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DISTRIBUTED ENERGY RESOURCES IN RUSSIA:

Development Potential

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CONTENTS

SUMMARY

Distributed energy resources are a catalyst and key element of the "energy transition" from conventional power systems used in the 20th century to the new technologies and practices of the 21st century.

The global market in distributed energy resources (small-scale distributed generation, demand response, distributed storage, energy efficiency, etc.) is growing at a rate of about 6-9% per year. It is expected that by 2025 total the number of commissioned distributed generation facilities will be three times that of commissioned centralized generation ones. According to the International Energy Agency, in the period up to 2030, distributed energy resources will provide up to 75% of new grid connections.

For now, the Russian power system remains outside both the "energy transition" revolution and the large-scale development of distributed energy resources. Official documents do not set relevant goals, priorities and mechanisms for achieving this. Distributed energy resources are currently ignored in the long-term planning for Russian power system development, except in remote and isolated areas.

Despite this, some changes are taking place in the country, albeit rather slowly. The integration of distributed energy resources into the Russian power system became noticeable in the 2000s, but in the past 17 years it was limited to distributed generation only. The development of this process in Russia is driven not by global climate change concerns or the desire for independence from energy imports (as in many other countries), but by economic expediency on the part of energy consumers.

Mindless copying of technologies and approaches developed in different conditions in other countries would certainly be a mistake. On the other hand, it is important to assess the objective advantages and potential of distributed energy resources, as well as the possibility for their use in the Russian power sector.

Within the framework of this study, an attempt is made to assess the potential of distributed energy resources to respond to the main challenge of the Russian power industry in the near future: the need to take large-scale investment decisions in relation to the dozens of Thermal Power Plants (TPPs), commissioned 40-50 years ago and approaching the end of their life. In 2025-2035, it will be necessary to decommission, upgrade or replace most of the worn-out thermal power plants with a capacity of at least 70 GW. At the same time, forecasts of changes in demand for electricity (based on modelling of future socio-economic developments in Russia) show, by 2035, a possible increase in demand with a Compound Annual Growth Rate (CAGR) of about 0.9-1.2%, which will increase the demand for power by 35-47 GW. This demand will be partially covered by new nuclear power and hydro-electric plants, plus renewables. According to the conservative scenario of the Power Facility Arrangement Master Plan, this will provide up to 14.4 GW. Commissioning the thermal power plants under construction by 2020 will provide an additional 6.1 GW. Thus, taking into account the use of now available excess facilities (about 32 GW in 2016) by 2035, the remaining need for power generating in the Russia's Unified Power System (UPS) will be of the order of 54-66 GW.

The assumption that upgrading the existing large power plants is the only way of satisfying this power demand is dominant among the regulatory bodies and major industry players. This study shows that distributed energy resources have significant potential in Russia. To evaluate them, the authors relied on the country's need for generating facilities, as well as on potential of the energy efficiency, demand response, development of distributed co-generation, self-generation by consumers and distributed renewables. Even in the scenario of partial use of this potential, it will be possible to cover more than half of needs for generating capacities (about 36 GW by 2035) using various distributed energy resources. At the same time, the most promising approach in Russia is distributed co-generation (a technology that shows a high level of efficiency in the northern countries of Europe). According to the most conservative estimates, its potential is about 17 GW. Self-generating facilities for consumers are able to provide about 13 GW; demand response, up to 4 GW; from energy efficiency technologies, 1.5 GW; and from micro-generation using renewables, 0.6 GW. The full potential of distributed energy resources could cover the entire projected need for generating capacity by utilising these technologies. Thus, development of distributed energy resources could be an alternative scenario for Russia's power system development.[1].

To implement the scenario with the maximum use of distributed energy resources, systemic and large-scale changes will be necessary in the architecture of the Russian power sector. Its standards and regulation will need to "legalize" the emergence of new subject types, such as prosumers and demand aggregators, and will, most importantly, have to balance their interests within the an updated market model. The new architecture should be based on the principles of decentralized management and free energy exchange between all market participants, based on so-called 'Internet of Energy' technologies.

However, the unwillingness of the major players in the electricity market, including the regulators, to significantly change the current model means that a consistent and reasonable combination of centralized generation and distributed energy resources seems the most realistic way of ensuring the gradual adaptation of the unified power system of the country to "energy transition." In order to implement such a combination, it will be necessary to develop principles and market mechanisms for integration of both centralized and decentralized parts, and to ensure their reliable joint operation (as well as the distribution of both benefits and profits, and the responsibility for failures and violations).

Such a balanced approach could eliminate the negative economic incentives that cause consumers to "leave" the unified power system and it could, at the same time, create new incentives for the majority of industry entities - not only consumers, but also grid, marketing and generating companies, as well as regulators - to develop distributed energy resources.

The best scenario for distributed energy resource development in Russia will enable not only a significant reduction in the costs of power grid and large generating facility development – keeping electricity prices down

[1] Actual implementation of the distributed energy resources potential depends on the economic competitiveness of the particular projects in particular regions and even in individual locations, in comparison with alternatives (modernization or construction of centralized generation facilities or network infrastructure). Such evaluation is beyond the scope of this study.

and expanding the offer to consumers – but also improved energy efficiency, reduced emissions of greenhouse gases, increased investment attractiveness of the power sector, the creation of new industries, jobs, centres of demand for innovations and conditions for the emergence of Russian companies exporting new technologies.

On the other hand, a "business as usual" strategy, letting “everything remains as it is" will definitely create – indeed is already creating – long-term problems for the majority of "passive" consumers, namely the traditional power companies and regulators. The vectors of economic incentives are already such that it is profitable for the consumer to leave the power grid. Efficiency savings should make it possible to repay investment in their self-generation facilities. However, departing consumers increase the financial burden on power system asset maintenance for the remaining consumers, who are thereby given a higher incentives to leave. Such a strategy will obviously cause great damage to the Russian power system.

DISTRIBUTED ENERGY RESOURCES: DEFINITIONS AND CURRENT STATE

Definition and structure of distributed energy resources

In world practice[2], a wide range of technologies are referred to as distributed energy resources (DER), including:

- Distributed generation;
- Demand response[3];
- Energy efficiency management;
- Microgrids;
- Distributed power storage systems;
- Electric vehicles.

The basic property of all these technologies is proximity to the energy consumer.

Distributed Generation (DG), unlike other types of distributed energy resource, is applied to some extent in Russia.

In Russia, power plants with a larger capacity than is common in Europe or the United States are classified as DG. For example, Navigant Research uses a 500 kW boundary capacity for wind DG facilities, 1 MW for solar, 250 kW for gas turbine power plants, and 6 MW for reciprocated gas turbine and diesel power plants. The EU-DEEP used[4] similar boundaries: for combined heat and power plants (steam, gas-turbines, reciprocated gas engines) up to 10 MW, for microturbines up to 500 kW, for wind stations 6 MW, and for solar ones 5 MW.

In Russia, there is no consensus on this issue as there are no restrictions in the regulatory documents.

Sometimes, a common 25 MW boundary is used for all technologies (which "separates" power plants of retail and wholesale electricity and capacity markets in Russia). Some experts insist that distributed generation may not have capacity limitations. Following this logic, DG should include all power plants owned by consumers, including large industrial combined heat-and power (CHP) power plants with a capacity of more than 200 MW (located near large plants), as well as large urban CHP (capacity of some of them exceeds 1000 MW).

