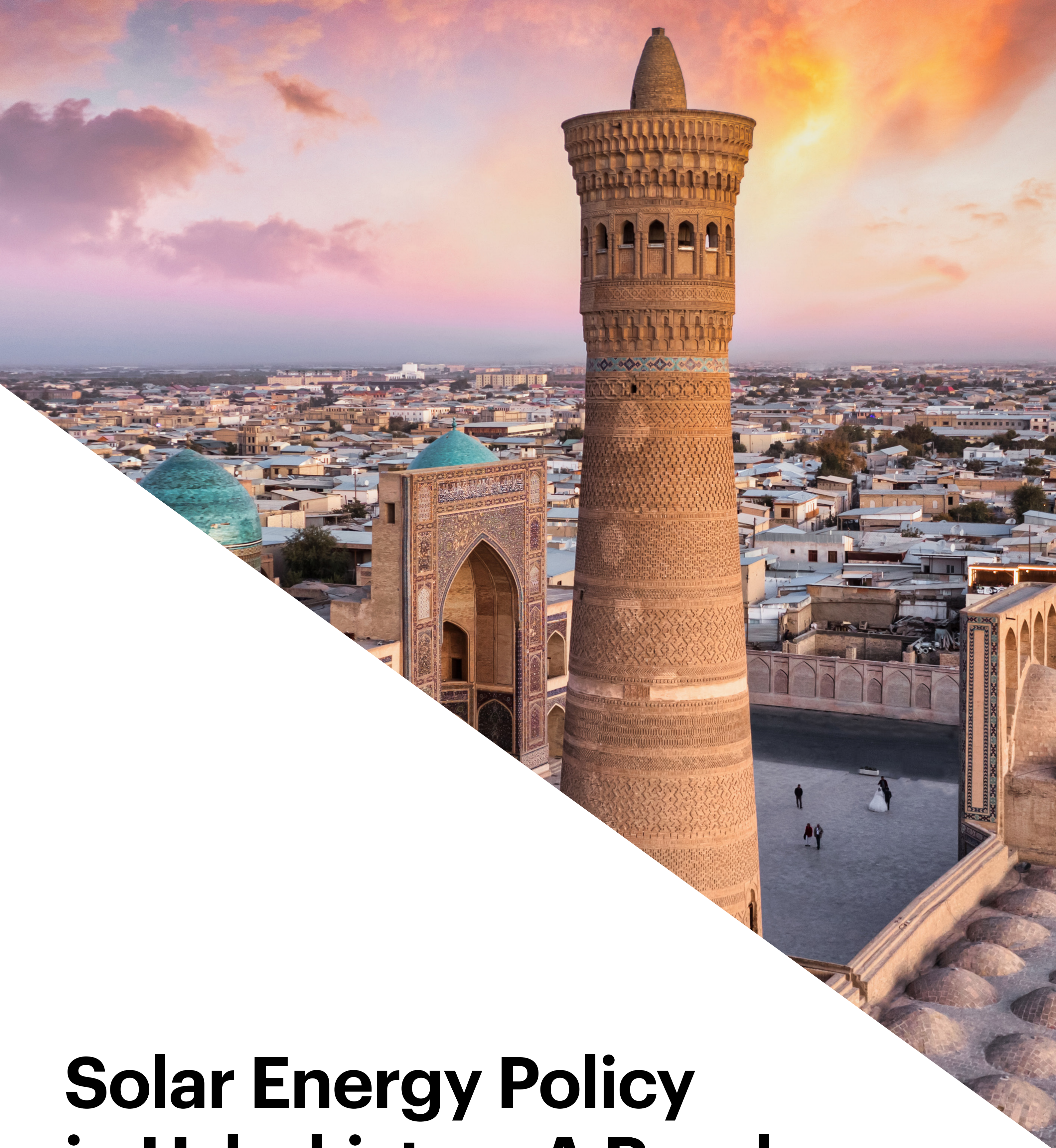

Solar Energy Policy in Uzbekistan: A Roadmap

International Energy Agency

Co-funded by the European Union

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INTERNATIONAL ENERGY AGENCY

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Overview

Purpose

This Solar Energy Policy in Uzbekistan Roadmap is part of the EU4Energy programme, a five-year initiative funded by the European Union. EU4Energy's aim is to support the development of evidence-based energy policy design and data capabilities in Eastern Partnership and Central Asian countries, of which Uzbekistan is a part.

The main purpose of this roadmap is to guide policy making at all levels to maximise the use of solar energy in Uzbekistan, and to serve as a precursor for a national solar energy strategy. The government of Uzbekistan is invited to consider incorporating the actions outlined in this roadmap so as to enhance the use of solar resources into a dedicated solar energy strategy.

This roadmap primarily focuses on increasing solar generation in Uzbekistan's electricity mix, but also touches upon solar heat potential to reduce its dependence on fossil fuels.

The roadmap aims to help Uzbekistan formulate its strategies and plans for solar energy deployment across all levels of government. It is also intended to support and guide the activities of other key stakeholders.

Structure

The report begins with an overview of the key institutions and stakeholders in the energy sector in Uzbekistan, followed by a description of the wider context of renewable energy in the country. It then provides a summary of the policy landscape for renewables in Uzbekistan. After discussing the possible barriers to the deployment of solar energy in Uzbekistan, the report presents a roadmap for solar energy by 2030. It provides examples of international best practices in solar energy deployment from IEA member and association countries. It then outlines the policies and measures needed for Uzbekistan to harness the benefits of solar energy securely. These are presented as a set of overarching policy actions. The roadmap focuses on:

- Maximising the benefits of solar energy in the energy system.
- The policy and regulatory frameworks enabling further solar energy deployment in Uzbekistan.
- Increasing power system flexibility to integrate the increasing amount of solar generation.

Finally, the recommended actions are a co-ordinated package of measures to implement to make solar energy the key energy source in Uzbekistan in 2030 and beyond.

Key institutions and stakeholders in the energy sector in Uzbekistan

Uzbekistan's energy sector is currently undergoing a large-scale transition. The key institutions and stakeholders for energy policy making and its implementation are summarised below.

The **Ministry of Energy**, established in February 2019, has overall responsibility for the development and implementation of energy policies, plans and programmes, and is authorised to play a central role in implementing renewable energy policy in Uzbekistan. It is also responsible for the regulation and supervision of the production, transmission, distribution and consumption of energy resources including electricity and the functioning of energy sectors, as well as the implementation of production-sharing agreements. Moreover, the ministry takes part in developing energy-related public-private partnerships (PPPs) and plays a role in improving the tariff policy in co-operation with the inter-ministerial tariff council to facilitate the development of a competitive business environment.

The **Ministry of Finance** exercises price regulation, including tariff-setting for electricity, and general control over the financial stability of the state sector, among other functions. Moreover, the PPP Development Agency under the Ministry of Finance plays a key role in developing PPPs in co-operation with Ministry of Investment and Foreign Trade and the Ministry of Energy.

The **Ministry of Investment and Foreign Trade** is responsible for implementing the state investment policy, including foreign direct investments in the energy sector, and co-operating with international financial institutions and foreign governmental financial organisations. It is also responsible for devising and co-ordinating state policies on foreign trade and international economic co-operation.

The **Ministry of Economic Development and Poverty Reduction** is in charge of analysing and forecasting macroeconomic indicators and development based on proposed economic management market mechanisms and strategies to develop the main industries, including energy. The ministry also formulates strategies for industrial development in Uzbekistan based on the effective deployment of production forces, rations and food production.

The **Cabinet of Ministers** approves the rules for electricity and gas use and monitors investment programmes in the energy industry.

The **State Committee of the Republic of Uzbekistan on Statistics** is the official authority collecting energy statistics. It will play an important role in the future in collecting data on off-grid solar photovoltaics and solar heat use in households.

The **Thermal Power Plants joint-stock company (JSC)**, a thermal power generation company, operates the majority of thermal power facilities in Uzbekistan, consisting of ten thermal power companies. As of 2021, Thermal Power Plants operates 11 thermal power plants, including co-generation[1] plants, with an installed capacity of 11 669 MW. Formerly, the power sector in Uzbekistan was vertically integrated and Uzbekenergo, a state-owned monopoly, was in charge of power generation, transmission, distribution and retail service, while serving the function of planning, investment, daily operation and regulation of the sector. With a view to strengthening competition in the sector, a decision was made in March 2019 to unbundle Uzbekenergo into three JSCs: Thermal Power Plants JSC, the National Electric Grid of Uzbekistan JSC and the Regional Electric Power Networks JSC.

Uzbekhydroenergo JSC is a state-owned company which operates hydropower plants, another important source of energy in Uzbekistan. The company was separated from Uzbekenergo JSC and established in May 2017. In total, it operates 37 hydropower plants with an installed capacity of 1 853 MW (EBRD, 2020).

The **National Electric Grid of Uzbekistan JSC**, the systems operator, is responsible for implementing centralised operational dispatch of all power plants and for operating transmission networks.

The **Regional Electric Power Networks JSC** is in charge of local electricity distribution. Its distribution and sales to consumers are handled by 14 territorial JSCs under its management.

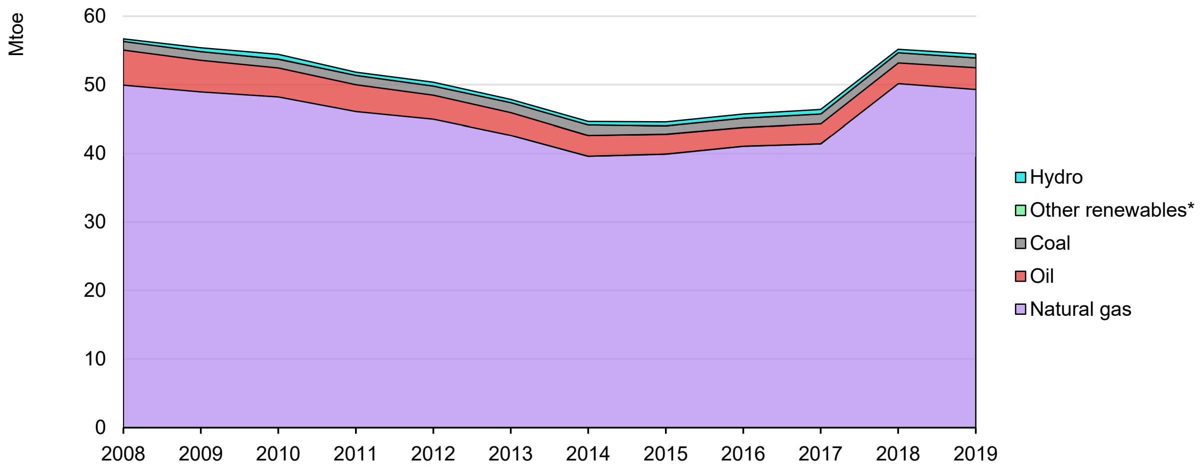
[1] Co-generation refers to the combined production of heat and power.

Context of renewable energy in Uzbekistan

Energy supply

Uzbekistan is one of the world's largest natural gas producers. Its energy production amounted to 54.5 million tonnes of oil equivalent (Mtoe) in 2019. Energy production reached a record high of 56.7 Mtoe in 2008. This amount had decreased by 20% by 2015, mainly due to the global economic crisis and a decline in natural gas reserves. It then recovered by 22% by 2019 from the 2015 level thanks to the development of gas projects in Uzbekistan. Natural gas is the dominant energy source in Uzbekistan, accounting for 90.5% of total energy production (49.3 Mtoe in 2019), while other energy sources include oil (5.8% in the same year), coal (2.6%), hydro (1.0%) and a negligible amount of biofuels (Figure 1).

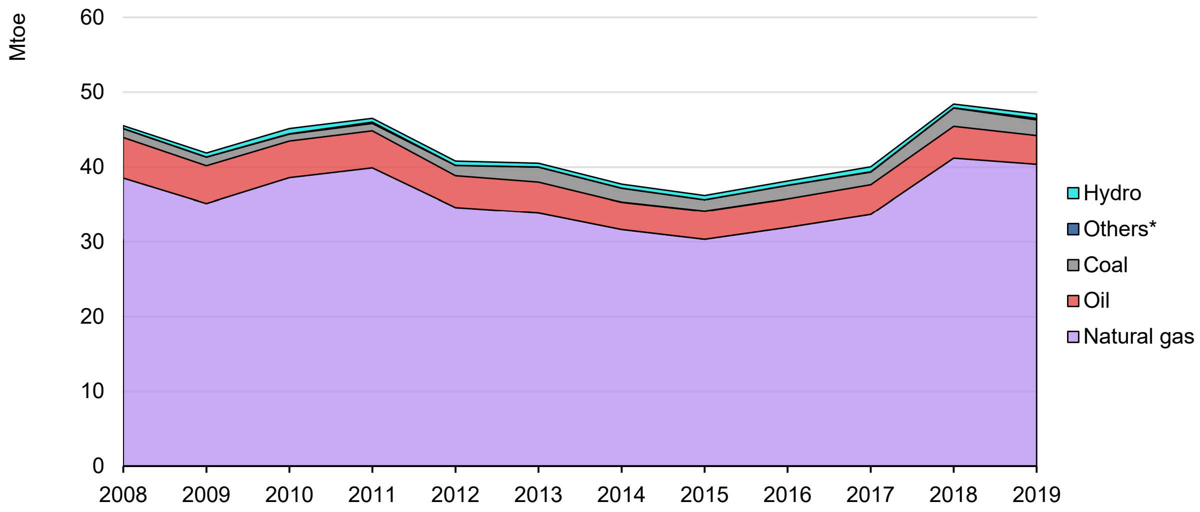
Figure 1 Energy production by source in Uzbekistan, 2008-2019



* This includes solid biofuels, wind and solar; not visible at this scale.
Source: Based on IEA (2021a), World Energy Statistics and Balances (database).

