Large-scale development of renewable energy sources and its impact on the electricity market and network infrastructure

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CONTENT

Notation and abbreviations

BAT – best available technology;

CAGR – compound annual growth rate;

CDC – Coordinating Dispatch Center;

CEPM EAEU – common electric power market of the Eurasian Economic Union;

CIS – Commonwealth of Independent States;

EAEU – Eurasian Economic Union;

Eff – efficiency;

EPC CIS – CIS Electric Power Council;

EPS – electric power system

FS – feasibility study;

GHG – greenhouse gases;

HPP – Hydro Power Plant;

IEA – International Energy Agency;

INDC – Estimated Nationally Determined Contribution;

IPS – integrated power system;

IPS – isolated power system;

IPS CA – Integrated Power System of Central Asia;

IRENA – International Renewable Energy Agency;

NDC SO – National Dispatch Center of the System Operator;

PS – polluting substance;

RES – renewable energy sources;

SDG – Sustainable Development Goal;

SPP – solar power plant;

TPP – thermal power plant;

UN –United Nations;

UNECE – The United Nations Economic Commission for Europe;

UPS – united power system;

VRE – variable renewables;

WG – working group;

WPP – wind power plant;

WPU – wind power unit;

Terms and Definitions

Renewable energy sources - energy sources continuously renewable due to naturally occurring natural processes: solar radiation energy, wind energy, hydrodynamic energy of water; geothermal energy: heat of soil, groundwater, rivers, water bodies, as well as anthropogenic sources of primary energy resources: biomass, biogas and other fuels from organic waste used to produce electric and (or) thermal energy, as well as other energy sources, defined as renewable, provided for under the laws of the CIS member states.

Environmental potential (effect) of renewable energy use – the amount of prevented emissions of greenhouse gases and pollutants into the atmosphere when burning fossil fuel.

Energy efficiency - efficient (rational) use of energy resources. The use of less energy to ensure the same level of energy supply for buildings or industrial processes. Achieving economically viable efficiency of using fuel and energy resources with the existing level of development of engineering and technology and observing environmental requirements.

The best available technology (BAT) - the technology of production of goods, performance of work, rendering of services, determined on the basis of modern achievements of science and technology and the best combination of criteria for achieving environmental protection goals, provided that it is technically feasible.

Reliability of the energy system - the ability of the energy system under certain conditions to fulfill the function of supplying consumers with electric energy and heat in a given volume (in terms of energy and power), subject to established requirements for energy quality, and not to allow situations dangerous to people and the environment

Synchronous zone - a set of all parallel operating power systems having a common system electric current frequency.

The synchronous zone of the UPS / IPS includes the electric power systems of Russia, Azerbaijan, Belarus, Georgia, Kazakhstan, Moldova, Mongolia, Latvia, Lithuania, Ukraine and Estonia. Through the power system of Kazakhstan, in parallel with the UES of Russia, the power systems of Central Asia - Kyrgyzstan, Tajikistan and Uzbekistan operate.

Executive summary

The project **Enhancing cross-border energy cooperation through the introduction of wind and solar energy in the energy systems of the CIS countries to achieve SDG7** is aimed at attaining Agenda 2030 for Sustainable Development. The beneficiary countries of this project include Armenia, Belarus, Kazakhstan, Kyrgyzstan, Tajikistan and Uzbekistan. The aim of the work is to support decision makers, energy companies and experts in faster deployment of renewable energy as part of National Sustainable Energy Action Plans. This report develops possible future energy scenarios for the period up to 2030 in the short, medium and long term and provides details on the current state of the renewable energy sector to help develop recommendations for implementation.

The energy sector is going through transition and experiencing undergoing significant structural changes to ensure **universal access to affordable, reliable, sustainable and modern energy sources for all**. Transforming energy systems by integrating various traditional and renewable energy sources in a wide range of capacities is key. By creating political, market and regulatory conditions, nations can attract investment and accelerate innovation through smart, efficient, reliable and sustainable technologies. Nonetheless, nations need to prepare to mitigate potential problems when attempting renewable energy integration.

The future of energy in the region in accordance with various development scenarios looks different. Fossil fuel industries will be affected most negatively, but at the same time they are necessary for economic welfare in economic transition.

In 2050, **half the energy** in the region will continue to be based on fossil fuels in any economically viable scenario. In all subregions, electricity generation, district heating systems and the transport sector will depend on fossil fuels. Thus, investments should be distributed to a wider range of technologies with minimal emissions to ensure a quick transition to sustainable energy.

The results of the report will be used in the development of specific recommendations to National Sustainable Energy Action Plans.

Under the conditions of energy systems transformation processes in the region, it is **advisable to perform the following work**:

• Determination of key areas and target vision for the development of the electric power industry of the CIS member states, taking into account the long-term prospects (for the period until 2050);

• Creation of an institutional framework, and in general - an integrated management system that defines the regulatory, technological and economic rules for the optimal development and functioning of the electric power complex of the CIS member states in the context of the processes of transformation of energy systems in the country and in the world;

• Creation of a joint program to develop a technological and economic basis for building a future efficient and sustainable integrated energy system of the CIS member states to meet SDG7.

In order to develop renewable energy in the beneficiary countries, we suggest the following **recommendations**:

• Integrate solar and wind energy into power systems;
• Create national institutes of future energy planning;

- Improve methods to unify relevant, reliable, and timely statistics;
- Develop legislative measures to support integration of variable renewable energy into power systems;
- Harness international experience to harmonize national and international energy standards;
- Utilize modern technologies for efficient solar and wind energy production;
- Implement measures to reduce greenhouse gas emissions in the power sector;
- Strengthen conditions for the modernization of energy systems with solar and wind energy;
- Establish a guide for potential investors on renewable energy systems;
- Train the national workforce to integrate solar and wind energy into power systems.

More detailed recommendations can be found in **Solar and Wind Energy for Transboundary Energy Cooperation in the countries beneficiaries.**

Introduction

In September 2015 the heads of 193 states, including the leaders of the Commonwealth of Independent States (CIS) member countries, agreed to the 2030 Agenda for Sustainable Development that comprises 17 Sustainable Development Goals (SDGs).[1]. The SDGs are global in nature and universally applicable but ensure that national conditions are taken into account..

SDG 7 - "Ensuring universal access to affordable, reliable, sustainable and modern energy sources for all" [2]. UNECE flagship project Pathways to Sustainable Energy defines "Sustainable Energy" through three pillars: i) energy security "securing the energy needed for economic development", ii) energy for quality of life "providing affordable energy that is available to all at all times", and iii) energy and environment "limiting the impact of energy system on climate, ecosystems and health"[3] International cooperation is a precondition to attract investment into development in renewable energy across the region one of the tools to expand the use of renewable energy. In this regard, one of the most important indicators of SDG 7 is the following indicator: *"By 2030, strengthen international cooperation to facilitate access to clean energy research and technologies, including renewable energy sources (RES), energy efficiency and advanced environmentally friendly technologies for the use of fossil fuels, as well as promoting investment in energy infrastructure and clean energy technologies"*[4].

Currently, all CIS countries have signed and ratified the Paris Climate Agreement, identified the appropriate contributions (INDC) and developed action plans for their implementation at the national level. Most CIS countries in the long-term development plans of the electric power industry include development of the large-scale renewable energy with the goal to limit greenhouse gas emissions GHG from energy sector.

The expansion of the use of renewable energy sources was made possible thanks to technological progress and significant reduction of cost of wind (WPP) and solar (SPP) power.

The global electric power industry has been going through significant structural changes with the aim to ensure universal access to affordable, reliable, sustainable and modern energy sources for all.[5]

This goal is achieved by the active integration of various traditional and renewable energy sources in a wide range of capacities from small distributed generation facilities to large network power plants, which entails the transformation of energy systems.

The ongoing technological changes are accompanied by the creation of an institutional framework that defines the regulatory, technological and economic rules for the reliable and effective development and functioning of energy systems in the new conditions.

In other words, there is a process of creating integrated electric power control system in line with modern power system.

Power System Transformation[6,7] means an active process of creating political, market and regulatory conditions, as well as the establishment of planning and operation of energy systems that accelerate investment, innovation and the use of intelligent, efficient, reliable and environmentally friendly technologies.

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[1] Sustainable Development Agenda, UN, 2020
https://www.un.org/sustainabledevelopment/development-agenda/

[2] Ensure access to affordable, reliable, sustainable and modern energy for all
https://sdgs.un.org/goals/goal7

[3] Pathways to Sustainable Energy, United Nations, 2020.
https://www.unece.org/energy/pathwaystose.html

[4] Decisions by Topic: Energy
https://www.unece.org/fileadmin/DAM/vision2030/BackgroundDocument_Rus.pdf

[5] Grid Modernization and Smart Grid, US Department of Energy, 2020.
https://www.energy.gov/oe/activities/technology-development/grid-modernization-and-smart-grid

[6] Status of Power System Transformation. System integration and local grids. IEA, 2017.

[7] Status of Power System Transformation. Advanced Power Plant Flexibility. IEA, 2018.

Now the installed capacity of wind farms and solar PV power plants reaches hundreds and thousands of MW, and the energy sector is undergoing a fundamental shift toward digitalized and decarbonized energy system.

An urgent task in this regard is to analyze the role of large-scale renewable energy deployment in a number of countries of the world; its impact (including negative) on traditional power generation, as well as on electricity market and grid infrastructure, and develop recommendations on how to overcome specific challenges in order to increase renewable energy investment in each of the CIS countries and to improve and optimize transboundary regional energy cooperation.

1. Objectives for the CIS member states

This chapter analyzes main goals and objectives of the electric power industry in the CIS and the EAEU countries that are enshrined in international and national laws and regulations. This includes the creation of a common electricity market, the deployment of renewable energy as well as the development of advanced innovative energy technologies.

Role the of the CIS Electric Power Council in attaining main goals and objectives of the electric power industry in the CIS member states

In accordance with the intergovernmental agreement on coordination in the field of electric power industry, in February 1992 the CIS Electric Power Council (EPC CIS) was established. The EPC CIS (hereinafter referred to as the Council) includes the heads of energy departments of the CIS countries. The Council is headed by the President, who is elected from among the members of the Council in rotation. Currently, the President of the Council is the Minister of Energy of the Russian Federation. The permanent working body of the Council is the Executive Committee, chaired by the Chairman, which organizes the activities of the Council as a whole and its various working groups (WGs), including the WG on ecology, energy efficiency and renewable energy.

The main goal of the CIS Electric Power Council is to conduct joint and coordinated actions of the Commonwealth states in the field of electric power, aimed at ensuring stable and reliable power supply to the economy and the population on the basis of the effective functioning of the electric power systems pool of the CIS member states:

The parallel operation of the electric power systems of the CIS member states is an important factor in ensuring the reliability and technological basis of integration processes in the electric power industry, which provides the participants with the following advantages and opportunities:

- Ensuring the electric current frequency stability;
- Reducing total required power reserves, including those result of the mismatch of the maximum load;
- Improving the reliability of energy systems and providing mutual assistance in emergencies, in particular by providing emergency assistance;
- Reducing costs for the development of grid infrastructure due to the reservation of power supply to its consumers through the electric networks of neighboring energy systems;
- Transmitting of electricity from one power system to another through a third power system;
- Ensuring mutually beneficial cross-border trade, as well as the formation of common electricity and power market;
- Implementing of joint energy projects.

Further development of cooperation between the CIS member states in the electric power industry will take place in the context of the transformation of energy systems, the active introduction of digital technologies, as well as increased attention in the CIS member states to environmental issues, energy efficiency, energy conservation and the development of renewable energy sources.

The implementation of the UN Sustainable Development Goals sets the following tasks for the CIS Electric Power Council:

• Assistance in the implementation of international agreements ratified by the CIS member states in terms of environmental protection and curbing climate change;

• Organization, together with partners of the EES of the CIS, elaboration of recommendations for the integration of renewable energy sources into energy systems, increasing energy efficiency and energy saving;

• Organization of work on the formation of a database on the best available technologies in the field of ecology and energy efficiency, including for manufacturers of power equipment, taking into account the possibilities of import substitution;

• Strengthening work on the dissemination of information on best practices, exchange of experience, including in the field of training in the field of renewable energy and energy efficiency.

Integration factor in the further development of cooperation between the CIS member states in the electric power industry.

Integration is caused by globalization and regionalization taking place in the world and suggests, when interacting with the CIS member states, to take into account:

The presence of areas of activity and tasks facing the CIS Electric Energy Council that require cooperation with other industry cooperation bodies of the Commonwealth (Interstate Council for Standardization, Metrology and Certification of the CIS, Interstate Environmental Council of the CIS member States, Council for Cooperation in the Field of Education of the Member States CIS and others);

The creation of the Eurasian Economic Union (EAEU), which includes half of the CIS member states, and the activities of its Eurasian Economic Commission in the electric power industry. Some of them are related to the activities of the CIS Electric Power Council in a number of areas (the formation of a common electric power market, technical regulation and interstate standardization, energy efficiency issues and development of renewable energy sources, etc.);

Enhanced participation of the Commonwealth states in regional international organizations (EAEU, Shanghai Cooperation Organization, Asian Development Bank, etc.), as well as in various UN structures (UN Economic Commission for Europe, UN Economic and Social Commission for Asia and the Pacific).

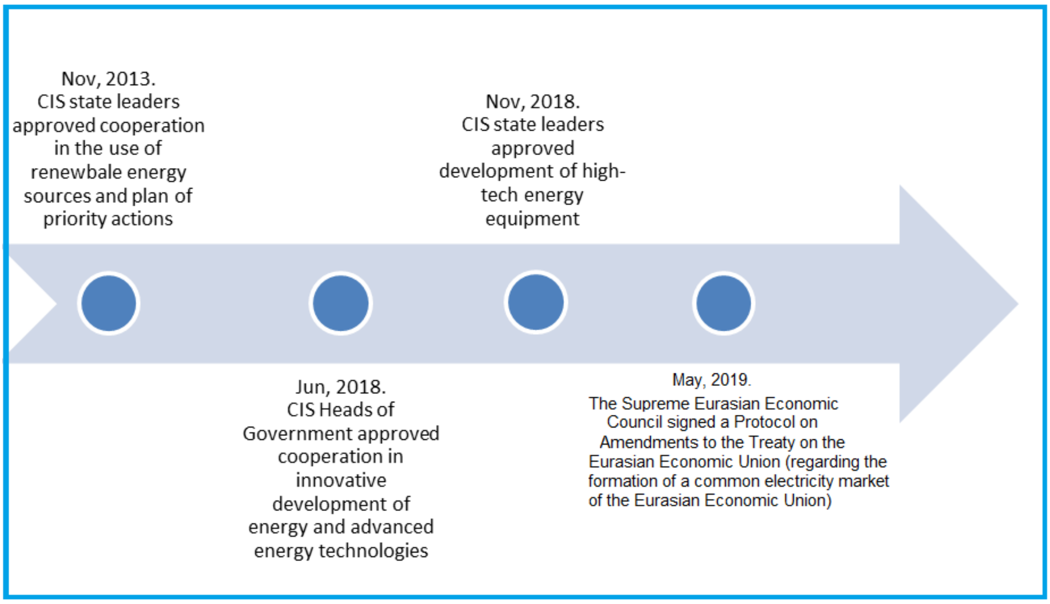


Fig. 1 – Timetable of Conceptual cooperation documents signing of the CIS member states in the field of renewable energy sources, innovative development of energy and the development of advanced energy technologies, for the development of production of high-tech energy equipment, as well as the Protocol on Amendments to the Treaty on the Eurasian Economic Union (in part of a common electricity market of the Eurasian Economic Union formation)[8]

[8] http://e-cis.info/page.php?id=23882

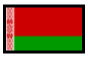
2. Overview of Energy systems in the CIS countries

This section analyzes energy systems in the CIS and the EAEU countries. In particular, it looks at the generation and network. and analyzes the status of renewable energy in the current systems.

2.1. Installed capacity of power plants and electricity production in the CIS member states in the period 2000-2019

The power industry of the CIS member states is more than 330 GW of installed capacity of power plants with an annual electricity production of about 1,400 TWh (Table 2.1.1, 2.1.2, Figure 2.1.1, 2.1.2).

Table 2.1.1 – Dynamics of the total installed capacity of power plants in the CIS member states in 2000-2019, MW

	The CIS member states	2000	2005	2010	2015	2017	2018	01.01.2020
	Republic of Azerbaijan	5046	5721	6449	7200	7172	7141	6706
	Republic of Armenia	3190	3207	3522	3523,8	3314	3341	3314
	Republic of Belarus	7838	8024	8426.7	9741.2	10143,4	10068.7	10098.14
	Republic of Kazakhstan	18361	18572	19440	21307.2	21672,9	21901,9	22936
	Republic of Kyrgyzstan	3781	3742	3746	3635	3930,4	3932	3932
	Republic of Moldova	2996	2988	2994	2994	2994.5	2995.2	3057
	Russian Federation	204600	210500	220290	243188	246867.45	250442.0	252030.7
	Republic of Tajikistan	4424	4355	5024	5346,47	5713,6	5746,5	6406
	Turkmenistan	2652	2931	4104.2	5179	5450	5450	6511
	Republic of Uzbekistan	11583	12359	12474	15945.7	14140.6	14140.66	15044
	TOTAL	264471	272399	286469.9	318060.4	321398.9	325159.0	330034.8

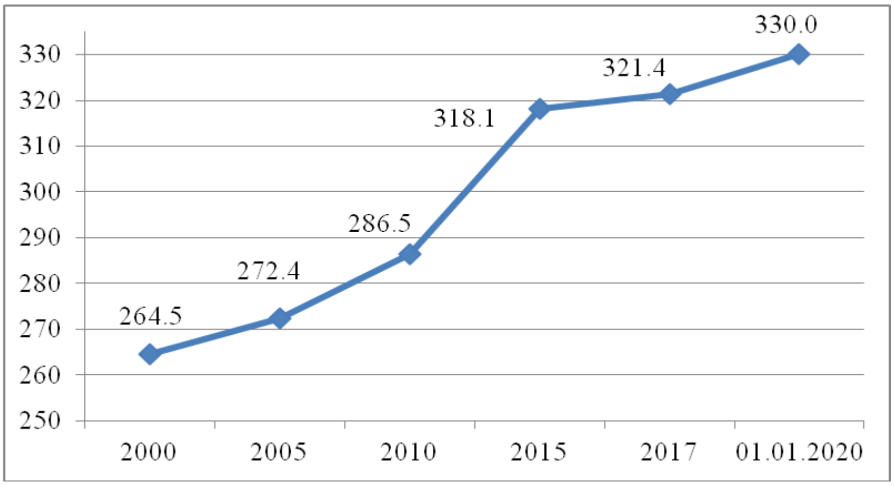


Figure 2.1.1 – Total installed capacity of power plants in the CIS member states in 2000-2019, GW

Table 2.1.2 – Electricity production in the CIS member states, billion kWh

	The CIS member states	2000	2005	2010	2015	2017	2018	2019
	Republic of Azerbaijan	18.6	22.3	18.4	22.5	22.34	25.0	23.8
	Republic of Armenia	6	6.3	6.4	7.8	7.8	7.8	7.6
	Republic of Belarus	26	30.96	34.8	34.1	34.3	38.8	40.26
	Republic of Kazakhstan	51.6	67.6	82.3	90.7	102.4	106.8	106.0
	Republic of Kyrgyzstan	14.9	14.9	12.1	12.8	15.34	15.65	15.05
	Republic of Moldova	3.23	4.2	6.01	5.76	4.7	5.1	5.62
	Russian Federation	877.8	935.6	1025.4	1049.9	1073.7	1091.69	1096.5
	Republic of Tajikistan	14.2	17.1	16.2	17	17.9	19.7	20.5
	Turkmenistan	9.9	12.34	16.08	22.4	26.0	27.0	22.93
	Republic of Uzbekistan	46.9	47.6	51.94	58.94	60.7	62.8	63.5
	TOTAL	1069.1	1158.9	1269.63	1321.9	1365.18	1400.3	1401.8

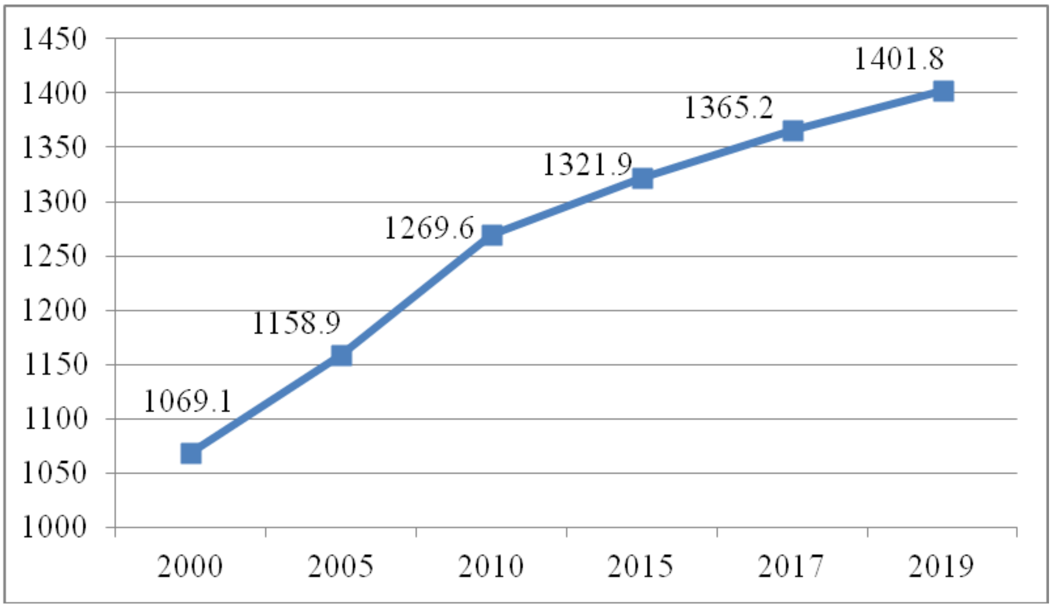


Figure 2.1.2 – Electricity production in the CIS member states. billion kWh

As part of the interconnection of the electric power systems of the CIS member states, seven national energy systems of the Commonwealth states (except for the power systems of the Republic of Armenia, the Republic of Tajikistan and Turkmenistan) operate synchronously. It should be noted that there was no such representation of parallel operating energy systems even during the period of the existence of the USSR, since the combined energy system of South Kazakhstan and the countries of Central Asia worked in isolation from the Unified Power System of the USSR. The formation of a regional power system, including Kyrgyzstan, Turkmenistan, Tajikistan, Uzbekistan and South Kazakhstan, as the Integrated Power System of Central Asia (IPS CA) was completed by 1991. It included 83 power plants with a total capacity of 25 GW. The energy mode of operation of the Central Asia Integrated Power System (IPS) was carried out taking into account the provision of contractual electricity flows between the energy systems of the Central Asian states.

Currently, the energy systems of the Central Asian IPS, coordinated by the CDC "Energy", work in parallel with the following energy systems: South and North of Kyrgyzstan, Uzbekistan, regions of the southern part of Kazakhstan, and “dead-end” areas of the North of Tajikistan. Work is underway to restore the parallel operation of the Tajik energy system with the IPS CA. With the participation of ADB in the amount of $ 35 mln, a project for the reconstruction of emergency automation is being considered. Equipment that will increase the reliability of the system will be installed at the junction points on 220 kV and 500 kV transmission lines. In addition, it is planned to launch two new points of connection of Tajik networks to the Uzbek power grid in the north. It is assumed that the installation of 500 kV transmission lines, 1.5 km long, which is designed to increase the stability of the parallel operation of the two power systems[9] .

Parallel operation of the Tajik energy system with the IPS CA is envisaged for 220-500 kV overhead lines. With the inclusion of the Tajik energy system, it will be possible to supply cheap excess summer electricity from Tajikistan's hydropower plants to Uzbekistan, unloading thermal power plants, with subsequent return in winter, which will increase the reliability of power supply to consumers. With the connection of the Tajik energy system to parallel work with the Central Asian IPS, the problem of the lack of regulatory capacity in the region will be largely solved.

Negotiations are under way between Uzbekistan and Turkmenistan on the inclusion of the Turkmen energy system for parallel work with the Central Asian power system. This will enable the start of a number of projects. For example, the TUTAP energy project (Turkmenistan - Uzbekistan-Tajikistan-Afghanistan-Pakistan) is considered in conjunction with the project “Regional Energy Market of Central Asia and South Asia” (CASAREM). This concept provides for the development of electricity trade between the countries of the two regions. It is implemented in the form of several projects and related investments, supported by relevant institutional mechanisms and legal agreements.

May 12, 2016 in Dushanbe, Republic of Tajikistan, the CASA-1000 project was launched as the first stage of the CASAREM concept. The project is designed for current energy capacities. After the completion of the construction of the Rogun hydroelectric station, the export potential will increase significantly and it will be possible to supply electricity all year round. The implementation of the CASA-1000 project will allow for the supply of electricity up to 300 MW to Afghanistan and up to 1000 MW to Pakistan.

On August 12, 2019, Russia, Azerbaijan and Iran concluded an agreement on the joint development of a feasibility study for a project to create a North-South energy corridor between the energy systems of the Republic of Azerbaijan, the Islamic Republic of Iran and the Russian Federation (the issue of connecting Russian energy systems and Azerbaijan and the Iranian energy system has been discussed since 2005). From Russia, the parties to the agreement were SO UES JSC and Rosseti PJSC, from Azerbaijan and Iran, Azerenerji OJSC and the TAVANIR Iranian Power, Transmission and Distribution Management Company.

In December 2015 Armenia, Georgia, Iran, and Russia signed a four-sided memorandum providing for an increase in the level of mutual energy flow control, safety and reliability of the energy systems of these countries, which will allow for the transit of electricity in a four-sided format. The project has, in addition to economic, the most important geopolitical significance for all participating countries, and, in addition, it is an integral part of the Caspian electric power ring (through the Russian Federation and Iran), the creation of which is planned by the countries of the region by the end of the 2020s.

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[9] Tajikistan, ADB sign grant for energy system, Azernews, 2018. https://www.azernews.az/region/141648.html

2.2. Countries Profiles

This section looks into general characteristics and basic indicators of the electric power industry of the CIS countries.