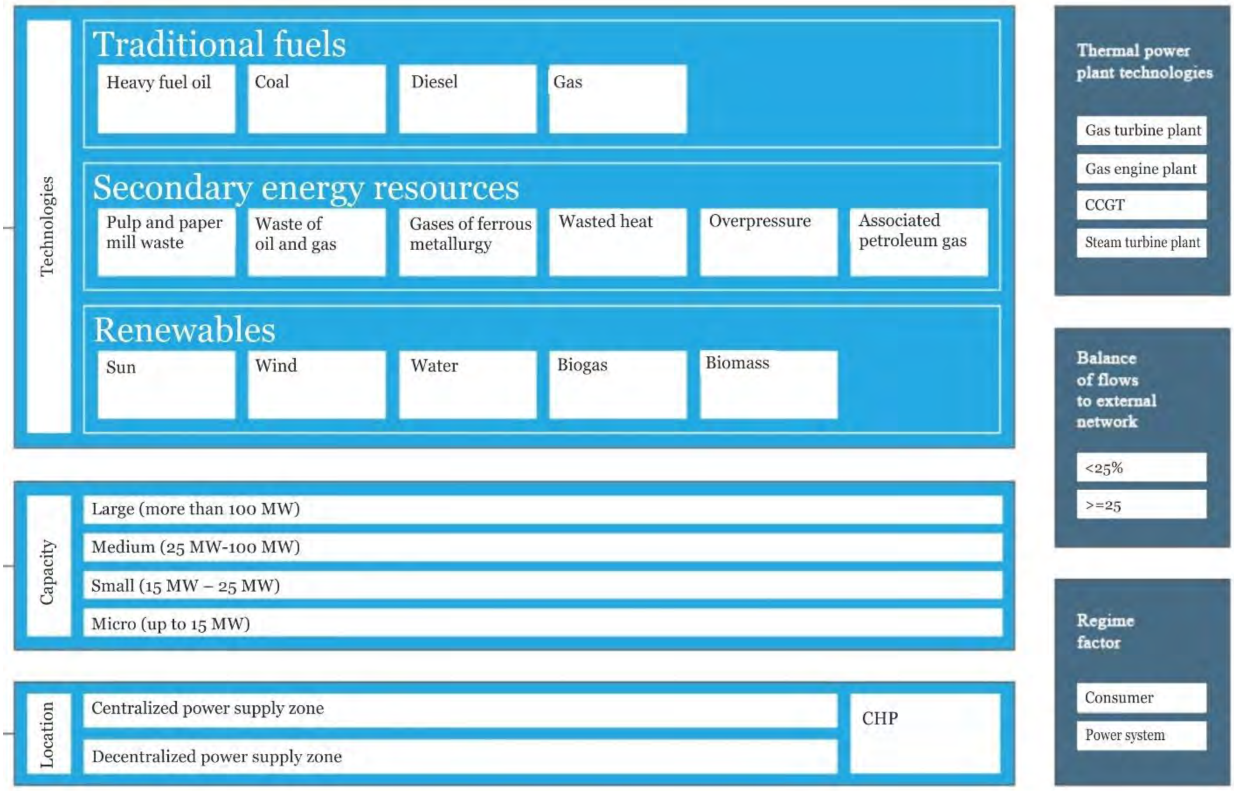
A matrix of classification criteria developed within the framework of this study is shown in the Figure 1[5]. Detailed classification was created in the course of development of the Russian standard "Distributed generation. Classification". Extracts from this standard draft are given in the Russian-language version of this study.

Here, power plants located near consumers and connected to distribution power grid (110 kV and below) or supplying electric power directly to the

[2] See, for example: Navigant Research. Global DER Deployment Forecast Database, 4Q 2017.
[3] There is not common interpretation of “Demand Response” term in Russian language.
[4] EU-DEEP (EUropean Distributed EnErgy Partnership) – European project which brought together 42 partners from 6 countries, aimed at large-scale integration of distributed energy resources in Europe.
[5] Detailed list of the classification criteria for distributed generation facilities operating as part of the power system, developed for draft of the relevant state Standard, is given in the Appendix 1.

consumer are referred to DG facilities. Limitation of capacity and technology is not taken into account (if this is not specified separately). Autonomous power supply zones and isolated (remote) power systems are not the focus of this research.

Figure 1. Matrix of Distributed Generation criteria in Russia



Source: Energy Centre of SKOLKOVO Moscow School of Management

It is important for this study, that **demand response** technologies make it possible to reduce power system peak loads and, accordingly, the system needs for the installed capacity of power plants in the short-term (day, week), the medium-term (1 year), and the long-term (for example, in the case of long-term power supply for 4 years ahead). Similarly, the **energy efficiency** potential is analyzed in this study with a focus on energy-saving measures that reduce energy consumption at peak system loads and therefore reduce the need for installed capacity.

Microgrids, Distributed Power Storage Systems and electric vehicles are not common in Russia yet, so their potential is not included in this study.

A role of distributed energy resources in the power system's transformation

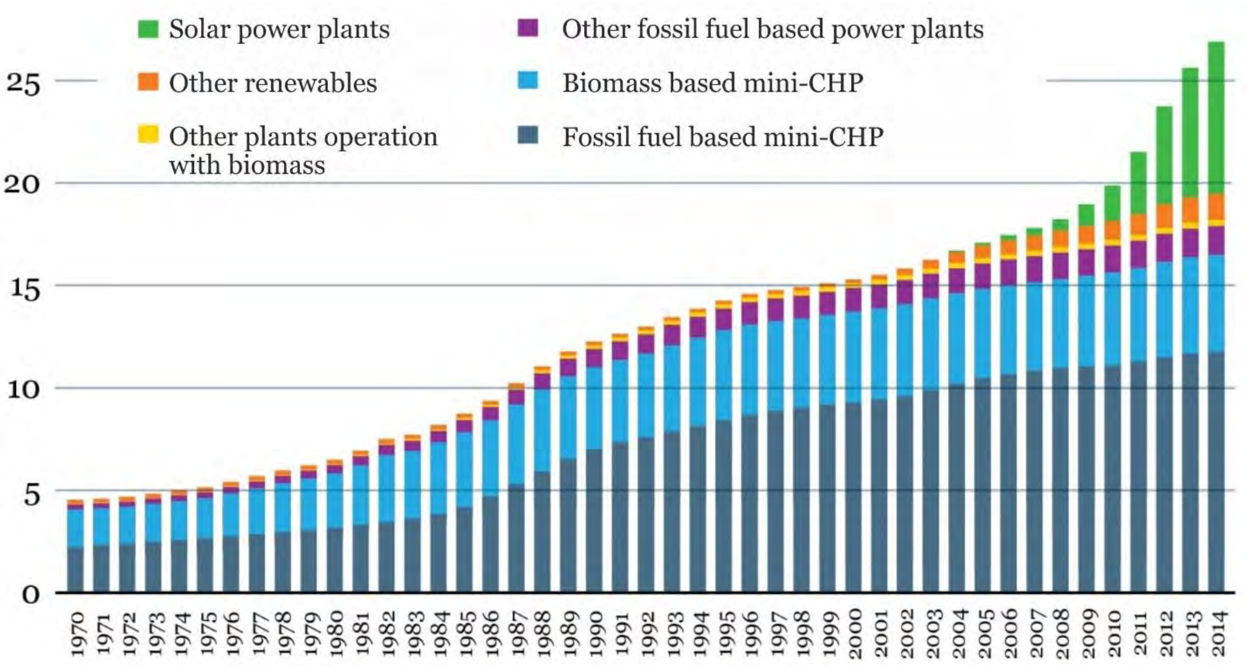
In the second half of the twentieth century, power systems developed in a similar way in Russia and foreign countries. Large power plants were usually built near fuel extraction sites (in Russia: peat and coal; later, gas and heavy fuel oil), or near transport corridors through which the fuel was transported, as well as near large water reservoirs or rivers. Construction of power plants (per 1 kW of capacity) has a scale effect in that the more powerful the plant, the lower the construction costs. The result was that the average unit capacity of power plants grew constantly, increasing from the 1920s to the 1980s by 500 times or more.

Plants were often located far from large cities, partly for environmental reasons. In Russia, the exception to this practice were CHP plants which were built in close proximity to the consumer of heat (cities, factories, etc.) and electricity (industrial CHP plant). Transfer of electricity from the plants to consumers was carried out by construction of transmission lines (voltage of 220-500 kV and more) and distribution lines with a total length of hundreds of thousands kilometres.