Uzbekistan is a net exporting country. Looking at its energy supply, total energy supply was 47.1 Mtoe in 2019. Total energy supply decreased by 22% between 2011 and 2015 due to a slump during the global financial crisis, but has grown by 30% over the last 5 years mainly due to an increase in residential sector consumption. Natural gas accounted for 85.8% of total energy supply in 2019, while the remainder was mainly from oil (8.2% in the same year), coal (4.4%) and hydro (1.2%) (Figure 2).

Figure 2 Total energy supply in Uzbekistan, 2008-2019



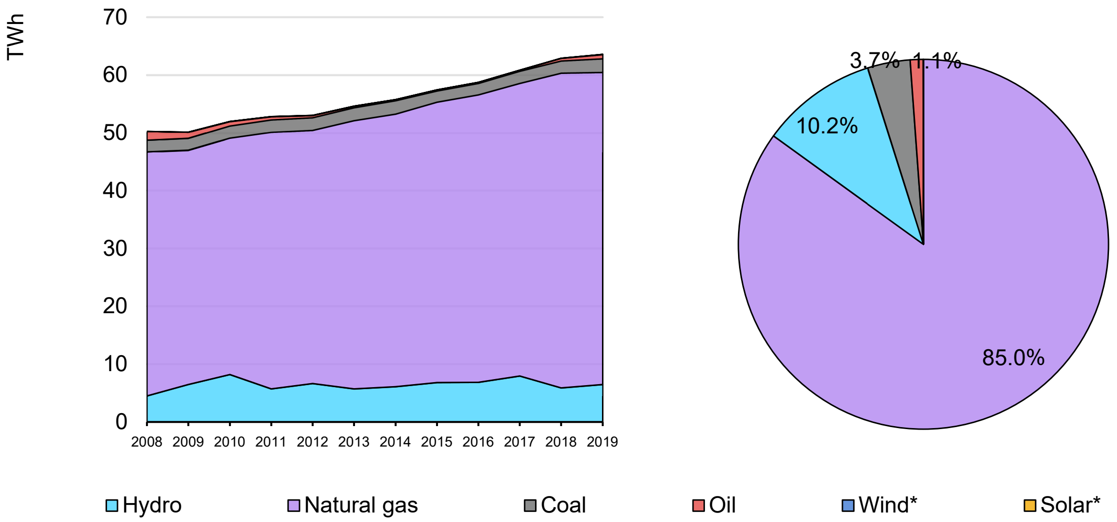
* This includes solid biofuels, wind and solar; not visible at this scale.

Source: Based on IEA (2021a), World Energy Statistics and Balances (database).

Electricity generation

Uzbekistan's electricity generation was 63.5 terawatt hours (TWh) in 2019 due to an increase in generation capacity. Overall generation has grown steadily, with an increase of 27% since 2008, most of which was supplied by natural gas. In 2019, natural gas accounted for 85% of overall generation, followed by hydro (10.2%) and coal (3.7%) (Figure 3).

Figure 3 Electricity generation by source in Uzbekistan, 2008-2019 (left panel) and generation mix in 2019 (right panel)



* Negligible.

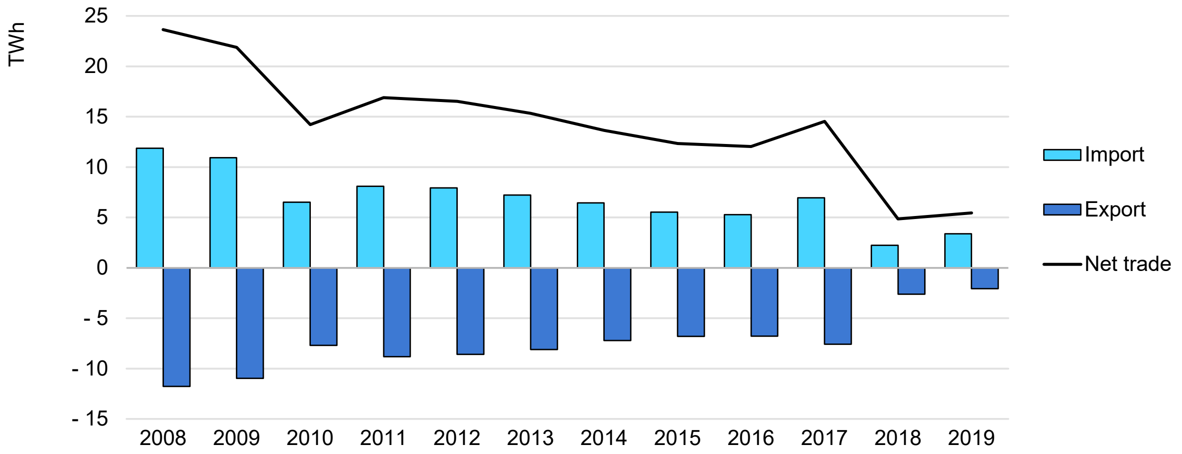
Source: Based on IEA (2021a), World Energy Statistics and Balances (database).

Total installed capacity was 12.9 GW in 2019, mainly consisting of 11 thermal power plants (TPPs), including co-generation plants (11.0 GW, or 84.7% of total capacity), and 42 hydropower plants (HPPs) (1.85 GW, or 14.3%).

Looking at renewables by technology, almost all renewable energy in Uzbekistan is generated by hydropower (6.5 TWh, or 10.2% of overall generation in 2019), while wind and solar power are negligible to date.

Uzbekistan's power system is part of the Central Asia Power Grid with Kazakhstan, Kyrgyzstan, Tajikistan and Turkmenistan. Interconnections of 220 kilovolts (kV) and 500 kV transmission lines exist with the 4 countries respectively as do 220 kV transmission lines with Afghanistan. The net volume of electricity trade remained relatively constant between 2010 and 2017, while the total trade electricity was on a downward trend mainly due to the withdrawal of individual countries from the Central Asia Power Grid, having decreased to 5.4 TWh in both directions (Figure 4). In August 2020, the government of Uzbekistan signed an agreement with the government of Afghanistan on ten-year electricity export, including the construction of a 500 kV interconnection line, which could help increase Uzbekistan's net electricity export.

Figure 4 Electricity trade with neighbouring countries, Uzbekistan, 2008-2019



Source: Based on IEA (2021a), World Energy Statistics and Balances (database).

Heat

Heat is the largest energy end-use in Uzbekistan, accounting for almost two-thirds of total final energy consumption. Thanks to energy efficiency improvements, Uzbekistan's total heat consumption has declined by more than one-third over the past decade. It represented close to 800 petajoules (PJ) in 2018. The buildings sector accounts for about two-thirds of total heat consumption and industry represents most of the remainder. Heat demand is almost exclusively met by fossil fuels, and in particular natural gas, which represents more than three-quarters of total heat supply in the country.

District heating networks supplied 120 PJ of heat in 2019, representing about one-seventh of total heat consumption. Natural gas accounted for 95% of district heat supplied in 2019, the remainder being mostly from coal. The buildings sector is responsible for over 80% of total district heat consumption, half of which occurs in the commercial and public sector, where it represents about one-third of total heat supplies.

Although limited data are available regarding traditional uses of biomass for heating, several kinds of biomass are traditionally used in rural areas, including cotton stalks for cooking, and livestock and poultry waste for fuel (IEA, 2020a).

Solar energy potential

Uzbekistan has considerable renewable energy potential, a substantial amount of which lies in solar energy. The solar energy gross potential totals 2 134 x 10^3 PJ, while technical potential is estimated at 7 411 PJ, which is equivalent to almost four times the country's current primary energy consumption (Table 1).

Table 1 Renewable energy source potential in Uzbekistan

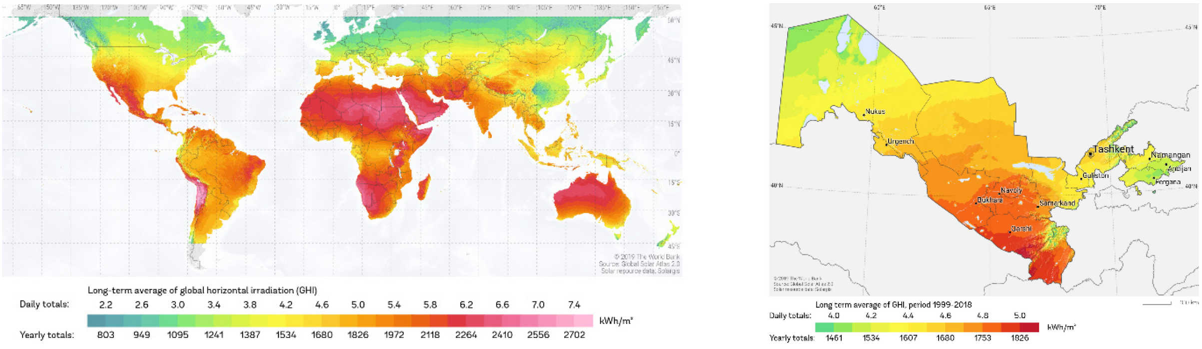
Renewable energy source	Gross potential	Technical potential
Hydropower	385 PJ	84 PJ
Wind power	92 PJ	17 PJ
Solar power	2 134 x 10^3 PJ	7 411 PJ
Geothermal energy	2 805 x 10^3 PJ	13 PJ
Total	**4 940 x 10^3 PJ**	**7 507 PJ**

Source: Based on IEA (2020a), Uzbekistan Energy Profile.

Uzbekistan benefits from high solar irradiation. Global horizontal irradiance (GHI) measures the density of solar resources available per horizontal surface area, including both direct and diffuse radiations.[2] The GHI serves as an indicator for assessing the potential of solar photovoltaics (PV), which converts both radiations into electricity. Uzbekistan's GHI is estimated at 4.52 kWh per square metre (m^2) per day in the median value (with a range of 4.0-5.0 kWh/m^2/day), which is higher than several European countries with good solar conditions, such as Spain (4.64 kWh/m^2/day) or Italy (4.07 kWh/m^2/day) (Figure 5).

[2] The direct radiation refers to the sunlight coming directly from the sun's disk, while the diffuse radiation refers to light coming from various directions.

Figure 5 Global horizontal irradiance, world (left panel) and Uzbekistan (right panel)

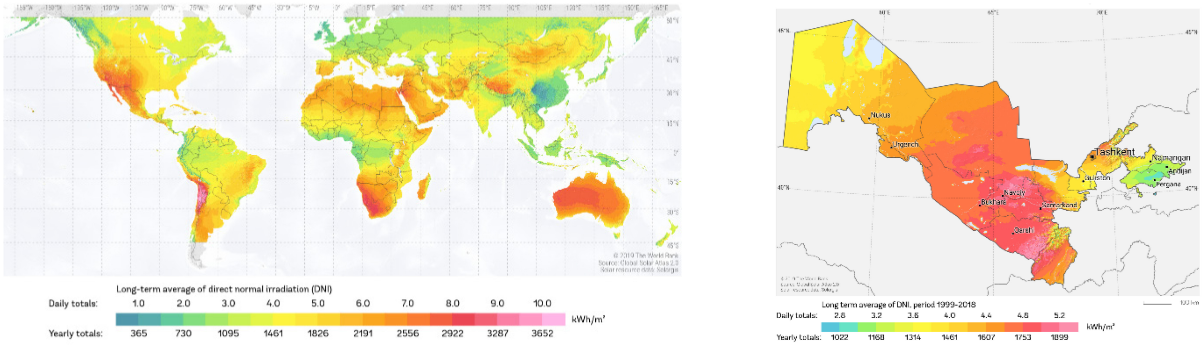


Notes: This map, adapted by the IEA, was obtained from the Global Solar Atlas 2.0, a free, web-based application, developed and operated by the company Solargis s.r.o. on behalf of the World Bank Group, utilising Solargis data, with funding provided by the Energy Sector Management Assistance Program (ESMAP). For additional information, see: https://globalsolaratlas.info. The works are licensed under the Creative Commons 4.0 Attribution International license, CC BY 4.0.

Source: World Bank Group, ESMAP and Solargis (2021), Global Solar Atlas. Global Solar Atlas: Uzbekistan.

Direct normal irradiance (DNI) is the relevant metric to consider the possibility of using concentrating solar power (CSP) and solar thermal technologies, which require direct irradiation. The DNI in Uzbekistan is 4.44 kWh/m²/day in the median value (ranging from 3.03 kWh/m²/day to 5.27 kWh/m²/day). In comparison, Spain and the United States, the major markets for CSP globally, show a slightly higher median DNI (5.34 kWh/m²/day and 4.76 kWh/m²/day, respectively), but these are on par with values observed in the southern regions of Uzbekistan (Figure 6).