The Republic of Azerbaijan

General characteristics and main indicators of the electric power industry

	**Electric power system of the Azerbaijan Republic** operates in a synchronous zone and has electrical connections with the UPS of Russia and the power systems of Georgia and Iran. Centralized dispatch control in most of the territory of the Republic is carried out by OJSC "Azenerji". On the territory of the Nakhichevan Autonomous Republic. electricity is distributed by the Energy Agency of the Nakhichevan Autonomous Republic.
	**Generation.** As of 01.01.2020, the total installed capacity of the generating sources of the energy system of Azerbaijan was 6679.4 MW. The total installed capacity of TPPs is 5554 MW, including large ones: Azerbaijan TPP (2400 MW, Janub ES (780 MW), Sumgait ES (525 MW), Shimal-1 (400 MW), Shimal-2 (409 MW).
	**HPP** Total installed capacity of HPPs (> 25 MW) -955 MW, including large ones: • Mingechevir HPP (424 MW) • Shamkir HPP (380 MW) • Yenikend HPP (150 MW)
	**RES** Small HPPs (<25MW) - 169MW, SES-24MW, WPP-66MW. The Decree of the Head of State dated December 5. 2019 "On measures for the implementation of pilot projects in the field of the use of renewable energy sources" stipulates solution to urgent issues on the allocation of land for pilot projects, the provision of state guarantees to investors, the economic evaluation of projects and preliminary proposals for strengthening the network and the integration of renewable energy sources into the power system.
	**Power Grid**. Conventionally, the electric network is divided into three parts: backbone. supplying and distribution networks. The backbone network includes substations and power lines with voltage of 220, 330 and 500 kV, supplying network - 110 kV, distribution network - 0.4. 6. 10. 35 and 110 kV. The electric grid complex of the Republic consists of several hundred substations, including: 2 substations 500 kV; 8 substations 300 kV; 12 substations 220 kV; 61 substations 110 kV. OJSC "Azenergy" is responsible for interstate power lines, backbone and supplying lines. Electric energy distribution is carried out by OJSC "Azerishig".

Republic of Armenia

General characteristics and main indicators of the electric power industry

	**Electric power system of the Republic of Armenia.** “Operator of the power system” CJSC carries out operational technological and economic regulation system planning, as well as ensuring the parallel operation of the power system of the Republic of Armenia with regional power systems.
   	**Generation.** As of 01.01.2020, the total installed capacity of the generating sources of the energy system of Armenia was 3350 MW. There are 217 power generating sources in the Republic, including: 3 TPPs with a total installed capacity of 1537 MW. The installed capacity of the Hrazdan TPP is 810 MW, the Hrazdan TPP (unit 5) - 485 MW, and the combined (steam and gas) cycle (CCGT) power unit at the Yerevan TPP - 242 MW. 1 nuclear power plant with 1 420 MW unit. 10 HPPs with a total installed capacity of 992 MW. The largest are the hydroelectric power plants of the Sevan-Hrazdan cascade with a total installed capacity of 561 MW. 189 small HPPs with a capacity of 385 MW, 1 biogas power plant, 3 wind power plants, 10 solar power plants with a total installed capacity of 15.2 MW. There are 20 solar power plants under construction with an installed capacity of up to 5 MW and a total capacity of 68.5 MW. As of 01.01.2020, 1,944 autonomous producers with a capacity of up to 500 kW signed contracts with CJSC Electric Networks of Armenia (total capacity of about 32.9 MW), and 123 more autonomous producers received technical specifications (total capacity of about 5.4 MW).
	**Power Grid** includes backbone power lines with a voltage of 220 and 110 kV, the length of which is 1419 and 3296 km. respectively. The length of distribution networks with a voltage of 6 kV is 3288 km. The number of backbone substations with voltage of 220 and 110 kV is - 14 and 123, respectively. The power grid is represented by the companies “High Voltage Electric Networks” CJSC and “Electric Networks of Armenia” CJSC.

The Republic of Belarus

General characteristics and main indicators of the electric power industry

	**Integrated Power System (IPS) of the Republic of Belarus.** The management of the Belarusian energy system is carried out by the State Electricity Association (SEA) Belenergo. subordinate to the Ministry of Energy. The Belenergo SEA includes, among others republican unitary enterprises (RUE), the dispatch control enterprise RUE DCE and six regional republican unitary electric power enterprises RUE-oblenergo, which are formed according to the territorial principle and are vertically integrated companies, including power plants, electric and heat networks, as well as the Republican Unitary Enterprise “Belarusian Nuclear Power Plant”. Currently the IPS of the Republic of Belarus works in parallel with the energy systems of the CIS and Baltic countries. On February 25, 2020, the Government approved the CONCEPT for the development of electricity generating capacities and electric networks for the period until 2030, which envisages the development of the Belarusian Integrated Power System under conditions of maintaining or withdrawing from parallel work with the Lithuanian electric power plants and the Integrated Power System of Ukraine.
  	**Generation.** The installed capacity of the Belarusian energy system - 10.098.14 MW. SPO Belenergo has 68 generating energy sources with a total installed capacity of 8,947.31 MW, including: • 3 condensing stations - with a total capacity of 4704 MW; • 15 CHPPs over 50 MW - with a total capacity of 3904 MW; • CHPP less than 50 MW - with a total capacity of 207 MW; • mini-CHP - 35 MW; • 25 HPPs with a total capacity of 88.11 MW; • 1 wind farm with a capacity of 9 MW; The total capacity of local sources that are not part of the Belenergo State Production Association is 1150.83 MW (of which renewable energy sources are 307.9 MW). The share of block stations in the total capacity of the power system is 11.4%. Starting from 2016, a set of measures has been implemented to effectively integrate the 2400 MW nuclear power plant under construction (2 power units of 1200 MW each) into the power system.
	**Power Grid.** The power grid complex includes: overhead high voltage electric lines 750 kV, 330 kV, 220 kV, 110 kV, 35 kV, 10 (6) kV, 0.4 kV, with a total length of 239.03 km; cable power lines - 40700 km; electrical substations with a voltage of 750/330/110 kV. 330/110 kV. 220/110 kV. 110/10 (6) kV. 35/10 kV. 10 (6) / 0.4 kV including 1,330 units of 35-750 kV transformer substations and 74,646 units of 10 (6) / 0.4 kV transformer substations. The backbone network is formed at a voltage of 220 - 750 kV.

The Republic of Kazakhstan

General characteristics and main indicators of the electric power industry

	**Integrated Energy System (IPS) of the Republic of Kazakhstan.** The central dispatch control of the IPS of the Republic of Kazakhstan is carried out by KEGOC JSC's branch “National Dispatch Center of the System Operator” (NDC SO). The operational dispatch control in the IPS of the Republic of Kazakhstan is organized according to the direct operational subordination of NDC SO of nine Regional Dspatch Centers (RDC). These are structural divisions of the branches KEGOC JSC Intersystem Electric Networks. Currently, the Unified Electric Power System of the Republic of Kazakhstan is operating stably in parallel with the power systems of the Russian Federation and Central Asian countries (Kyrgyzstan and Uzbekistan).
  	**Generation.** As of 01.01.2020, the total installed capacity of Kazakhstan's power plants - 22 936 MW. Electricity production in Kazakhstan is carried out by 150 power plants of various ownership forms (most private). Power plants in Kazakhstan are divided into power plants of national, industrial and regional purpose. 5 large thermal and 4 hydraulic power stations are considered as power plants of national importance. Power plants of industrial importance include 5 thermal power plants with combined production of electric and thermal energy, which serve for the electric heat supply of large industrial enterprises and nearby settlements. Regional power plants are power plants integrated with territories that sell electricity through networks of regional power grid companies and energy transmission organizations, as well as heat supply to nearby cities. Structuring by type of energy used for electricity production is as follows: coal - 69.7%; gas - 20.0%; hydroelectric power stations (excluding small hydroelectric power stations) - 9.0%; renewable sources (including small hydropower plants) - 1.3%. The total generating capacity for renewable energy sources is 1361 MW, including 21 WPP - 335.9 MW; 37 SPP-797.6 MW; 37 HPPs - 224.6 MW; 4 BioPP - 2.82 MW.
	**Power grid.** KEGOC JSC has on its balance sheet electric transmission lines with voltages from 35 to 1150 kV with total length of 26.7 thousand km. as well as 78 substations with a voltage of 35 - 1150 kV. Transmission and distribution of electricity is carried out by 152 power transmission organizations including 19 regional power grid companies, which operate electrical networks in voltage classes from 0.4 to 220 kV. According to the results of 2019, electricity losses in the IPS amounted to 2.9 billion kWh. which is 6.27% with respect to the supply of electricity to the network.

The Republic of Kyrgyzstan

General characteristics and main indicators of the electric power industry

	**Energy System of the Kyrgyz Republic.** The management of the Kyrgyz energy system is carried out by OJSC National Energy Holding Company. The production of electric and thermal energy in the Republic is carried out by JSC Power Plants. The energy system of the Kyrgyz Republic operates as part of the Central Asian IPS, coordinated by the operational and technological activities of the Energy Center located in Tashkent.
  	**Generation.** As of 01.01.2020, the total installed capacity of the Kyrgyz energy system - 3932 MW. In total, there are 18 power plants in the Republic: 7 hydroelectric power plants, 2 thermal power plants and 9 small hydroelectric power plants. The basis of the electric power industry of the Republic of Kyrgyzstan is hydroelectric power plants with a total capacity of 3030 MW, including: • Toktogul HPP - with a capacity of 1200 MW; • Kurpsayskaya HPP - with a capacity of 800 MW; • Tash-Kumyrskaya HPP - with a capacity of 450 MW; • Shamaldy-Say HPP - with a capacity of 240 MW; • Uch-Kurgan HPP -180 MW; • Kambar-Ata 2 HPP - with a capacity of 120 MW; • At-Bashinskaya HPP - with a capacity of 40 MW. In the Republic, there are 2 TPPs with a total electric capacity of 862 MW. including: • Bishkek CHP with a capacity of 812 MW, using coal, as the main fuel and. • Osh TPP with a capacity of 50 MW operating on liquid fuel (fuel oil). • Nine power plants operating on renewable energy sources (SHPPs) have a total capacity of 40 MW.
	**Power grid.** The electric network of the energy system of the Kyrgyz Republic includes: power lines with a voltage of 110-500 kV, a total length of 6 683 km, including: OHL 500kV - 541 km; OHL 220 kV - 1.748 km; OHL 110kV - 4 353km; OHL 35 kV - 41 km, 190 substations with a voltage of 110 kV and higher with a total capacity of 8.929.2 MVA,. including: 500 kV substation - 2/1829 pcs / MVA; 220 kV substation - 14/2902 units / MVA; 110 kV substation - 174 / 4188.2 pcs / MVA. Intersystem communications with power systems of the Republic of Kazakhstan, Uzbekistan and the Republic of Tajikistan are organized at a voltage of 220-500 kV.

The Republic of Moldova

General characteristics and main indicators of the electric power industry

	**The energy system of the Republic of Moldova.** The transmission network and system operator - State Enterprise "Moldelectrica" implements a unified operational and technological management of the electric power system and transmission of electric energy through the main network of the power system on the basis of a license issued by the National Agency for Energy Regulation (ANRE). The main functions of the regulatory body are the development and approval of the Electricity Market Rules. This includes the development of a methodology for calculating and approving tariffs in force in the market. licensing market participants. establishing legal relations between them on the basis of contracts, encouraging competition and investment (including foreign ones) in the Republic’s electric power industry and protecting consumer rights. One of the fundamental principles of organizing the functioning and development of the electric energy market in the Republic of Moldova is the separation of the main activities.
 	**Generation.** As of 01.01.2020, the total installed capacity of Moldova's generating sources - 3057 MW. There are 17 power plants in the Republic of Moldova, including 13 thermal power plants with a total capacity of 2850 MW: • Moldavskaya GRES with an installed capacity of 2,520 MW; • Chisinau CHP-2 (electric capacity 240 MW); • Chisinau CHP-1 (electric capacity 66 MW); • CHP-Nord, Balti (electric capacity 20.4 MW); • Power plants belonging to sugar processing plants, including 9 thermal power plants (97.5 MW); • Dubasarskaya HPP (48 MW);
	**RES.** Kosteshtskaya HPP (16 MW, SES - 0.5 MW, WPP - 3.7 MW, other renewable energy - 25 MW). The government supports a project for the development of a 180 MW wind turbine park in the south of the country, which will be commissioned in 2022. The EBRD is working to organize a series of auctions in Moldova for large-scale renewable energy projects, during which it is planned to conclude contracts for 80 MW of wind energy, 25 MW of photovoltaics and 8 MW of biogas.
	**Power Grid.** High-voltage power lines OHL-110, OHL-330 and OHL-400 kV of the Moldavian Power System (MPS) are connected to the power systems of Ukraine and Romania. The power system has over 15 thousand transformer substations with a voltage of 6-400 kV with a total capacity of more than 10 thousand MW. The capacity of the interstate interconnections of MPS with the Romanian Power System is 150 MW at a voltage of 110 kV and 1000 MW at a voltage of 400 kV.

Russian Federation

General characteristics and main indicators of the electric power industry

	**Electric Power System of the Russian Federation** consists of the UPS of Russia and isolated energy systems. The unified power system of Russia is unique highly automated integral technological complex including 7 interconnected power systems: East. Siberia. Ural. Middle Volga. South. Center and Northwest. All IPSs are connected by inter-system power lines with a voltage of 220-750 kV and operate in synchronous mode with the exception of the IPS
   	**Generation.** As of 01.01.2020, the total installed capacity of UPS of Russia – 246342.45 MW. The UPS of Russia includes about 843 power plants with a capacity above 5 MW. **NPP.** The Russian nuclear industry is a unified energy-industrial complex, which is one of the leading in the world in terms of scientific and technical developments, operating experience and qualifications of NPP personnel. NPP projects with pressurized water power reactors (VVER) have proven their reliability in the course of thousands of reactor-years of trouble-free operation. All NPP equipment is of domestic production, the technical level of which is not inferior to the world. As of 01.01.2020, the total installed capacity of 10 NPPs of the UPS of Russia amounted to 30,313.18 MW (12.3% of the total capacity of the UPS of Russia). **HPP.** The hydropower industry in Russia is 87 large hydroelectric power plants, including 21 hydroelectric power plants with a capacity of over 500 MW. The 6 largest companies account for almost 95% of the installed capacity of HPPs, half of which are at PJSC RusHydro. All equipment of domestic production and its technical and economic indicators are not inferior to modern foreign counterparts. As of 01.01.2020, the total installed capacity of the HPP was 49870.29 MW (20.24% of the total capacity of the UES of Russia). **TPP.** The installed capacity of TPPs of UPS of Russia amounted to 164,612.14 MW (66.82% of the total capacity of UPS of Russia). The installed capacity of the CCGT unit is over 26.0 GW. **RES.** As of 01.01.2020, the installed capacity of WPPs located in the UPS of Russia amounted to 184.12 MW (0.08% of the total capacity of the UPS of Russia), and the installed capacity of SPPs - 1362.72 MW (0.55% of the total capacity of the UPS of Russia).
	**Power Grid.** The total length of electric networks of all voltage classes is almost 2650 thousand km.. including power lines with a length of over 150 thousand km of 220-1150 kV rated voltage. which make up the main backbone network. The Rosseti Group of Companies is one of the largest electric grid companies in the world in terms of the number of consumers and the length of voltage networks up to 110 kV: the length of transmission lines is about 2.3 million km. with 517 thousand substations of total transformer capacity more than 802 GVA.

The Republic of Tajikistan

General characteristics and main indicators of power industry

<table>
<tr><td></td><td>The electric power system of Tajikistan works as a single system and connects four separate regions: Sogd (North), Khatlon (South), Dushanbe and the surrounding areas and Regions of republican subordination (RRS).
Open Joint-Stock Holding Company OAHK “Barki Tochik” controls power plants and networks, generation, transmission and distribution of electricity in the Republic, with the exception of the Gorno-Badakhshan Autonomous Region (GBAO), which operates in isolation (has no connection with the main electricity system of Tajikistan).</td></tr>
<tr><td></td><td rowspan="3">Generation.
As of 01.01.2020, the total installed capacity of the Tajik energy system was 6406.5 MW (including the Rogun HPP).
HPP. Hydro power plants are the main available energy resource and the main source of electricity in Tajikistan. The largest HPPs of the republic are:
Nurek HPP on the Vakhsh river with a capacity of 3.000 MW;
Baipazinskaya hydroelectric power station with a capacity of 600 MW;
Sangtudinskaya HPP-1 with a capacity of 670 MW;
Sangtudinskaya HPP-2 with a capacity of 220 MW.
In addition. a cascade of Vakhsh HPPs- 3 HPPs with a total capacity of 285 MW;
on the Varzob River - Cascade of Varzob HPPs - 3 HPPs with a total capacity of 25 MW, on the Syrdarya River - Kairakkum HPP. with a capacity of 126 MW, in the Pamir, on the Gunt Khorogskaya HPP and Pamir HPP-1 with a total capacity of 37 MW.
Thermoelectric Power Plants. In Tajikistan. two TPPs are in operation: Dushanbe TPP (198 MW), gas and fuel oil, and Dushanbe – 2 TPP (400 MW), coal fired. Javanese CHP with capacity of 120 MW is on conservation.
Renewable energy sources. Tajikistan has significant renewable energy resources. Over 285 operating small hydropower plants with a capacity of 5 to 4300 kW are registered in the republic. Of this amount 16 small HPPs were built and operated by “Barki Tojik” and are state owned. “Pamir Energy” operates eleven small and mini hydropower plants with a total installed capacity of 44.16 MW.</td></tr>
<tr><td></td></tr>
<tr><td></td></tr>
<tr><td></td><td>Power Grid. In the integrated power system of Tajikistan. 500 kV. 220 kV and 110 kV power lines are system forming. The length of the 500 kV lines is about 683.8 km (including the 195 km Rogun - Dushanbe power transmission line), the 220 kV lines - 1942 km and the 110 kV lines - 3077 km. The system includes three 500 kV substations, 29 220 kV substations and 178 110 kV substations.</td></tr>
</table>

Turkmenistan

General characteristics and main indicators of the power industry

	**Electric Power System** of Turkmenistan. The Turkmenenergo State Electric Power Corporation of Turkmenistan Energy Ministry provides for the operation and maintenance of energy facilities, provides centralized power supply to consumers of the national economy and heat supply in a number of cities, and also exports electricity to other countries. It is planned to connect the country's energy nodes via overhead power lines with a voltage of 500 kV into a single unit, creating a ring between the main energy nodes. In addition, it is planned to build a power line with a voltage of 500 kV, which will make it possible to fulfill the plans for exporting electricity to Iran and Turkey in transit through the Iranian energy system.
 	**Generation.** As of 01.01.2020, the total installed capacity of the generating sources of Turkmenistan was 5178.4 MW According to the Ministry of Energy of Turkmenistan, the system of the State Electric Power Corporation "Turkmenenergo" includes 12 state power plants. The first “Hindu Kush” hydropower plant in Turkmenistan with a total capacity of 1.2 MW was built on the Murghab River as early as 1913. It continues to generate electricity becoming a kind of museum. The first power unit of the flagship of the Turkmen energy industry. “Mary” State District Power Plant was commissioned in 1973. With the commissioning of the eighth power unit in 1987 the installed capacity of the plant amounted to 1685 MW. With the commissioning in October 2014 of three small gas turbines with a total capacity of 146.7 MW, the capacity of the power plant amounted to 1831.7 MW. Currently, the construction of a combined cycle gas turbine power plant with a capacity of 1574 MW is underway on the territory of “Mary” GRES power plant. All power plants operate on natural gas from the nearest gas fields in the country. Fuel oil and diesel fuel of Turkmenistan refineries are used as reserve fuel.
	**Power Grid.** In order to reliably provide electric energy to consumers in the city of Ashgabat and five provinces (regions). Power Engineering and Electrification Production Enterprises (PEEPE) carry out maintenance of electric networks and oversee energy equipment located within the respective territories. About 50 thousand km of overhead power transmission lines, as well as almost 12 thousand transformer substations of various voltage classes are on the balance of production associations.

Republic of Uzbekistan

General characteristics and main indicators of the electric power industry

	**Electric Power System of Uzbekistan.** State regulation of the processes of production, transmission, distribution and consumption of electrical and thermal energy is carried out by the Ministry of Energy of the Republic of Uzbekistan, formed in accordance with the Decree of the President of the country dated 01.02.2019 No. UP-5646 "On measures to radically improve the management system of the fuel and energy industry Republic of Uzbekistan ". On the basis of Uzbekenergo JSC, three joint-stock companies were organized: Thermal Power Plants, National Electric Grids of Uzbekistan and Regional Electric Grids. The power system of the republic is conditionally divided into 5 territorial power centers: North-West; Southwestern; Southern; East and Central.
 	**Generation.** As of 01.01.2020, the installed generating capacity of the republic is 15044 MW, of which: TPP - 13115 MW, HPP - 1682 MW, SHPP - 247 MW. The main source of generation is 11 thermal power plants, including 3 thermal power plants. The capacity of modern energy efficient power units is 2,825 MW or 25.6 percent of the total capacity of the TPP. In 2019, TPPs generated 89.6% of the total electricity generated within the republic. Hydropower includes 42 HPPs, including 12 large ones with a total capacity of 1,682 MW (90.8% of the total HPP capacity), 28 SHPPs with a total capacity of 247 GW (13.5%) and 2 micro HPPs with a total capacity of 0.5 MW. 30 hydroelectric power plants with a capacity of 532 MW operate along the watercourse (4 large - 317 MW and 26 SHPPs - 215 MW). The reservoirs have 10 hydroelectric power plants with a total capacity of 1400 MW.
	**Power Grid.** Electric energy is transmitted from generating untis to JSC “Regional Electric Grids” by JSC “National Electric Grids of Uzbekistan” via trunk electric grids of 220-500 kV, with a total length of more than 9.7 thousand km. Electricity is sold to consumers in the republic by 14 territorial distribution and distribution enterprises of electric grids operating in each territorial formation as joint-stock companies within JSC Regional Electric Grids. On the balance sheet of enterprises are power lines with a total length of more than 250.4 thousand km and substations with voltage up to and including 110 kV in the amount of 1700 units. The most branched, with a length of more than 223.8 thousand km, are electric networks with a voltage of 0.4-6-10 kV through which electricity is mainly supplied to consumers of the republic.

3. Development of RES

This chapter analizes quantitative indicators of the development of renewable energy in the world, including the USA, China, the EU including Germany for the period 2010 - 2018 and forecast indicators until 2050.

3.1. Role of RE – global overview

The expansion of the use of non-traditional renewable sources of electric energy (RES) was made possible thanks to technological progress in this area, which allowed, first, to significantly reduce the cost of electricity production by various types of wind (WPP) and solar (SPP) power plants (Fig. 3.1.1). The cost of new SPPs in the world since 2010 has decreased by 70%, WPPs - by 25%[10].

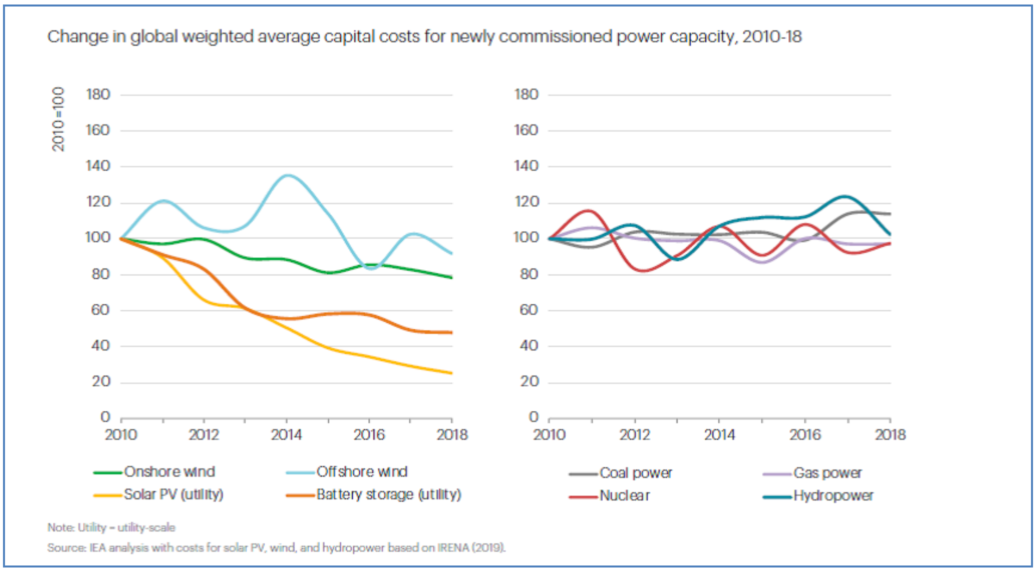

Figure 3.1.1 – Dynamics of weighted average prices of newly commissioned capacities, 2010-2018

Since 2010, the development of renewable energy sources has accelerated, reaching record levels and ahead of the annual commissioning of traditional capacities in many regions. Among all renewable energy technologies, wind energy after hydropower has dominated the renewable energy industry for many decades[11].

Since 2000, wind energy has developed with an aggregate average annual growth rate (CAGR) of more than 21 %. In the early years of the deployment of wind energy, Europe was a key region for the global introduction of wind turbines. In 2010, the region accounted for 47% of global commissioning of land-based wind turbines. After 2010, the rapid development of wind energy has been observed in other regions, especially in China, where the CAGR index is about 27%. By 2018, China was ahead of Europe and became the largest land-based wind energy market with almost one-third of installed capacity in the world. For the European Union, 2018 was a record year in terms of financing new wind energy, with almost 16.7 GW of future wind energy projects receiving a final positive investment decision. In 2018, almost $ 29.4 billion was invested in new wind farms, with specific average cost of $ 1.54 million per MW for onshore wind energy and $ 2.57 million per MW offshore[12].

[10] https://webstore.iea.org/download/direct/2738?fileName=WEI2019.pdf

[11] FUTURE OF WIND Deployment, investment, technology, grid integration and socio-economic aspects A Global Energy Transformation paper, https://www.irena.org/publications/2019/Oct/Future-of-wind

[12] “WindEurope – history”, https://windeurope.org/about-wind/history, (accessed 10 September 2019.

At the end of 2018, the total combined installed capacity of onshore wind energy reached 542 GW[13] and at the end of 2019, 621 GW[14]

Given the availability of resources, great market potential and economic competitiveness, it is expected that over the next decade, onshore wind energy will contribute to the overall increase in the use of renewable energy in a number of regions. According to IRENA, over the next three decades, onshore wind farms will have an average annual CAGR of more than 7 % (Figure 3.1,2).