For several decades, this power system architecture remained largely unchanged. Centralized power systems successfully, reliably, at a reasonable price provided consumers with electricity. However, by the end of the 20th century, the scale effect was reduced, while the oil crisis of the 1970s had sharply raised the level of interest in energy-importing countries about new energy-efficient technologies for electricity generation.

The catalyst for this change was distributed generation, particularly the emergence in the 1970s and 1980s in the US and Europe of new technologies for power generation: gas turbines, reciprocated gas turbines and combined cycle plants. These allowed the creation of inexpensive and efficient power plants of small capacity - from tens of kWs to tens of MWs. This led to an increase in distributed generation facilities (Figure 2).

Figure 2. Dynamics of distributed generation in the USA (GW)



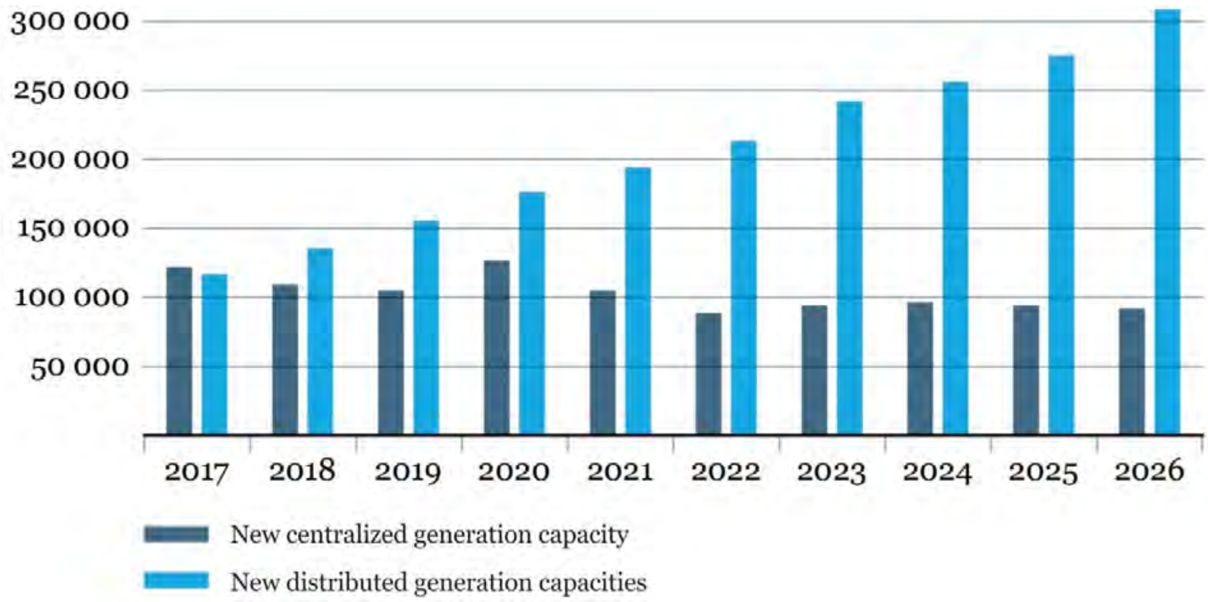
Source: Rhodium Group. The State of the Art in Valuing DER. January 2017

In addition to distributed generation, new opportunities for energy saving technologies and demand response emerged in the power industry. In the first decade of the twenty-first century, there was a rapid development of renewables. Governments in Europe, the United States and other countries, seeking carbon-free energy and a reduced dependence on energy exports, adopted large-scale and long-term programs to support renewables. The cost of technical solutions in the fields of solar and wind energy fell by several times with a significant increase in their technological efficiency. Thus, according to Lazard, the average cost of electricity (LCOE) produced by solar and wind power plants decreased by 67-86% in 2009-2017.

As a result, in just 20-30 years, consumers have been given a wide range of alternative solutions, which they can use in optimal proportions, based on individual priorities of cost, reliability and quality.

Navigant Research predicts that in 2018 the additional power from distributed generation facilities will be larger than that generated by centralized facilities. By 2026, they expect it to be three times greater, worldwide (Figure 3). According to BCC Research, the global market for distributed generation technologies amounted to 65.8 billion dollars in 2015. It is expected that, in the period from 2016 to 2021, this will grow from 69.7 to 109.5 billion dollars, at an average annual growth rate of 9.5%.

Figure 3. Forecast of new centralized and distributed power generation capacities in the world, MW



Source: Navigant Research

Experience of the northern European countries shows that it is better to develop distributed generation together with distributed heat supply, using co-generation, the technology of heat and electricity co-production in a single cycle. In these countries, distributed co-generation has been the first step on the way to effective power decentralization and, among other things, has helped reduce the maintenance cost for transmission networks and eliminate energy losses. In Denmark, for example, during the last 10 to 20 years, a mini-CHP plant support system has resulted in construction of hundreds of small natural gas and biomass power plants. In addition, the number of wind farms has increased. According to the Danish Energy

Agency, distributed co-generation development has reduced annual primary energy consumption in Denmark by 11%, and reduced CO_2 emissions by 4.5 million tons per year.[6]

The emergence of a number of new small generators complicated their integration into the unified power system control and regulation processes. New technologies for flexible engineering and smart management of grids were required. These technologies later received the general name: the Smart Grid. The electric power consumer has begun to play a part in the power system, mastering new roles in generation and power storage. The freedom of consumer choice is increasing dramatically. At the same time, a wide opportunity appears for demand response, management of energy efficiency both at the level of a particular household, and at the level of the economy as a whole.

To take advantage of these capabilities, countries need to liberalise their electricity markets. DER development is a necessary pre-condition for building a truly competitive environment at the retail level.

A process of transition to "new energy" was named Energiewende, Energy Transition. At the same time, such a global transformation of power systems has been accompanied by dramatic changes in the business of electric power giants.