Figure 6 Direct normal irradiance, world (left panel) and Uzbekistan (right panel)

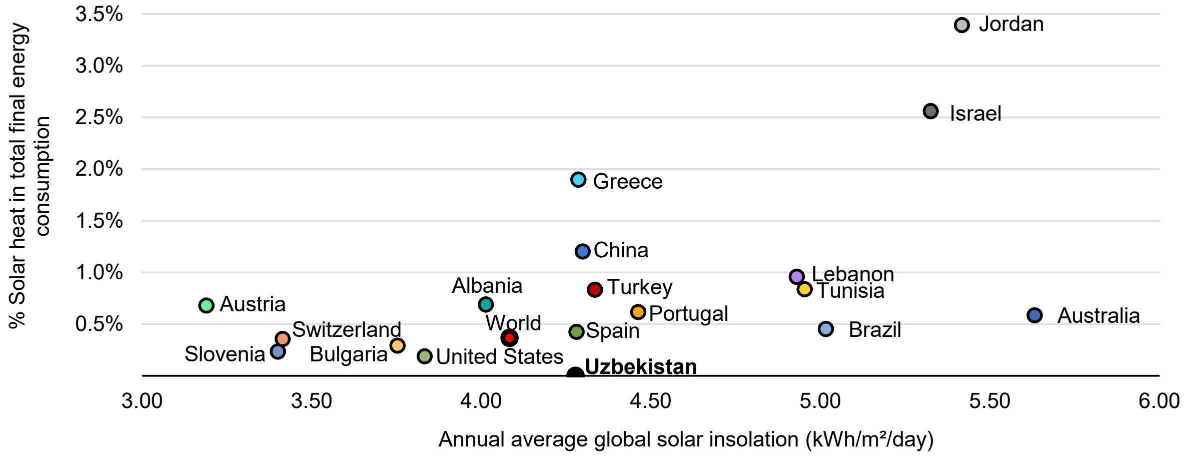


Notes: This map, adapted by the IEA, was obtained from the Global Solar Atlas 2.0, a free, web-based application, developed and operated by the company Solargis s.r.o. on behalf of the World Bank Group, utilising Solargis data, with funding provided by the Energy Sector Management Assistance Program (ESMAP). For additional information, see: https://globalsolaratlas.info. The works are licensed under the Creative Commons 4.0 Attribution International license, CC BY 4.0.

Source: World Bank Group, ESMAP and Solargis (2021), Global Solar Atlas. Global Solar Atlas: Uzbekistan.

As shown in Figure 7, solar thermal is used in a number of countries with levels of solar insolation similar to those in Uzbekistan. While the majority of applications globally correspond to domestic solar thermal water heaters, solar thermal heat can also be used for space heating in buildings and greenhouses, space cooling (when collectors are paired with an absorption or adsorption chiller), low- to medium-temperature industrial processes (e.g. drying, sterilisation), and wastewater treatment. There are significant opportunities for the integration of solar thermal heat use in district heating networks as well.

Figure 7 Share of solar thermal heat consumption in total final energy consumption, in selected countries and regions, 2019



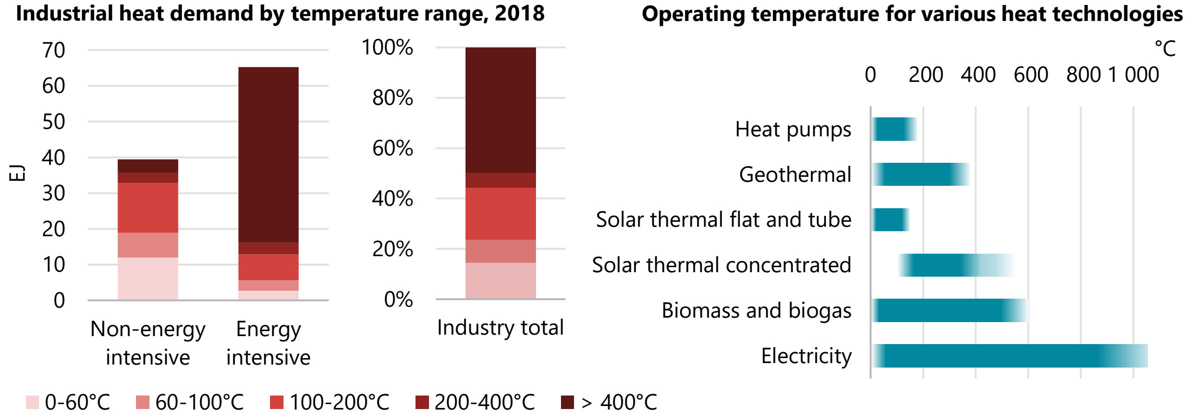
Notes: The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

Sources: Based on IEA (2021a), World Energy Statistics and Balances (database); World Bank Group, ESMAP and Solargis (2021), Global Solar Atlas.

Other solar heating solutions are also emerging, such as solar PV-to-heat (PV2heat), which consists of PV modules directly (and solely) connected to an electric resistance water heater using DC power without inverters (Figure 8). The simplicity of installation, reliability and cost-competitiveness of PV2heat systems offer perspectives for deployment in various regions of the world, including, potentially, in Uzbekistan.

Electric heat pumps, while not necessarily related to solar energy, are becoming more popular in many markets thanks to lower installation costs relative to potential savings on energy spending and higher energy performance. In 2020, electric heat pumps only met up to 7% of heating needs in buildings globally, but they could easily supply more than 90% of global space and water heating at a lower level of CO_2 emissions than condensing gas boiler technology (IEA, 2021b).

Figure 8 Global industrial heat demand by temperature range (left panel) and technology suitability (right panel)



Note: EJ = exajoule.
Sources: Left panel: based on IEA (2019a), World Energy Outlook 2019. Right panel: IEA SHC TCP (2019), Process heat collectors: State of the art and available medium temperature collectors; BNEF (2019), Industrial Heat: Deep Decarbonization Opportunities.

Large-scale solar PV projects in Uzbekistan

With the help of international financial institutions such as the World Bank Group, the Asian Development Bank, and the European Bank for Reconstruction and Development, since 2019, the government of Uzbekistan has implemented competitive bidding processes with a view to developing large-scale solar PV projects through increased foreign direct investment. Ten large-scale solar projects totalling 2 050 MW have been put out to tender mostly in the southern and south-western regions of the country where the GHI is higher than the national average. Of this, 1 300 MW had been awarded as of August 2021; the 100 MW project in the Navoi region began operation in August 2021 (Table 2).

Table 2 Announced large-scale solar PV projects in Uzbekistan

Year awarded	Project location	Offered capacity	Awarded tariff	Supply period	Awarded company
2020	Karmana district, Navoi region	100 MW	26.79 USD/MWh	25 years	Abu Dhabi Future Energy Company PJSC (Masdar)
2021	Samarkand region	100 MW	n/a	25 years	Total Eren
2021	Nurata district, Navoi region	200 MW	n/a	25 years	Phanes Group
2021	Samarkand region	220 MW	17.91 USD/MWh	25 years	Masdar

Year awarded	Project location	Offered capacity	Awarded tariff	Supply period	Awarded company
2021	Jizzakh region	220 MW	18.23 USD/MWh	25 years	Masdar
2021	Sherabad district, Surkhandarya region (Phase I)	457 MW	18.045 USD/MWh*	25 years	Masdar
	Guzar district, Kashkadarya region (Phase II)	300 MW	(TBD)	(TBD)	(TBD)
	Xorazm region	100 MW	(TBD)	(TBD)	(TBD)
	Namangan region	150 MW	(TBD)	(TBD)	(TBD)
	Bukhara region	200 MW	(TBD)	(TBD)	(TBD)

* This tariff includes the cost of transmission lines; the solar tariff alone was 16.144 USD/MWh.

Sources: World Bank (2020), Pioneering solar power plant to take off in Uzbekistan with World Bank Group support; Total Eren (2021), Total Eren secures the financing of the Tutly solar project in Uzbekistan from EIB, EBRD, and PROPARCO; Phanes (2021), Phanes Group signs both power purchase agreement and investment agreement to develop 200 MW_{AC} solar power plant in Uzbekistan; IFC (2021), Uzbekistan announces winner of the tender for solar power plants in the Jizzakh and Samarkand regions; Renews (2021), Masdar wins 457MW Uzbekistan solar gig; TaiyangNews (2021), Uzbekistan launches solar tender for up to 500 MW capacity under International Finance Corporation's Scaling Solar Initiative.

Policy landscape for renewables in Uzbekistan

To ensure energy security and promote renewable energy use, the government of Uzbekistan has adopted a wide range of strategies and laws related to energy.

The **Strategy of Action for the Five Priority Development Areas of Uzbekistan in 2017-2021**, adopted in February 2017, provides key directions for economic development. In terms of energy, the strategy indicates the need for reducing the energy intensity and resource intensity of the economy, the widespread introduction of energy-saving technologies in production, and expanding the use of renewable energy sources.

The government expects the share of renewable generation in the power mix to increase to at least 20% by 2025 (compared to 9.4% in 2018), as indicated in the **Strategy for Innovative Development of the Republic of Uzbekistan for 2019-2021**, adopted in September 2018.

Building reliable electricity networks is essential for the deployment of more renewables in the power sector. In this regard, the **Strategy for the Development of Electric Networks in the Republic of Uzbekistan until 2025** was formulated in July 2019. It provides an overall plan for the construction of new and the modernisation of existing transmission and distribution lines and substations up to 2025.

In order to implement comprehensive measures to deepen structural reforms, modernise and diversify key sectors such as agriculture and manufacturing, and balance the socio-economic development of its territories, the government adopted the **Strategy for the Transition of the Republic of Uzbekistan to the Green Economy for the Period 2019-2030** in October 2019. It encompasses a wide range of objectives within several priority areas, including the energy sector. As regards renewable energy technologies, it makes reference to:

- further developing renewables by raising their share in the power mix to more than 25% by 2030 (compared to 10.2% in 2019)
- modernising the infrastructure of industrial enterprises and applying clean and environmentally safe technologies and industrial processes more widely
- using solar collectors for water heating
- increasing the automation of technological processes while reducing electric energy consumption for transmission and distribution
- improving the main power network configurations and modernising them to increase power system stability
- equipping power consumption systems with smart meters.

In response to the Strategy for 2019-2030, the government developed the **Concept Note for ensuring electricity supply in Uzbekistan in 2020-2030** in May 2020. This concept note defines medium- and long-term objectives and directions for the development of the power sector. It identifies six main objectives to improve electricity supply: 1) satisfying the country's power demand; 2) improving the nation's energy efficiency; 3) increasing the energy efficiency of power generation and transmission; 4) reducing the damage of power facilities; 5) developing and expanding the use of renewables and their system integration; and 6) developing an efficient electricity market. With a view to meeting the growing power demand while expanding renewable generation capacity, the following targets have been set:

- increase power capacity from the 12.9 GW in 2019 to 29.2 GW by 2030 and electricity generation from 63.6 TWh in 2019 to 120.8 TWh by 2030
- increase the capacity of renewable energy generation to 5 GW for solar power and 3 GW for wind by 2030 (compared with no large-scale solar PV plants operational in 2019).

The Uzbek government is currently planning to set a renewable capacity target of 4 GW for solar power and 4 GW for wind by 2026 (MoE, 2022). The country is also considering increasing the 2030 renewable capacity targets from 5 GW to 7 GW for solar PV and from 3 GW to 5 GW for wind (MoE, 2021a).

The **Law on the Use of Renewable Energy Sources**, adopted in May 2019, defines opportunities and incentives for individuals and manufacturers of renewable energy installations, including exemption of property and land tax. At the same time, the **Law on Public-Private Partnership (PPP)** was enacted to allow/encourage private sector participation in public sector infrastructure projects, including those in the power sector. Multiple PPP projects are currently underway.

The Decree on Accelerated Measures to Improve Energy Efficiency of Economic and Social Sectors, the Introduction of Energy-Saving Technologies and the Development of Renewable Energy Sources was approved in August 2019. This decree defines the share of renewable electricity in the power mix to reach at least 25% by 2030. It also specifies subsidies to individuals and companies that install energy equipment, including solar PV facilities.

The **Law on the Rational Use of Energy,** amended in April 2020, stipulates the role of the Ministry of Energy in implementing a unified state policy on rational energy use applicable to all economic sectors and social facilities. In other words, it positions the ministry as a pillar for implementing the country's energy policy, including renewables.

The **Programme of Measures for Further Development of the Hydropower Sector for 2017-2021**, adopted in May 2017, addresses projects for the construction of new and the modernisation of existing HPPs and the provision of tax incentives for imported equipment required for these projects.

In its **Nationally Determined Contributions**, ratified in November 2018, Uzbekistan committed to decreasing specific GHG emissions per unit of GDP by 10% by 2030 from 2010 levels. As regards renewable energy, to improve energy efficiency in various sectors, the Nationally Determined Contribution proposes the development and broader use of renewable energy sources, such as constructing large solar PV power and biogas plants and scaling up wind power generation. Moreover, during the recent United Nations' Climate Change Conference COP26 in Glasgow in 2021, the government announced its intention to reduce GHG emissions per unit of GDP by 35% by 2030. To achieve this ambitious target, the government needs to find a way to increase the total generation capacity of solar and wind to 8 GW by 2026, which means the current target needs to be achieved four years ahead of the schedule.

In close co-operation with international financial institutions, the government of Uzbekistan has been also developing several master plans to secure energy supply while achieving a carbon-neutral power sector in the long term. The **Power Sector Masterplan to 2030**, developed with the technical support of the Asian Development Bank (September 2019), identifies ways to diversify the power mix and provides plans for achieving lower cost generation and reliable transmission development.

The **Roadmap to Carbon-Neutral Electricity Sector in Uzbekistan 2050** was developed with the support of the European Bank for Reconstruction and Development and the government of Japan in January 2021. It provides insights on the policies, technologies and investments necessary to achieve a carbon-neutral power sector by 2050, and leverages advanced energy system modelling and scenario analysis tools. It also explores possible future development pathways for its power sector. The roadmap is not (yet) reflected in the government's official targets.