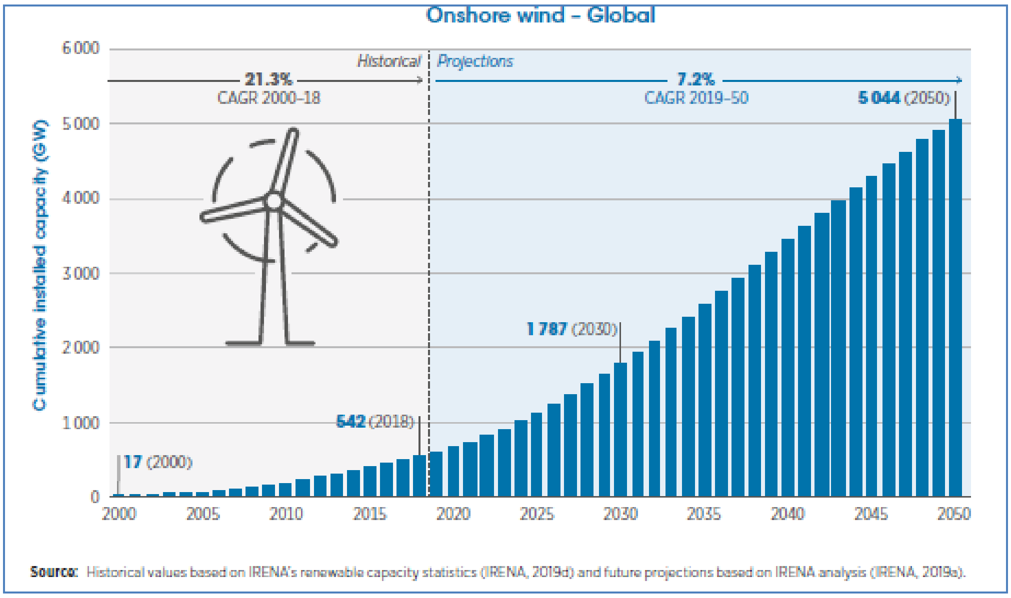

Figure 3.1.2 – Growth of the total installed capacity of onshore wind energy by 2050, GW

This means that by 2030 the total installed capacity of onshore wind energy will grow more than three times to 1,787 GW and almost 10 times by 2050, approaching 5044 GW, compared with 542 GW in 2018.

Offshore wind energy technologies enable countries to exploit generally higher and sometimes more stable wind resources by implementing gigawatt projects near densely populated coastal areas that are widespread in many parts of the world. This makes offshore wind energy an important addition to the portfolio of low-carbon technologies available for decarbonizing the energy sector in many countries. Offshore wind energy is one of the new renewable energy technologies that has reached maturity in the last two to three years, because the rapid improvement of technology, the efficiency of the supply chain and logistics in closely related markets in Europe have led to a rapid reduction in costs and the beginning of significant implementation in new markets. Given political support and financial incentives, offshore wind energy is gaining momentum because it provides an additional alternative to some of the problems that land-based wind turbines face, mainly due to network and land restrictions that complicate the development of land-based wind energy, for example, in Europe.

Currently, 90% of the global installed capacity of offshore wind energy is commissioned and operated in the North Sea and near the Atlantic Ocean. In 2018, almost 4.5 GW of new offshore wind power capacity was commissioned; most of these additions were concentrated in China (about 37% of the total annual volume of additions), the UK (29%) and Germany (22 %). In 2019, five European countries and three in Asia added a record 6.1 GW offshore (an increase

[13] *Renewable capacity statistics 2019*, International Renewable Energy Agency, Abu Dhabi. https://www.irena.org/publications/2019/Mar/Renewable-Capacity-Statistics-2019

[14] file:///C:/Users/Moy/Downloads/Annual-Wind-Report_2019_digital_final_2r.pdf

of 35.5% compared to 2018), increasing global offshore capacity to over 29 GW[15]. In the coming years, the development of offshore wind energy is expected in North America and Oceania.

Over the next three decades, the total installed capacity of offshore wind farms will increase to 228 GW in 2030 and about 1000 GW in 2050 (Figure 3.1.3).

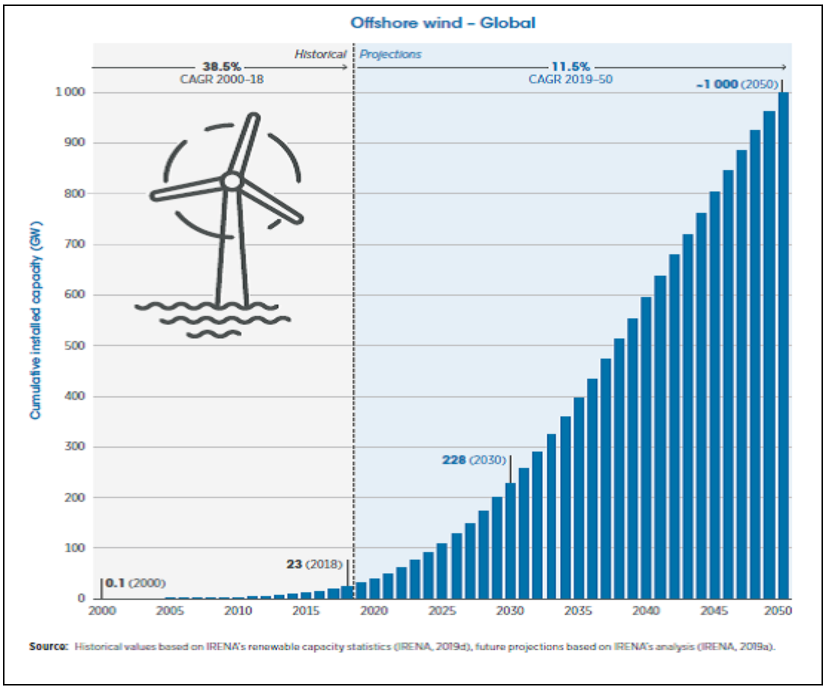

Figure 3.1.3 – Growth in the total installed capacity of offshore wind energy by 2050, GW

By 2050, offshore wind energy will account for almost 17% of the world's total installed wind energy capacity of 6044 GW[16]. The average CAGR of offshore wind energy over the next three decades will be 11.5%, significantly lower than the historical average of 38.5% between 2000 and 2018. The nearly 20-fold increase in the total offshore wind power projected by IRENA by 2030 is fully consistent with the GWEC Global Wind Energy Council report on offshore wind resources published in 2019, which states that the total offshore wind energy capacity will exceed 200 GW[17].

Over the past two decades, photovoltaics has evolved from a niche market product into one of the main sources of electricity production. Growth dynamics are becoming less dependent on government incentive programs and are more determined by market investment decisions.

By the end of 2019, the global installed capacity of solar photovoltaic energy reached 627 GW with an aggregate annual growth rate of AGRT of almost 43% since 2000, and it remains the second most installed renewable energy sector after wind energy (650 GW). In 2019, solar photovoltaic systems again dominated the total renewable energy capacity with added capacities of about 115 GW, which is twice as much as wind and more than all fossil fuels and nuclear fuel.[18]

New global investments in renewable energy and fuel (not including hydropower projects with a capacity of more than 50 MW) amounted to $ 301.7 billion in 2019, according to

[15] https://gwec.net/record-6-1-gw-of-new-offshore-wind-capacity-installed-globally-in-2019/

[16] Global energy transformation: A roadmap to 2050 (2019 edition), International Renewable Energy Agency, Abu Dhabi. https://www.irena.org/publications/2019/Apr/Global-energy-transformation-A-roadmap-to-2050-2019Edition

[17] Global offshore wind report 2018, Global Wind Energy Council, Brussels. https://gwec.net/wp-content/uploads/2019/04/GWEC-Global-Wind-Report-2018.pdf

[18] file:///G:/REN%2021/gsr_2020_full_report_en.pdf

BloombergNEFi. This was 5% more than in 2018, partly due to increased costs for small solar PV systems.

In accordance with the REmap scenario, Asia will continue to lead global solar photovoltaic installations, with 65% of the total capacity installed by 2030 (Fig. 3.1.4.).

In Asia, significant development will be observed in China, where, according to forecasts, the installed capacity will reach about 1,412 GW by 2030. North America will have the second largest installed capacity of solar photovoltaic power, reaching 437 GW by 2030, with more than 90% of these installations in the United States.

By 2030, Europe will represent the third largest region with an installed capacity of 291 GW of solar PV. A similar picture is expected on the horizon of 2050, when Asia will continue to dominate with almost half of the total installed global capacity of 4,837 GW[19].

Large markets in South America and Africa are also expected[20].

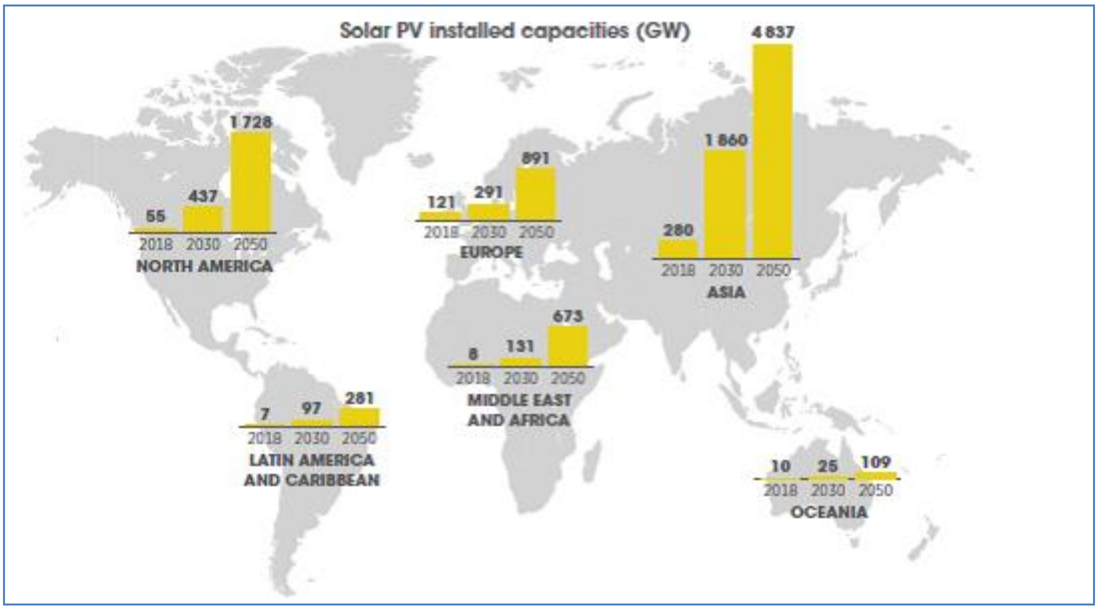

Figure 3.1.4 – Installed capacity of PV generation facilities by region of the world - actual data

In the first half of 2019, the BNEF baseline for full reduced electricity costs (LCOE) was $57 per MWh for a non-tracking photovoltaic system and $ 49 per MWh of tracking photovoltaic systems[21]. The share of costs for solar panels in the reference photovoltaic system fell below 30%. The impact of CAPEX on the LCOE of solar photovoltaic electricity has decreased significantly, while other costs, such as operating and maintenance costs, permits and administration, fees and duties, as well as financing costs, play a more dominant role. Therefore, it is necessary to achieve a further significant reduction in these variables and intangible costs.

Over the next decade, overall renewable energy growth is expected to continue in several regions. Based on today's level, REmap IRENA analysis shows that the total global capacity of solar PV installations can grow almost six times over the next ten years, reaching 2840 GW by 2030 and increasing to 8519 GW in 2050. This implies the total installed capacity in 2050 is almost 18 times higher than in 2018 (Fig. 3.1.5).

[19] file:///G:/REN%2021/gsr_2020_full_report_en.pdf

[20]https://irena.org/-media/Files/IRENA/Agency/Publication/2019/Nov/IRENA_Future_of_Solar_PV_summary_2019.pdf?la=en&hash=A626155A0775CC50427E23E7BE49B1AD2DD31073

[21] https://wedocs.unep.org/bitstream/handle/20.500.11822/29752/GTR2019.pdf?sequence=1&isAllowed=y

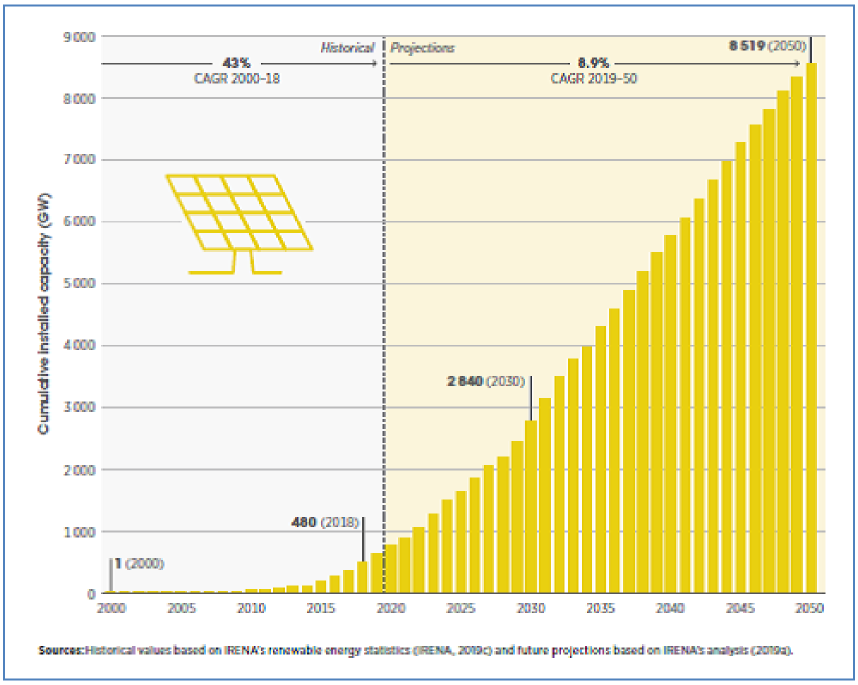

Figure 3.1.5 – Global installed capacity of PV generation facilities by regions of the world - actual data for 2018 and the Remap IRENA forecast until 2050

At the global level, about 60% of the total solar photovoltaic power in 2050 will be networked, while the remaining 40% will be distributed (roof). Although grid projects still dominated in 2050, REmap's analysis suggests that distributed solar photovoltaic plants will grow at a faster pace thanks to policy and support measures, as well as consumer involvement in clean energy production.

With ongoing technological advances and cost reductions, IRENA anticipates that the market for solar PV systems will grow rapidly over the next three decades. Along with increasing power, replacing solar panels at the end of their life is also important and plays a key role, especially considering the old panels, giving way to advanced technologies. The annual capacity increase by 2030 will more than double (270 GW) compared to the current level, and by 2050 it will increase four times higher than in 2018 (372 GW versus 94 GW per year) (Fig. 3.1.6).

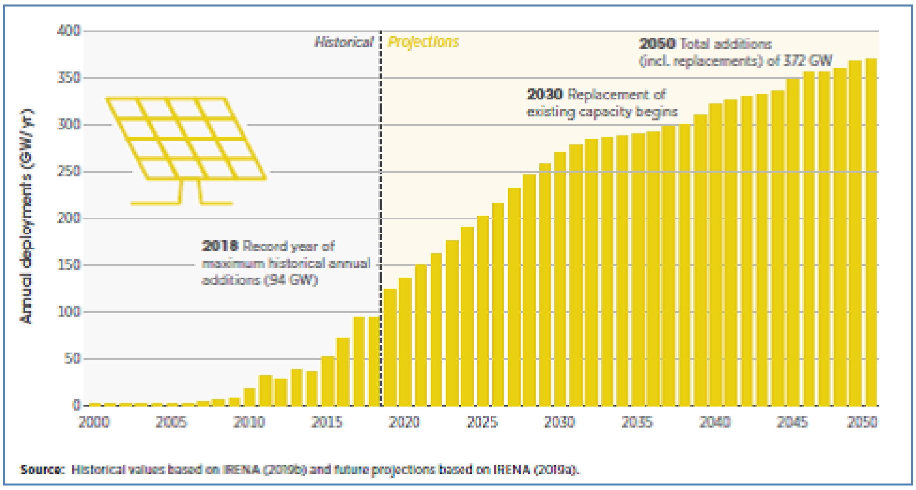

Figure 3.1.6 – Global annual additions of installed capacity of PV generation facilities - actual data for 2018 and the Remap IRENA forecast until 2050

For 10 years since 2009, $ 3.07 trillion was invested in green energy in the whole world of which more than $ 1 trillion - in the last three years (Fig. 3.1.7). Investment are mainly spent on the development of renewable energy (including bioenergy) and smart energy-efficient technologies[22].

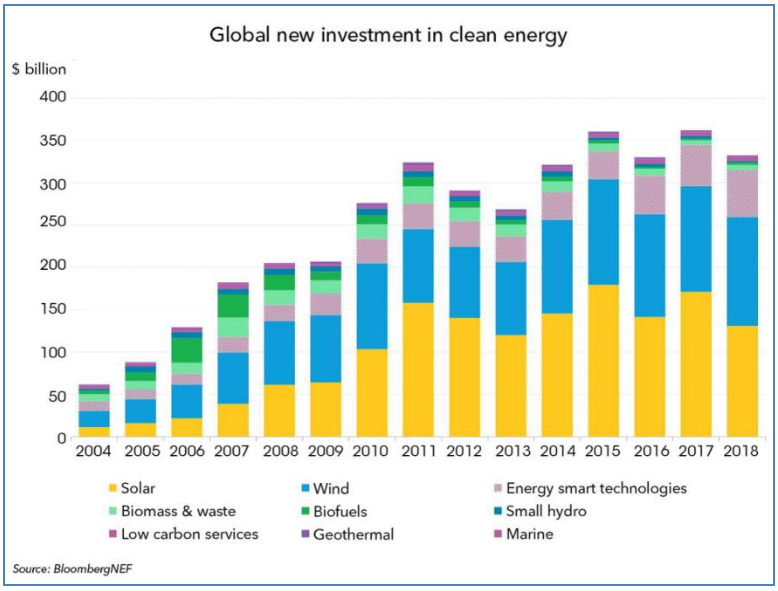

Figure 3.1.7 – Global new investment in clean energy

The absolute leader in terms of investments in renewable energy is China. In 2018, $ 100.1 billion, or almost a third of the total investment in the industry, was invested in China's renewable energy. Investments in green energy in the EU amounted to $ 74.5 billion, in the US - $ 64.2 billion, all over the world - $ 332.1 billion.

Since 2012, more than half of the increase in generating capacity in the world has been attributable to renewable energy facilities. In 2018, their share in the increase in the capacity of the world electric power industry reached 65%[23]. This means that for each additional megawatt of fossil-fuel generating capacity, renewable energy responded with two megawatts.

By the end of 2019, the installed capacity of renewable energy-based power plants in the world amounted to 1347 GW (excluding hydroelectric power stations). Renewable generation capacity increased by 176 GW (+ 7.4%) in 2019. Solar energy continued to grow, increasing by 98 GW (+ 20%), followed by wind energy with 59 GW (+ 10%). Hydropower capacity increased by 12 GW (+ 1%), and bioenergy - by 6 GW (+ 5%). Geothermal energy increased slightly less than 700 MW. Solar and wind energy continued to dominate the expansion of renewable capacities, which in 2019 accounted for 90% of all net renewable additions[24].

Political commitments have played an important role in increasing the share of renewables in electricity production. In 2019, 143 countries applied a regulatory policy on renewable energy in the electric power industry (for example, preferential tariffs or quotas for utilities) compared to 75 countries in 2010. In a number of countries, a strategic vision, investment in research and development, and an industrial strategy have reduced global costs for renewable energy technologies and attracted private sector funding. Based on the successes of the pioneering countries, renewable energy technologies along with effective integrated policy measures and business models have spread around the world[25].

[22] https://data.bloomberglp.com/professional/sites/24/BNEF-Clean-Energy-Investment-Trends-2018.pdf

[23] https://www.ren21.net/wp-content/uploads/2019/05/gsr_2019_full_report_en.pdf

[24] https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Mar/IRENA_RE_Capacity_Highlights_2020.pdf?la=en&hash=B6BDF8C3306D271327729B9F9C9AF5F1274FE30B

[25] file:///G:/REN%2021/gsr_2020_full_report_en.pdf

According to the forecast of the International Energy Agency WEO - 2019 and the Roadmap for Global Energy Transformation (Roadmap to 2050), meeting the growing global energy needs will differ radically from the last twenty-five years: leading positions are taken by natural gas, rapidly developing renewable energy, as well as energy efficiency. Improving energy efficiency reduces the need for increased energy production. Without growing energy efficiency, the growth in final consumption would more than double. Renewable sources account for a significant increase in primary energy consumption.

Figure 3.1.8 shows [26] the increase in the share of electricity in final energy consumption, the increase in electricity production and the installed capacity of renewable energy power plants.

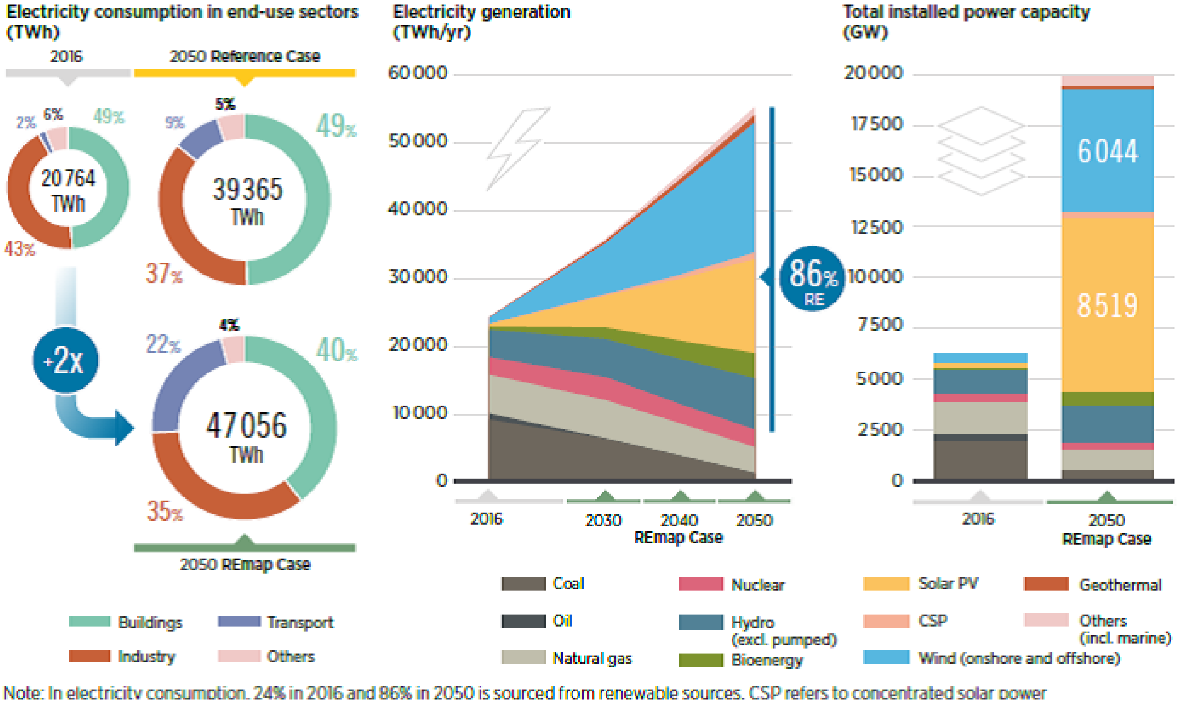

Figure 3.1.8 – Wind and solar energy dominate the growth of renewable energy generation

By 2050, solar energy with an installed capacity of 8,500 GW and a wind power of 6,000 GW will account for three fifths of the world's electricity production. Electricity consumption in end-use sectors will more than double compared to current levels.

By 2050, the share of renewable energy in generation will be 85%, compared to about 25% in 2017. Solar and wind power will lead, increasing from 800 GW today to 13,000 GW by 2050. In addition, the production of geothermal energy, bioenergy and hydropower will increase by 800 GW per period. The annual increase in installed renewable energy capacity doubles to around 400 GW per year, 80% of which will be variable-generation technologies such as solar and wind energy. The decentralized production of renewable energy will grow from 2% of the total production today to 21% by 2050, that is, it will increase 10 times.

Modern renewable energy in the construction sector should increase significantly. Up to three quarters of energy consumption in buildings can be provided by renewable energy sources. Electricity will provide nearly 56% of the sector’s energy needs.

[26] Global energy transformation: A roadmap to 2050 (2019 edition) https://www.irena.org/publications/2019/Apr/Global-energy-transformation-A-roadmap-to-2050-2019Edition

According to the REmap Case, industry should increase its share of renewable energy in direct use and fuel to 48% by 2050. If you include renewable electricity, this share will increase to about 60%. Bioenergy sources will have the greatest contribution, mainly due to the waste used for direct heating and combined heat and power (CHP). In percentage terms, the greatest increase will be due to solar thermal heat for low-temperature processes, as well as heat pumps for similar low-temperature heat needs. When switching to electrical heating, electricity should provide 41% of the energy needs of the industry by 2050.

Figure 3.1.9 shows the increase in energy efficiency and the increase in the share of renewable energy in final global energy consumption.

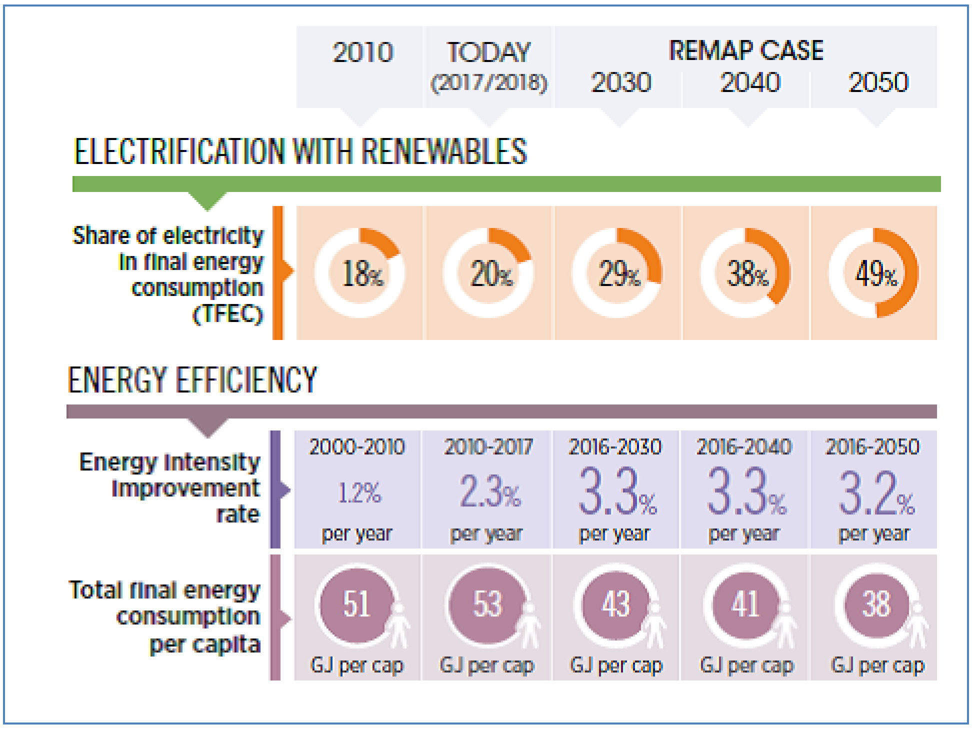

Figure 3.1.9 – Improving energy efficiency and increasing the share of renewable energy in final energy consumption

In the United States, the production of electricity from natural gas and renewable energy sources is increasing as a result of lower prices for natural gas and lower costs for solar and wind renewable energy, which makes these fuels more and more competitive [27](Fig. 3.1.10).