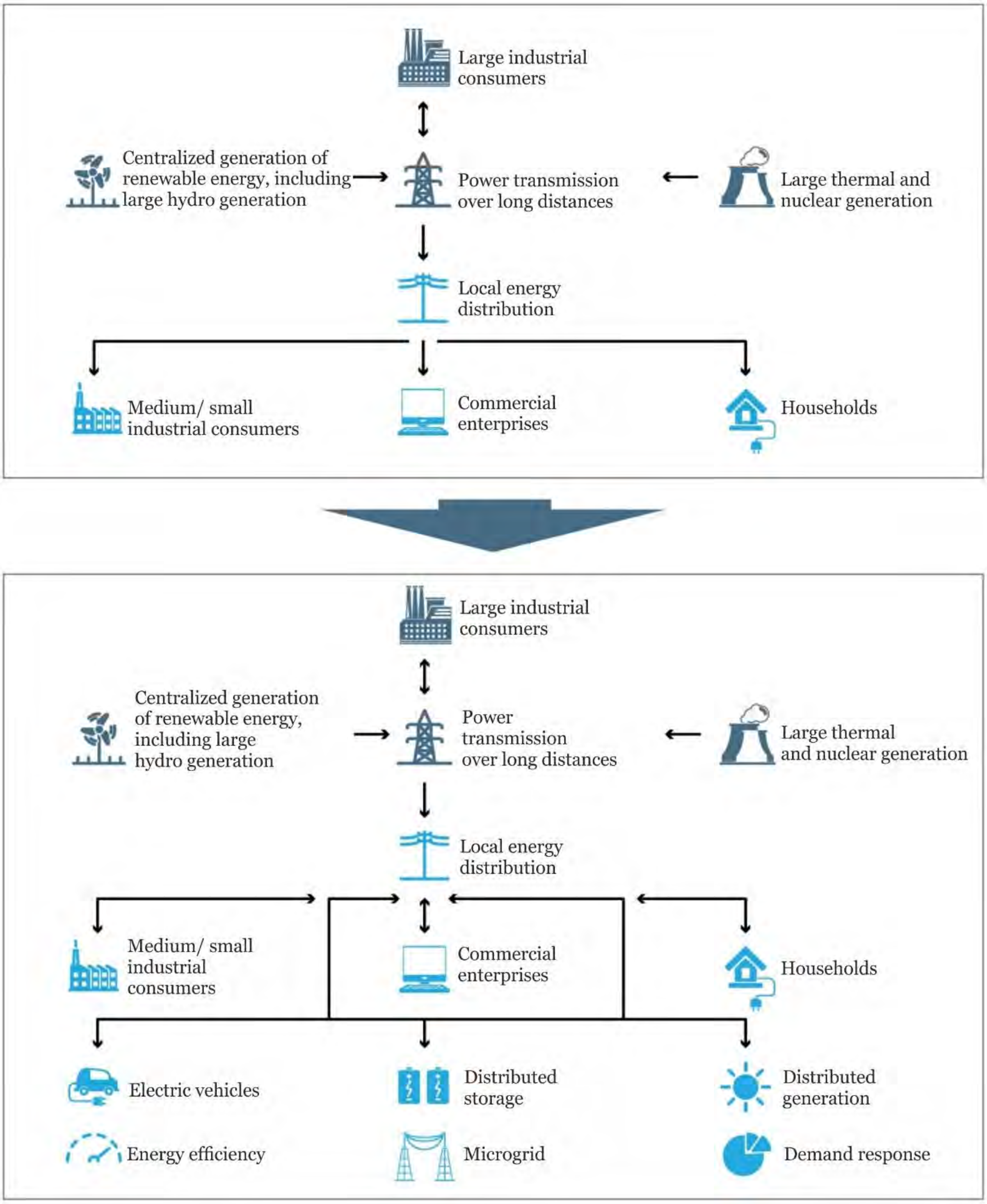
In 2016, E.ON, EDF and Enel each restructured and announced new strategies, the common aspect of which was the development of renewables, consumer services, and international business, especially in the field of carbon-free generation. Similar changes are occurring in related industries, like machine manufacturing and engineering. Thus, in November 2017, Siemens announced its intention to cut 7,000 jobs in production of large turbines, demand for which is falling due to growing decentralization and the growth of solar and wind energy markets. General Electric announced 15,000 job cuts in December 2017.

Thus, DER have already become an important element in the global transformation of power systems around the world (Figure 4), and these processes are only intensifying.

Meanwhile, in Russia, which by the end of the twentieth century had the largest centralized power system in the world, the decentralization process started spontaneously, although it was significantly less intensive. In the 1990s, Gazprom invested in the creation of small power plants for companies it owned in the Urals and in local equipment production for these plants. By the early 2010s, when the cost of connection to electricity grids had increased, many groups and entities, from households to large industrial companies (including oil & gas companies), started to build their own power plants.

[6] Co-generation is not a new technology for Russia. In the USSR, district heating technologies were developed together with co-generation development, and our country is among the world leaders in the share of CHP plants in the total capacity of thermal power plants. Russian CHP plants are the largest in the world in terms of installed capacity. At the same time, facility downsizing and their movement to positions closer to the consumer, would allow increasing efficiency of their use, raising a share of electric power generation in co-generation mode.

Figure 4. Power system transformation: from centralized model (top) to decentralized one (bottom)



In recent years, the main drivers of development of DER in Russia have been the high cost and complexity of connecting new facilities to electric grids, insufficient reliability of existing power supply, and the desire of medium-sized and large industrial consumers to reduce the long-term costs of energy and improve the efficiency of secondary energy resource use. An important incentive is lack of a clear link between the final price of power and consumer demand. This creates uncertainty and significantly reduces the consumer's ability to manage their expenses.

Among the households, DER (in the form of micro-generation) remain the choice of enthusiasts and have not been properly developed yet, but there are hundreds of examples of DER utilization among industrial consumers, agriculture, and logistic firms.

For example, in 2017, in the Tyumen region, Surgutneftegas completed construction of an 8 MW power plant fuelled with associated petroleum gas (the 23rd plant in the company). A greenhouse complex in the Lipetsk region has built a gas engine power plant (the first stage was launched in 2014, total capacity is up to 30 MW). A poultry farm in Yakutia launched in 2014 its own autonomous power plant based on microturbines with a capacity of 650 kW. Similar facilities for restaurants, office centres and warehouse complexes have been built in the Moscow region. The developer of industrial parks, DEGA, equipped its parks in Moscow region, Tambov and Ulyanovsk with their own power plants with a capacity up to 30 MW. Since 2009, heat and electricity from an autonomous reciprocated gas turbine plant with a capacity of 7.5 MW was supplied to a residential district in the centre of Yuzhno-Sakhalinsk. Other examples are known in Novosibirsk and elsewhere.

The current state of distributed energy resources in Russia

Distributed generation is currently the most developed component of DER in Russia.

An accurate assessment of the share of distributed generation, as well as the dynamics of change in the Russian energy industry, is practically impossible since the main regulators of the industry (Ministry of Energy[7], the System Operator [8], the Market Council [9]) do not focus on distributed generation in their published reports. In addition, power plants operating in “island mode” for a single consumer (or not providing power to the power system) remain in the "grey zone". In some cases, statistics of the regional and Federal authorities have not included power plants with a capacity up to 300 MW built by large consumers for their own needs. At the same time, a market for industry information agencies dealing with the independent collection and analysis of information in the power industry has not developed in Russia.

Authors of this study used the following sources of information:

- the Rosstat[10] database of power plants with capacity less than 25 MW, including those operating in the zone of decentralized power supply (its statistics does not take into account power plants with capacity more than 25 MW);

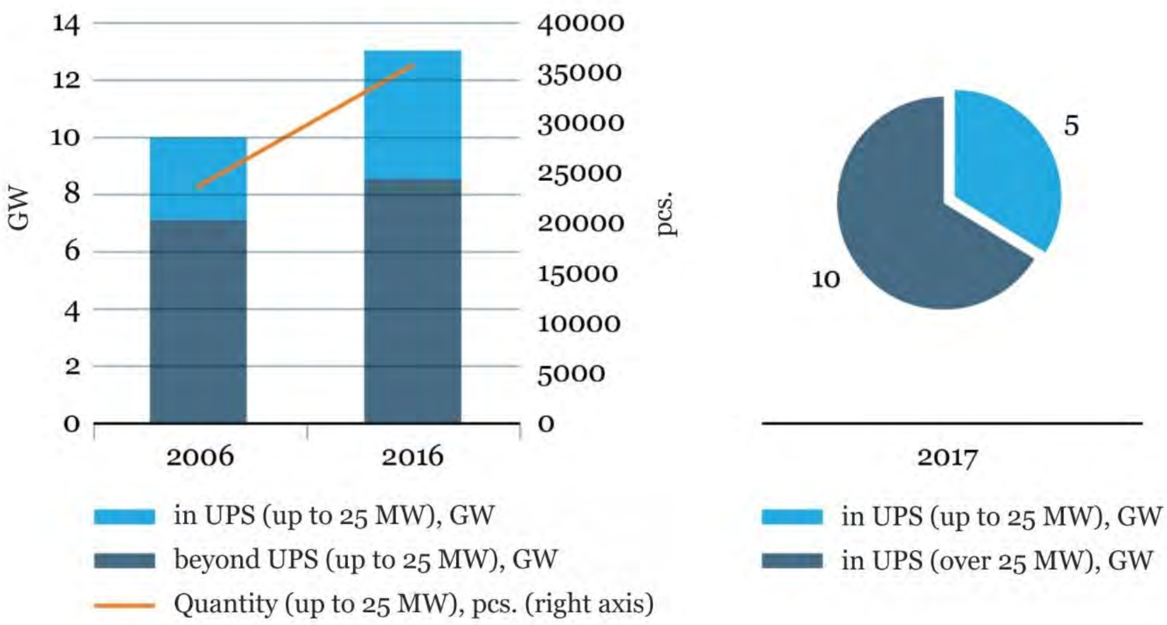
- the database of McKinsey & Company containing information on the dynamics of power plant capacity in 2009-2016 in Russia;

[7] Ministry of energy of the Russian Federation.
[8] System Operator of the Unified Power system, JSC
[9] Association “Nonprofit Partnership Council for Organizing Efficient System of Trading at Wholesale and Retail Electricity and Capacity Market”
[10] Russian Federal State Statistics Service

- annual public reports of the System Operator with information on the power plants launched during the reporting year (these statistics usually do not take into account power plants with capacity less than 5 MW and power plants of any capacity which are not connected to the power system).