With a view to ensuring sufficient power supply in the medium term, the **Transmission Network Development Plan to 2030**, developed with the assistance of the World Bank, was being finalised at the time of writing. The **Distribution Network Development Masterplan** is also under development, with the support from the Asian Development Bank.

In terms of heat, for the purpose of consistent heat supply to consumers and efficient use of energy resources, the **Decree on the Program for the Development of the Heat Supply System for the period 2018-2022** was adopted in April 2017. It identifies the following as priorities for further development of the heat system in Uzbekistan: 1) introducing new energy sources, including renewables; 2) developing a decentralised heat supply system for apartments and other social facilities; 3) modernising and reconstructing outdated inefficient heating boilers; and 4) introducing an automated accounting system for the consumption and production of energy sources.

Table 3 summarises renewable generation and solar capacity targets.

Table 3 Current and targeted renewable generation ratio and solar capacity in Uzbekistan

	2019	2025	2030
Renewable generation ratio	10.2%	20%	25%
Solar power capacity	–	(no target)	5 GW*

* The government of Uzbekistan is currently considering increasing 2030 solar capacity targets to 7 GW.

Sources: IEA (2021a), World Energy Statistics and Balances (database); MoE (2020), Concept Note for ensuring electricity supply in Uzbekistan in 2020-2030; MoE (2021a), Uzbekistan's Ministry of Energy plans to increase its 2030 renewables targets.

Possible barriers to the deployment of solar energy in Uzbekistan

This section explores barriers that could hamper the deployment of solar energy technologies in Uzbekistan by taking a look at its current solar policy. The section discusses Uzbekistan's situation from the following perspectives, drawing on the approaches developed by Solar Energy: Mapping the Road Ahead (IEA and ISA, 2019):

- solar resource information and workforce
- policy, regulatory and market frameworks
- non-economic barriers
- financing and economic factors
- integrating solar projects into the Uzbek energy system and infrastructure.

Solar resource information and workforce

Adequate resource information could help to determine the appropriate solar technologies based on the local conditions. Moreover, a high-quality workforce could promote growth in the renewable energy sector. Internationally harmonised standards could make timely project development possible (Table 4).

Table 4 Possible barriers to the deployment of solar energy in Uzbekistan: Solar resource information and workforce

Possible barriers	Instances
Inadequate resource information	• Lack of good quality solar resource information needed to develop a detailed solar strategy
Lack of information on technology readiness and applicability	• Lack of knowledge about the availability and performance of renewable technologies
Shortage of qualified workforce	• Shortage of local experts in solar technologies for all sectors, which may limit the choice of projects and numbers of installations that can be developed • High cost of operations and maintenance due to lack of local qualified personnel
Information asymmetry/shortage	• Technologies and components are not standardised, leading to perceived risks for deployment/performance • Lack of knowledge about technological options available internationally

Notes: This table shows the possible barriers with instances against solar energy technology deployment illustrated in IEA and ISA (2019); not all instances are necessarily applicable to the context of Uzbekistan.
Source: Adapted from IEA and ISA (2019), Solar Energy: Mapping the Road Ahead.

As regards solar resource information, publicly available resource maps have been used to determine the potential of solar power generation in specific areas. Due to the lack of accuracy in the data, the potential locations of the solar stations were selected based on such criteria as existing infrastructure and distance to transmission lines, while the accuracy of the selection has been checked using accurate measurements of the solar energy flux (pyranometers and pyrheliometers certified by the World Meteorological Organization and the International Organization for Standardization) directly on site throughout the year. In addition to the measurement of solar radiation, other meteorological parameters such as satellite data and weather forecast serve as the initial data for planning solar generation.

The Presidential Decree on Measures for the Development of Renewable and Hydrogen Energy, approved in April 2021, calls for the establishment of a the National Renewable Energy Research Institute under the Ministry of Energy. One of its main objectives is to train a highly qualified workforce in the fields of renewable and hydrogen energy. Moreover, to create an educational base for renewable energy, a new Master of Science curriculum on renewable energy sources and sustainable environment will be developed, compatible with European standards, in six Uzbek universities in the framework of the RENES project (RENES, 2020).

In terms of technology standardisation, the State Committee for Standardization, the Academy of Sciences and the Ministry of Energy are carrying out a basic study on the renewable energy standards of the International Electrotechnical Commission and the International Organization for Standardization. They have been drafting a list of standards required for adaptation.

Policy, regulatory and market frameworks

Although the cost of renewable energy has been rapidly decreasing over the decades, government policy and regulations still play a critical role in attracting private investment and ensuring an appropriate energy market (Table 5).

Table 5 Possible barriers to the deployment of solar energy in Uzbekistan: Policy, regulatory and market frameworks

Possible barriers	Instances
Policy and regulatory framework	• “Stop-and-go” policy approaches and retroactive changes have undermined investors’ confidence • Insufficient transparency or excessive complexity of policies and legislations • Strong requirement for “local” procurement
Land availability/building access for installation	• Statutory restrictions apply to site; site has other economic/landscape value • Land may have historic value • Lack of clarity for rights of roof access

Possible barriers	Instances
Market barriers	• Energy pricing that is not cost-reflective • Subsidies for fossil fuels • Externalities and the failure of costing methods to include social and environmental costs
Electricity market design	• Ensuring recovery of investment for solar and non-zero marginal cost facilities • Curtailment may result from lack of space in the market • Large shares of variable renewable energy, e.g. from solar PV, may require power market modification

Notes: This table shows the possible barriers with instances against solar energy technology deployment illustrated in IEA and ISA (2019); not all instances are necessarily applicable to the context of Uzbekistan.

Source: Adapted from IEA and ISA (2019), Solar Energy: Mapping the Road Ahead.

As discussed above, the Law on the Use of Renewable Energy Sources and the Law on PPP serve as a regulatory framework to accelerate the implementation of renewable energy projects, including financial incentives for the use of renewable energy sources. The Regulation for Connecting Businesses provides detailed technical aspects for integrating renewable energy facilities into the electricity system, but the permitting procedure is still unclear.

In terms of land availability, while no specific difficulties are reported for obtaining plots for the construction of large-scale solar farms, citizens who want to obtain plots to build small-scale solar power generators do seem to be encountering difficulties.

The Interdepartmental Tariff Commission under the Cabinet of Ministers, established in 2018 and whose working body is led by the Ministry of Finance, determines electricity tariffs. Electricity tariffs in Uzbekistan have been on an upward trend, reaching approximately 0.028 USD/kWh for households and 0.043 USD/kWh for others (IEA, 2020a). However, they are still lower than in neighbouring countries and lower in an international comparison, remaining inadequate to recover operation and maintenance costs and increasing financing for new projects. In this regard, the Interdepartmental Tariff Commission is working on setting electricity tariffs based on reasonable expenses for its production, transmission, distribution and sales, considering the reimbursement of capital costs and maintaining 10-20% profitability. Moreover, in line with the Concept Note for ensuring electricity supply in Uzbekistan in 2020-2030, differentiated tariffs for electricity for residential consumers based on time of day, working days and holidays will begin in 2022, while feed-in-tariffs for purchasing surplus electricity generated by own renewable sources will begin in 2023.

As regards the electricity market, Uzbekistan is transitioning to a competitive wholesale electricity market to be fully implemented in 2023, which would oblige all power generators to participate in the market and allow new market participants transparent and non-discriminatory access to the electricity network. To this end, the following measures will be undertaken:

- approve the models of: wholesale market (monthly contracts, day-ahead trade, intraday trade) and interim stages; balancing market; market operating rules; and market participant licensing rules (by 2022)
- establish an electricity market regulator – an independent body responsible for regulating, licensing and controlling functions in the power and natural gas markets (originally planned to be undertaken by 2021).

To promote the use of solar heat in the building sector, all new and refurbished buildings, except for individual houses, are required to be equipped with certified solar water heating installations for hot water supply, in accordance with the Decree on the Program for the Development of the Heat Supply System for the period 2018-2022. All state institutions also are set to be switched from the centralised hot water supply to solar water heating plants from 2022. Moreover, with a view to stimulating the use of solar heat in individual houses, in 2020, the government started to provide subsidies to individuals who purchase solar water heaters. The subsidies cover 30% of their upfront cost. In addition, the government approved a targeted programme for the installation of water heaters with a capacity of about 200 litres to cover 2-2.5% of households, as well as for the installation of 150 000 rooftop solar PV with a capacity of 2-3 kW by 2025.

Non-economic barriers

A range of non-economic barriers, including administrative and environmental issues, could prevent the deployment of a renewable technology. These possible barriers are expected to evolve depending on the level of the maturity and deployment of renewable technologies, therefore addressing the non-economic barriers will gradually become important (Table 6).

Table 6 Possible barriers to the deployment of solar energy in Uzbekistan: Non-economic barriers

Possible barriers	Instances
Institutional and administrative	• Lack of strong, dedicated institutions; lack of clear responsibilities; and lack of co-ordination among agencies • Slow, opaque permitting procedures, often due to insufficient capacity to manage applications in a timely fashion • Developers lack competence in preparing applications • Difficulty in getting projects connected to the grid
Public acceptance	• Local opposition prevents the construction of new grid connections, linked to experience with planning regulations and public acceptance of renewable technologies
Environmental	• High restrictions on soil artificialisation or visual impacts

Notes: This table shows the possible barriers with instances against solar energy technology deployment illustrated in IEA and ISA (2019); not all instances are necessarily applicable to the context of Uzbekistan.

Source: Adapted from IEA and ISA (2019), Solar Energy: Mapping the Road Ahead.

As previously mentioned, the Ministry of Energy was established in 2019 as a pillar for implementing a unified state energy policy including renewable energy.

Public acceptance and environmental concerns have not been raised as emerging issues so far due to the limited generation capacity of solar power in Uzbekistan. Rather, existing environmental parties in Uzbekistan support the construction of renewable energy facilities. Large-scale solar PV plants have yet to be developed in the country, but no local opposition to the construction of wind generators has been met so far.

Financing and economic factors

Access to financing for solar energy technologies is a precondition for their deployment. Technological viability depends on financing costs due to the high upfront capital costs involved, the long-term economic lifetimes and the impact of the weighted average cost of capital (Table 7).

Table 7 Possible barriers to the deployment of solar energy in Uzbekistan: Financing and economic factors

Possible barriers	Instances
Investment costs and economics	• Solar technology's levelised cost of electricity may be uncompetitive relative to other sources of power • The levelised cost of solar thermal heat may be uncompetitive relative to other sources of heat • Solar technologies can compete on a levelised cost basis, but upfront capital investment costs are too high
Investor confidence and perceived risk	• Technology risks are considered too high by investors • Lack of previous investment experience in target countries makes commitments too risky • Instability in the policy and/or regulatory framework • Mismatch of currencies for revenue and repayment
Availability of financing	• Project promoter or developer unable to provide equity for project. Investment banks may be unwilling to offer project financing • In the buildings sector, those who pay for energy services may not take the decisions on new supply-side investments

Notes: This table shows the possible barriers with instances against solar energy technology deployment illustrated in IEA and ISA (2019); not all instances are necessarily applicable to the context of Uzbekistan.

Source: Adapted from IEA and ISA (2019), Solar Energy: Mapping the Road Ahead.

As was described earlier, the Uzbek government, with financial and technical assistance from international financial institutions, has implemented competitive bidding processes to attract private sector investment in large-scale solar power projects since the enactment of the Law on PPP in 2019. Looking at one of the latest bidding projects, Abu Dhabi Future Energy Company PJSC, known as Masdar, was awarded a 220 MW solar PV project in the Samarkand region to supply electricity through the National Electric Grid of Uzbekistan JSC (NEGU) for 25 years at 17.91 USD/MWh (IFC, 2021). This is already lower than the global average auction prices for solar PV.

In line with the Law on the Use of Renewable Energy Sources Business, entities and individuals who install renewable energy facilities are eligible for the following benefits and incentives, including tax incentives:

- Manufacturers of renewable energy facilities are granted the right to create local networks and conclude agreements with legal entities and individuals for the sale of energy.
- Renewable energy generators are exempted from property tax for these installations and from land tax on the sites occupied by these installations (more than 0.1 MW) for ten years from the date of their commissioning. They are also granted the right to create local networks and conclude agreements with legal entities and individuals for the sale of energy.
- Individuals are exempted from property tax on property owned by persons using renewable energy facilities in residential premises with complete disconnection from the existing energy networks for three years from the date of using the facilities.

Integrating solar projects into the Uzbek energy system

Different levels of variable renewable energy sources, including solar and wind, require an evolving approach to providing power system flexibility, which is defined as the ability of a power system to reliably and cost effectively manage the variability and uncertainty of demand and supply across all relevant timescales, from ensuring instantaneous stability of the power system to supporting long-term security of supply (IEA, 2019b). Sufficient grid infrastructure and its appropriate operation could help maximise the development of solar energy capacity and encourage the development of solar projects (Table 8).