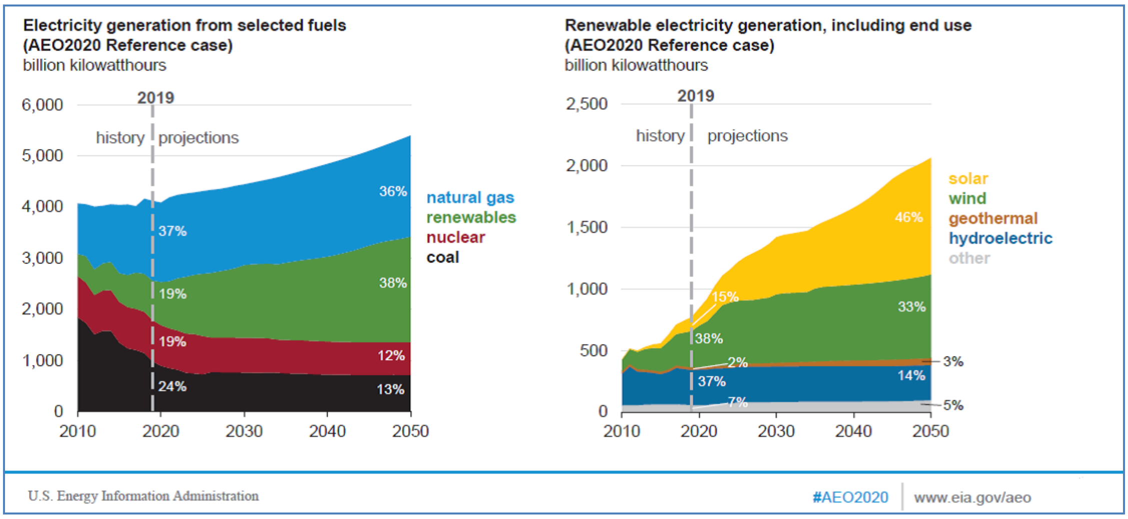

Figure 3.1.10 – US electricity production from selected fuels and renewables, 2010-2050

In the long-term trends in electricity production, AEO 2020 is dominated by increases in solar and natural gas power; Coal, nuclear and less efficient generation of natural gas contribute to the loss of capacity (Fig. 3.1.10-3.1.11).

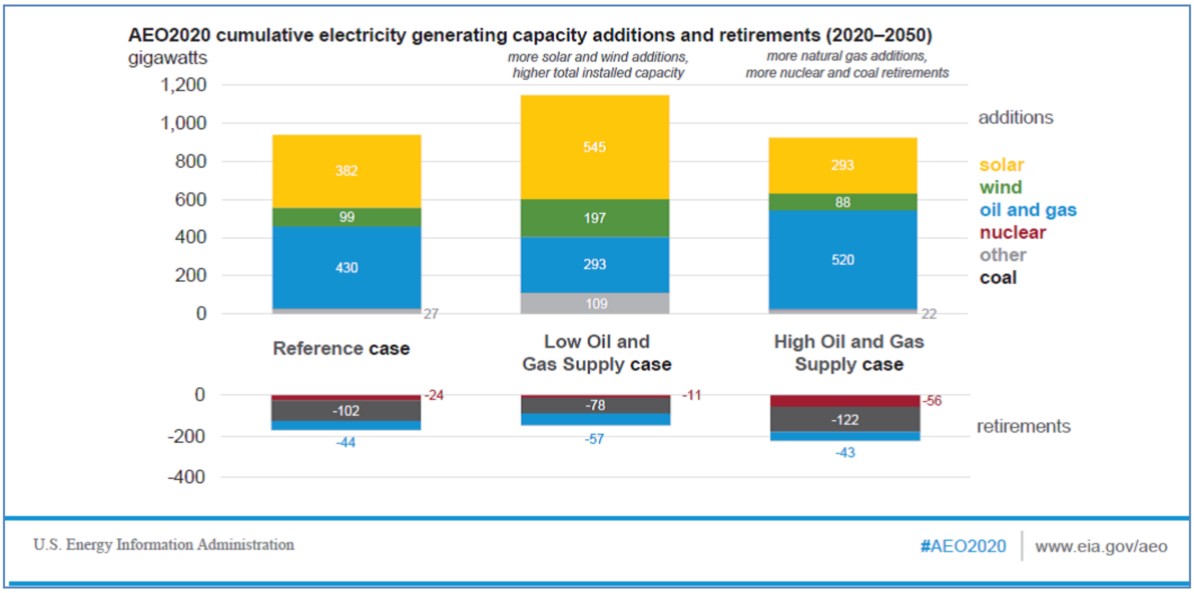

Figure 3.1.11 – Total additions and retirements of generating capacities in the USA, 2020–2050

Chicago will switch to renewable energy by 2025, Atlanta and Massachusetts by 2035, Hawaii and California by 2045, Puerto Rico by 2050. Las Vegas already today provides 100% of its electricity needs from renewable energy. In 2018, the newly elected governors of the states of Illinois, Colorado, Maine, Nevada, and New Mexico announced their intention to introduce a norm in local legislation on the transition to renewable energy. In particular, Colorado plans to switch to renewable energy by 2040.

[27] https://www.eia.gov/outlooks/aeo/pdf/AEO2020%20Full%20Report.pdf

The immediate plans of the states of Illinois and Nevada foresee to increase the share of renewable energy sources to 25% by 2025. The remaining states have not yet decided on the final goals[28].

The heads of 58 American cities recently announced their readiness to switch completely to RES[29]. In the UK, more than 90 cities supported the initiative to switch to RES by 2050[30]. The Scandinavian cities of Oslo, Helsinki, Stockholm and Copenhagen are going to switch to renewable energy sources. In addition, the Swedish city of Malmo is already using green energy. According to the CDP, more than 100 cities in the world receive the bulk (at least 70%) of electricity from renewable energy sources, and 42 cities - 100%[31].

Many large companies have made the transition to renewable energy an integral part of their climate and energy strategy.

At New York Climate Week 2014, the RE100 global corporate leadership initiative was formulated and formalized, bringing together influential companies committed to 100% renewable energy. The goal of RE100, led by the Climate Group in partnership with CDP, is to accelerate the transition to zero carbon networks globally.[32].

This initiative aims to increase corporate demand and, in turn, to offer renewable energy by:

– Uniting large companies seeking to supply 100% renewable electricity globally as soon as possible (no later than 2050);

– Establishing a corporate leadership benchmark in renewable energy, holding members accountable and promoting their achievements in order to encourage others to follow them;

– Providing convincing arguments in favor of renewable energy sources for companies, utilities, market operators, politicians and other key authorities;

– Broad communication of any barriers to the realization of the commercial and economic benefits of renewable energy, as reported by RE100 members;

– Work with RE100 members and in partnership with others to identify and remove political and market barriers to providing renewable energy to corporations.

The RE 100 group, which unites companies that support meeting their energy needs entirely through RES, includes such well-known global brands as IKEA, Facebook, General Motors, Google, Goldman Sachs, H&M, HP, HSBC, Microsoft, Sony, Unilever , Vestas, Walmart and others. In total, today the group includes 229 companies[33].

Companies in the commercial and industrial sector account for about two thirds of final energy consumption in the world. Switching this demand to renewable energy is transforming the global energy market and accelerating the transition to a clean economy.

It should be noted that the development of renewable energy creates several social and economic benefits, such as growing employment. According to IRENA, the number of jobs in the sector can grow rapidly from 10.3 million in 2017 to almost 29 million in 2050. In the entire energy sector, only 20–25% of workers are women, in contrast to 35% in the renewable energy sector. It is also important to use this shift to achieve the goals of gender equality in the rapidly growing renewable energy sector[34], which is crucial for several reasons:

– Wider participation of women allows the sector to attract additional talent;

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[28] http://renen.ru/five-new-us-governors-are-aimed-at-a-complete-transition-of-their-states-to-renewable-energy/?fbclid=IwAR1TGuKslE92NjU5d8RB90myra_4BzryUP-jTS2tn- 7APb6WWRHl-HFElj4I

[29] https://impact.vice.com/en_us/article/kzn3an/with-50-us-cities-committed-to-100-percent-clean-energy-2018-presents-new-renewable-challenges?utm_campaign=sharebutton

[30] https://www.uk100.org/

[31] https://www.theguardian.com/cities/2018/feb/27/cities-powered-clean-energy-renewable

[32] http://there100.org/re100

[33] http://there100.org/companies

[34] https://www.worldfuturecouncil.org/re-a-catalyst-for-gender-equality/

– Diversity of the workforce at all levels, including senior management, brings significant benefits to organizations in terms of growth, culture and sustainability;

– In ensuring a fair transition to energy aspects, the fairness of its benefits is taken into account in social and economic groups.

In 2017, in accordance with the laws of Austria was created an international non-profit organization - the Global Organization «Women for Energy» (GWNET).

GWNET empowers women in the energy field through multidisciplinary communication, advocacy, training, coaching and mentoring, as well as project and financing services. GWNET seeks to address current gender imbalances in the energy sector and promote gender-responsive action during the energy transition in all parts of the world[35].

3.2. Problems and solutions for the integration of renewable energy variables in the energy system

Analysis indicate that electric power sector is undergoing significant structural changes, the purpose of which is to ensure universal access to affordable, reliable, sustainable and modern energy sources for all[36].

This goal is achieved by the ongoing increasing / growing deployment of various traditional and renewable energy sources from small distributed generation facilities to large network power plants

The main factors determining the rapid transformation of energy systems in the world include:

– Desire to improve the reliability and efficiency of energy systems;

– Desire to expand the availability of energy using innovative technologies;

– Desire to ensure a high level of environmental and climate safety (including a radical reduction: air pollution, CO_2 emissions, energy use of fresh water), and to achieve the goals of the Paris Climate Agreement (2015). At the same time, the use of renewable energy sources in combination with increased energy efficiency is considered as the main measures to achieve this climate solution;

– Significant reduction in the cost of technologies for the production and consumption of electricity, including wind and solar power plants, distributed generation, electric transport, demand management and energy storage systems;

– Development of electrification of the economy;

– Expansion of digitalization and automation of energy systems.

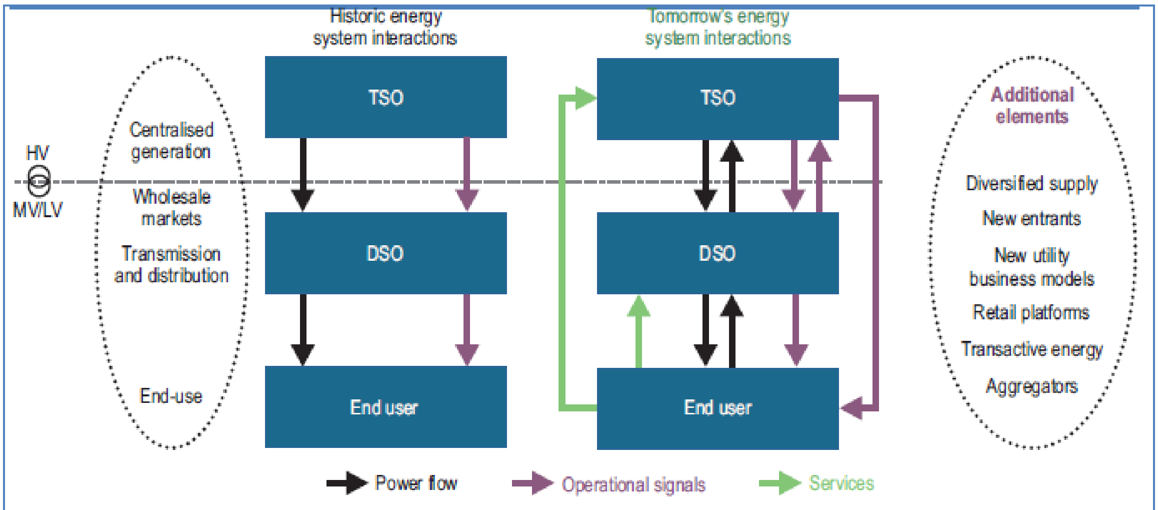
The ongoing technological changes are accompanied by the creation of an institutional framework that defines the regulatory, technological and economic rules for the reliable and effective development and functioning of energy systems in the new conditions.

In other words, there is an active process of creating political, market and regulatory conditions, as well as the establishment of planning and functioning of energy systems that accelerate investment, innovation and the use of intelligent, efficient, reliable and environmentally friendly technologies.

The ongoing transformation of energy systems leads to a change in the interaction between the transmission and distribution electric networks, shown in Fig. 3.2.1.

[35] https://globalwomennet.org/wp-content/uploads/2019/09/GWNET_flyer.pdf

[36] https://www.energy.gov/oe/activities/technology-development/grid-modernization-and-smart-grid



Notes: HV = high voltage; LV = low voltage; MV = medium voltage.
Source: Adapted from Birk et al. (2016), "TSO/DSO coordination in a context of distributed energy resource penetration".
Key point • More complex energy flows and operational signals require new forms of co-ordination.

Figure 3.2.1 – Changes in the interface between transmission and distribution networks (according to IEA)

Electric networks of low and medium voltage are changing from the paradigm of passively distributed electricity for consumers to intelligent, actively controlled systems with bi-directional flows of electricity and information. A successful transition will require due consideration of three key aspects: technical, economic and institutional:

technological: ensuring reliable and efficient operation of the energy system in changing conditions leads to new priorities for energy companies and regulatory bodies. The use of advanced information and communication technologies (digitalization) improves the visibility and management of energy systems and opens up opportunities for a significant expansion of demand management;

economical: the growth of distributed generation and the increase in the efficiency of energy storage devices require reforms in retail pricing and taxation of electricity supplies, taking into account the payment of the electricity they supply and covering part of the cost of the total infrastructure;

institutional: the roles and responsibilities of management entities will change. Priority will be given to improving coordination between transmission and distribution network operators. In addition, completely new actors, such as aggregators, should be included in management.

We can conditionally distinguish four stages of VRE integration and related key problems, differentiated by the increasing impact of the growing share of VRE generation on energy systems (Table 3.2.1).

At the first stage, when the share of renewable energy sources in the annual production does not exceed 3%, special measures for its integration are usually not required, unless the renewable energy sources are very localized in the power system. At the second stage, when the share of renewable energy is 3-15%, it is necessary to adapt the available regulatory resources, technologies and methods for managing the energy system. At the third stage, when the share of renewable energy exceeds 15% of the annual output, as well as in the subsequent stages, a deep restructuring of the energy system and the introduction of new means and instruments to support the operation of the energy system are already required. The fourth stage - more than 50% of the annual output of renewable energy generation.

For the successful integration of such a volume of renewable energy generation into the energy system, it is necessary, first of all, to resolve the standardization of technical requirements for used renewable energy equipment. The automation of limiting the reduction and increase of voltage and frequency must correspond to the parameters of the system. It costs almost nothing at the design stage, but it becomes costly when the projects are already implemented. It is also necessary to take into account that in different countries the standards for deviations of the frequency of electric current differ, respectively, the response to changes in frequency can also be different for generating equipment of different manufacturers. If RES does not meet the necessary technical requirements, they can become a potential source of accidents. The same applies to the relay protection of these objects. All these technical requirements can and should be established at the level of documents of regulators,

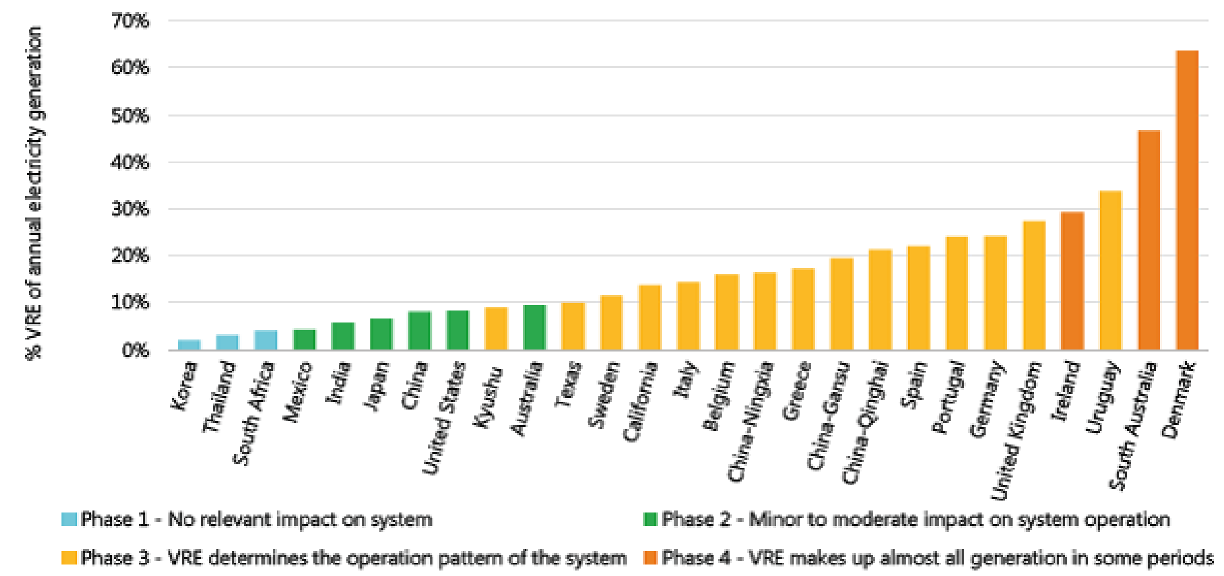
In addition to the standardization of technical requirements for renewable energy equipment, for reliable operation of energy systems with a significant amount of renewable energy sources, it is necessary to develop predicting systems for renewable energy sources generation. Since in the absence of reliable forecasts of their operation in the energy system, it is necessary to constantly maintain full redundancy in the amount of renewable energy sources, which in fact means the need for additional inclusion of thermal generation and its work in uneconomical modes and / or electric networks capacity reservation.

Table 3.2.1 – Four phases of VRE integration[37]

	Attributes (incremental as progressing along VRE phases)			
	Phase 1	Phase 2	Phase 3	Phase 4
Characterisation from a system perspective	VRE as a non-noticeable load at system level	VRE becomes noticeable at the system level to the SO	Flexibility is becoming relevant with greater swings in the supply/demand balance	Stability is becoming relevant. VRE covers significant share of demand at certain times
Impacts on the existing generator fleet	No noticeable difference between load and net load	No significant rise in uncertainty and variability of net load, but there are small changes to operating patterns of existing generators	Greater variability of net load; major differences in operating patterns; reductions in power plants running continuously	Very few power plants are running around the clock; all plants adjust output to accommodate VRE
Impacts on the grid	Local grid condition near points of connection, if any	Very likely to affect local grid conditions; transmission congestion possible driven by changes in power flows across the transmission networks	Significant changes in power flow patterns across the transmission network; increased vertical flows between networks of different voltage levels	System-wide grid strength is weakened and the ability of the grid to recover from disturbances.
Challenges depend mainly on:	Local conditions in the grid	Match between demand and VRE output, and the availability of data from VRE plants	Availability of flexible resources	System strength to withstand disturbances

Phase 4 is currently the highest VRE integration phase that has been achieved in practice. A small number of countries and regions (for example, Denmark, Ireland and South Australia) have reached phase 4, but many other energy systems are still in phases 1 and 2 and have 5-10% VRE shares in annual electricity production (Fig.3.2.2).

[37] Status of Power System Transformation. System integration and local grids. IEA, 2017. https://webstore.iea.org/status-of-power-system-transformation-2017



Note: China = the People's Republic of China.

Source: IEA (forthcoming), *Renewables 2019: Analysis and Forecasts to 2024*.

Figure 3.2.2 – VRE annual share and related system integration in selected countries / regions, 2018

However, the general direction of this transition is already clear: for most countries, higher stages of system integration are expected, which is reflected in an increase in VRE deployment levels. At the fourth stage, development does not stop and the fifth and sixth phases can be distinguished. For the rational distribution of renewable energy in average annual volumes exceeding 50% (phase 5), in order to avoid artificial limitation of production and, consequently, deterioration of the generation economy, the electrification of various sectors of final energy consumption is required. Under conditions of VRE dominance (phase 6), it becomes necessary to convert electricity to chemicals (synthetic gases, such as methane and hydrogen). The transition between phases does not occur suddenly from one to another. Issues related to flexibility will gradually appear in the second stage before becoming a hallmark of the third stage. In turn, some problems associated with the stability of the system may become apparent already in the third stage.

The share of VRE in many countries has grown over the past few years[38]. In 2015, there were just over 30 countries with an annual VRE generation share of over 5%. By 2018, this number has increased to almost 50 countries. VRE shares in many countries and / or regions are expected to grow from 5-10% to 10-20% over the next five years. Jurisdictions with shares of 20-40% are also expected to increase significantly, as shown in Fig. 13 (IEA, 2018)[12].

As the number of countries with medium and high proportions of VRE increases significantly, it is expected that the flexibility of the energy system will become a more important problem in the coming years. To solve integration problems, a number of technical and economic measures are considered, differentiated by the stages of VRE deployment, which are presented in Fig. 3.2.3.

[38] https://www.iea.org/reports/status-of-power-system-transformation-2019

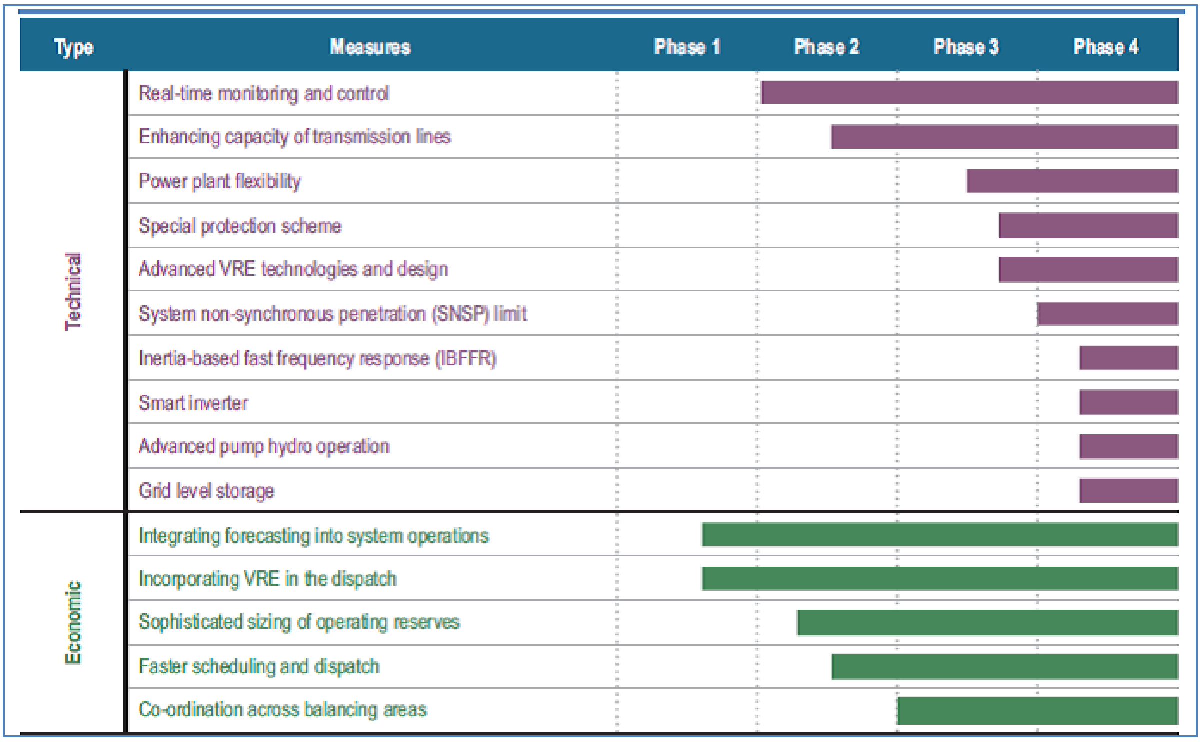


Figure 3.2.3 – Technology and operational practices for various phases of VRE development

Wind and solar energy can be "painlessly" integrated into the system using appropriate integration strategies, including:

1) The provision of solar and wind power system services. This requires appropriate changes in the regulatory framework.

2) Deployment of renewable energy generation facilities in those areas where they can provide greater systemic value (for example, closer to places of highest demand).

3) Diversification of energy sources - a mutual complement of solar and wind generation. Parallel development of hydropower (an example of Brazil, which develops both wind energy and new hydropower).

4) Local integration with other resources. We are talking about increasing the share of our own (local) energy consumption produced locally through the use of a complex (package) of solutions. For example, the combination of solar power plants with energy storage and the use of demand management mechanisms. This reduces the need for investment in distribution networks.

5) Optimization of the generation period. The design of wind and solar installations can be optimized to facilitate their integration into the network. For example, the use of large blades on a wind turbine with the same power reduces integration challenges because they produce electricity with greater stability. Detailed modeling in the framework of the IEA project showed that such a design produces electricity with a higher value for the system.

6) Integrated planning, monitoring and control. The cost of various generation technologies and the electricity they produce are dynamically changing. Therefore, the optimal generation structure also changes over time, which requires regular adjustment of strategies.

To ensure the coordinated work of various types of generating sources, energy transmission and distribution systems, demand management systems, energy storage devices and other systems, integral planning is of key importance, which in the new conditions should include the solution of the following pressing issues:

- Accounting for stochastic electricity generation by wind and solar power plants;
- Demand side management;

- Integrated planning of the system of generation, transmission and distribution of electricity;
- Planning and operation of low and medium voltage networks, taking into account the development of distributed generation;
- Intersectoral planning between the electric power industry and other sectors, including heat supply, cooling, transport.

The main results of identifying key problems and pressing issues arising in the process of transformation of energy systems during the integration of renewable energy sources are summarized in table 3.2.2. The table shows the transformable elements of the energy system, key problems requiring solutions and a list of specific innovative solutions[39,40].

