharma, urban planner by education is a researcher and programme manager at NIUA.

T. C. Sharma, demographer by education is a data specialist at NIUA.

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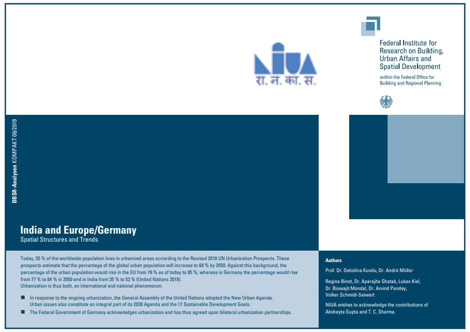

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Deichmanns Aue 31–37, 53179 Bonn

Coordination

Dr. André Müller
andre.mueller@bbr.bund.de
Antonia Milbert
antonia.milbert@bbr.bund.de

Editing

Marius Gaßmann

Typesetting and layout

Bettina Mehr-Kaus

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Information

The chapters of this publication visualise the spatial analysis of SDG 7. Alternating maps illustrate the spatial perspectives on SDG 7 in India, Germany and Europe by taking national as well as supranational views wherever feasible. The colour code used follows the choice of the United Nations, which assigned an orange-yellowish colour to SDG 7.

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