Table 8 Possible barriers to the deployment of solar energy in Uzbekistan: Energy infrastructure

Possible barriers	Instances
Infrastructure obstacles	• Insufficient grid capacity; delayed arrival and late connection of new projects to grid
Grid connection constraints	• Transmission system operator may lack capacity to enable grid connection (or have no interest) • Point of connection may be disputed among developers or with the transmission owner • Long distance between potential site and grid node can be a barrier due to costs or existing rights-of-way

Possible barriers	Instances
Curtailment and other operational constraints	• Impact on voltage, frequency and power quality and system stability
Mismatch with solar availability	• Differences between annual solar availability and the load curve may be significant
Solar thermal for district heating	• Change in operation due to solar resource variability • Inadaptability of network temperature levels for efficient solar production • Strong competition from natural gas networks, leading to suboptimal results

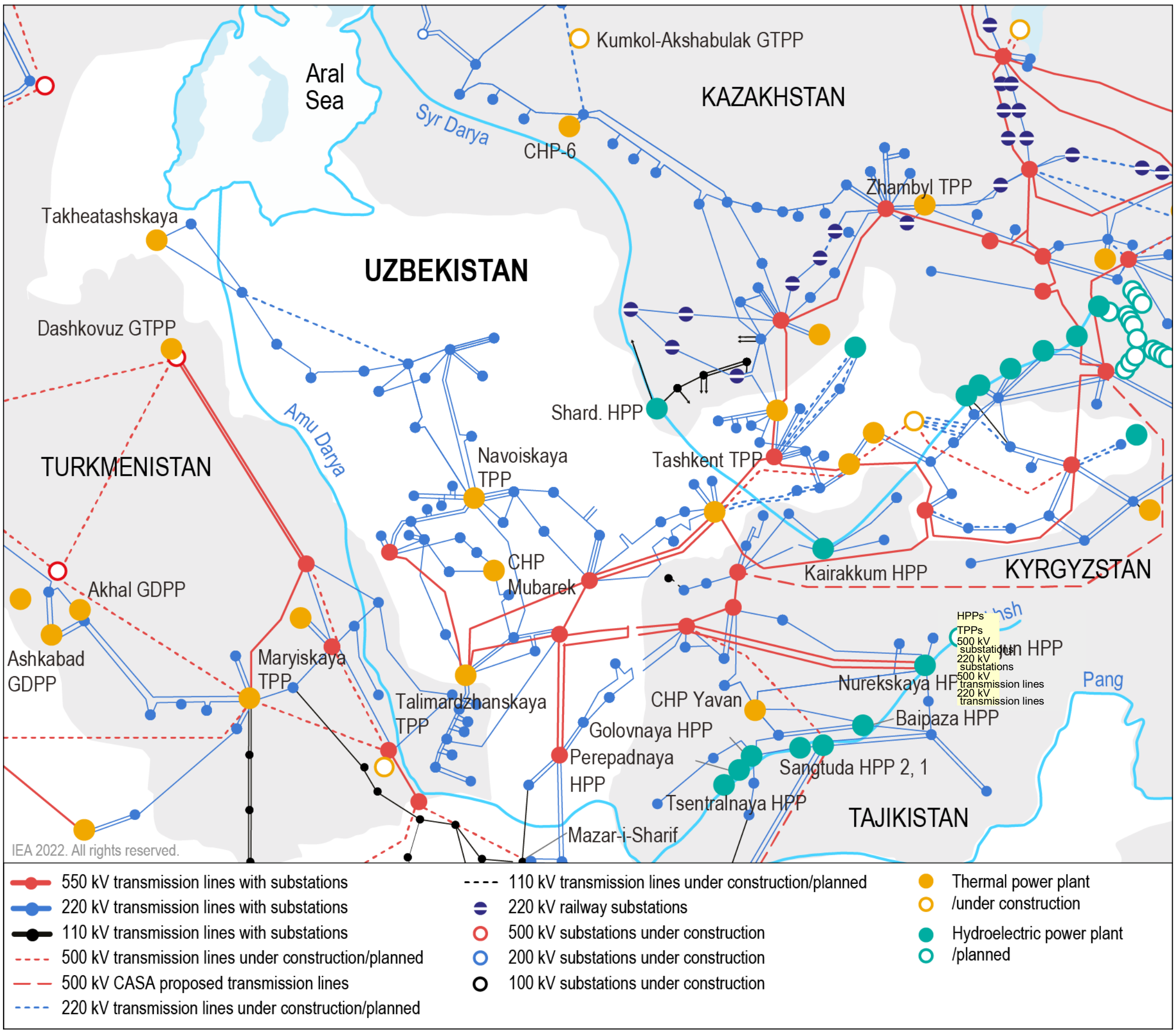
Notes: This table shows the possible barriers with instances against solar energy technology deployment illustrated in IEA and ISA (2019); not all instances are necessarily applicable to the context of Uzbekistan.

Source: Adapted from IEA and ISA (2019), Solar Energy: Mapping the Road Ahead.

Currently, the domestic electricity network in Uzbekistan consists of more than 9 700 km of transmission lines (220-500 kV) and more than 250 000 km of distribution lines (0.4-110 kV) owned by NEGU and the Regional Electric Power Networks JSC, respectively (Figure 9). With a view to ensuring further power supply stability and allowing new generation assets to connect to the network, more than 700 km of the transmission lines in the north-western region of Uzbekistan (Republic of Karakalpakstan and the Navoi region) are expected to be developed by 2025 in line with the Concept Note for ensuring electricity supply in Uzbekistan in 2020-2030, which could also help take advantage of an enormous potential of solar and wind energy in the region. Moreover, to help NEGU modernise obsolete transmission/distribution lines and substations, the World Bank approved the Electricity Sector Transformation and Resilient Transmission Project in June 2021, which includes the rehabilitation, upgrade and expansion of 22 existing high-voltage substations and the construction of a 500 kV transmission substation and associated transmission lines (World Bank, 2021).

More than 260 km of interconnection lines are planned to be constructed by 2025 between Uzbekistan and its neighbouring countries Afghanistan and Tajikistan, to exploit the potential electricity trade and interoperation. With regard to the distribution lines, more than 18 000 km will be modernised or constructed by 2025.

Figure 9 Main electricity network in Uzbekistan



Notes: This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.
Source: Based on USAID (2015), Central Asia Electric Grid.

The National Dispatch Centre under NEGU is in charge of dispatching all power plants in accordance with the Rules for the Production, Transmission and Distribution of Electrical Energy approved by the Cabinet of Ministers. Both NEGU and territorial JSCs under the Regional Electric Power Networks JSC are responsible for electricity transmission and distribution, respectively. The TPPs and some HPPs with reservoirs provide flexibility to the power system, and are dispatched depending on electricity demand.

Business entities such as independent power producers are guaranteed connection to the energy system, including electricity and thermal, and contract with NEGU to supply energy produced from renewable energy sources; the cost of connecting to the energy system, including grid enhancement, is mainly borne by the entities. The technical procedure of the grid connection, including non-discriminatory access to the system for the business entities, is defined by the Regulation for Connecting Businesses that Produce Electricity, Including from Renewable Energy Sources, to the Unified Electric Power System, approved in July 2019.

A solar energy roadmap for Uzbekistan by 2030

Uzbekistan has great renewable energy potential, especially for solar energy. With a view to ensuring energy security while optimising renewable energy resources, the government has implemented a wide range of measures to promote the integration of renewable energy into the energy system and private sector participation in the energy sector, including in large-scale solar energy projects.

Uzbekistan has made a positive effort toward that end, including by setting clear targets and reforming the energy sector and has been progressing toward achieving the solar power capacity target of 4 GW by 2026 and 5 GW by 2030. Nevertheless, a more comprehensive set of policies and support mechanisms will be required to reach Uzbekistan's maximum capacity of solar energy and further increase solar energy toward 2030. The government should consider bundling the range of actions needed to ensure the use of all types of solar energy resources.

This section presents a solar energy roadmap for Uzbekistan by 2030. It is based on current measures being implemented in Uzbekistan to break down the possible barriers to solar energy deployment discussed in the previous section. It aims to facilitate the government's deliberation of its solar energy strategy and focuses on:

- maximising the benefits of solar energy in the energy system
- policy and regulatory frameworks enabling further solar energy deployment
- increasing power system flexibility to integrate the increasing amount of solar generation.

Maximising the benefits of solar energy in the energy system

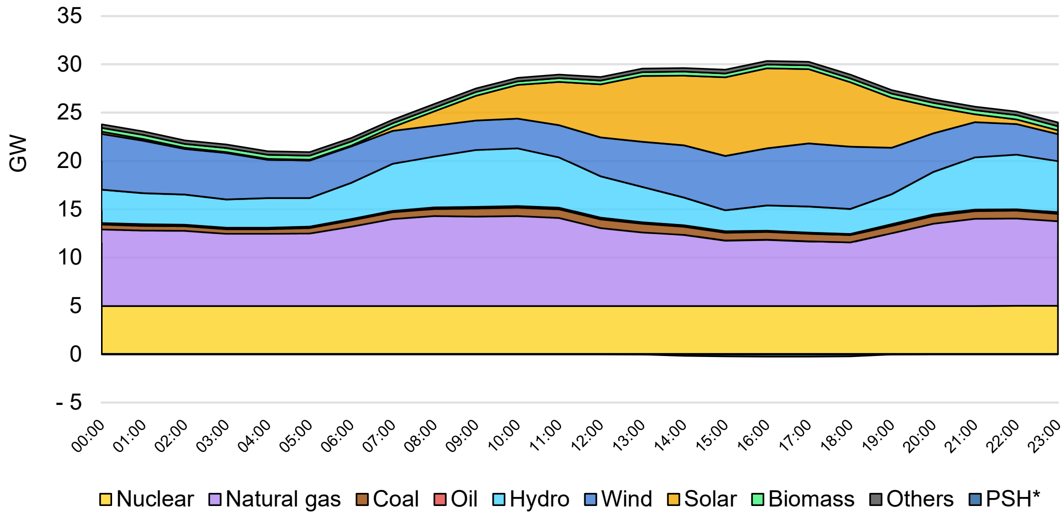
Transparent information on electricity infrastructure and markets

To maximise the benefits of solar energy, solar plants need to be installed in places where they can bring the highest value for the entire power system, i.e. they generate power where and when it is needed the most. This depends on the whole system infrastructure, including the grid network and other non-solar power assets, as well on electricity demand profiles.

Transparent information on electricity infrastructure and markets is therefore essential for creating an efficient electricity system as well as for providing current and prospective market participants with a level playing field and electricity market predictability. For example, EU member states are required to submit fundamental information such as generation, load and transmission for publication through the ENTSO-E Transparency Platform based on the EU's Transparency Regulation (Figure 10). Another example can be found in Germany, where one of the transmission system operators voluntarily makes its hourly network load data public.

In the context of Uzbekistan, locational and capacity information on existing major power plants and transmission lines are available on the Ministry of Energy's and the JSCs' websites, while actual data such as generation by technology and network load currently are not available. As a part of the ongoing electricity market reform, the government should also consider improving the transparency of information and requiring the JSCs to provide this information.

Figure 10 Actual hourly generation by technology, based on publicly available data on ENTSO-E's Transparency Platform (Spain, 1 June 2021, as an example)



* PSH: pumped storage hydropower.
Source: Based on data from ENTSO-E's Transparency Platform.

Small-, medium-scale and off-grid solar projects

Large-scale solar PV projects have been subject to competitive bidding processes in Uzbekistan since 2019 and an awarded project can sign a long-term contract with NEGU at a fixed tariff, as noted above. The government of Uzbekistan also aims to develop small- and medium-scale solar projects. The President stresses the need for encouraging citizens and enterprises to develop renewable energy sources for their own demand (MoE, 2021b).

Looking at small-scale projects, in order to increase solar PV generation while promoting self-consumption by individuals and businesses, the government approved a targeted programme for the installation of 150 000 rooftop solar PV with a capacity of 2-3 kW and the installation of solar water heaters with a capacity of about 200 litres to cover 2-2.5% of households by 2025. Moreover, the government plans to develop off-grid solar PV in remote areas and regions known for ecotourism. The government will also promote medium-scale plants by which enterprises and industrial parks can cover their own power demand.

Exploiting the potential of solar energy applications for both electricity and heat in Uzbekistan and encouraging investment in solar projects regardless of size and technology requires setting clear policy targets and complementing them with attractive incentive mechanisms, e.g. that foster self-consumption while avoiding unintended negative system integration impacts, such as real-time self-consumption schemes at a value-based price fixed by the regulator. Moreover, in certain areas with low population density and good solar insolation, an off-grid solar PV system with batteries and solar thermal, possibly in complement of other local low-carbon energy sources, can offer an interesting alternative to new developments or the refurbishment/upgrade of transmission lines (Box 1).

As shown by the experience in other countries, it will be important for the government to put monitoring processes in place and to rapidly adjust incentives, as appropriate and if needed. This is important to: 1) ensure that small-scale projects for self-consumption are economically attractive to foster investment; and/or 2) avoid unintended over-remuneration and negative system integration impacts.

Box 1 Off-grid renewable hybrid project in Australia

Coober Pedy, an iconic mining town in South Australia, as many other remote areas in the world, relied on diesel generation to supply electricity. To take advantage of renewable energy potential while reducing fossil fuel consumption, the Coober Pedy Hybrid Renewable Project started commercial operations in 2017, led by Energy Developments Pty Limited with support from the Australian Renewable Energy Agency (EDL, 2019).

The project consists of 1 MW solar PV, 4.1 MW wind power, 1.5 MW/0.49 MWh battery and other integration technologies with diesel power as a backup. Renewable generation has gradually increased, achieving 75.6% of electricity demand in FY2019, while realising a reliable power supply with unplanned outages at 0.52 hours in the same period, which was almost 80% lower than those of the pre-project period.