Table 3.2.2 – Transformable elements of the energy system and key problems requiring solutions in the context of large-scale development of renewable energy

Advanced Technologies 	• Energy storage technologies that can support a variety of renewable energy resources and participate in the provision of various services • Technologies that contribute to the electrification of other industries, thus creating new markets for renewable energy generation, as well as new ways to store excess electricity • Digital technologies that allow the introduction of new applications aimed at expanding the boundaries and dynamics of the industry and supporting the optimization of renewable energy resources • New and "smart" networks, both small local and more powerful, complementing each other and allowing the use of new methods to control a variety of renewable energy resources • Modernization of existing assets in order to adapt them to new conditions and needs of EPS
Business models 	• Business models that expand the capabilities of consumers, turning them into active participants in the process • Innovative schemes that provide favorable conditions for the supply of electricity generated on the basis of renewable energy sources, both in autonomous energy regions and in areas connected to EPS
Market structure 	• New rules for the operation of wholesale markets, which provide a flexible mechanism for participation, more reliable price signals and more correct formation of fees for system services • Changes in the structure of the regulatory framework of the retail market to ensure flexible participation of both end-users and consumer-producers (consumer / prosumer)
EPS Management 	• The introduction of distributed generation requires the use of new methods in the management of such an EPS and facilitating the conditions for the participation of such generation in the market • New requirements for ODE, which allow to increase the flexibility of EPS • New energy management methods that allow you to not reduce the supply of renewable energy resources due to network constraints, reducing the need to strengthen the network

[39] https://nangs.org/analytics/irena-innovation-landscape-for-a-renewable-powered-future-february-2019-eng-pdf
[40] https://www.eprussia.ru/epr/374/9315497.htm

3.3. Role of renewable energy in the UNECE region

The Role of RE in the UNECE region is analyzed based on exploring three distinctive scenarios:

The reference scenario is based on shared socio-economic pathway (SSP2), a "Middle of the Road" or Business-as-Usual Pathway, as point of departure. Its socio-economic, market and technology assumptions represent middle-of-the-road developments. SSPs do not include climate mitigations policies or measures other than those existing in 2010. SSP2 provides an appropriate 'base case' for the exploration of multiple (alternative) pathways and is also basis for the Intergovernmental Panel on Climate Change (IPCC) work.

The NDC scenario assumes the implementation of the Nationally Determined Contributions (NDCs) under the Paris Agreement up to 2030 and then maintains them effectively forever.

The P2C scenario is a techno-economic scenario, where regional CO2 constraints consistent with NDC through 2030 are assumed to continue reduction.

Today, roughly 80% of UNECE energy mix is fossil fuel-based. Even though fossil fuels underpin the quality of life across the whole region, this high dependence implies that accelerated decarburization of the entire energy system coupled with technology change is crucial for the UNECE to play its part towards meeting 2°C.

The challenge is significant. In 2015, the region's 56 countries accounted for 39% of the world's primary energy consumption to produce 41% of world GDP. The region produced 40% of the world's primary energy resources and emitted 39% of global CO2 from fossil fuel combustion. When averaged across the entire region, the share of fossil fuels in total primary energy supply is 80% (similar to the global ratio of 81%). When evaluated across the subregions, the least share is in Western Europe at 71%, and the greatest is in Central Asia at 94%.

Under an economically rational scenario that meets the 2^{0}C target while delivering on the other dimensions of the 2030 Agenda, fossil fuels (coal, oil and gas) will still account for 56% of the regional energy mix by 2050 (see Figure 3.3.1). This implies that alternative energy technologies are either more expensive or cannot be deployed within the timeframe of the model. For example, although renewable energy may be suited for electricity generation, deploying renewable energy in transport sector remains a challenge until costs of batteries further decline and infrastructure adapts to support wider public utilization of electric vehicles.

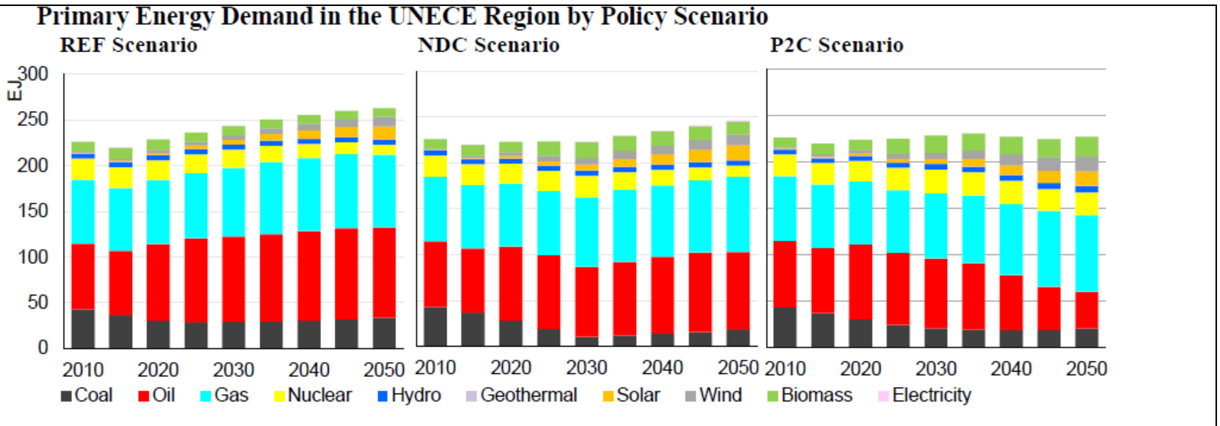


Figure. 3.3.1 – Primary Energy Demand in the UNECE Region by Policy Scenario

Similarly to the primary energy mix, the final energy mix in the region is fossil fuel-based (see Figure 3.3.2). In the REF scenario, the total final energy demand grows after 2020 by 0.7% annually reflecting demographic change. It is based on oil-liquids followed by natural gas and electricity. Driven by the transportation sector and non-energy uses, demand for liquids is expected to increase through to 2050.

In the NDC scenario, final energy demand is not expected to significantly decline. Minor reduction in demand of about 6% is expected by 2050. This will be influenced by energy efficiency gains, fuel shifting and infrastructure adaptation. Between 2020 and 2050, final energy demand increased for all fuels (albeit at a lower pace than REF) except for district heating and natural gas.

Liquids and electricity (gradually generated from renewable energy) are anticipated to substitute gas in the final energy mix.

After initial modest growth, in the P2C scenario, final energy demand declines steadily reflecting climate mitigation induced energy system transformation. In comparison to the REF scenario, final energy demand is expected to contract by about 25%, mainly driven by efficiency and intensity improvements, technology and structural and lifestyle changes, while oil-liquids and natural gas contract, nuclear energy stays strong over time period, consistent with its low carbon foot print.

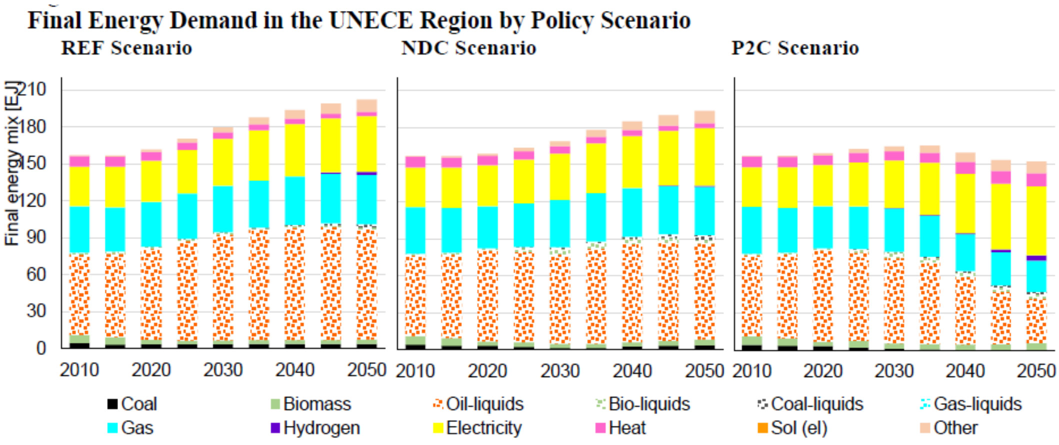


Figure 3.3.2 – Final Energy Demand in the UNECE Region by Policy Scenario

Since access to electricity and reliance on clean fuels and technology are the key indicators to measure achievement of SDG 7, for the purposes of this study energy supply in UNECE primarily focuses on role of various technologies in electricity generation (Figure 3.2.3).

The electricity generation mix in the UNECE region today is predominantly fossil fuel-based (coal and natural gas), followed by nuclear energy and hydro. The traditional electricity supply system is defined by large scale plants that generate single-directional, predominantly fossil-fuel based, power and heat to end-users.

Similarly to the final energy mix, the electricity generation mix is expected to experience significant structural changes only under the P2C scenario after 2030. In the NDC scenario, the slight increase in the electricity output is anticipated compared to the REF scenario, primarily driven by the uptake of electric mobility.

The P2C scenario, implies a higher degree of diversification with fast up-take of low-carbon emitting technologies. On the back of the expected widespread electrification of the energy system, 30% higher electricity demand is expected by 2050. Firstly, renewable energy experiences rapid expansion from 2025 primarily driven by wind and solar PV. This is under the assumption that required investments will be targeted towards regions where renewable energy infrastructure is still underdeveloped, such as the Caucasus, Central Asia, East and South

East Europe. Secondly, retrofitted coal and gas with CCS will slowly be introduced from 2030 and will increasingly gain traction through to 2050. Whilst conventional coal is expected to slowly phase out, some coal-fired power generation with CCS is expected to retain the role of coal in the power generation mix.

Gas and coal with CCS have great potential in the region and if accelerated can serve as an immediate solution to limit CO2 emissions from the energy sector.

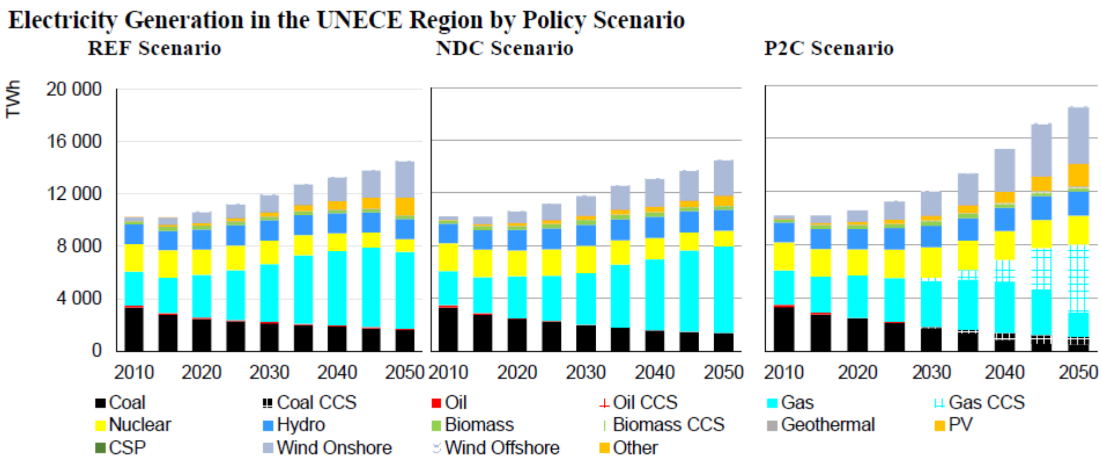


Figure 3.3.3 – Electricity Generation in the UNECE Region by Policy Scenario

In the NDC scenario, the generating capacity structure differs only marginally from the REF scenario. Until 2030 coal and oil are expected to suffer from regional GHG emission limits and are gradually substituted by a varied portfolio of low carbon capacities ranging from natural gas, nuclear, hydro, solar PV and wind. From 2030 the continuation of NDC emission reductions leads to further substitutions of coal, oil but also natural gas (2030 to 2040) by additional non-fossil fuel capacities.

Intermittent generation is expected to provide 25% of total generation by 2050 causing ‘rebound’ of gas capacities after 2040 for load balancing purposes. By 2050 coal generating capacities are 27% lower than in the REF scenario. This, however, does not imply the end of coal – 200 GW of relatively new coal-fired power plants are still operational in 2050.

Moreover, limited coal plants equipped with CCS emerge in the market after 2040 - including gas and biomass CCS capacities.

In the P2C scenario by 2050, renewable energy is expected to account for 55% (3,050 GW) of electricity generation. This translates into a replacement ratio of 18:1 of fossil fuels capacities by 2050 driven almost exclusively by the policy imposed global GHG emission budgets and associated readjustments of final energy mix (higher shares of electricity and, to a minor extent, hydrogen). While coal capacities continue to be part of the mix (152 GW by 2050), they are dominated by plants equipped with CCS (86 GW). Essentially all new gas fired capacities built after 2030 are expected to be plants with CCS. Existing infrastructure is expected to be progressively retrofitted. Nuclear and hydro capacities supplement dispatchable baseload from coal and gas (all with CCS) – nuclear power capacities double compared with the REF scenario, i.e. range slightly above current levels (286 GW). The future of the energy industry in the region looks very different under the various scenarios and there will be winners and losers in all levels of society. The fossil fuels industries will be most negatively impacted but, at the same time, are essential for economic wellbeing during the transition which will last at least until the end of this century. Hence the pace of the energy transition depends on the agility of the utilities and fossil fuels sector towards new business models and innovation. In 2050, half of the region’s energy will still be fossil fuels-based under any economically rational scenario. In all subregions, power generation, district heating system as well as transport sector continues to rely on fossil fuels Investments thus need to be distributed across the broader range of zero emission technology options and across all subregions to enable a swift energy transition towards sustainable energy. The renewable energy sector in the Caucasus, Central Asia, East and South East Europe is still in its infancy. The opportunities in renewable energy remain untapped. There is a need for institutional investments and transaction frameworks. Poor governance, lack of long-term goals coupled with lack of technical local capacity and data on potential of renewable energy technologies have been regularly identified as the main barriers impeding the deployment of renewable energy in these subregions.

4. Priorities, targets and key problems of renewable energy development in the CIS member states

Assessment of priorities and key problems of renewable energy development in the CIS member states was carried out on the basis of analysis of open data and information, as well as the results of a questionnaire developed within the Terms of Reference of the project and agreed with UNECE, IRENA, REN21, IEA. The purpose of this questionnaire is to supplement the available data and information to determine the priorities for the implementation of various types of renewable energy in each of the CIS countries, assess the effectiveness of support for the development of renewable energy at the political / regulatory and institutional levels, analyze key issues and relevant issues of the integration of solar and wind generation in the process of transformation energy systems in the countries in question. Results of the analysis of responses, as well as the analysis of the project "National Sustainable Energy Action Plans", showed:

The power industries of almost all CIS countries (with the exception of the Republic of Kazakhstan) operate on “low-carbon” and / or “carbon-free” energy sources: the vast majority of electricity in the Republics of Tajikistan and Kyrgyzstan is produced at large hydropower plants; thermal power plants in the Republic of Belarus, Uzbekistan, which form the basis of the electric power industry in these countries, operate on natural gas; in the structure of generating capacities of the Republic of Armenia is played by nuclear power plants, hydroelectric power plants and thermal power plants on natural gas.

The climatic and environmental conditions of the beneficiary countries provide many opportunities for the use of renewable sources, which play an important role in diversifying the energy balance, reducing harmful emissions and greenhouse gases into the atmosphere. Summarized data on the installed capacity (MW) of renewable energy facilities, including hydroelectric power plants, in the CIS countries in 2010-2020 are given in table. 4.1. and 4.1.

Table 4.1. – Dynamics of the installed capacity of renewable energy facilities, including hydroelectric power plants, in the CIS countries from 2010 to 2020, MW

	The CIS member states	2010	2011	2012	2013	2014	2015	2016	2017	2018	01.01. 2020
	Republic of Azerbaijan	997	999	1024	1125	1120	1154	1184	1189	1389	1279
	Republic of Armenia	1127	1152	1253	1292	1301	1289	1315	1332	1353	1389
	Republic of Belarus	34	93	99	116	133	137	186	294	391	472
	Republic of Kazakhstan	2364	2514	2665	2680	2734	2807	2851	2898	3088	3 606
	Republic of Kyrgyzstan	3064	3072	3072	3572	3672	3676	3677	3680	3680	3673
	Republic of Moldova	64	64	64	65	66	69	72	72	72	103
	Russian Federation	47375	47418	49384	50041	50959	51304	51338	51854	52224	55190
	Republic of Tajikistan	4759	4766	4768	4771	4991	4990	4989	4989	5631	5273
	Turkmenistan	1	1	1	1	1	1	1	1	1	1
	Republic of Uzbekistan	1746	1746	1746	1747	1762	1762	1797	1844	1844	1943
	TOTAL	61631	61871	64133	65470	66787	67096	67566	70821	71639	72929

Source of information: IRENA Report "Renewable Capacity Statistics 2020[41]

Figure 4.1 – Dynamics of the installed capacity of renewable energy facilities, including hydroelectric power plants. in the CIS countries from 2010 to 2020. MW

Summarized data on the installed capacity (MW) of wind farms in the CIS countries in 2010-2020 are given in table. 4.2 and figure 4.2. and of solar power plants in the table. 4.3 and in figure 4.3.

Table 4.2 – Dynamics of installed capacity of onshore wind energy facilities in the CIS countries from 2010 to 2020, MW

	The CIS member states	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**01.01.2020**
	Republic of Azerbaijan	2			3	3	8	16	16	66	66
	Republic of Armenia	3	3	3	3	3	3	3	3	3	3
	Republic of Belarus	2	2	2	2	3	43	68	83	101	109
	Republic of Kazakhstan			2	4	53	72	98	112	121	284
	Republic of Kyrgyzstan										
	Republic of Moldova				1	1	1	2	9	29	29
	Russian Federation	10	10	10	10	10	11	11	11	52	102
	Republic of Tajikistan										
	Turkmenistan										
	Republic of Uzbekistan								1	1	1
	TOTAL	**17**	**15**	**17**	**23**	**73**	**138**	**198**	**235**	**373**	**594**

[41] file:///C:/Users/Moy/Downloads/IRENA_RE_Capacity_Statistics_2020%20(2).pdf

Figure 4.2 – Dynamics of installed capacity of onshore wind energy facilities in the CIS countries from 2010 to 2020, MW

Table 4.3 – Dynamics of installed capacity of solar PV power plants in the CIS countries from 2010 to 2020, MW

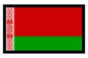
	The CIS member states	2010	2011	2012	2013	2014	2015	2016	2017	2018	01.01.2020
	Republic of Azerbaijan	0	1	1	1	2	5	25	28	35	37
	Republic of Armenia							1	2	17	50
	Republic of Belarus				1	4	13	51	153	154	157
	Republic of Kazakhstan				21	5	57	57	59	209	542
	Republic of Kyrgyzstan										
	Republic of Moldova					1	1	2	2	4	4
	Russian Federation				1	5	61	76	275	535	1 064
	Republic of Tajikistan										
	Turkmenistan										
	Republic of Uzbekistan			1	1	1	1	2	3	4	4
	TOTAL	**0**	**1**	**2**	**25**	**18**	**138**	**214**	**522**	**958**	**1858**

Figure 4.3 – Dynamics of installed capacity of solar PV power plants in the CIS countries from 2010 to 2020, MW

In the considered time period 2010 – 2020, two stages can be distinguished. At the first stage of 2010-2014, there was a moderate increase in the installed capacity of wind and solar energy. From 2014 to the present, the commissioning of solar and wind generating capacities has been progressing. If during this period the installed wind power capacity of the CIS member states increased from 73 to almost 600 MW, then the installed solar power capacity from 18 MW approached the 2 GW milestone. All the CIS countries have signed and ratified the Paris Climate Agreement, identified relevant contributions (INDC) and developed action plans for their implementation at the national level (Table 4.4-4.5).

The introduction of renewable energy is considered as one of the main measures to fulfill the commitments made.

Table 4.4 – Dates of signing and ratification of the Paris Agreement by the CIS member states

The CIS member states	GHG percentage for ratification	Date of signing	Effective Date
Republic of Azerbaijan	0.13%	April 22. 2016	February 8. 2017
Republic of Armenia	0.02%	September 20. 2016	April 22. 2017
Republic of Belarus	0.24%	April 22. 2016	November 4. 2016
Republic of Kazakhstan	0.84%	August 2. 2016	January 5. 2017
Republic of Kyrgyzstan	0.03%	September 21. 2016	November 12. 2019
Republic of Moldova	0.04%	September 21. 2016	July 20. 2017
Russian Federation	7.53%	April 22. 2016	September 21. 2019
Republic of Tajikistan	0.02%	April 22. 2016	April 21. 2017
Turkmenistan	0.20%	September 23. 2016	November 19. 2016
Republic of Uzbekistan	0.54%	April 19. 2017	October 3. 2018

Table 4.5 – Nationally determined contributions (INDC) for CIS member states

	Nationally Determined Contributions (INDC) for CIS Member States
Republic of Azerbaijan	35% reduction in GHG emissions by 2030 compared to 1990
Republic of Armenia	For 2015 – 2050, the GHG emission limit is 633 million tons. or 5.4 tons per capita
Republic of Belarus	By 2030, reducing GHG emissions by at least 28% compared to 1990
Republic of Kazakhstan	By 2030, reducing GHG emissions by at least 15% compared to 1990
Republic of Kyrgyzstan	By 2030, the reduction of GHG emissions by 11.49 - 13.75% compared to 2010
Republic of Moldova	By 2030, GHG emissions are reduced by 64 - 67% compared to 1990 levels.
Russian Federation	Reduction of greenhouse gas emissions by up to 70% compared to the 1990 level, taking into account the maximum possible absorptive capacity of forests and other ecosystems and subject to sustainable and balanced socio-economic development of the Russian Federation.
Republic of Tajikistan	By 2030, the potential for reducing GHG emissions in the Republic of Tajikistan will provide 65-75% of the 1990 level
Turkmenistan	By 2030, the goal is to reduce the growth rate of GHG emissions in relation to GDP growth; reduce energy consumption and CO2 production per unit of GDP; after reaching GHG emissions of 135.8 million tons in CO2-eq. and provide stabilization at this level
Republic of Uzbekistan	By 2030, the reduction of specific GHG emissions per unit of GDP by 10% from the 2010 level

Between 1990 and 2017, the gross CO2 emissions from fossil fuels in the CIS countries decreased by almost 750 million tons or 26.5% (Table 4.6. Figure 4.4). The reduction was due to a significant decrease in coal consumption (tab. 4.7. fig. 4.5).

Table 4.6 – Gross CO2 emissions from the burning of fossil fuels (coal, gas, fuel oil), mln tons

The CIS member states	1990	1995	2000	2005	2010	2015	2017	2017/ 1990. %
Republic of Azerbaijan	53.5	32.4	27.3	29.0	23.5	30.8	30.8	-42.4
Republic of Armenia	19.8	3.4	3.4	4.1	4.0	4.7	5.2	-74.0
Republic of Belarus	99.9	57.0	52.1	55.0	59.5	52.6	54.1	-45.9
Republic of Kazakhstan	237.3	170.5	112.0	156.9	221.1	245.8	255.8	7.8
Republic of Kyrgyzstan	22.8	4.5	4.5	4.9	6.0	9.9	8.9	-60.9
Republic of Moldova	30.5	11.9	6.5	7.8	7.9	7.6	7.5	-75.3
Russian Federation	2163.5	1548.3	1474.4	1481.9	1529.2	1534.5	1536.9	-29.0
Republic of Tajikistan	11.0	2.5	2.2	2.3	2.3	4.2	5.8	-47.0
Turkmenistan	44.6	33.3	36.7	48.1	56.9	69.1	69.0	54.5

Republic of Uzbekistan	114.9	94.6	115.1	105.6	100.6	92.2	81.2	-29.4
TOTAL	**2797.8**	**1958.1**	**1834.2**	**1895.7**	**2011.2**	**2051.3**	**2055.1**	**-26.5**

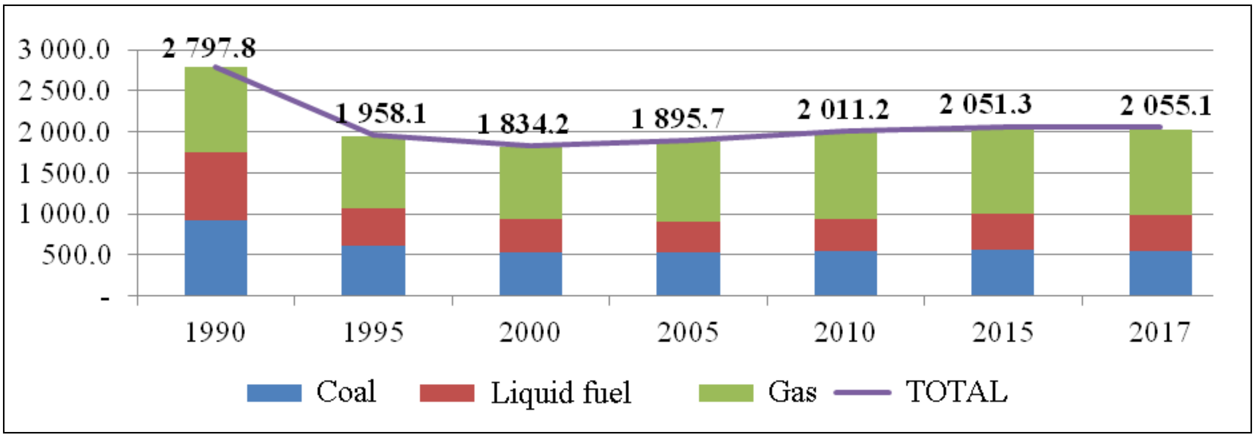


Figure 4.4 – Dynamics of CO2 emissions from fossil fuel combustion in the CIS countries, mln tons

Table 4.7 – CO_2 emissions from coal combustion in the CIS member states, mln tons

The CIS member states	1990	1995	2000	2005	2010	2015	2017	2017/ 1990 %
Republic of Azerbaijan	0.4	0.0						-100.0
Republic of Armenia	1.0	0.0			0.0	0.0	0.0	-100.0
Republic of Belarus	9.6	5.5	3.8	2.4	2.1	2.9	3.3	-66.1
Republic of Kazakhstan	158.7	114.3	74.7	102.7	137.6	141.9	146.8	-7.5
Republic of Kyrgyzstan	10.2	1.3	1.9	2.2	2.8	4.5	3.6	-65.1
Republic of Moldova	7.9	2.3	0.5	0.4	0.4	0.4	0.4	-94.8
Russian Federation	707.2	483.7	443.1	413.6	405.0	411.1	387.9	-45.1
Republic of Tajikistan	2.5	0.1	0.0	0.2	0.4	1.8	3.5	38.9
Turkmenistan	1.2							-100.0
Republic of Uzbekistan	14.0	4.5	4.6	4.3	4.2	6.6	7.6	-45.6
TOTAL	**912.6**	**611.7**	**528.7**	**525.8**	**552.6**	**569.3**	**553.1**	**-39.3**

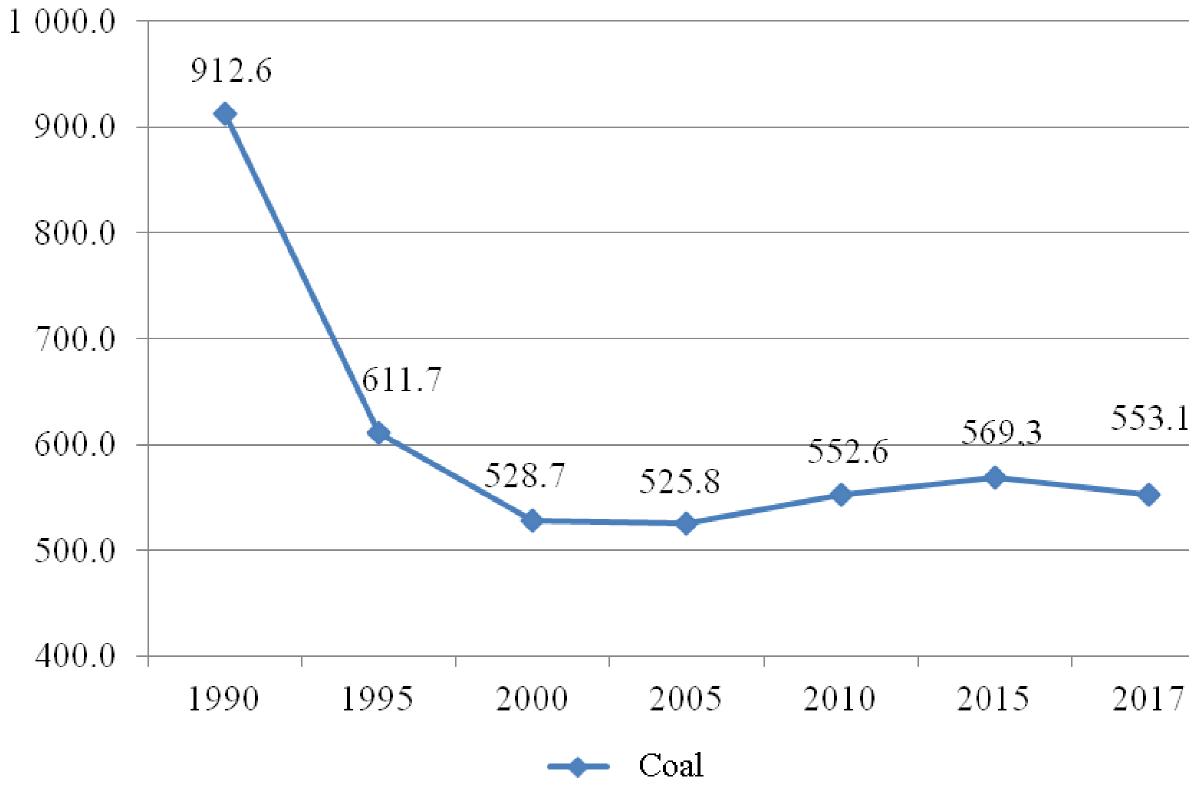


Figure 4.5 – CO2 emissions from coal combustion in the CIS member states, mln tons

Policies and goals are important factors in attracting investment in renewable energy and energy efficiency. Political processes in the region are still developing, with priority being given to setting goals and regulatory policies (Table 4.7). Almost all countries have strategic documents setting out their priorities for at least one renewable energy technology.