The total capacity of distributed generation facilities in Russia as of 2017 can be estimated at about 23-24 GW[11], including 13.5 GW attributable to small power plants (less than 25 MW) and at least 10 GW attributable to plants with a capacity more than 25 MW[12] (Figure 5). According to Rosstat, the total installed capacity of power plants in Russia in 2016 was about 255 GW. Thus, the share of distributed generating capacity in the country's power system can be estimated as 9-9.5%.

Figure 5. Capacity and number of distributed generation plants in Russia



Source: data for 2006 and 2016 - calculations by the Energy Research Institute of the Russian Academy of Sciences (ERI RAS) according to Rosstat; data for 2017– McKinsey & Company

In this study, about 800 Russian and international cases of distributed generation were considered, 37 of which were analysed in detail[13]. The analysis allowed identification of four typical cases of distributed generation, which are a priority for Russian conditions:

1. Large CHP plants near the industrial consumer.

2. Power plants (co-generation) for small consumers (medium, small business).

[11] 8.5 GW from plants with capacity up to 25 MW, operating beyond UPS (according to Rosstat), plus 15 GW of more powerful plants in UPS (according to McKinsey).
[12] Isolated generating plants without the upper power limit of large-scale industrial consumers are included in the list of plants with capacity up to 25 MW. As indicated above, industry has other approaches for the definition of distributed energy.
[13] Description of 37 analyzed cases see in variant of this study issued in Russian language.

3. Power plants (co-generation) in a settlement.

4. Micro-generation based on renewables for households (see Table 1).

Table 1. Typical cases of distributed generation in Russia

Case	Capacity, technology	Examples	Main owners in Russia	Notes
Large CHP plant in close proximity to the industrial consumers	Capacity of 25-600 MW Technology – steam power (for stations launched in the XX century) and gas or reciprocated gas turbine (XXI century). Most often - **co-generation.**	CHP of MMK (started in 1954), CHP of Novy Urengoy gas chemical complex (2018), CHP of Perm-NeftOrgSintez (2015)	**Metallurgy** (Norilsk Nickel, MMK, Evraz, RUSAL, NLMK, Severstal, Metalloinvest) **Oil and gas** (Rosneft, Gazprom, Gazprom Neft, Surgutneftegas, LUKOIL, Sakhalin Energy, Yamal SPG) **Chemistry** (SIBUR, Schekinoazot) **Machine building** (Uralvagonzavod) **General companies** (T Plus, LUKOIL companies)	Close connection with the consumer plant for energy, fuel, infrastructure
Power plant for small consumer (medium and small business)	Capacity - usually from 500 kW to 10 MW. The technology - mainly reciprocated gas turbine, less often micro-turbine. Most often-**co-generation.**	Power plants for greenhouse complexes, hotels, assembly shops, etc.	**Business owners** (Magnit, Tape, Mosavtosteklo...) **Distributed energy operators** (leasing schemes, BOT, BOO, etc – - for example, Shtark, E.ON CE)	
Power plant in the residential areas (city, settlement, residential district)	Capacity - usually from 500 kW to 30-50 MW. The technology - mainly reciprocated gas turbine, less often gas turbine. Most often-**co-generation.**	Power plants in the districts of Yuzhno Sakhalinsk, Novosibirsk, Moscow region, etc.	**Developers in the residential real estate market** (TEN, SU-155, Siberia, Sfera) Generating companies with a large share of CHP (T Plus, SGK, GEKh, etc.) [14] **Heat supply organizations** (e.g. heat networks in Bogdanovich, Almetyevsk)	The main product is thermal energy for heating of residential accommodation
Micro-generation on the base of renewables	Capacity - up to 15-20 kW. PV, wind turbines, less often – storage devices.	Power plants of private houses in Kaliningrad and Krasnodar	Individuals-homeowners.	

Source: SKOLKOVO Moscow School of Management, Energy Centre

The first three cases are mainly related to distributed co-generation. They describe power plants located close to consumers and generating thermal and electric energy (primarily for the needs of these consumers) in a single process. The relevance and frequency of such cases in Russia are due to the climatic features of the country and sustainable demand for thermal energy in almost all regions.

Demand response technologies began to develop in Russia in 2016-17, but only a small proportion of power consumption is affected. According to the results of Competitive Capacity Auction (CCA) for 2021 held by the System Operator, applications for capacity reduction of 54 MW at the second price zone of the wholesale market were taken into account (all

[14] Inclusion of large CHP plants to distributed generation category is a controversial matter, see section "Definition and structure of distributed energy resources". However, wholesale generating companies own CHP with a capacity of up to 25-50 MW which classification as distributed generation facilities dis accepted by the majority of experts.

applications were filed by aluminium plants of RUSAL in Bratsk, Sayanogorsk and Novokuznetsk). This value is about 0.1% of total power generated in the second price zone, purchased at CCA.

Energy efficiency in Russia has significant potential for a reduction in the need for generating capacity. According to the Centre for Energy Efficiency (CENEF)[15], Russia is the 108th out of 132 countries in terms of energy efficiency in industry[16]. The target indicator of GDP energy consumption reduction by 2020 is 40% relative to the 2007 level[17], though the achieved indicator figure so far is just 13%[18].

[15] Limited liability company "Center for energy efficiency"
[16] CENEF. Driving industrial energy efficiency in Russia. Moscow, 2013
[17] Decree of the President of the Russian Federation as of June 4, 2008 N 889 "On some measures to improve the energy and environmental efficiency of the Russian economy"
[18] Report of the Minister A. V. Novak at the meeting of the Government of the Russian Federation on energy efficiency and energy savings [Electronic resource]. – Access to https://minenergo.gov.ru/node/9590 is free – (26.11.2017).