Floating solar PV

A floating solar PV system is a set of solar panels built on a framed foundation that floats on a body of water, mostly on water reservoirs, irrigation ponds and industrial basins. The system is particularly suitable for countries/regions where land availability is limited, and has the following advantages:

- existing electricity infrastructure including transmission lines can be used if solar PV plants are built on existing reservoirs of HPPs, contributing to reducing additional grid construction and lowering grid connection costs
- solar panels can be cooled by water beneath them, which leads to higher generation efficiency
- variable solar electricity benefits from the local flexibility provided by dispatchable, highly flexible hydropower, thus limiting impacts on the power system.

There are currently 25 reservoirs in Uzbekistan, with a total water surface of 1 500 km^2, 4 of which are hydropower reservoirs totalling 890 km^2 (CAWater, 2021). For comparison, the area of the hydropower reservoirs are more than 15 times the size of the world's largest solar park in India, which has an installed capacity of 2.25 GW. In this regard, the potential of floating solar PV on the hydropower reservoirs is a realistic opportunity to further increase solar PV capacity in Uzbekistan (Box 2).

Box 2 Floating solar PV system in Thailand

The government of Thailand aims to increase the share of generation capacity by renewable energy to 36% by 2037 in line with the 2018 National Power Development Plan. In response to the plan, the Electricity Generating Authority of Thailand (EGAT), a state-owned electricity company, was committed to building 16 floating solar PV farms on its hydropower reservoirs over the next 20 years, with a combined capacity of 2 725 MW.

EGAT recently finalised the construction of Thailand's largest floating solar PV project at Sirindhorn Dam in Ubon Ratchathani Province with 45 MW of capacity. Commercial operation started in November 2021, and also serves as a tourist attraction for the province. The project also uses an energy management system to provide stable power supply at optimal efficiency and to address the variability of solar generation by providing flexibility to the power system.

Figure 11 Floating solar projects at Sirindhorn Dam, Thailand

© EGAT

Source: EGAT (2020), EGAT releases first set of floating solar panels for Thailand's largest Hydro-floating Solar Hybrid Project at Sirindhorn Dam.

Solar PV-to-heat (PV2heat) for domestic hot water

PV2heat systems are becoming increasingly popular in several regions of the world, especially for domestic hot water. These systems consist of PV modules directly and solely connected to an electrical element that heats the water with DC power, without the need for inverters. Some systems also usually include an AC element connected to the electricity grid to heat the water when the sun is not shining (IEA SHC TCP, 2021a). PV2heat systems benefit from a simple installation, only requiring wiring from the panels to the water tank instead of insulated pipes, as is the case with traditional solar water heaters. They can also be integrated into existing water tanks. In comparison with traditional solar thermal, PV2heat systems can be particularly relevant in areas with lower insolation and colder temperatures. One downside of the simplicity of this installation is that it is also at higher risk of theft in some areas.

Although PV2heat generally requires a larger area for PV panels than solar thermal collectors for water heaters, declining costs of PV over the past years make this technology competitive. By December 2020, approximately 11 700 PV2heat systems with an estimated total PV capacity of 9.9 MWp were installed in South Africa. This emerging technology could have significant potential to contribute to sustainable hot water preparation in the residential sector in Uzbekistan.

Solar thermal for district heating

As discussed above, district heating networks in Uzbekistan represent about one-seventh of total national heat consumption. Natural gas accounted for 95% of district heat supplied in 2019, the remainder mostly came from coal. The buildings sector is responsible for over 80% of total district heat consumption, half of which occurs in the commercial and public sector, where it represents about one-third of total heat supplies.

By the end of 2020, 262 large-scale solar district heating systems (> 350 kilowatts thermal (kW_{th}); 500 m²) with an installed capacity of 1.410 megawatts thermal (MW_{th}) (2 million m²) were in operation worldwide. Denmark was in the lead followed by the People's Republic of China (IEA SHC TCP, 2021b). Uzbekistan's district heat infrastructure offers excellent perspectives for the integration of solar thermal into district heat supplies. It will be necessary to take the characteristics of existing district networks (e.g. efficiency, operating temperature) into account to assess the potential for district solar systems and to plan future developments.

Electric heat pumps

Electric heat pumps are becoming a more attractive option due to their lower installation costs and higher energy performance. Enhancing electric heat pumps with solar PV deployment simultaneously could help accelerate a higher renewable energy ratio and lower CO_2 emissions. Subsidies have proven effective in several countries to offset the upfront cost of heat pumps and initiate market dynamics that accelerate their uptake in newly constructed buildings (IEA, 2021b).

Electric heat pumps are out of the scope of this roadmap, but considering that heat accounts for almost two-thirds of total final energy consumption in Uzbekistan, the potential of facilitating electric heat pumps in parallel with solar PV development could be worth considering.

Key policy actions for exploiting the potential of solar energy applications

- Explore the techno-economic potential of solar energy applications for both electricity and heat, including solar thermal in buildings, industry and district heat systems.
- Ensure there is transparent information on electricity markets and infrastructure, including on generation facilities and transmission/distribution lines, in order to foster the development of solar installations in places where they maximise value to the whole power system.
- Encourage investment in small- and medium-scale solar projects by setting clear policy targets with attractive incentive mechanisms, and monitor economic

attractiveness as well as unintended system integration impacts and make relevant adjustments, if needed.

- Explore the relevance of off-grid solar PV, solar thermal and solar PV2heat applications in remote areas.
- Assess the potential of floating solar PV on existing hydropower reservoirs.
- Assess the options to integrate solar thermal energy into district heating networks, taking advantage of existing district heating infrastructure.
- Consider the possibility of facilitating electric heat pumps.

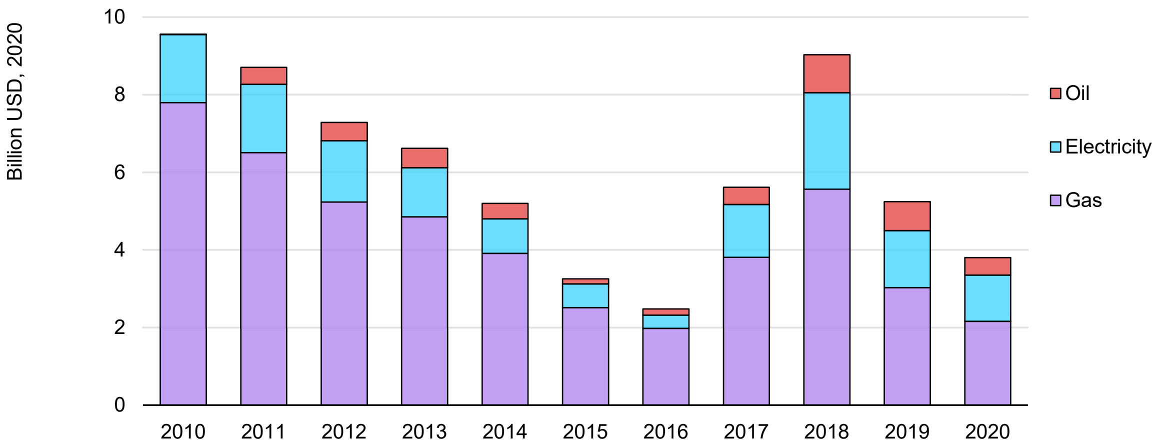
Policy and regulatory frameworks enabling further solar energy deployment

Phasing out fossil fuel subsidies

Fossil fuel subsidies could not only create structural risks to government budgets and the financial performance of the energy sector, but also hamper cleaner and more efficient energy in the future by increasing fossil-based carbon emissions. During the COP26 in November 2021, almost 200 countries, including Uzbekistan, agreed to phase out inefficient fossil fuel subsidies.

Such subsidies have significantly decreased in Uzbekistan in recent years, from USD 9.0 billion in 2018 to USD 3.8 billion in 2020 (Figure 12), but they still amount to 6.6% of total GDP in Uzbekistan (IEA, 2021c). As the power mix in Uzbekistan is dominated by natural gas, fossil fuel subsidies are also reflected in electricity prices.

Figure 12 Fossil fuel subsidies by fuel in Uzbekistan, 2010-2020



Notes: Fossil fuel subsidies for electricity in this figure stand for the subsidies used to produce electricity.
Source: Based on IEA Fossil Fuel Subsidies Database.

To create a level playing field for all energy sources to facilitate private investment in the renewable energy sector, phasing out fossil fuel subsidies must be progressive and carefully implemented, accompanied by other policies (e.g. fiscal measures) protecting the poorest and most impacted parts of society.

Access to the power grid for all generating companies

As described above, new entrants to the power sector, including independent power producers, are allowed to connect to the energy system in line with the Regulation for Connecting Businesses that Produce Electricity, Including from Renewable Energy Sources, to the Unified Electric Power System. However, the detailed procedure for the grid connection is thus far unclear.

To encourage private investment in the renewable energy sector and exploit the potential of solar energy applications in Uzbekistan, when developing the electricity markets and regulation, it will be essential to ensure non-discriminatory access to the power grid regardless of entity and generation capacity through a transparent procedure and fair grid connection cost. Clearer rules on permitting for project installation and grid construction should be also considered.

Transparent, participative and long-term planning for renewable development

The government of Uzbekistan, in co-operation with international financial institutions, has announced tenders for large-scale solar projects amounting to 2 050 MW, 1 300 MW of which had been awarded at competitive prices as of December 2021 (see Table 2).

Substantial progress has been made toward achieving the solar power capacity target of 5 GW by 2030. To continue encouraging private investment in solar energy for both electricity and heat as well as to aim for further solar energy development in 2030, transparent and long-term plans for solar energy deployment covering small- to large-scale projects should be integrated into the government’s solar energy strategy. The solar energy deployment plan needs to go hand-in-hand with long-term grid expansion planning, which needs to be periodically updated by the government (Box 3).

The government may also want to consider the option of developing a masterplan with solar parks to further attract investors and reduce overall costs. Solar parks have proven to be an effective tool in other countries, e.g. in India.

Moreover, energy planning should include the active participation of all stakeholders, including citizens, in order to best tailor energy development to the concrete energy needs of the population and avoid conflicting projects and social opposition, while considering and monitoring the social and environmental impact of the development.

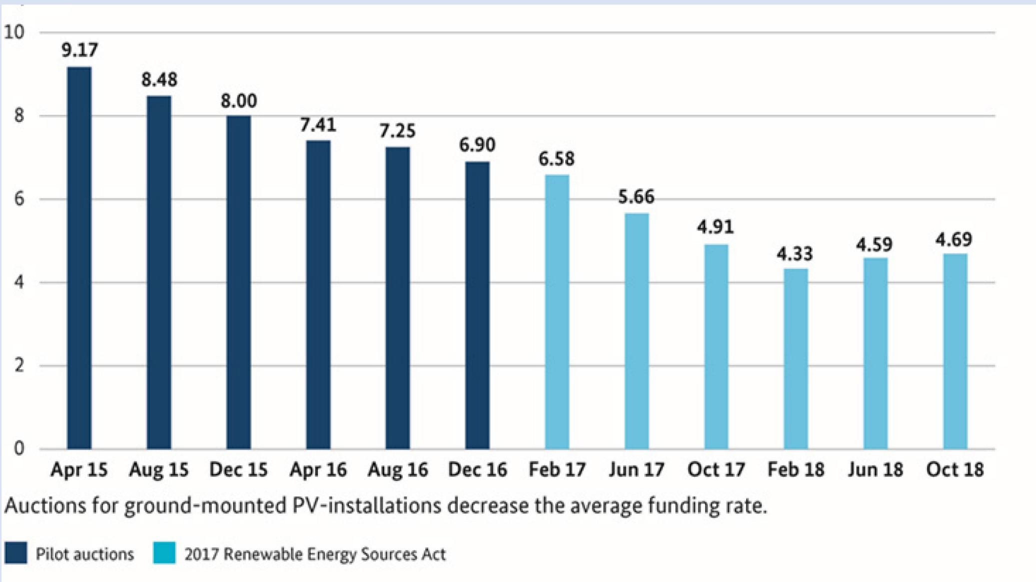
Box 3 Long-term planning for renewable tender and grid development in Germany

Renewable generation in Germany has significantly increased over the last two decades: from 6% in the power mix in 2000 to 42% in 2019, which well exceeded the 2020 target of 35%. Renewables also play an important role in the heat sector, reaching 15% in 2019 in the final energy consumption for heating and cooling. Solar PV became the second-largest renewable electricity source after onshore wind. Its capacity amounted to 47.5 GW in 2019.

Competitive tenders for solar PV officially started in 2017 (after the pilot tenders in 2015) and the average awarded tariffs have remarkably decreased, from 9.17 euro cent (ct)/kWh (equivalent to 99.2 USD/MWh) in 2015 to 4.69 ct/kWh (53.9 USD/MWh) in 2018.

To increase the share of renewable electricity to 65% by 2030 and achieve carbon neutrality before 2050, the German government amended the Renewable Energy Sources Act in 2020. The act set out auction volumes for individual technology up to 2028. As regards solar PV, an annual volume between 1.95 GW to 6.0 GW will be tendered with a view to increasing its cumulative capacity to 100 GW by 2030.

Figure 13 Average awarded tariffs for ground-mounted solar PV systems in Germany, April 2015-October 2018



© BMWK

Source: BMWK (2021a), [Erneuerbare energien [Renewable energy]].