Table 4.7 – Renewable energy projects support mechanisms

										
Regulatory policy										
Biofuel commitment / mandate			X			X				
Obligatory quotas of networks for the purchase of electricity		X	X			X	X*			
Reduced rates / bonus payments	X	X	X	X	X	X	X**			
Heat purchase commitments / mandate						X				
Clean measurements	X	X	X			X				
Renewable Energy Development Goals	X	X	X	X	X	X	X	X		
Holding tenders				X		X	X			
Tradable green certificates			X		X	X		X		

Tax incentives and government funding										
Capital subsidies / discounts			X				X			
Energy production payment	X	X	X	X	X		X	X		
Investment or production tax incentives			X	X	X			X		
Government investments, loans or grants	X	X	X	X	X	X		X		

Notes:
* Provides for the obligation of power grid organizations in retail markets, first of all, to purchase electricity generated on the basis of the use of renewable energy sources to compensate for losses.
** Guaranteed payments for the capacity of renewable energy facilities.

Republic of Armenia. In the Republic there are over 200 power generating plants using renewable energy. including: 189 small hydroelectric power plants, 1 biogas power plant, 3 wind power plants, 9 solar power plants with a total installed capacity of 414 MW.

The constructing small hydroelectric power plants (SHPPs) in Armenia is a priority. In the Republic, the majority of SHPPs, including those designed, built and operated, are derivation-type stations on natural watercourses.

Distributed solar thermal energy is also rapidly developing in Armenia, including almost 2.700 solar water heaters.

The target indicators for the development of solar and wind generation in Armenia are given in Table 4.8.

Table 4.8 [42]

year	Electricity production. GW * h		Installed capacity. MW	
	Solar	Wind	Solar	Wind
2025	80	232	80	100

Republic of Belarus. The State Cadastre of Renewable Energy Sources of the Republic of Belarus has over 300 operating installations with a total capacity of 500 MW. Among them. 98 installations for the use of wind energy (110 MW, 95 installations for the use of solar energy (over 150 MW), 29 hydropower (86.06 MW) and 32 biogas plants (41.3 MW)[43].

According to the concept of energy security of the Republic of Belarus, the share of primary energy production from renewable sources should be 6% in the gross consumption of fuel and energy resources in 2020, 8% in 2030, 9% in 2035. Decree of the President of the Republic of Belarus on September 24, 2019 No. 357 "On Renewable Energy Sources" establishes that the creation of installations for the use of renewable energy sources is carried out within the limits of quotas for the creation of such installations.

Based on the results of the meeting of the Republican Interdepartmental Commission for the Establishment. Distribution. Release and Removal of Quotas for the Creation of Installations for the Use of Renewable Energy Sources, held on April 29 2020, the following quotas were established for 2022-2023.

[42] https://www.energycharter.org/fileadmin/DocumentsMedia/EERR/ARMENIA_IDR_2017_Final_EN.pdf
[43] https://www.belta.by/comments/view/kak-v-belarusi-razvivaetsja-vozobnovljaemaja-energetika-7063/

Table 4.9 Quotas for the creation of installations for the use of renewable energy sources for 2022-2023 (MW)

Renewable energy source	2022	2023
using wind power	19.8	10.0
using biogas energy	5.0	10.0
using the energy of the sun	0	10.0
using the energy of the natural movement of water flows	0	29.16
using the energy of wood fuel. other types of biomass	2.6	3.0
using the heat of the earth and other energy sources that are not non-renewable	0	40.0
TOTAL:	27.4	102.16

In the Republic of Belarus, the priority areas for the development of renewable energy sources and mitigation of the consequences of the integration of generating renewable energy sources into the grid are:

- Bioenergy is a priority area for the development of renewable energy sources along with the development of solar and wind generation facilities;
- Use of renewable energy sources in the production of thermal energy;
- Participation of RES in the regulation of the power system load;
- Use of market mechanisms in the pricing of electricity produced by renewable energy sources to achieve a balance between the efficiency of investments in renewable energy and the competitiveness of prices for electricity produced from renewable energy sources;
- Site selection for the construction of generators using renewable variables in order to avoid concentration in one place;
- Complex auctions, incl. within the framework of the mechanism for allocating quotas, on which a plot will be set up indicating the range of possible power generation capacity (quota), depending on the connection of the power source, the estimated cost of payments to local budgets, etc.;
- Expanding the use of energy generated from renewable energy sources intended exclusively for the entrepreneurial activities of their owners, to ensure those processes for which the schedule of electricity demand coincides with the schedule of electricity production.

Republic of Kazakhstan. The strategic documents of the Republic of Kazakhstan (Concept for the transition to a "green economy". Strategy "Kazakhstan-2050") set a goal to significantly increase the share of alternative and renewable energy in the country's energy balance. Currently, the document “On Amending the Decree of the Government of the Republic of Kazakhstan dated June 28, 2014 No. 724 “On Approving the Concept for the Development of the Fuel and Energy Complex of the Republic of Kazakhstan until 2030” is currently under discussion. Considering the current state of the electric power industry and environmental obligations of Kazakhstan, the scenario of balanced development of traditional and alternative energy is considered as the basic one. The implementation of this scenario will make it possible to fulfill obligations to reduce greenhouse gas emissions according to the Paris Agreement to ensure an optimal balance between traditional and renewable energy and to reduce the impact of renewable energy facilities on electricity tariffs for end users. In order to ensure investment attractiveness and increase the share of renewable energy sources in the overall energy balance, it is planned to build new maneuverable generating capacities at traditional power plants, as well as the development of small autonomous and distributed renewable energy generation facilities.

According to the Concept of Transition to a “Green Economy” and the Strategic Development Plan of the Republic of Kazakhstan until 2025, the share of RES in the total volume of electricity production should be 3% by 2020, 6% by 2025, 10% by 2030, and 50% (alternative and renewable energy) in 2050 (Figure 4.6).

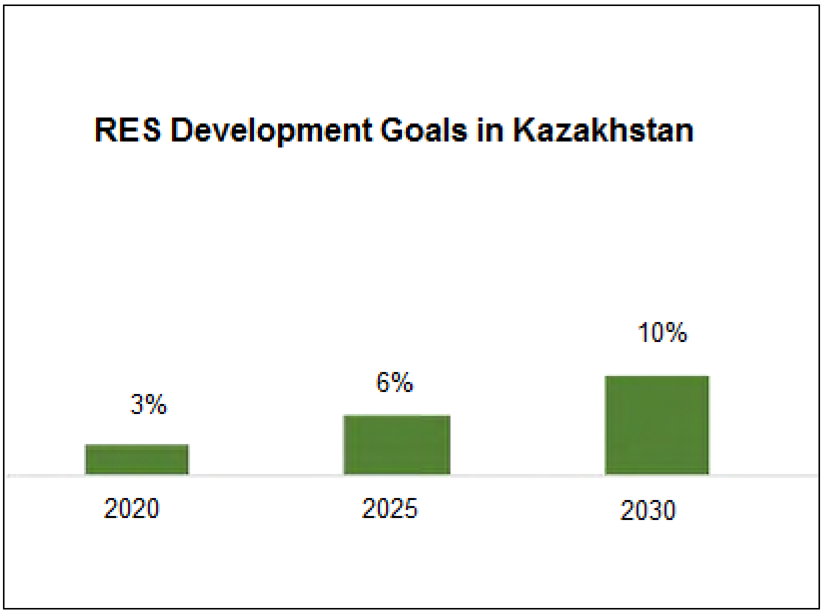


Figure 4.6 – Target indicators of RES development in Kazakhstan

Currently, the document "On Amending the Decree of the Government of the Republic of Kazakhstan dated June 28, 2014 No. 724 "On Approval of the Concept for the Development of the Fuel and Energy Complex of the Republic of Kazakhstan until 2030" is under discussion. Taking into account the current state of the electric power industry and environmental obligations of Kazakhstan, a scenario of balanced development of traditional and alternative energy is considered as a baseline. The implementation of this scenario will allow fulfilling the obligations to reduce greenhouse gas emissions under the Paris Agreement, ensure an optimal balance between traditional and alternative energy and reduce the level of impact of RES facilities on electricity tariffs for end users. In order to ensure investment attractiveness and increase the share of renewable energy sources in the total energy balance, it is planned to build new flexible generating capacities at traditional power plants, as well as develop facilities for small autonomous and distributed generation of renewable energy sources. The share of renewable energy sources, including hydroelectric power plants, in the structure of the installed capacity of the UPS of the Republic of Kazakhstan, at the level of 2030, according to the basic version, will be at least 20%.

Republic of Kyrgyzstan. For Kyrgyzstan the priority for the introduction of small and micro hydropower plants is distributed / autonomous generation in isolated (not connected to a single power system) areas.

Nine power plants operating on renewable energy sources (SHPPs) have a total capacity of 40 MW. At the same time, the country practically does not realize the existing potential for the development of other types of renewable energy sources, for example, solar energy, with the exception of small pilot projects.

Since 2016, the Kyrgyz Republic has been a member of the Global Partnership for Action on a Green Economy (PAGE). a joint initiative of five UN agencies - UNDP. UNEP. ILO. UNIDO and UNITAR[44].

The partnership is achieved by providing technical and financial support to analyze the possibilities of green economy reform policies across all sectors of the economy and build individual and institutional capacities for sustainability.

[44] https://www.kg.undp.org/content/kyrgyzstan/ru/home/projects/partnership-for-action-on-green-economy.html

The Ministry of Economy of the Kyrgyz Republic is the beneficiary of this initiative and the main government coordinating body for the implementation of PAGE in the Kyrgyz Republic.

In 2019, the government adopted the Green Economy Development Program for 2019[45]-2023 with a corresponding action plan. The program has identified seven priority areas: green energy; green agriculture; green industry; low-carbon and environmentally friendly transport; sustainable tourism; waste management; and green cities. The government is currently focused on implementing the Program's priorities.

By 2023, it is planned to commission at least 50 MW of renewable energy capacity. including small hydroelectric power plants, solar and biogas plants.

In 2020, a new Green Economy and Climate Change Coordination Council was established.

The Republic of Tajikistan. Tajikistan possesses significant energy reserves of renewable energy resources. More than 285 operating small hydroelectric power plants with a capacity of 5 to 4300 kW are registered in the republic. Of this number, 16 small hydroelectric power plants have been built and operated by Barki Tojik OJSC and are State owned. Pamir Energy operates eleven small and mini HPPs with a total installed capacity of 44.16 MW.

According to the estimates of the Ministry of Energy and Water Resources, at present. Tajikistan uses less than 4% of the available potential from the technical possible and economically efficient reserves of hydro resources and less than 1% from other types of renewable energy sources. About 10% of the population of Tajikistan lives in mountainous areas inaccessible along the valleys of small rivers and watercourses far from centralized power supply systems. The most promising here is the use of modern renewable energy sources: energy from small rivers, solar energy, geothermal waters, wind energy and bioenergy.

In 2016 the National Development Strategy of the Republic of Tajikistan for the period up to 2030 was approved, one of the key objectives of which is to ensure energy security and efficient use of electricity in the Republic of Tajikistan. This strategy sets the goal of a threefold increase in the country's energy capacity (from 17 to 45 billion kWh), which will give a powerful breakthrough for the development of the country's energy sector[46]. More than 15% of the total state budget of the country or more than 300 million US dollars is annually allocated for the development of the fuel and energy complex[47].

Republic of Uzbekistan. In the Republic of Uzbekistan, long-term targets for the development of renewable energy sources have been approved, providing for an increase in the share of electricity production using renewable energy sources to at least 20% by 2025 and to at least 25% by 2030[48]. To achieve the renewable energy development indicators, it is planned to build almost 10 GW of new renewable energy facilities, including 5 GW of solar (excluding individual household capacities). 3 GW of wind and 1.9 GW of hydroelectric power plants (Fig. 4.7).

[45] http://mineconom.gov.kg/froala/uploads/file/8df6cce6ee2693ee40b9568a9d695c9727610028.pdf

[46] Chorshanbiev S.R. Energy strategy and ongoing projects in the Republic of Tajikistan / Chorshanbiev S.R., Nazirov Kh.B., Naimov Sh.B. // Proceedings of the 1st International Scientific and Practical Conference "The introduction of innovative technologies to improve the energy efficiency of the electric power industry of the Republic of Tajikistan", Dushanbe, September 17, 2018 - pp. 32 - 37.

[47] http://www.tj.undp.org/content/dam/tajikistan/docs/library/UNDP_TJK_SE4ALL _Rapid_Assessment_and_gap_analysis_Rus.pdf.

[48] https://minenergy.uz/ru/lists/view/32

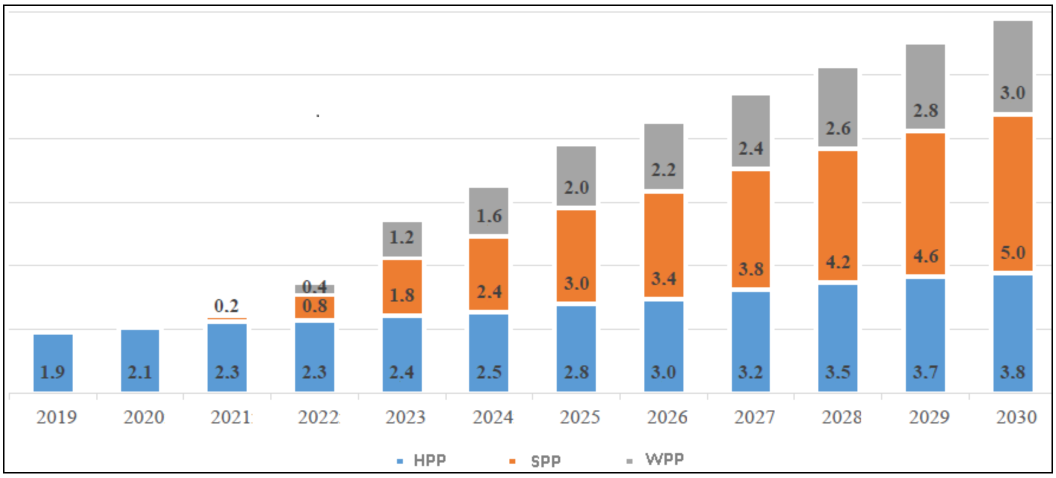


Figure 4.7 – The structure of generation of the Republic of Uzbekistan based on renewable energy by 2030. MW

In wind energy, the priority will be the construction of large wind farms with a unit capacity of 100-500 MW, most of which will be concentrated in the North-West region. In the remaining regions of the republic, solar power plants with a capacity of 50-200 MW will be built. At the same time, large solar photovoltaic power plants (totaling more than 300 MW) will gradually be equipped with energy storage systems on an industrial scale to ensure stabilization of variable generation and regulation of peak loads. Attention will also be paid to the creation of isolated (not connected to a single electric power system) solar PV power plants of low power in remote settlements of the republic, as well as in regions where the development of ecotourism is planned. In addition, the construction of medium-sized solar power plants (1–20 MW) will be developed to produce electric energy for the own needs of industrial enterprises and industrial parks.

Taking into account the possible increase in the ability of consumers to generate electric energy for their own needs and supplying excess to integrated power system, as well as in order to stimulate the activation of intra-republican investment potential, a targeted program for the installation of about 150 thousand solar photovoltaic power plants (with a capacity of 2-3 kW each) and water heaters (an average of 200 liters) in 2-2.5 percent of households in 2021-2025 was approved.

Analysis of the current state and long-term plans for the development of national energy systems. as well as the answers of the respondents, allow us to highlight the following key problems of the electric power industry and renewable energy sources that are typical for almost all project beneficiary countries:

- High level of wear and tear of electrical and heating networks; main and auxiliary equipment of TPP and HPP;
- Lack of interest of energy producing organizations in the implementation of energy efficient and energy saving technologies;
- Shortage of maneuverable power plants;
- Low efficiency of existing ash collection and gas cleaning units at coal-fired thermal power plants;
- The current standards for emissions of harmful substances, which are significantly inferior to the standards of advanced countries;
- Underdeveloped processing of ash and slag waste from coal thermal power plants;
- Lack of long-term plans for the development of electricity and heat supply systems in the regions;
- Relatively low electricity tariffs;
- Decrease in the level of training of highly qualified personnel;

- Low wages and. as a result, a lack of qualified personnel for energy production;
- Lack of investment in the modernization of fixed assets;
- A limited amount of reserve electrical power at a fast pace of commissioning of facilities for the use of renewable energy sources;
- Weak development of autonomous and distributed generation. at the level of individual areas of households and farms using renewable energy sources.
- The main constraints on the development of renewable energy sources in the countries under consideration are regulatory and financial factors.

Almost all respondents noted that the existing training system for the development of renewable energy sources does not meet the future requirements (in the context of large-scale introduction of renewable energy sources) and all its elements require fundamental improvement.

5. Conclusions

The electric power industry in many countries of the world is undergoing significant changes, with the purpose to ensure universal access to affordable, reliable, sustainable and modern energy sources for all - **SDG 7**[49]. This goal is achieved by the active integration of various traditional and renewable energy sources in a wide range of capacities from small distributed generation facilities to large network power plants, which entails the transformation of energy systems.

The main factors determining the rapid transformation of energy systems in the world are the:

• Desire to improve the reliability and efficiency of energy systems;
• Desire to expand the availability of energy using innovative technologies;
• Desire to ensure a high level of environmental and climate safety.

At the same time, the use of renewable energy sources in combination with increased energy efficiency is considered **as the main measures to achieve climate solutions;**

• Reduction in the cost of technologies for the production and consumption of electricity;
• Development of electrification of the economy;
• Expansion of digitalization and automation of energy systems.

A successful transition will require due consideration of three key aspects: technical, economic and institutional. Priority will be given to improving coordination between transmission and distribution network operators. In addition, completely new actors, such as aggregators, should be included in management.

In many countries of the world. there is an active process of **creating political, market and regulatory conditions,** as well as the establishment of planning and functioning of energy systems practices that accelerate investment, innovations and the use of intelligent, efficient. reliable and environmentally friendly technologies. To ensure the coordinated work of various types of generating sources, energy transmission and distribution systems, demand management systems, energy storage devices and other systems, integral planning is of key importance. Currently, **all CIS countries have signed and ratified the Paris Climate Agreement**, identified relevant contributions (INDC) and developed action plans for their implementation at the national level.

One of the problems that many countries are currently facing in their efforts to make large-scale use of renewable energy sources is the lack of qualified technical personnel. The power sector of the CIS member states is more than 325 GW of installed capacity of power plants with an annual electricity production of about 1.400 TWh. As part of the unification of the electric power systems of the CIS member states, seven national energy systems of the Commonwealth states (except for the power systems of the Republic of Armenia, the Republic of Tajikistan and Turkmenistan) operate synchronously. The power industries of many CIS countries operate on “low-carbon” and / or “carbon-free” energy sources:

• The vast majority of electricity in the Republic of Tajikistan and Kyrgyzstan is produced at large hydropower plants;

• Thermal power plants in Turkmenistan, the Republics of Belarus,Uzbekistan, Moldova and the Azerbaijan Republic, which form the basis of the electric power industry in these countries, operate on natural gas;

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[49] https://www.energy.gov/oe/activities/technology-development/grid-modernization-and-smart-grid

• In the structure of generating capacities of the Russian Federation and the Republic of Armenia, a significant role is played by nuclear power plants. hydroelectric power stations and thermal power plants.

Despite the progress made, the diversification of sustainable energy sources has not yet been achieved. More urgency is needed to deploy renewable energy technologies and invest in future sustainable energy systems.

Under the conditions of energy systems transformation processes in the region, it is **advisable to perform the following work**:

• Determination of key areas and target vision for the development of the electric power industry of the CIS member states, taking into account the long-term prospects (for the period until 2050);

• Creation of an institutional framework, and in general - an integrated management system that defines the regulatory, technological and economic rules for the optimal development and functioning of the electric power complex of the CIS member states in the context of the processes of transformation of energy systems in the country and in the world;

• Creation of a joint program to develop a technological and economic basis for building a future efficient and sustainable integrated energy system of the CIS member states to meet SDG7.

In order to develop renewable energy in the countries beneficiaries we suggest the following **recommendations**:

• Integrate solar and wind energy into power systems

• Create national institutes of future energy planning

• Improve methods to unify relevant, reliable and timely statistics

• Develop legislative measures to support integration of variable renewable energy into power systems

• Harness international experience to harmonize national and international energy standards

• Utilize modern technologies for efficient solar and wind energy production

• Implement measures to reduce greenhouse gas emissions in the power sector

• Strengthen conditions for the modernization of energy systems with solar and wind energy

• Establish a guide for potential investors on renewable energy systems

• Train the national workforce to integrate solar and wind energy into power systems

More detailed recommendations can be found in **Solar and Wind Energy for Transboundary Energy Cooperation in the countries beneficiaries.**

Appendices

A.1 The main goals and objectives of the CIS member states in the use of renewable energy sources, the innovative development of energy and the development of advanced energy technologies, the development of the production of high-tech energy equipment

On November 20, 2013, the Decision of the Council of CIS State Leaders approved the Concept of Cooperation of the CIS member States in the Use of Renewable Energy Sources (RES) and the Plan of Priority Actions for its Implementation[50]. The concept represents a set of agreed views and approaches of the CIS member states to cooperation in the field of renewable energy use and defines the goals, objectives, principles, mechanisms and main directions of such cooperation.

The goals of cooperation among the CIS member states in the use of renewable energy include, inter alia:

- Improving the level of energy security and reliability of energy supply;
- Involving in the fuel and energy balance of additional fuel and energy resources and its optimization;
- Reducing the costs of production, distribution and transportation of electric energy and fuel;
- Reducing of anthropogenic impact on the environment;
- Ensuring the effective use of the energy potential of the CIS member states and the sustainable development of the common energy potential of the Commonwealth;
- Development of innovative technologies and science in the field of renewable energy use.

The main tasks of the CIS member states in the field of renewable energy use include, but are not limited by:

- Formation and development of an effective technical and technological base for the use of renewable energy;
- Consideration of possible approaches to the harmonization of technological norms and rules of the CIS member states when using renewable energy sources;
- Development of a common information space in the field of renewable energy;
- Study and dissemination of international experience and the experience of the CIS member states in the field of renewable energy development;
- Ensuring accessibility and unification of statistics in the field of renewable energy use.

Thus, among the goals and main tasks of the cooperation of the CIS member states in the area of renewable energy include the development of a study, exchange of international experience, ensuring the availability and unification of statistical data in the field of renewable energy

On June 1, 2018, the Decision of the Council of the Heads of Government of the CIS approved the Concept of cooperation of the CIS member states in the field of innovative development of energy and the development of advanced energy technologies and the Plan of priority measures for its implementation, which formulate the main goals of cooperation, including:

[50] http://e-cis.info/page.php?id=23882

- Promoting the development of energy in the CIS member states based on new technologies with high export potential that are competitive both in the domestic and foreign markets;
- Reducing the energy intensity of the economy and the large-scale introduction of energy-efficient technologies, including the use of alternative and renewable energy sources;
- Reducing the anthropogenic impact on the environment and climate in the framework of production (production) and use of energy resources.
- The main objectives of cooperation in the field of innovative development of energy and the development of advanced energy technologies include:
- Development of a system of interstate interaction and coordination of innovation in the fuel and energy sector;
- Development of interstate cooperation in the field of innovative development of energy and the development of advanced energy technologies;
- Development of proposals for the introduction of economic incentives and mechanisms to increase the innovative activity of energy companies;
- Development of scientific and technological potential in the field of innovative development of energy sector and development of advanced energy technologies;
- Exchange of experience in the field of innovative development of energy sector and the development of advanced energy technologies, training and advanced training in this area.