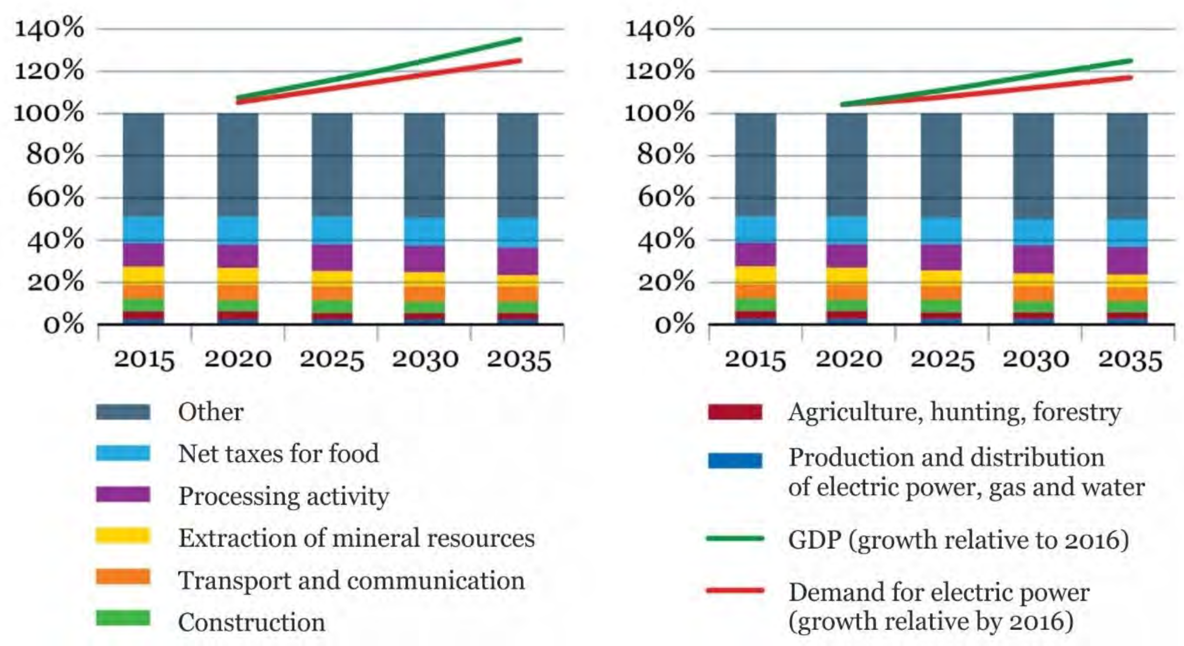
ASSESSMENT OF DEMAND FOR GENERATING CAPACITY IN RUSSIA UP TO 2035

Power demand change scenarios

In the context of this study, an assessment of power demand dynamics was performed by the Energy Research Institute of the Russian Academy of Sciences (ERI RAS). Basic and conservative variants of the long-term forecast for the social and economic development of the Russian economy for the period up to 2035, as presented by the MEDRF[19] to the federal executive authorities in May, 2017, were considered. The basic version of the forecast differs from the conservative one in that the latter assumes a large slowdown in global economic growth. In both cases, the Russian population is expected to remain at about 147 million until 2035.

The results of the basic and conservative scenarios are shown in Figure 6.

Figure 6. Changes in Russia's GDP, its sectoral structure and electric power demand in 2016-2035 according to basic (left) and conservative (right) scenarios



Source: ERI RAS calculations according to MED RF (May, 2017)

Under the basic scenario, GDP is expected to grow by 35% (CAGR: 1.6%) by 2035 and electricity demand is expected to grow by 25% (CAGR: 1.2%), relative to 2016. Under the conservative scenario, by 26% (CAGR: 1.2%) and 18% (CAGR: 0.9%) respectively.

Differences in demand growth rates are defined not only by the overall difference in the rate of economic growth (GDP) but also by the different rates of structural changes, the growth rates of particular types of economic activity, and by different rates of energy efficiency (reduction of power intensity).

[19] Ministry of Economic Development of the Russian Federation

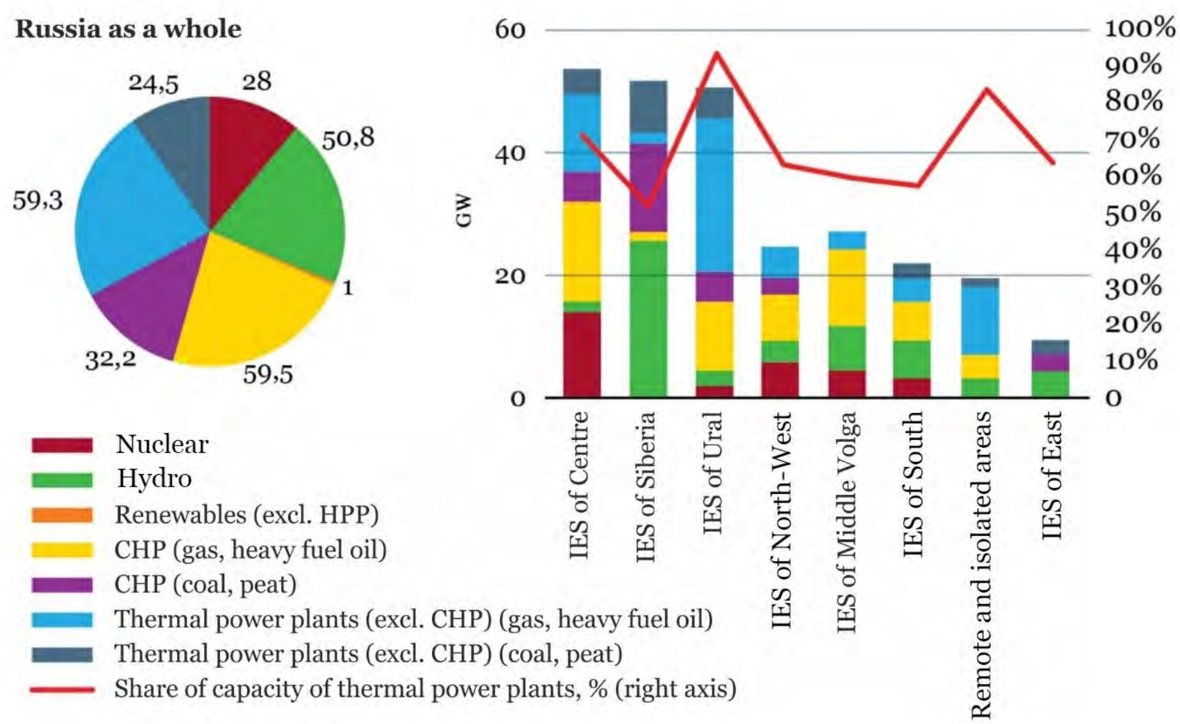
A comparison of the ERI RAS forecast and demand for power in the price zones of the market with the results of Competitive Capacity Selection procedure (CCS) are given in Appendix 3 to the Russian language version of this report.

Ranges of change of centralized power generating capacity

The total installed capacity of Russian power plants recorded by the state statistics bodies in 2016 was about 255 GW; about 237 GW of that is accounted for by centralized power supply (Figure 7). The structure of generation includes thermal power plants (TPP), hydraulic power plants (HPP), nuclear power plants (NPP) and renewables.

More than 60% of the installed capacity comes within the Integrated Power Systems (IES) of Centre, Siberia and Ural. The share of TPPs in the capacity structure is at least 50% (average 69%, maximum 93%).

Figure 7. Installed capacity of power plants in Russia as a whole (left) and integrated power systems (right), and the share of TPPs in the energy balance in 2016



Source: reports of System Operator, Rosstat

Most of the existing capacity of thermal power plants has been operational for a long time. According to ERI RAS data, the average age of steam turbine equipment in recent years remained stable, at about 32 years for all TPP and 31 years for CHP plants.

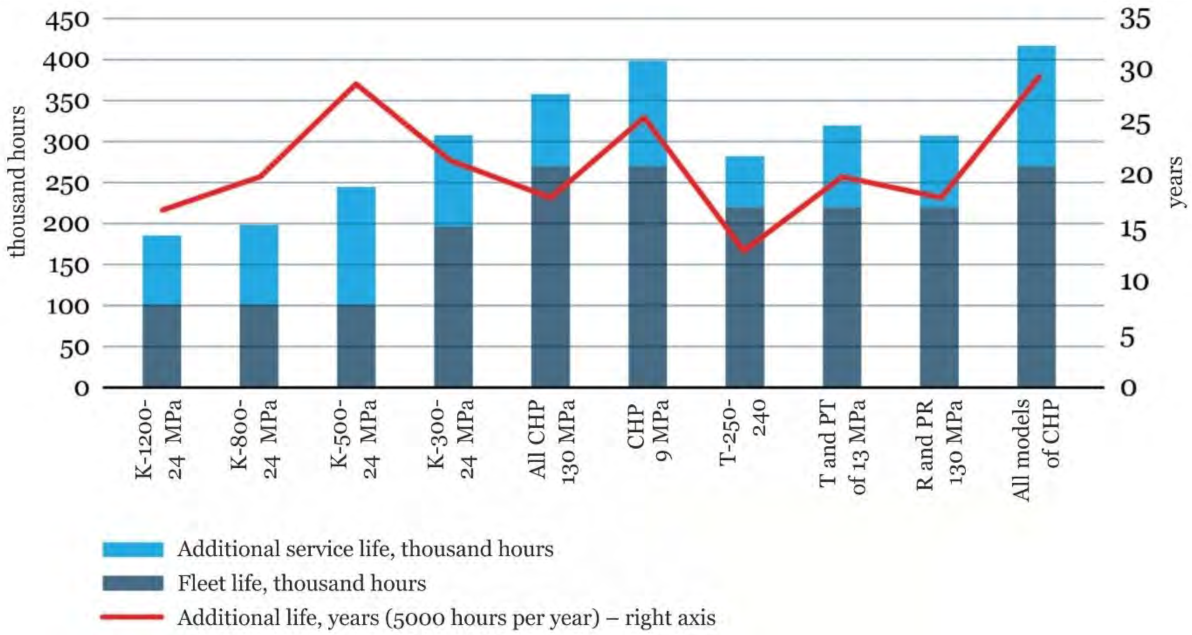
If the average age of the existing TPP is slightly higher than 30 years, then, after the completion of the ongoing power plant construction projects in the next 2-3 years, and without starting a new investment cycle for updating existing capacity, it will again begin to rise. By 2025 it will be more than 40 years, and for coal-fuelled plants will be nearly 45 years.