The electricity grid, in the meanwhile, plays a critical role in ensuring secure and affordable power supply of renewables and achieving a successful energy transition. The major transmission lines in Germany have a total length of 37 000 km. One of the main challenges Germany is facing is to develop long-distance transmission lines to deliver wind power generated in the north and the east of Germany as well as the North Sea to the demand centres in the south and west of the country, which will mean constructing or upgrading more than 7 500 km of transmission lines in the next few years.

In order to properly facilitate grid expansion, the government approved the Electricity Grid Action Plan in 2018 which adopts two approaches: 1) optimising existing grids using new technologies and operating strategies; and 2) accelerating grid expansion by simplifying planning procedures and using forward-looking operation. This was followed by the endorsement of the 2019-2030 Grid Development Plan in 2019 which outlines grid expansion and optimisation up to 2030.

Sources: BMWK (2021a), Erneuerbare energien [Renewable energy]; BMWK (2021b), Ein stromnetz für die energiewende [An electricity grid for the energy transition].

Treatment of end-of-life solar panels

Over the last decade, solar PV capacity has significantly increased globally owing to the sharp decline in price, amounting to more than 600 GW total installations in 2019. The more solar PV is deployed globally, the more end-of-life solar panels will be disposed of in a couple of decades. Currently, the cumulative solar panel waste is much less than installed solar PV capacity, but it is estimated to reach 5.5-6 million tonnes by the 2050s (4% of installed PV panels), given an average panel lifetime of 30 years (IRENA and IEA PVPS, 2016). The management of end-of-life solar panels could be an integral part of solar PV policy in terms of recycling valuable materials and components, but also for the proper treatment of hazardous substances such as tin and lead.

Solar PV capacity in Uzbekistan is still negligible, but the government aims to rapidly increase its capacity up to 5 GW by 2030. Considering the average solar panel lifetime, the treatment of end-of-life solar panels is not a pressing issue in Uzbekistan, but it is important to incorporate appropriate policy measures into the current regulations with the possible future challenge in mind (Box 4).

Box 4 End-of-life solar panel treatment in Japan

To increase renewable energy sources in the power mix in Japan, the Japanese government introduced a feed-in-tariff system in 2012, which led to a massive surge in solar PV capacity to 56 GW in FY2019, up from 5.6 GW in FY2012.

Solar PV project developers in Japan are required to dispose of appropriately their end-of-life solar panels based on the Waste Management Law. The decommissioning cost is taken into account in the feed-in tariffs. However, there is a looming risk of illegal disposal after their 20-year contract because the ownership of the solar PV projects tend to change frequently.

To avoid the risk and ensure the proper treatment of end-of-life solar panels, the government decided to develop a fund dedicated to end-of-life solar panel disposal in 2020 by externally accumulating part of the feed-in tariffs.

Sources: METI (2021a), Recommendation on procurement cost, etc. from FY2021; METI (2021b), Detailed design of the Renewable Energy Reform Act.

Key policy actions for establishing policy and regulatory frameworks for further solar energy deployment

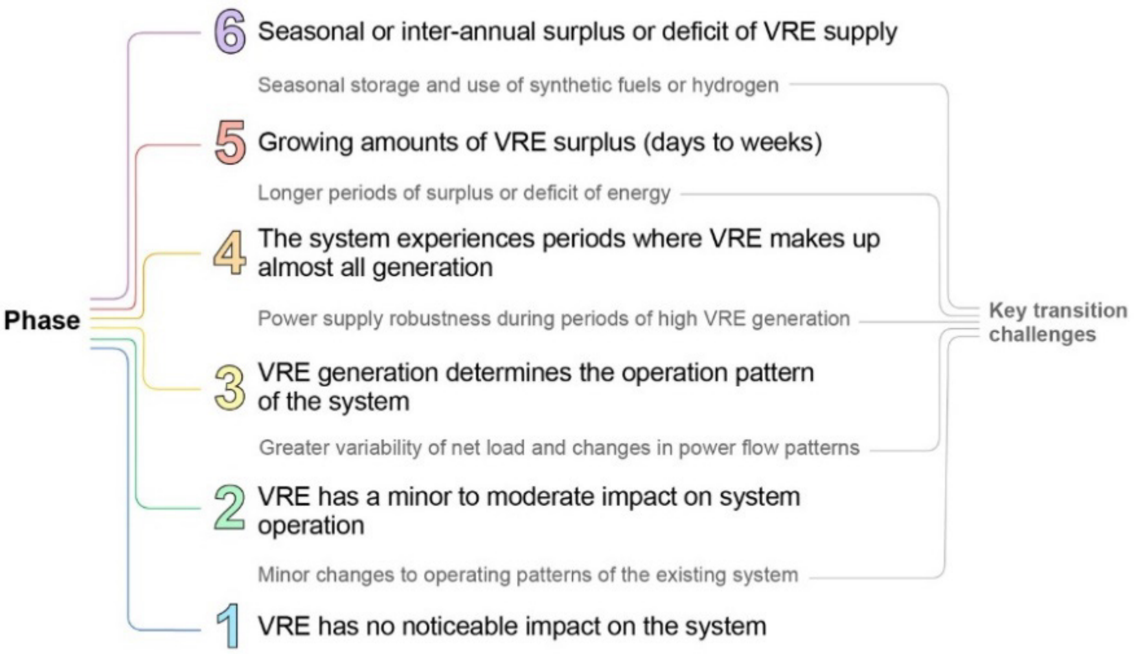
- Progressively phase out fossil fuel subsidies to level the playing field with renewables while protecting the most economically vulnerable consumers.
- Consider the possibility of implementing fossil fuel bans in new building constructions.
- Ensure non-discriminatory access to the power grid for all generators with a transparent procedure and fair grid connection cost.
- Formulate clearer rules on permitting for project installation and grid construction.
- Integrate transparent, participative and long-term planning for renewable development into a solar energy strategy in Uzbekistan.
- Develop long-term power grid development planning in line with renewable development.
- Consider appropriate measures to dispose of end-of-life solar panels.

Increasing power system flexibility

Thanks to a sharp cost decline and continued policy support, electricity generation from variable renewable energy (VRE) sources has been rapidly expanding globally, having reached double-digit shares in several countries. However, VRE output fluctuates over time due to the variability of sunlight and wind availability, making it increasingly important to address power system flexibility to enable further integration of VRE into the power system.

The IEA categorises VRE integration into six phases (Figure 14). In Phase 1, VRE deployment has no noticeable impact on power system operations, while the power system is able to address minor operational changes through existing system resources including conventional generators and operational practices in Phase 2. The significant integration challenges appear in Phase 3, in which power systems are required to become flexible enough to adequately respond to supply-demand fluctuations within minutes to hours. In Phase 3 through Phase 6, the following implication needs to be considered: 1) VRE determines the operating pattern of the whole power system; 2) additional investments in flexibility are required; 3) there are structural surpluses of VRE generation that lead to curtailment; and 4) the seasonal and inter-year structural imbalances in energy supply require sectoral coupling.

Figure 14 Key characteristics and challenges in the different phases of variable renewable energy system integration



Source: IEA (2021d), Secure Energy Transitions in the Power Sector.

Looking at the status of VRE integration in Uzbekistan, the VRE share in the power mix was negligible, at 0.02% (15.6 GWh) in 2019, meaning that today VRE has almost no impact on the power system (see Figure 3). However, Uzbekistan should achieve a renewable electricity share (including hydropower generation) of 25% by 2030 in line with the Strategy for the Transition of the Republic of Uzbekistan to the Green Economy for the Period 2019-2030. It could reach the advanced VRE integration stage where the system operation needs to address greater fluctuation of VRE generation and facilitate additional flexibility sources (Phase 3 in Figure 15).

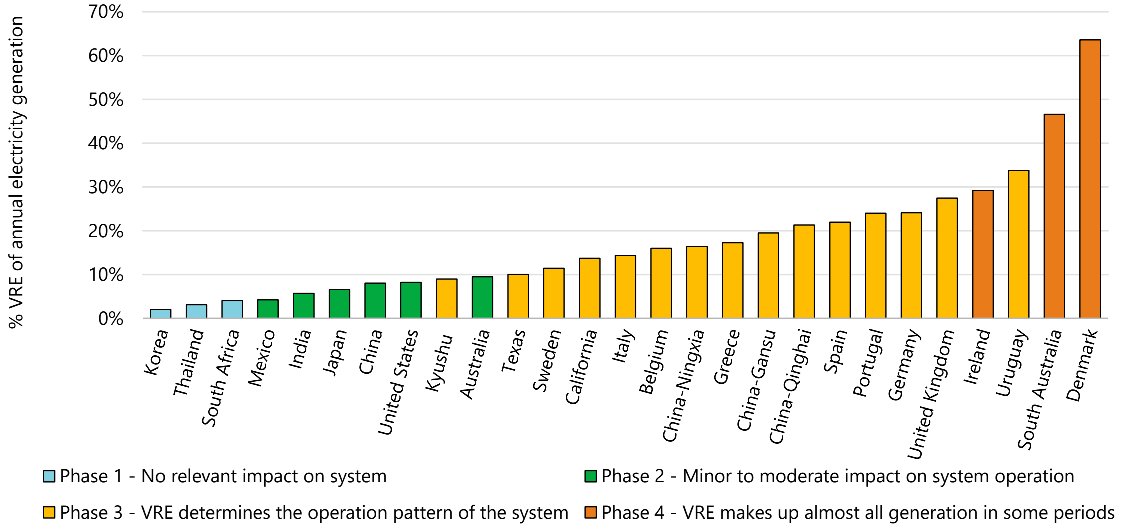
Flexibility has been traditionally and globally supplied by thermal and hydropower generation together with other options such as pumped storage hydropower (PSH) and interconnections. This conventional rotating generation is based on synchronous machines, providing inertia to the system.

In Uzbekistan, TPPs account for a large portion of electricity assets (14.0 GW, or 88.1% in 2019) followed by HPPs (1.9 GW, or 11.9% in the same year) (IEA, 2020a), and both technologies not only ensure sufficient power supply, but also should be served as flexibility sources through optimised system operation in the medium term.

It must be kept in mind that solar PV plants themselves can provide flexibility to the power system, e.g. through tracking and oriented depending on demand requirements, and hybrid systems with storage. In this respect, the introduction of locational and time adjustments into bidding levels could be worth considering to foster solar generation where and when it maximises value to the power system.

Moreover, the government should also explore other flexibility sources such as PSH and batteries when considering further deployment of solar generation in the decade and beyond. Appropriate conditions need to be in place for the balancing market so that these sources are incentivised enough to participate in the market.

Figure 15 Annual variable renewable energy share and corresponding system integration phase in selected countries/regions, 2018



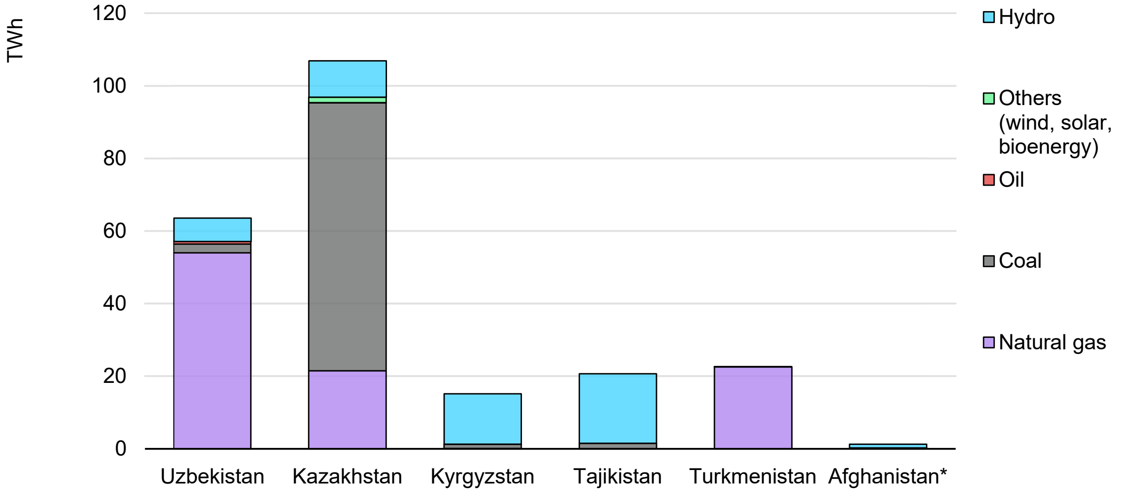
Note: VRE: variable renewable energy. In this figure, Kyushu is the third largest of the four main islands of Japan.
Source: IEA (2019b), Status of Power System Transformation 2019.

Interconnections

Interconnections not only enable electricity trade between neighbouring countries, they can also enlarge the area where energy balancing can be made to address mismatches in demand patterns beyond national boundaries. Interconnections remain a key enabler of system integration of VRE, providing system flexibility of about 170 GW globally in 2017 (IEA, 2018).

As previously described, Uzbekistan has interconnections with five neighbouring countries (Afghanistan, Kazakhstan, Kyrgyzstan, Tajikistan and Turkmenistan), and new 500 kV interconnection lines will be constructed between Afghanistan and Tajikistan by 2025 in accordance with the Concept Note for ensuring electricity supply in Uzbekistan in 2020-2030. Given the fact that interconnections contribute to securing power supply to these countries as well as to using each others' thermal and hydropower assets as flexibility sources in the medium to long term (Figure 16), further developing interconnections and creating a single electricity market among the neighbouring countries could be key options.