On November 20, 2018, the Decision of the CIS State Leaders Council approved the Concept of cooperation of the CIS member states in the development of the production of high-tech energy equipment, which includes the following goals of cooperation:

- Reduction of dependence on the supply of tools and technologies from third countries that ensure the development of the energy industry;

- Deepening of cooperative ties between economic entities of the energy industry of the CIS member states;

- Developing of innovative technologies and science in the energy sector;

- Increasing the competitiveness of related industries.

- Exchange of experience in the field of power equipment;

- Creating a knowledge base in the field of development, production and operation of power equipment.

These goals can be achieved by solving the following tasks:

- Study and dissemination of the experience of relevant departments and organizations of the CIS member states in the energy sector;

- Promoting the development of favorable conditions for the implementation of projects for the use of energy equipment manufactured in the CIS member states;

- Formation and development of an effective technical and technological base;

- Rapprochement of technological norms and rules of the CIS member states;

- Development and strengthening of interaction between the relevant departments and organizations of the CIS member states;

- Development of scientific and technical base and conducting joint research and development, as well as the organization of joint production.

A.2 Electric Power Infrastructure Development – Case Studies

2.1 Italy[51]

Italy began the development of solar photovoltaic and wind projects in the early 2000s. VRE capacity increased from about 1 GW to almost 5 GW over five years (2004–2009). It was mainly installed in the southern regions, while the main load centers remain in the cities of the north of the country. This changed the energy flow patterns (Fig.1) and led to oversaturation and undersupply of electricity (Fig.2). In 2018, solar photovoltaic and wind installations in Italy exceeded 20 GW and 10 GW, respectively.

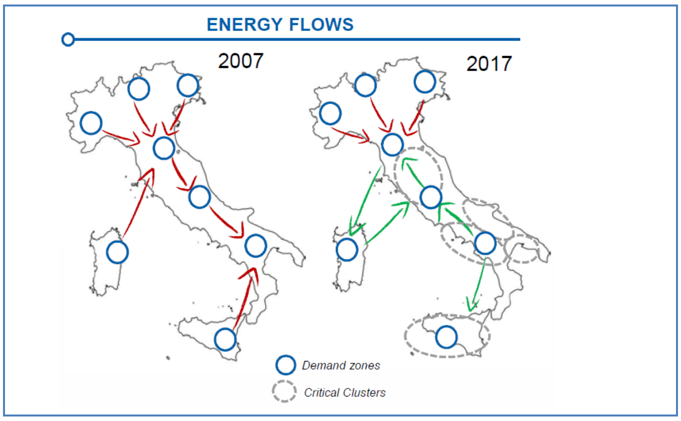


Fig. 1. Energy sweat patterns in Italy

Since then, a number of measures have been applied in the country, and an increase in dynamic line throughput (DLR) has made a significant contribution to reducing electricity shortages due to transmission restrictions. Increasing DLR is a relatively inexpensive measure with a short implementation period, which has played an important role in significantly reducing electricity shortfalls to 1-2% in Italy in a very short period. Since then, these levels have not changed much thanks to other measures, such as the development of transmission lines and the continuous development of intelligent networks in the Apulia region.

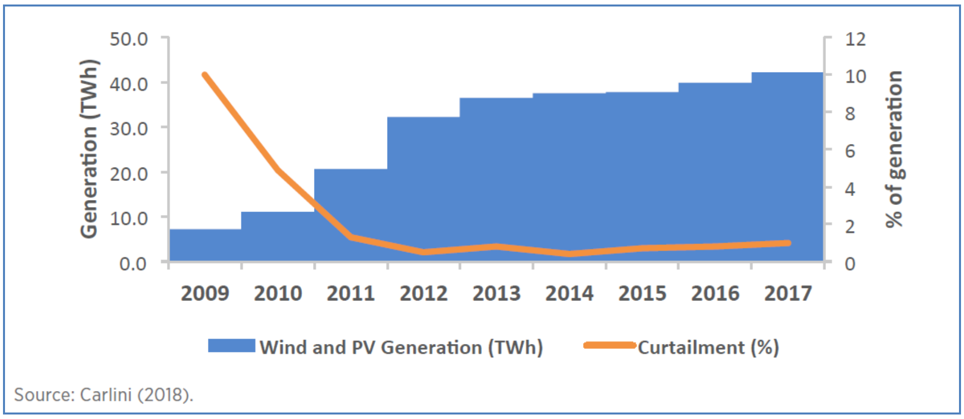


Fig.2. Reducing the level of electricity shortages in the Apulia region

In addition to supporting the growing amount of distributed PV generation, which requires active grid management, the smart grid project should also include in the short term the phasing out of large coal-fired power plants that remain in operation to control the voltage in the region's power system. In this context, synchronous compensators reduced the number of

[51]https://www.irena.org//media/Files/IRENA/Agency/Publication/2019/Jun/IRENA_G20_grid_integration_2019.pdf

stations considered necessary for the security of the power system in Sardinia, saving millions of euros.

2.2.Germany

German experience has shown that greater expansion of connections between energy systems in different areas reduces reserve requirements. Previously, reserves were purchased by four German TSOs separately, which ultimately led to the simultaneous activation of reserves in opposite directions (positive / negative). German cooperation within the network codex solved this problem, which led to the creation of a common control reserve market where bidders can offer their products in all TSO zones. Together with shorter market intervals (up to 15 minutes in the spot market), reserve requirements and price decreased between 2008 and 2014, and VRE capacity increased by almost 50 GW over the same period.

In addition, changes in the country's network code have allowed the integration of more renewable energy sources while maintaining the reliability of the energy system. Due to the large number of photovoltaic projects in a distributed network (70% of the total), the German Network Code has special provisions regarding reactive power requirements in low-voltage distribution networks, as well as frequency deviations that can cause an avalanche effect due to a simultaneous shutdown all photovoltaic systems (the notorious problem with a frequency of 50.2 Hz). In this regard, incentives were introduced for the modernization of old facilities.

The participation of renewable energy sources in the German energy system is expanding, and throughout the week recently 65% of the demand was satisfied by renewable energy sources, after a record year in 2018, during which 40% of the demand was satisfied by renewable energy sources. In addition, on March 3, 2019, renewable energy accounted for 90% of total energy consumption - especially windy Sunday (Agora Energiewende, 2019).

Such strong growth, however, put significant pressure on the system.

The German energy system was balanced by conventional power units in addition to exports to neighboring countries. However, re-dispatch cases occurred due to an imbalance of energy and voltage resulting from bottlenecks in the German power system. The number of these events increases year by year and, in fact, occurs at the moments of glut in the north-south direction, when power plants in the south and west should increase production to meet the needs of the region, which were previously planned to be met by wind from the north. Due to delays in expanding the network and temporary decommissioning of network assets, as well as increased exports to neighboring southern Austria and the early shutdown of a nuclear power plant, re-dispatch in 2015 was common (Tennet, 2016).

In 2015, re-dispatching costs reached 412 million euros, which is about three times higher than in 2010. Recently, re-dispatching costs have fallen from 391 million euros in 2017 to 351 million euros in 2018, and a further decrease is expected when new power lines appear in the system (BNetzA, 2019).

The federal law on the expansion of the network provides for the construction of 7,700 km of power lines in order to expand and strengthen the network.

To date, 1,800 km have been approved and 1,100 km have been implemented (BNetzA, 2019). An increase in the number of new lines from 150 to 1,100 km had a positive effect on the German energy system. For example, the cost of managing bottlenecks in the TSO zone of 50 Hertz decreased from 346 million euros in 2015 to 187 million euros in 2017. This progress is associated with the commissioning of power lines in the southwest in 2017 and an additional 5 GW of capacity in the south, which is also important for the further decommissioning of nuclear plants in the south. Although improvements have been made, the network still requires further improvement.

While overall strengthening networks is effective as a means of supporting the integration of renewable energy sources, a stronger integrated European market that increases cross-border trade can also increase re-dispatch costs in the case of Germany. This can happen after clearing

European markets one day ahead will consider Germany as a single node, not taking into account the internal limitations of the network. The German strategy also includes connecting sectors using electric vehicles, electrifying heating and using energy to produce hydrogen.

2.3 China

The rapid introduction of VRE over the past decade in China has been accompanied by significant electricity shortages. Nevertheless, a number of measures made it possible to take into account the growing share of solar and wind energy, as a result of which the reduction levels significantly decreased (Fig. 3).

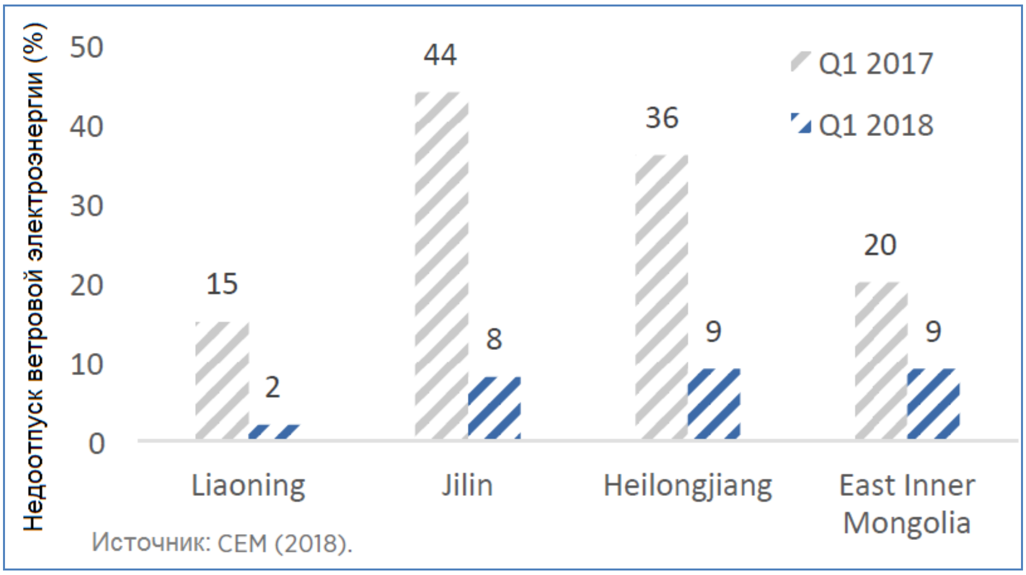


Fig. 3. Reducing the level of electricity shortages in the regions of China

As in many other countries, wind power projects are located away from load centers. In addition, in the same regions where wind power was developing, the rest of the power generation was provided by inflexible coal-fired power plants, which account for a significant share of thermal and electric energy (CHP). These units are crucial for the supply of heat in the winter and, therefore, operate at high operating levels during the season (minimum load is 70%).

The level of electricity shortfalls in wind farms decreased to 7% in 2018 from 13% the previous year, while at solar PV stations it decreased to 3% from 5.8% for the same period.

The rigidity of coal-fired power plants presents very limited opportunities for the development of VRE generation. Because of this, the Chinese government has upgraded old coal-fired power plants to reduce minimum load levels. This has proven to be the most feasible approach to add flexibility in the short term due to lower lead times and lower costs compared to investing in open-cycle gas turbines or pump storage, among other options. In addition, financial instruments have provided power plants with incentives for flexibility, such as the provision of ancillary services and pilot projects in the spot market. These new revenue streams also played an important role in offsetting revenue losses due to reduced working hours.

Strengthening the energy system and other actions to improve the use of network assets, such as creating reserve sharing mechanisms for regional electricity networks, real-time balancing, and electricity trading centers at the national and provincial levels, also supported the development of VRE in China.

In addition to priority attention to the scheduling of VRE projects, China in 2016 also launched a dynamic (annual) risk notification system to prevent further development of wind generation in places with network restrictions until the necessary measures are taken, redirecting investments to where the network is ready to place additional variable generation.

A.3 Key challenges and opportunities for decentralization

Decentralization relies on several technologies with different implications for the network:

— **Distributed generation** from renewable sources (primarily photovoltaic solar) reduces demand during the sunny hours of the day.

— **Distributed storage** stores electrical energy locally for use during peak periods or as backup power, balancing demand peaks and dips.

— **Energy efficiency** reduces energy consumption by providing the same services, which reduces overall demand.

— **Demand management** allows you to control energy use during periods of peak demand and high prices, reducing peak demand.

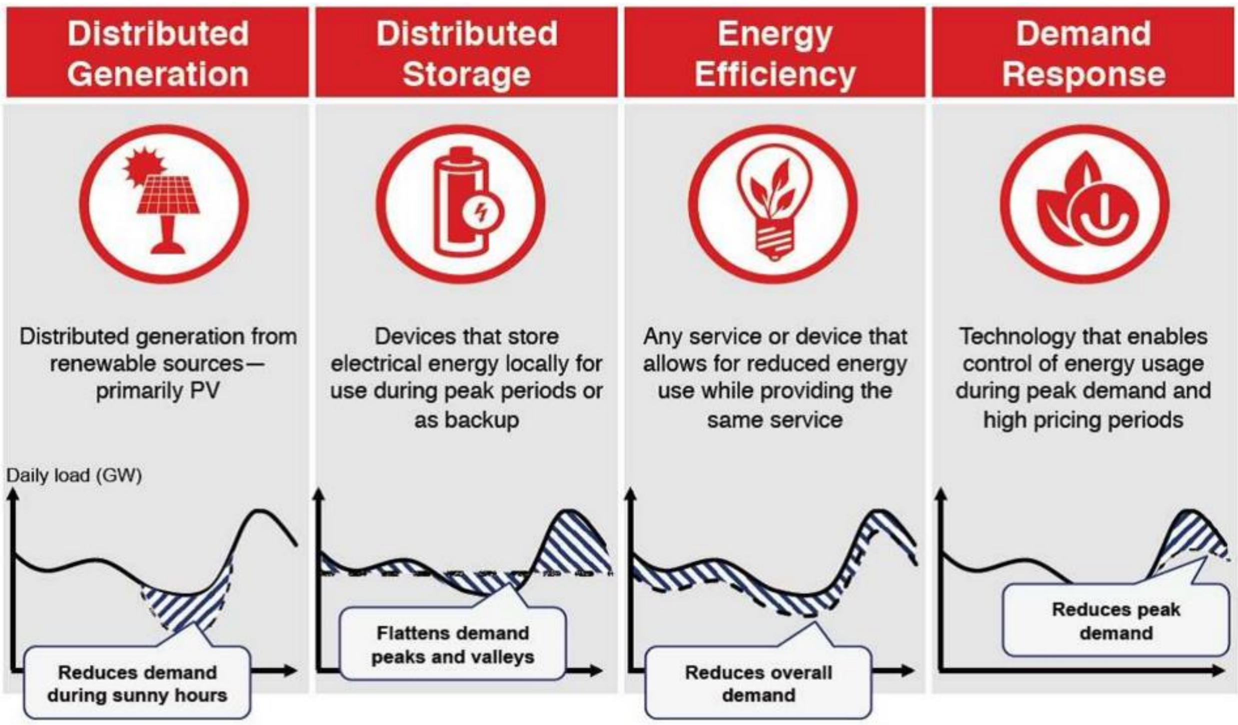


Fig. 4. Decentralization technology

3.1. Distributed generation

Incentive programs aimed at encouraging distributed generation in the form of solar PV roof technologies are extremely effective in many cases, and consumers have adopted them in many countries. In recent years, the deployment of solar PV panels has increased dramatically: the global installed capacity reached 260 GW (peak in gigawatts) in 2015 and is expected to exceed 700 GW by 2020. This increase has led to a reduction in the established price for household solar PV systems from about $ 7 per watt in 2009 to $ 3 per watt in 2015 in the United States (and less than $ 3 in some parts of Europe, for example, Germany). New technologies, such as rooftop solar shingles and the integrated photovoltaic system, are now available, expanding the future potential of distributed generation.

Challenges

The traditional regulatory framework for the power supply system was designed for a limited number of large-scale centralized generating assets connected to a network through which electricity was transmitted to consumers, and shared a one-way flow of energy with different costs for different types of consumers.

With distributed generation, distribution networks become active and electricity flows in both directions, with a large number of active consumers involved in managing and changing the load profile, reducing demand from centralized generation. Requirements that allow real-time control of electricity flow, including revised roles of network operators and appropriate network technologies, have not yet been fully developed in most countries, along with reliable schemes for evaluating distributed generation services.

Opportunities

The traditional regulatory framework for the power supply system was designed for a limited number of large-scale centralized generating assets connected to a network through which electricity was transmitted to consumers, and shared a one-way flow of energy with different costs for different types of consumers.

With distributed generation, distribution networks become active and electricity flows in both directions, with a large number of active consumers.

Distributed generation can benefit consumers and the system in several ways. For consumers, solar energy can be an attractive and economical option, especially in sunny areas where PV plants generate more electricity. For the system as a whole and for public utilities, distributed generation can supply electricity directly to a certain percentage of consumers and, depending on the state of the network infrastructure, allows you to save capital investments on maintenance and upgrading of networks and related services during periods when they become less economical.

In some cases, distributed generation may be the most affordable and appropriate way to meet load growth, especially when it is too expensive or time consuming or difficult to add new infrastructure. For example, in Southern California, the closure of the San Onofra nuclear power plant and the lack of centralized capacity led to an increase in demand for electricity in the tense area of the power system in western Los Angeles. As a result, hundreds of megawatts were purchased from distributed resources, which corresponds to almost 10% of the covered load. In Hawaii, high land prices and very mountainous terrain combined with sunny climates make distributed generation a pragmatic solution. These technologies can also play a role in rural micro networks, which will be especially important in areas where there is no access to electricity.

3.2. Distributed storage

As new capacities of renewable energy sources appear, the need for accumulation will become more acute. Without accumulation, when too much electricity is supplied to the grid on sunny and windy days or days with reduced demand, supply exceeds demand and negative pricing occurs. Thus, accumulation offers a way to smooth out supply peaks and dips and prevent economic losses.

Today, energy-scale storage (in front of the meter) accounts for most of the installed battery capacity, providing numerous system functions, and is also an effective way to supplement peak power plants. Accumulation behind the meter allows consumers to store electricity generated by solar panels on the roof and use it later when necessary, for example, after sunset.

Forecasts suggest that the demand for energy storage, with the exception of hydroaccumulation, will increase from 400 MWh in the world in 2015 to almost 50 GWh in 2025. Lithium-ion batteries will make up a large part of the market, and they are likely to become more economical, as they are being developed and distributed in large quantities for use in electric vehicles, a market in which demand for these batteries can reach 293 GWh by 2025. Accumulation becomes cheaper as a result of technological advances and the growth of single capacities, which allows to increase the scale of implementation. According to current forecasts, by 2023 mains batteries could be a viable alternative to peak power plants. As the cost of batteries decreases, the cost of storage can reach network parity at the end of the 2020s, a tipping point after which system operators can replace the maneuverability of peak stations by using stored electricity from renewable energy sources.

Challenges

Structural barriers include the lack of price signals to encourage distributed accumulation, the lack of a clear definition of battery as an asset, and poor integration with current planning processes. Efficient storage depends on the accumulation and delivery of electricity at the optimal time, and this, in turn, depends on clear and automatic price signals sent to intelligent storage systems. Currently, in most electrical systems, such price signals are not available in real time at the consumer level.

At the network level, ownership structure and potential income have not been consistently and clearly developed, and this uncertainty delays potential investment in network assets. Accumulation can also provide a solution to some local congestion problems at the distribution level and, therefore, delay or avoid potential investments in upgrading the network infrastructure. However, accumulation is usually not included in the planning processes of the system and, therefore, its influence cannot be fully realized.

Opportunities

However, accumulation achieves its greatest effect at the system level when it is connected to the network, and the full range of services can be implemented at various levels, such as network management services (frequency regulation, voltage support), network services (adequacy of resources, reduction of glut) and customer service (backup power, reduced consumption charges).

3.3. Energy efficiency

In the IEA, investments in efficiency since 1990 have helped to avoid the consumption of electricity equivalent to approximately 5 million homes a year.

Lighting consumption has fallen by more than 75%, as compact fluorescent lamps and LEDs replace incandescent lamps. In the United States, Energy Star EPA-certified products confirm 46% of new refrigerators, 84% of new dishwashers, 93% of new LCD monitors, 53% of new computers and 67% of new compact fluorescent lamps.

Challenges

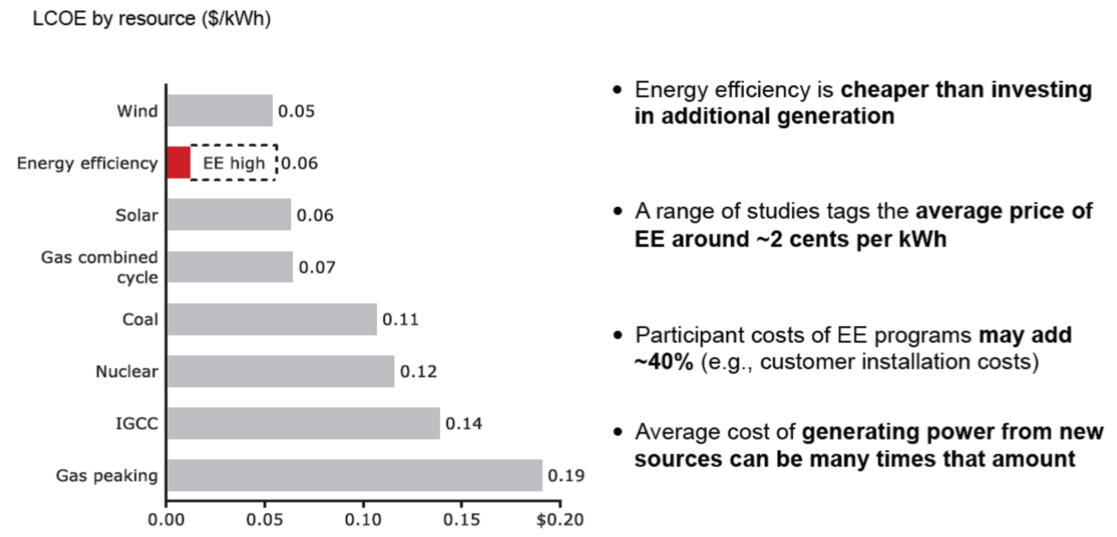
Despite this obvious success, the introduction of energy-efficient products is still associated with long cycles of replacing instruments and equipment (nine or more years) and is largely based on technological innovations and incentives.

Standards and mandates have proven effective in accelerating replacement cycles, but not all energy efficiency programs have been equally successful. Some were adopted in a limited manner and did not have the proper impact, especially processing and marketing programs, which are based on consumer approval.

For example, the Green Deal program in the UK, which provided loans to finance energy efficiency measures, received less than 1% of loan repayments in the first 16 months, and funding was later stopped. Refining and marketing programs were more effective, such as Energy Star and programs that promote LED lighting.

Opportunities

Despite limitations, energy efficiency products and programs are noteworthy because they are often the cheapest way to meet resource requirements. Reducing demand in kilowatt hours is usually cheaper than satisfying demand with any other available resource. With an average price of about 2-3 cents per kWh, including all components of the price, energy efficiency is a cost-effective resource and much cheaper than investing in additional generation (see Fig. 5).



Source: Lazard "Levelized Cost of Energy Analysis 9.0", ACEEE "Best Value for America's Energy Dollar", LBL "The Total Cost of Saving Electricity", Greentech Media

Fig. 5. Total reduced costs (LCOE) by resources

According to IEA estimates, every dollar spent on energy efficiency avoids more than $ 2 on investments in generation.

3.4. Demand management

Energy policies around the world increasingly recognize the importance of demand management and begin to tackle challenges that impede its full development. As more distributed energy resources (MEDs) appear in the network, demand response programs can become even more flexible and, according to some estimates, can reduce the necessary annual investments in US network infrastructure by 10%. Many programs target commercial and industrial consumers, as the residential sector can be more complex due to a number of factors, including the high acquisition costs for individuals and the limited range of flexibility available to them. However, new smart devices, such as pre-cooled air conditioners, smart refrigerators and dim lighting that can respond to automatic price signals, as well as advances in digitalization that expand the technical capabilities of aggregation, help simplify demand response programs even for residential customers.

Public and private efforts demonstrating these new technologies are successful. In Gotland, Sweden, several hundred electricity consumers participated in a program that combined price signals (such as lower prices at off-peak times) with a smartphone app that allowed them to choose between four preset levels.

At the beginning of the program, 23% of total electricity consumption was spent on the five most expensive hours. In the first and second year of the program, it fell to 19% and 20%. In addition, companies began offering more advanced demand management programs. Opower alerts customers of peak times with text messages or email messages. Enernoc offers a turnkey demand response program to system and network operators, as well as commercial and industrial companies.

Challenges

Three main problems hinder demand management: lack of market integration, including market access, definition of standardized processes for measurement, verification and calculation, unclear role or unresolved independent aggregation, lack of price signals and inconvenience.

Opportunities

Demand flexibility creates benefits for consumers and the power system by reducing customer accounts (up to 40%), reducing peak demand and shifting consumption to a lower price zone during off-peak hours. Demand flexibility can also help suppliers, in some cases, avoid or delay investments in centralized generation, transmission and distribution, as well as in power plants.

3.5. Digitalization

Digital technologies allowing devices across the network to interact and provide data that is useful to customers, as well as to manage and operate the network. Smart meters, new smart sensors / IoT sensors, network remote control and automation systems, as well as digital platforms focused on optimization and aggregation, allow real-time management of the network and its associated resources and collect network data to improve situational awareness and network services.

Data from smart devices and distributed resources in general will be critical to new business models and to facilitate customer acquisition and implementation of the latest technologies. Correctly provided and detailed data can improve the quality of customer service in several aspects, such as improving customer service by providing better access to more information and providing automated operations that will help customers flexibly manage their electricity needs and optimize costs.

Challenges

Deployment of digital technologies in the network may be hindered by outdated regulation when the settlement model is oriented towards investments in the network infrastructure due to potentially cost-effective alternatives in the field of digitalization and operation of distributed resources. As digitalization continues and more digital devices are deployed, communication between them will be vital. Broadband infrastructure supporting a wide range of services - both network and subscriber - is the foundation for digitalization. Lack of technological standards may hamper the development of this communications infrastructure and may slow innovation.

The lack of a clear legal structure for customer data and distributed resources limits growth in this area. The lack of a dynamic pricing model that would help economically justify the adoption of smart devices is another hurdle. High purchase margins and long replacement cycles of these devices delay their mass deployment.

Opportunities

The growing deployment of modern measurement infrastructure provides clear opportunities for improving the quality of service, monitoring the low-voltage network and collecting data (this data provides opportunities for automatic detection of interruptions in operation, location for distributed generation facilities and energy efficiency, more detailed forecasting of demand). Some power systems are taking serious steps in this direction, introducing millions of smart meters in the United States, Europe and Asia.

Digital network transformation is a clear opportunity for the cost-effective development and management of the power supply system with proven returns in improving the quality of service (duration and frequency of outages, service time) and the cost of maintenance. There are many technical advantages to smart grids and smart meters.