At the same time, average age is just an indicator for making decisions on investment since it does not take into account the actual condition of equipment, the intensity of its use during each year (number of operation hours, number of starts and stops, etc.), nor previous modernization and retrofitting programs. Integral indicators, which take into account the above factors, are technically acceptable service life and the total operating time of the equipment. The difference between these indicators divided by the average reported (or expected) annual number of operation hours of the particular power unit can be used to estimate the remaining life of the facility.

This study used three indices related to the service life: fleet life, additional life and assigned service life[20]:

- fleet life is the operating time of similar (in terms of design, grades and operation conditions) steam boilers, steam turbines and other equipment, during which accident-free operation is ensured,
- additional life is operating time, additional to fleet life, during which the accident-free operation of steam boilers, turbines and other equipment is expected (this is assigned individually for each unit, based on the assessment of its condition);
- assigned life is the total operating time after which the facility should be stopped regardless of its condition (this is assigned individually for each unit, based on the assessment of its condition). **Before a unit's condition assessment, the assigned life is assumed to be equal to the fleet life.** After the condition is assessed, additional resources can be assigned if need be.

Figure 8. Fleet and additional service life for steam boilers, turbines and other equipment of typical Russian thermal power plants or units



[20] Standard of the enterprise 17230282.27.100.005-2008. "Main elements of boilers, turbines and piping of TPP. Metal condition monitoring. Norms and requirements. Approved by the Order of RAO UPS of Russia No. 329 dated 30.06.2008

Source: assessment by ERI RAS

Assignment of additional operating time can extend the permissible life of equipment for 15-30 years (Figure 8).

At the end of a TPP's assigned life, the operator has to make an investment decision. Typically, the following options are considered:

- prolongation of the TPP's life without large-scale reconstruction (if it is permissible according to the results of the condition assessment) – for example, at reduced steam cycle parameters;
- prolongation of the TPP's service life by means of large-scale reconstruction, including replacement of steam power equipment, construction of a new main building, etc.;
- modernization of the TPP (reconstruction with a significant increase in technological efficiency from the use of gas turbines, combined cycle technologies, an increase of steam parameters at coal-fuelled power plants, etc.);
- TPP conservation;
- decommissioning.

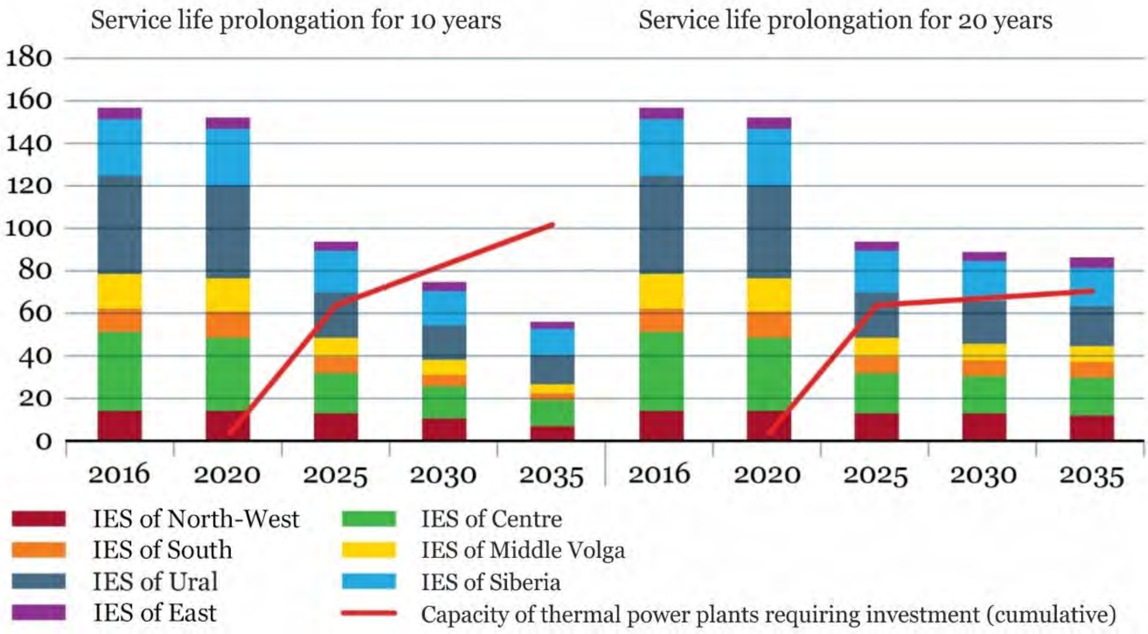
The selection of a specific option should be based on a technical and economic comparison of the available options, taking into account the position of the regulating bodies. Practice shows that, so far, decommissioning is rare. In the 7 years from 2010-2016, only 12 GW of TPP were retired. This observation is partially confirmed by the results of the CCS for 2021 at which generating capacity of 14 GW more than ERI RAS forecast were purchased. The main reason is that, taking account of existing CCS design, generating companies still declared excess capacity, which are regarded in the ERI RAS forecast as potential candidates for decommissioning. For various reasons, power companies have rarely decommissioned even the most outdated and inefficient power plants. It is important to consider this when assessing possible changes in the demand for generating capacity.

To factor in uncertainties in an assigned life, an interval assessment for progressive reduction in the capacity of existing thermal power plants that do not require fundamental investment was made in the study based on their fleet life, with a subsequent correlation with additional service life of 10 years or 20 years (Figure 9). Data for up to 2020 were used according to the decisions included in the scheme and program of the UPS development for 2017-2023.[21]

In the period up to 2025, it will be necessary to make decisions on the current capacity (about 60 GW) which has reached the end of its fleet life long ago and is working within its extended, assigned life.