Figure 16 Electricity generation by source in Uzbekistan and neighbouring countries, 2019



* Data for Afghanistan are estimated based on the UNSD data.

Source: Based on IEA (2021a), World Energy Statistics and Balances (database).

Pumped storage hydropower

Pumped storage hydropower (PSH) plants globally accounted for about 150 GW in 2017 and 97% of energy storage capacity, providing short- and medium-term energy storage (IEA, 2018). There are no PSH plants in Uzbekistan today, but in April 2021 Uzbekhydroenergo and French electric company EDF announced plans to develop a PSH plant (200 MW) along with floating solar PV on its reservoir in Tashkent region (Hydropower&dams, 2021).

The government is committed to increasing HPP capacity up to 3.8 GW by 2030 (1.54 GW of new HPP development and 0.19 GW in refurbishment/upgrading of existing HPP) in the Concept Note for ensuring electricity supply in Uzbekistan in 2020-2030. Adding pumped storage options should also be considered to secure further flexibility sources in the future.

Concentrating solar power

Concentrating solar power (CSP) is a technology for generating electricity from irradiation, concentrating solar rays to heat a fluid which directly or indirectly runs an electrical generator. While a solar PV system can use direct and diffuse solar radiations, CSP only uses direct irradiation and thus needs a daily minimum of sunshine to generate electricity, which limits its use to hot, dry areas with clear skies. Compared to solar PV, the predominant solar technology accounting for more than 600 GW globally in 2019, the installed CSP plant capacity is quite limited (6 GW in the same year) (IEA, 2020b), but CSP plants with built-in thermal storage is a dispatchable technology, providing power system flexibility and stability while securing a low-emission power supply.

If direct normal irradiance is high enough, CSP could be a promising option to satisfy increasing solar generation in the power mix and provide system flexibility. Uzbekistan has a lot of sunshine throughout the year, with DNI at 4.44 kWh/m²/day (median value). The south-western region including Kashkadarya and the Samarkand region especially has relatively higher DNI (about 4.9 kWh/m²/day) (see Figure 6). A detailed feasibility study on the deployment of CSP plants could be valuable.

Demand response

Demand response (DR) is another flexibility source provided by the demand side, reducing or shifting electricity use by consumers. It is a cost-effective way to reduce electricity demand during peak periods, providing an alternative to increasing electricity generation. Moreover, DR allows using excess electricity more efficiently by shifting electricity demand if the share of VRE increases in the electricity mix and its output is high during certain times of the day.

Because DR is a cost-effective and sustainable flexibility option, the potential of developing DR schemes with cost-reflective energy tariffs should be taken into account. Once its potential is positively assessed, DR should be included in power system planning and operations, but should be placed on a level playing field with supply-side flexibility sources through appropriate mechanisms (e.g. demand-side bidding in electricity markets).

Key policy actions for ensuring power system flexibility

- Optimise the operation of conventional power plants (TPPs and HPPs) as a system balancing option.
- Consider introducing locational and time adjustments into solar PV bidding levels with a view to fostering solar generation where and when it maximises value to the power system.
- Enhance interconnections with neighbouring countries.

- Facilitate sufficient storage development, including PSH and batteries.
- Consider the potential of CSP plants in terms of low-emission power sources and system flexibility provider.
- Develop appropriate conditions for the balancing market to incentivise diversified energy sources such as PSH and batteries to supply flexibility to the power system.
- Investigate the potential for DR schemes.

Solar energy in Uzbekistan: Vision for 2030

This section provides a vision of solar energy in Uzbekistan in 2030. It outlines the sustainable energy environment solar energy could deliver and offers a timeline up to 2030.

The vision for 2030

In this vision, Uzbekistan succeeds in maximising the benefits of solar energy capacity for both electricity and heat, making solar energy one of the country's major energy sources.

Solar energy potential with specific technologies – including solar PV, floating solar PV, CSP, PV2heat, solar thermal, district solar heating and electric heat pumps – is properly estimated. In addition to mega-scale solar projects, small- to medium-scale solar projects including rooftop solar PV become attractive to developers and consumers thanks to appropriate policy targets and measures. Off-grid solar energy systems could secure clean energy supply in remote areas with good solar resources but no access to the grid.

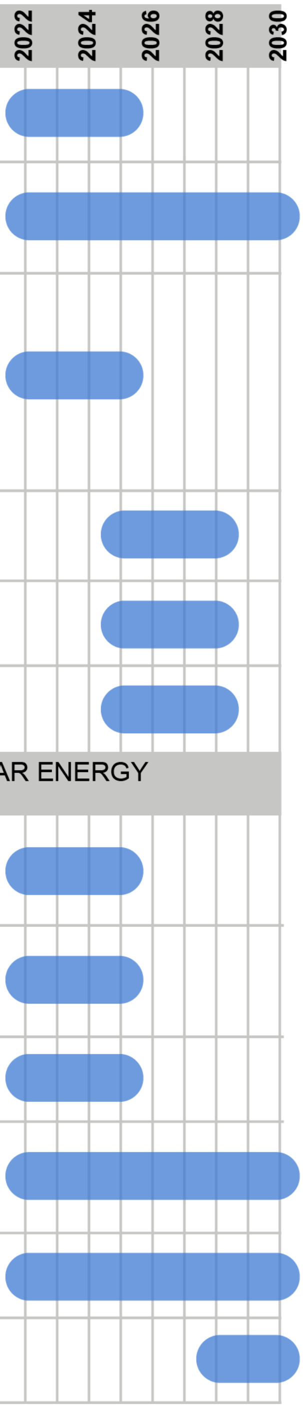
Transparent and sound **policy and regulatory frameworks** create a level playing field for all energy sources, enabling various developers to participate in the energy market and get access to the energy system. This is strengthened by the phasing out of fossil fuel subsidies and the possible additional support for renewable sources. Moreover, long-term energy and grid development planning provides developers with business stability and predictability in Uzbekistan, contributing to further solar energy deployment in a cost-competitive manner.

Due to the increase in the share of VRE in the power mix, **power system flexibility** increasingly becomes a key issue, while conventional power plants remain a major power source in Uzbekistan providing flexibility to the power system. A properly designed balancing market enables low-emission energy sources such as PSH and batteries to serve as new flexibility options. Furthermore, DR and enhanced interconnections with neighbouring countries also serve as additional flexibility sources while securing power supply in these countries.

Attaining the vision: A timeline to 2030

This section outlines a timeline for key actions through 2030 to help Uzbekistan create the conditions necessary to achieve the solar energy vision laid out in this roadmap. The government of Uzbekistan needs to periodically monitor its progress toward a solar energy future and to review policies and actions where appropriate.

ACTION	SUB-CATEGORY
MAXIMISING THE BENEFITS OF SOLAR ENERGY IN THE ENERGY SYSTEM	
Explore the potential of solar energy applications for both electricity and heat	Technology
Ensure transparent information on electricity infrastructure and market towards 2025 and 2030 renewable energy targets	Policy and strategy
Encourage investment in small- and medium-scale solar projects by setting clear policy targets with attractive incentive mechanisms and monitor economic attractiveness as well as unintended system integration impacts and make relevant adjustments	Policy and strategy
Explore off-grid solar PV in remote areas, PV-to-heat and solar thermal applications	Technology
Assess the potential of floating solar PV on hydropower reservoirs	Technology
Consider the possibility of facilitating electric heat pumps	Technology
POLICY AND REGULATORY FRAMEWORKS FOR FURTHER SOLAR ENERGY DEPLOYMENT	
Progressively phase out fossil fuel subsidies to level the playing field with renewable energy sources	Tariff reform
Ensure non-discriminatory access to power grid for all generators with transparent procedure and fair grid connection cost	Policy and strategy
Formulate clearer rules on permitting for project installation and grid construction	Policy and strategy
Integrate transparent, participative and long-term planning for renewable development into a solar energy strategy	Policy and strategy
Develop long-term power grid planning in line with renewable deployment	Policy and strategy
Consider appropriate measures to handle end-of-life solar panels	Environment



ACTION	SUB-CATEGORY	2022	2024	2026	2028	2030
SECURING POWER SYSTEM FLEXIBILITY						
Optimise the operation of conventional power plants as a system balancing option	Policy and strategy					
Consider introducing locational and time adjustments into solar PV's bidding levels	Policy and strategy					
Enhance interconnections with neighbouring countries	Policy and strategy					
Facilitate sufficient storage development including pumped storage hydropower	Technology					
Consider the potential of concentrating solar power plants	Technology					
Develop appropriate conditions for balancing market which incentivise diversified energy sources	Market					
Consider developing demand response schemes as a cost-effective and sustainable flexibility tool	Market					

Preparing for post-2030

This roadmap provides a timeline through 2030 with key actions. In addition, in order to further enhance solar energy use beyond 2030 and move progress toward clean energy transitions, the government of Uzbekistan may need to also consider decarbonising other sectors.

This includes focusing on reducing emissions in hard-to-abate sectors, including heavy industry and long-distance transport, through measures such as the roll-out of electric vehicles and the development of solar hydrogen production and use.

Conclusion

Uzbekistan has abundant renewable energy potential, most of which lies in solar energy thanks to high solar irradiation. However, until now energy supply has been dominated by fossil fuels, with renewable energy – almost exclusively hydropower – accounting for only 1% of its total energy production in 2019.

To satisfy growing energy demand while promoting renewable energy use, the government of Uzbekistan has adopted a wide range of energy strategies and laws and has been undertaking energy sector reform to increase solar energy use and make it a key energy source by 2030.

These efforts could be complemented by: further exploring the potential of solar energy applications; establishing policy and regulatory frameworks to enable greater deployment of solar energy facilities; and increasing power system flexibility to address the variability of VRE generation. These aspects include phasing out inefficient fossil fuel subsidies while protecting economically vulnerable consumers, implementing tariff reform, and investing in upgrading and improving the capacity and reliability of the power transmission system. All of this would allow Uzbekistan to better integrate increasing amounts of solar energy through 2030.

Moreover, integrating the country's solar energy strategy into the larger Uzbek energy strategy, while also looking towards increased regional co-operation, particularly on electricity trading, will allow Uzbekistan to truly take advantage of its significant solar potential in a cost-efficient manner.

The possible actions need to be undertaken in a timely and systematic manner to achieve a solar energy future in Uzbekistan by 2030. As a first step through 2025, the solar roadmap should duly consider short- and medium-term policy targets already set, including the formation of an electricity market formation 2023 and the renewable generation ratio of 20% by 2025. Accordingly, the government should properly explore the potential of solar energy applications for both electricity and heat with clear targets and attractive incentive mechanisms, while progressively phasing out fossil fuel subsidies to level the playing field with renewable energy sources. During the process of developing electricity market design and regulations, the government also needs to ensure non-discriminatory access to the power grid for all generators and formulate clearer rules on permitting. The needs for power system flexibility remain limited during this term, but the government should consider necessary measures to ensure that existing conventional power plants and solar PV itself could serve as flexibility options.

From 2025 onward, additional efforts could be required to achieve the 2030 policy targets of renewable electricity ratio at 25% and solar power capacity at 5 GW. The government could further unlock the vast solar energy potential by exploring other applications such as CSP, floating solar PV, off-grid solar PV in remote areas, solar PV2heat and electric heat pumps. The treatment of end-of-life solar panels is not an urgent issue in Uzbekistan, but it could be worth considering incorporating appropriate policy measures into the regulations early on.

After 2025, power system flexibility gradually becomes visible as an issue, with the increase in VRE generation. The government should consider appropriate conditions for balancing the electricity market, which enables diversified low-emission energy sources such as PSH and DR to supply flexibility to the power system. It should be also kept in mind that enhancing interconnections with neighbouring countries could serve as an additional source of flexibility, while enhancing power supply security among these countries.

Throughout the timeline from today up to 2030, in parallel with the step-by-step actions listed above, the government needs to continue ensuring the availability of transparent information on electricity infrastructure and markets to foster solar energy deployment. The government should also support the optimisation of conventional power plant operation as a flexibility option, depending on the penetration level of renewable energy sources. Moreover, it should be kept in mind that transparent, participative and long-term planning for renewable development needs to be properly incorporated into the overall solar energy strategy, while long-term power grid planning must remain in line with renewable deployment.

To further promote solar energy use beyond 2030, the government might also consider decarbonising other sectors, e.g. through the roll-out of electric vehicles and the development of solar hydrogen production.

As illustrated in the roadmap, there are various examples of international best policy practices in the area of renewable energy, which Uzbekistan could learn from and adapt according to its national context. To enhance the use of solar energy resources in Uzbekistan, we recommend the government consider incorporating, as appropriate, all measures listed in the roadmap into its solar energy strategy toward 2030 and beyond.

Acronyms and abbreviations

CSP	concentrating solar power
CT	euro cent
DNI	direct normal irradiance
DR	demand response
EGAT	Electricity Generating Authority of Thailand
GHI	global horizontal irradiance
GW	gigwatt
GWh	gigawatt hour
HPP	hydropower plant
IEA	International Energy Agency
JSC	joint-stock company
kv	kilovolt
kWh	kilowatt hour
Mtoe	million tonnes of oil equivalent
MW	megawatt
MWh	megawatt hour
NEGU	National Electric Grids of Uzbekistan JSC
PJ	petajoule
PPP	public-private partnership
PSH	pumped storage hydropower
PV	photovoltaics
PV2heat	solar PV-to-heat
TPP	thermal power plant
TWh	terawatt hours
USD	United States dollar (currency)
VRE	variable renewable energy

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