On the part of the consumer, as the cost of sensors decreases, the possibilities of using more intelligent technologies expand. Intelligent devices are the most important factor in supporting the latest technologies, and the data from them will help inform about new innovative products and services, which, in turn, will help accelerate further implementation.

3.6. Geographic Information Technologies [52]

GIS can efficiently manage power distribution information for consumers and information describing each customer’s attributes, such as location and use of electricity. Electricity companies already find GIS very useful in distribution management. The power industry realized that GIS is a valuable tool not only for mapping objects, but also for improving the decision-making process and better managing the infrastructure. Although the needs and uses of GIS in the energy sector are somewhat different from other industries, GIS can be equally valuable information technology in the power industry. In automated mapping (AM), this tool helps network services quickly create digital maps of their supply area using software digitization tools. These maps in digital form contain detailed information about the land serviced by the utility, as well as the exact location and technical information about the utility distribution network equipment that is installed on site. In object management, the files of digitized maps, which are so created with all the necessary intellectual capabilities built into them, can now be used to meet the needs of object management. So, GIS in the field of electric power is used to study and analyze electric distribution systems, analysis and design, applications are also being developed to solve the problem of designing a power supply system for a new residential complex, for process automation in order to provide its customers with high quality service, rebuild the draft work procedures in the power grid. GIS and GPS are also integrated for mapping and analysis of electrical distribution networks[53].

The need to balance the development of new markets, improve system reliability and reduce operating costs is the biggest challenge for today's decision-makers in the field of energy systems. This problem is successfully solved with the help of GIS. GIS provides solutions for the entire rhenium adoption cycle: for applications in business, design, environmental management and other disciplines necessary for comprehensive and effective management of electricity generation and transmission.

Challenges

To expand the capabilities of GIS, it is necessary to follow the new requirements from companies working in the electric power industry and focused on more accurate modeling of the underlying assets that are tracked in the GIS. Accuracy in this context is defined as modeling assets more closely to how they exist locally, rather than generalizing them or abstracting them

[52] https://www.esri.com/library/brochures/pdfs/gis-sols-for-power-generation.pdf
[53] https://www.ripublication.com/irph/ijert_spl/ijertv6n6spl_06.pdf

into a GIS. For consumers of electricity, most of the operational attention has shifted to modern distribution management systems, as well as distributed resource management systems. Although both of these systems provide advanced decision-making and analysis capabilities in the power grid, at a basic level they depend on an accurate and detailed geospatial network and asset information.

In addition, in the electric power industry, there is a general desire to provide true asset management at a more detailed level by tracking the smaller internal components of locations and devices that in the past could be modeled as a single composite location. An electrical example is a group of transformers. In the past, we could simulate three separate air transformers in one place with one point on the map. Now we see that some consumers of this data require modeling of three separate transformer assets and, in even more detailed cases, the corresponding fuses and lightning arrestors that exist as part of the transformer. This single transformation point should now be expanded to three or even nine map objects[54].

Opportunities

GIS is used to plan and monitor power generation resources. Sophisticated spatial analysis is useful for determining the optimal generation potential, developing "what if" scenarios, studying environmental impacts and managing asset assets. GIS is used for spatial analysis of network congestion, to consider growth opportunities for the use of renewable energy sources, to determine the feasibility of a site and to create scenarios of the energy market.

Energy companies can intelligently plan, build, monitor and manage their transmission networks using GIS technology.

A GIS geodatabase is a key component for maintaining and managing accurate data on transmission assets such as substations, lines, and related structures. GIS is used to assess the reliability levels of the power system and make plans to improve reliability, comply with compliance requirements, determine the location and control of transmission corridors, take inventory and plan maintenance on the go, as well as analyze load growth or changes in load shape or load on substation capacities.

3.7. Coal technology

World coal consumption in 2018 rose for the second year in a row, although it remained at about 160 million tons of coal equivalent (Mtce) below its peak in 2014. There was again a shift in consumption to Asia, as coal use in China increased in India, Indonesia and several other countries in South and Southeast Asia. Demand for electricity in Asia continues to grow, and coal remains at some distance the largest source of electricity in Asia and one of the cheapest.

At the same time, in many advanced economies, coal is steadily being squeezed out of the energy balance due to a combination of environmental policies and competitive pressures from increasingly competitive renewable energy sources, and in some markets also from natural gas.

The United Kingdom, whose industrial revolution was built on coal, now lasts a long time without the use of coal. Germany, the stronghold of coal demand in Europe, plans to abandon coal by 2038, and recent data show that coal-based electricity production drops sharply in 2019 [55].

In order to be a relevant player in the future structure of energy consumption, coal energy efficiency and costs must improve, and research and development in technology promise to do just that.

Although most experts agree that coal will remain the main source of fuel to provide the base load in the near future in several regions, the struggle of coal energy to maintain economic

[54] https://www.tdworld.com/smart-utility/article/20973162/the-future-of-gis-part-4-to-the-geospatial-future-and-beyond

[55] World Energy Outlook 2019 www.iea.org/weo

importance in the face of serious market failures and environmental problems is widely discussed. The industry's response to numerous issues affecting the sector has been multifaceted. Generic approaches require regulatory reform action or seek to recognize the contribution of the existing coal fleet to energy security and safety.

Recently, many stakeholders have also been reinforcing calls for increased investment in coal generation technologies through research and development (R&D), demonstration and deployment.

The technologies noted are "preparing for large-scale pilot tests, and some are preparing for a commercial demonstration," the joint initiative notes.

About 250 GW of super-supercritical power is currently connected to the network - 90% (224 GW) falls on Asia (where another 88.2 GW is being built, mainly in China and Japan), and most of the remaining 10% falls on Europe (19.2 GW), and efficiency gains continue. For example, the Waigaoqiao No. 3[56] ultra supercritical steam thermal power plant in Shanghai, China, has increased its initial efficiency from 43% to over 47%, which is a huge achievement. Meanwhile, nickel superalloys are currently being tested, which can help achieve a set steam value of 700 ° C in advanced systems with ultra-supercritical parameters (AUSC) (Fig. 1) - and increase efficiency up to 50% in the USA.

3.8. Hydrogen power

Hydrogen can be used in the "large" electric power industry (while it will replace natural gas and oil products), in transport (substitution of oil products); in the building sector (for heating and power supply, including autonomous, with the replacement of natural gas or oil products); in industry - as a raw material and a substitute for traditional hydrocarbons.

Hydrogen is also distinguished by the relative convenience of long-term large-scale storage and transportation at any distance, including using existing infrastructure related to natural gas (including liquefied gas). Thus, the transportation of hydrogen becomes an alternative to the development of backbone electric networks - and this opens up new opportunities for a fairly large number of regions of the world that are rich in renewable energy, but remote from energy consumption centers.

In one of the scenarios for the integration of hydrogen technologies in the US energy complex, considered by laboratories of the Ministry of Energy of this country (DOE), by the middle of the century, hydrogen will assume the role of the second universal energy carrier after electricity.

More than 90% of the energy for hydrogen production will be provided by electricity, while the consumption of primary energy sources - coal, gas and oil - will fall, respectively, by 73%, 34% and 18%, and the share of renewable energy will increase four to five times.

In the European Union, Germany and the United Kingdom are the most active. But in 2017, the Pan-European initiative Fuel Cells and Hydrogen Joint Undertaking (FCH JU) [57] was launched, which as of May 2018 has already united 89 regions and cities from 22 European countries. The participants in this European initiative declare their desire to use hydrogen technologies in their energy strategies as part of the "energy transition", including the implementation of projects with a total value of about 1.8 billion euros over the next five years.

The Japanese program (roadmap) Strategic Roadmap for Hydrogen and Fuel Cells[58] was launched in the summer of 2014. The goal of the program is to build a "hydrogen-based community". The roadmap contains specific key indicators - in the production, storage, transport and use of hydrogen - with milestones in 2020, 2025, 2030 and 2050. So, the goal in terms of hydrogen use in Japan is from the current 200 tons per year to 10 million tons in 2050 (an

[56] https://www.power-technology.com/projects/waigaoqiao-power-station-shanghai/
[57] https://hydrogeneurope.eu/fuel-cell-and-hydrogen-joint-undertaking-fch-ju
[58] https://www.meti.go.jp/english/press/2019/0312_002.html

increase of 50 thousand times!). The volume of state funding for the program in 2017 amounted to about 310 million euros. Japan's leadership is internationally recognized.

The United States hydrogen program has been operating under various names since the 1970s. The annual funding of the US DOE Hydrogen and Fuel Cells Program[59] reaches $ 120 million (approximately twice as much between 2004-2011).

During 2018–19, California, Australia, and South Korea announced their hydrogen strategies.

At the corporate level, the best-known association in the field of hydrogen technology is the Hydrogen Council. The organization, founded in Davos in 2017, by the end of 2018 brought its membership to 53 corporations from 11 countries with a total number of employees of 3.8 million and an annual income of 1.8 trillion euros. The organization’s long-term vision is to create a $ 2.5 trillion hydrogen and hydrogen technology market by 2050, create 30 million jobs and increase the role of hydrogen as an energy carrier in final world energy consumption from 0% to 18%.

Nowadays, hydrogen is mainly produced through steam methane reforming (SMR, steam methane reforming) - from natural gas or after coal gasification. This industrially developed, cheap process will not have competitors for a long time at the cost of produced hydrogen ($ 1-2 / kg depending on the price of gas and coal).

But in the era of the “energy transition”, their carbon footprint becomes an equally important characteristic of processes. Steam methane conversion leads to carbon dioxide emissions of 10 kg CO2 / kg H2. Therefore, such hydrogen is called "gray" - depending on the raw material (gas or coal), it is either comparable to ordinary natural gas, or 2.5 times worse than this in this indicator.

One of the alternatives is the production of "gray" hydrogen only in combination with carbon capture and storage technologies (CCS). Hydrogen obtained in this way is called “blue”. Unlike SMR, CCS technology is far from full-blown commercialization. According to the Global CCS Institute, in 2018 there were only 18 large projects with CO_2 capture technology in the world, another five were under construction and 20 were in various stages of development. Three projects are known in the world in which steam methane conversion is integrated, as well as partial capture, transport and storage of CO2 - these are Port Arthur[60] in the USA, Quest[61] in Canada and Tomakomai[62] in Japan. According to IEAGHG, the addition of CCS increases the capital costs of SMR technology by up to 87%, and operating costs by up to 33%. The present value of the hydrogen produced in this case is growing almost one and a half times - up to 1.8 euros per kg, and the cost of utilization of CO2 - up to 70 euros per ton of CO_2.

In April 2019, the Hydrogen Energy Supply Chain demonstration project[63], developed under the control of the Japanese Kawasaki, for the production of “blue” hydrogen from the brown coal of the Latrobe Valley Basin in Australia, followed by the export of hydrogen to Japan, received a positive environmental impact assessment. For Australia, this is a step towards the possibility of using huge reserves of brown coal in a low-carbon economy. This example shows that “blue” hydrogen has good prospects in countries exporting fossil fuels, where its price is low - although the commercialization of CCS technology will require considerable effort.

The second alternative to “gray hydrogen” is “green” hydrogen, obtained by electrolysis using energy with a minimum carbon footprint - primarily from renewable energy sources. Not every hydrogen produced by electrolysis can be called “green” - it all depends on the carbon

[59] https://www.hydrogen.energy.gov
[60] https://www.globalsyngas.org/resources/world-gasification-database/ap-port-arthur-hydrogen-plant-i
[61] https://www.nrcan.gc.ca/science-and-data/funding-partnerships/funding-opportunities/current-investments/shell-canada-energy-quest-project/18168
[62] https://www.cslforum.org/cslf/Projects/Tomakomai
[63] https://www.industry.gov.au/funding-and-incentives/hydrogen-energy-supply-chain-pilot-project

footprint of the electricity used for this. Only "green" hydrogen obtained by using renewable energy sources can be used in other sectors besides the electric power industry - therefore, it is a cornerstone for the hydrogen economy as a whole; studies in most hydrogen programs are concentrated around it.

At the same time, energy companies with a significant nuclear generation portfolio also claim their place in the global hydrogen market. In April 2019, the French EDF, which owns 58 nuclear power units, announced the launch of a subsidiary of Hynamics[64], which will focus on the supply and maintenance of electrolyzers, as well as refueling hydrogen vehicles.

According to the IEA, over the past seven years, an average of about 10 MW of electrolytic cells were commissioned annually in the world. In 2018, 20 MW were commissioned, and by the end of 2020, another 100 MW is expected to be commissioned. Investments in electrolytic cells are growing - the aggregate capacity of plants can almost triple in the next 2-3 years, reaching 150 MW. For full commercialization, you need to cross the border of 90 MW / year.

Steam methane conversion and electrolysis are the basic technologies around which, according to most researchers, the hydrogen production sector will develop. Among other methods, plasma reforming can be distinguished; ion membrane reforming; methane conversion with sorbent amplification; microchannel reactors; decomposition (pyrolysis) of methane with the release of carbon in solid form; high temperature gas cooled nuclear reactors, etc.

[64] https://www.edf.fr/en/the-edf-group/dedicated-sections/journalists/all-press-releases/edf-launches-hynamics-a-subsidiary-to-produce-and-market-low-carbon-hydrogen

A.4 Extracts from the reports of the 47th CIGRE session

4.1 Report A1-101 (USA): Joint Operation of Gas Turbines with Battery Energy Storage: Functional and Economic Indicators

This report addresses one of the most important issues facing electricity generating companies, which are forced to work in conditions of a very high and growing share of renewable energy entering the market. The availability of relatively cheap renewable energy sources led to the closure of large fossil fuel-generating facilities. Nevertheless, there is still a requirement to ensure the operation of traditional energy sources, for example, gas turbine generators, in order to generate energy in case of insufficient power generation by renewable energy sources and / or to stabilize the electric power system. This report demonstrates the complexity of the problem with the California electricity market. One of the possible solutions proposed in this document is the use of a gas turbine unit combined with an energy storage device based on a battery. The report provides a detailed description of the first installed system of this kind and a discussion of the economic and functional indicators of the system.

4.2 C4-119: Risk Assessment and Regulatory Reserves for Energy Systems with a High Utilization of Wind Power Installations

This article proposes a risk assessment method for quantifying the safety of energy systems with a significant share of the use of wind power plants (wind turbines). The proposed risk assessment method provides for the assessment of steady-state voltage and overloads, as well as frequency response control. In the framework of the presented study, the proposed approach was used to assess operational risks for an energy system with nine tires, with characteristics corresponding to the characteristics of the system in Tasmania, Australia. The results show that wind turbine integration has a significant impact on the operational risks of the system, in particular on frequency control. The influence of various factors on the security of the system was examined, including inaccuracies in the forecasting of the load and wind turbines, the replacement levels of wind power plants, as well as the operational reserve. It is also shown that the proposed approach can help system operators plan modes, including installing a wind turbine shutdown and determining operational reserves.

4.3 C4-101: Difficulties arising in the design of filters, taking into account low harmonics voltages generated by wind farms (wind farms)

This article describes the difficulties encountered in identifying harmonic and reactive power compensation devices used to reduce the voltage distortions generated by wind farms in Brazil. A method and process for estimating harmonics parameters for a wind farm in Brazil is presented. The article discusses the importance of improving the efficiency of analysis procedures used to assess voltage fluctuations that occur during the operation of wind farms, as well as the need to use operating experience and results and research. Such an increase in efficiency is necessary due to the following aspects: (1) the development and importance of wind farms in the Brazilian energy system, (2) the cost of the filters used, and (3) the complexity of the projects and the difficulties of operation. Finally, the article concludes that it is necessary to reconsider the research method required for Brazil, since its inconsistency was demonstrated to provide a realistic forecast of voltage distortions caused by wind farms.

4.4 Report C5-107: Electricity Market in India - Data Analysis for a Decade of Experience

The report describes the structure of the electricity market in India. Key features noted include the use of decentralized planning and scheduling based on contract schedules as the basis for operation with free participation in the spot market. In addition to considering the market as a whole, the report noted a number of initiatives regarding the use of renewable energy resources, including a certificate scheme confirming the generation of electricity using renewable energy sources, which creates an obligation to acquire certificates. A national platform for trade in electricity from renewable energy sources was identified. In 2012, an energy efficiency regime was established and a mechanism for selling certificates was determined.

An important developmental aspect in response to an increase in the share of renewable energy systems refers to the 5-minute market for a number of support services to manage the high rate of change in load and to reduce the proportion of the reserve that should be planned.

4.5 Report C5-202: Aspects of the integration of renewable energy sources in the Greek electric market.

This report proposes a study of the electricity production and transmission system in Greece, as well as an electricity transmission system with a focus on the integration of renewable energy sources. The report considers the impact of rising demand for electricity on electricity production, taking into account the capacities of solar power plants / solar cells and wind power plants, imports, the age structure of power plants and CO2 emissions. The report uses a feasibility study of continental Europe's electricity sector called ATLANTIS to analyze the Greek system. The national development strategy of Greece until 2027 was chosen for the simulation. The results demonstrate an increase in electricity imports from neighboring countries, a high increase in renewable energy production, and a reduction in CO2 emissions in the Greek energy system. The report notes that the shorter technical life of renewable energy systems should be considered for future development strategies, and it is concluded that future expansion of renewable energy technologies after 2017 will ensure further expansion of the network.

4.6 Report C5-206: Tasks and measures for the integration of renewable energy sources and storage systems in the energy system and the electricity market in Brazil.

This report presents the challenges that arise for the Brazilian electrical system, given the significant increase in the proportion of intermittent sources and alternatives for introducing storage resources. The characteristics of the variability and inconstancy of wind generating systems provide intermediate and strategic consequences: increasing the conformity of long-term and short-term planning resources, providing appropriate transmission systems to include such sources, managing the increasing system reserve and requirements for auxiliary services. It also describes the challenges facing the Brazilian system to ensure that resource estimates are consistent with the planning of systems and operations, and in relation to market parameters. This report discusses a number of advantages that storage systems can provide to increase the efficiency of wind generation parameters, for example, and proposes a number of methods to increase the efficiency of the energy network.

A.5 Education as a tool to overcome barriers to the widespread integration of renewable energy sources in energy systems

While education and training are some of the key barriers, overcoming this barrier will be the solution to all other barriers[65].

The lack of knowledge and appropriate skills to identify and address clean energy development needs is characteristic of politicians, regulators, financiers and the private sector in developing countries and countries with economies in transition. These barriers hinder the wider adoption of clean energy policies and projects by policy makers and stakeholders. Often, even successful projects in the field of energy efficiency and renewable energy sources cannot be reproduced due to the lack of market support conditions, such as the limited knowledge of financial institutions about financing such projects. The limited capacity of local suppliers and installers of technology is another obstacle to the development and expansion of clean energy projects[66].

To ensure long-term sustainability, it is vital to build competencies in the following issues related to sustainable energy development [67]:

- **Energy and the environment**: the relationship between all stages of the energy cycles (from development to decommissioning) and the environment should be clearly explained to relevant stakeholders (planners, developers and classified users)

- Energy efficiency and renewable energy: it is necessary to develop and promote technologies, strategies and methods for ensuring energy efficiency throughout energy cycles, starting from resource exploitation, resource delivery and conversion, generation, transmission, distribution, use and decommissioning of energy systems. The role of renewable energy technologies in sustainable energy development must be clearly understood. The development of renewable energy technologies should encompass energy efficiency and energy conservation.

- **Socio-economic and financial aspects:** Developing skills to link energy consumption and socio-economic aspects is vital. Issues related to the financing mechanisms for sustainable energy projects should be part of the issues addressed in capacity-building.

- **Policy and governance issues:** The success of implementing sustainable energy education programs depends on a clear policy. Therefore, issues related to capacity building in the field of energy policy and management should be an ongoing process in any country.

- **Research and Development (R&D):** R&D on all of the above issues should be a concerted effort by all key stakeholders, including the industrial sector, government and academia.

Market development requires local capacity to support suppliers and consumers.

Local Technology Centers

Local research and training centers are the most effective platform for creating such a pool of experts. Not only can RE training centers offer CBs to individuals, they can also promote the implementation of RE technologies by conducting technological research, analyzing local framework conditions, supporting reform processes, facilitating dialogue between local and international stakeholders, and participating in policy development processes[68].

Many countries have set up their own training centers and continuing education programs. For example, according to UNDP-GEF, seven universities and educational institutions in Brazil, Canada, China, Cuba, Denmark, Egypt, and Russia have created a decentralized

[65] https://www.researchgate.net/publication/332321054_Capacity_Building_for_Sustainable_Energy_Development_The_Role_of_the_Academia
[66] https://www.iiec.org/key-activities/training-capacity-building
[67] https://www.sciencedirect.com/science/article/pii/S1876610216306002
[68] https://openei.org/w/images/8/80/Best_Practices_in_Capacity_Building_Approaches.pdf

network to provide postgraduate and postgraduate programs. Another example is the Mediterranean Renewable Energy Center (MEDREC[69]), created by the governments of Italy and Tunisia. Its goal is to offer training, the dissemination of knowledge and information, networking and the development of renewable energy projects in the region (partners: Algeria, Egypt, Libya, Morocco and Tunisia).

There are several interesting initiatives aimed at youth. For example, the E.ON Energy Experience[70] is an initiative to help teachers in England, Scotland and Wales educate young people (target group - children aged 5 to 16 years) about energy, different sources of use, different production of new energies, options, and relevance of applying these various energy sources locally, nationally, and globally. They provide educational support materials to help teachers integrate energy issues into geography and science curricula, such as energy information cards and assignment cards, to teach children energy issues and test their knowledge, all of which can be downloaded for free from their web page.

There are initiatives / programs that should be considered in the joint competence building and know-how transfer process for the wind and solar energy sectors:

- World Bank - Energy Sector Management Assistance Program (ESMAP[71])
- UNDP - Technology Needs Assessment (TNAs[72])
- Africa-EU Energy Partnership (AEEP[73])
- OPURE & RenKnow.Net[74]
- UNIDO - REMAP [75]
- Asia Pacific Global Change Research Network [76]
- BMZ - Federal Ministry for Economic Cooperation and Development of Germany [77]
- InfoDev, DFID - Climatic technology program [78]
- Carbon funds
- EU - Solar installations for the European research area (SFERA[79])
- Spain - Renewable Energy Education Foundation (FFER)
- UNEP - Capacity Building
- UNESCO - Global Renewable Energy Education and Training Program (GREET). The regional offices of UNESCO participate in the implementation of the Program. This is also facilitated by: "The program of UNESCO Chairs" with the participation of twelve established departments on renewable energy sources;
- “International Center for Sustainable Energy Development” - ISEDC - was established in Moscow as a category 2 center under the auspices of UNESCO[80].

Networks

Most of the training strategies / initiatives reviewed include the creation and use of new or existing networks as an important element in the success of their activities. Networking not

[69] http://www.medrec.org/En/home_46_2
[70] https://www.edcomsteachers.com/resource-library/the-energy-experience-energy-town/
[71] https://www.esmap.org
[72] https://www.undp.org/content/dam/undp/library/Environment%20and%20Energy/Climate%20Strategies/Technology_Needs_Assessment_Handbook.pdf
[73] https://www.africa-eu-partnership.org/en/projects/africa-eu-energy-partnership-aeep
[74] http://renknow.net
[75] https://www.unido.org/sites/default/files/files/2018-12/SustainableEnergySolutionsCIS_RUS.pdf
[76] http://www.apn-gcr.org/images/publications/informationMaterials/brochures/APN_2007_Brochure_%20Russian.pdf
[77] https://www.bmz.de/de/service/kontakt/bonn/index.html
[78] https://www.proz.com/kudoz/english-to-russian/international-org-dev-coop/793205-department-for-international-development-dfid.html
[79] http://sfera.sollab.eu
[80] http://www.unesco.org/new/en/natural-sciences/science-technology/engineering/renewable-and-alternative-energies/

only contributes to the dissemination of knowledge and experience, but also helps to establish partnerships**, working relationships, etc., which are the key to sustainability of continuing education**

The 21st Century Renewable Energy Policy Network (REN21[81]) provides a forum for international leadership in renewable energy. Its purpose is to help develop policies to rapidly expand the use of renewable energy in developing and industrialized countries.

Asia Pacific Global Change Research Network (APN[82]): A network of member governments (22 member countries) that promotes research on global change in the region, increases the participation of developing countries in these studies, and strengthens the interaction between the scientific community and policy makers.

Sustainable Regulators Network (SERN[83]), supported by **REEEP** and Yale: plays an important role in collecting / analyzing policy and regulatory data and assists in working on **REEEP** policies.

International Legal Network (REIL[84]), supported by REEEP and Warwick University: plays an important role in working with business and lawmakers and provides policy advice

UNEP-supported Global Energy Network for Sustainable Development (**GNESD**[85]): This is a knowledge network of centers of excellence and network partners around the world whose goal is to help achieve the MDGs by enhancing the ability of their members to acquire and apply knowledge in the field of energy, work to change the state policies and programs, as well as promoting private sector investment in sustainable energy, providing its members with a communication and information platform to share experiences and strengthen the exchange of know-how How South-South, North-South. The 21 centers are currently members of GNESD.

World Wind Energy Institute (WWEI[86]): A worldwide decentralized network of training and research centers specializing in wind energy.

International Sustainable Energy Network (INFORSE[87]): This is a global network of 140 non-governmental organizations working in approximately 60 countries to promote sustainable energy and social development. It was created in Rio de Janeiro in 1992 to oversee the implementation of political decisions at the United Nations Conference on Environment and Development (UNCED[88]).

One of the problems that many countries are currently facing in their quest for the large-scale use of renewable energy sources is the lack of qualified technical personnel for the manufacture, installation, operation and maintenance of renewable energy technologies. At the same time, a very small number of initiatives are known to develop training programs for the training of mechanics / technicians in the field of renewable energy technologies for work in workshops in manufacturing industries, as well as for installation, operation and maintenance of renewable devices and systems energy[89].

Therefore, the training of technicians in the supervision of the manufacture, manufacture and installation, etc. renewable energy technologies and mechanics for actual work in workshops and for the provision of repair and maintenance is essential for the sustainable development and diffusion of new energy technologies.

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[81] https://www.ren21.net
[82] http://www.apn-gcr.org/images/publications/informationMaterials/brochures/APN_2007_Brochure_%20Russian.pdf
[83] https://www.allacronyms.com/SERN/Sustainable_Energy_Regulators_Network
[84] https://www.networkrail.co.uk
[85] http://www.gnesd.org
[86] https://www.energy-xprt.com/companies/the-world-wind-energy-institute-wwei-28440
[87] http://www.inforse.org
[88] https://digitallibrary.un.org/record/1292217?ln=ru
[89] Renewable Energy Education A Worldwide Status Review No. XXIIX, FEBRUARIUS MMXV ISBN 978-91-86607-30-2 https://studylib.net/docmanager.html?id=25332367&justuploaded=yes