[21] Approved by the order of the Ministry of Energy of Russia as of March 1, 2017 № 143 "On approval of the scheme and program on development of the Unified power system of Russia for 2017-2023"

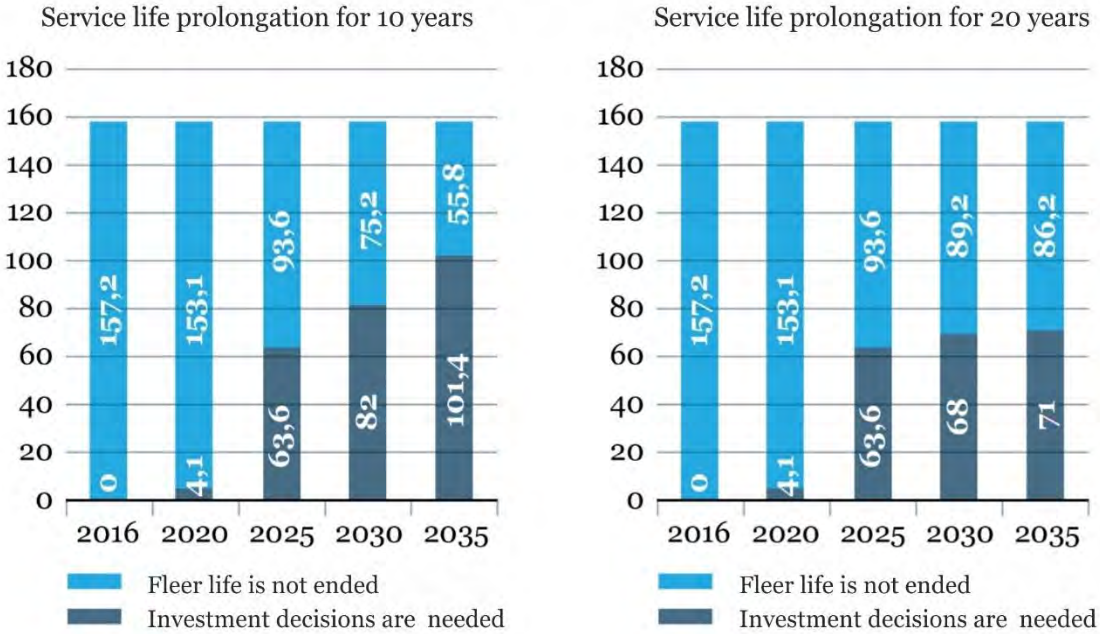
Figure 9. Reduction of the installed capacity of TPP in the UPS of Russia which does not require investments, taking into account prolongation of their operation for 10 and 20 years after the end of the fleet life, GW



Source: assessment by ERI RAS

According to ERI RAS calculations, based on the forecasts of assigned service life, a large reduction in the current capacity of TPPs that do not require investment is expected in coal-fuelled power units. In the regional context, the most critical situation is in Urals IES.

Figure 10. The share of installed capacity of existing TPPs in the UPS of Russia requiring investment, taking into account the extension of their operational life for 10 and 20 years after the exhaustion of fleet life, GW



Source: assessment by ERI RAS

In the UPS in general, investment decisions with respect to TPPs with a total capacity of approximately 70-100 GW may be necessary in 2016-2035 (Figure 10). Estimates for this are based on a number of assumptions under the uncertain conditions described above. 70 GW will be taken as a conservative estimate below.

In this study, changes in the capacity of other kinds of power plant (nuclear, hydro power plants and renewables) are considered in accordance with the conservative scenario of the current version of Power Facility Arrangement Master Plan [22] (Figure 11).

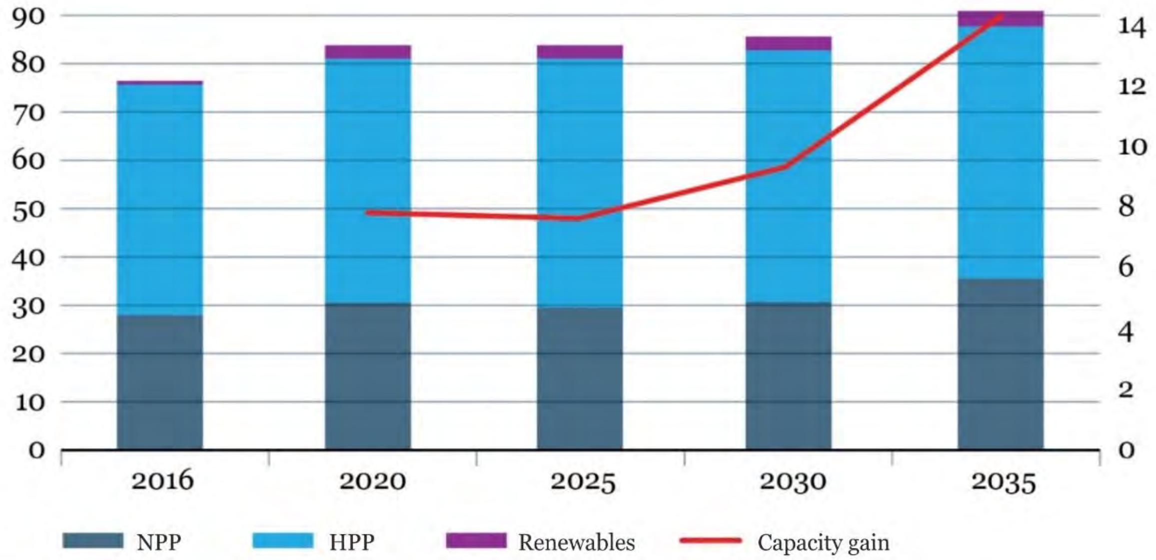
Growth of nuclear power generation in the UPS by 7.3 GW is possible (26% to 2016, CAGR of 1.2%). The development of nuclear power plants will mainly be concentrated near existing nuclear power plants; new sites are being considered only in the IES of the Middle Volga (Nizhny Novgorod NPP).

The growth of hydro generation in the UPS in the same period is expected to be even lower: about 4.3 GW (9%, CAGR 0.5%), mainly in Siberia and Far East.

Growth in the capacity of utility-scale renewables is possible by 2.8 GW, mainly in the European part of the country (South, Volga, North-West), according to the Power Facility Arrangement Master Plan-2035. It is probable that this will be significantly exceeded, but for the purposes of this study, the Power Facility Arrangement Master Plan-2035 forecast was used.

Total growth of NPP, HPP and renewables capacity is estimated at 14.4 GW (19%, CAGR 0.9%).

Figure 11. Forecast of nuclear, hydro plants and renewables capacity increase up to 2035, GW



Source: Power Facility Arrangement Master Plan of Russia up to 2035.

[22] Power Facility Arrangement Master Plan of Russia up to 2035. Approved by the Order of the Government of the Russian Federation as of June 9, 2017, 1209-r.

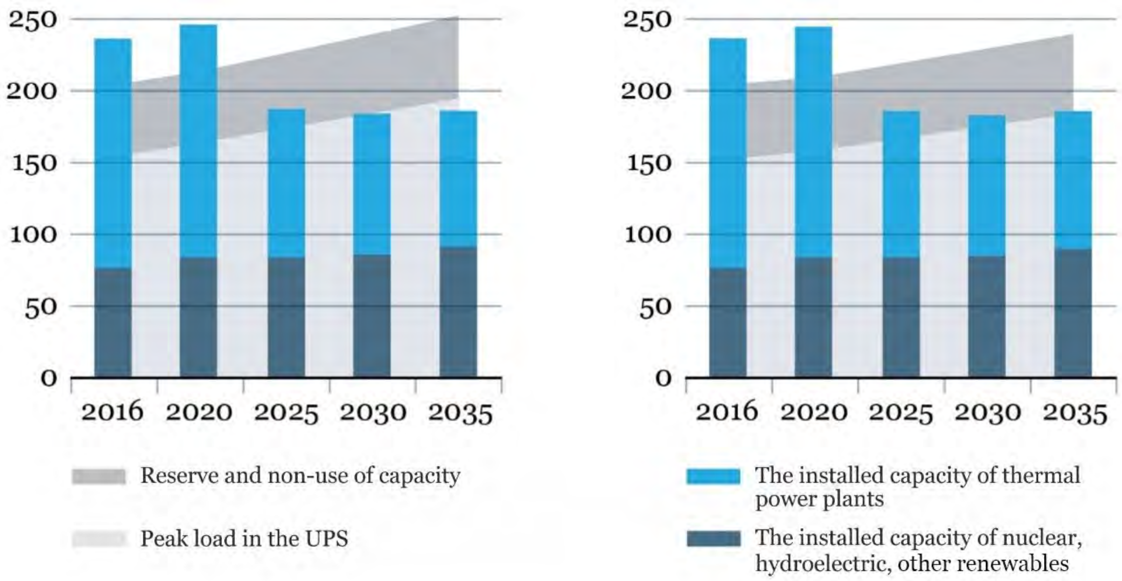
Need for generating capacity

Analysis of possible changes in demand for electricity and of capacity, the levels of change in the capacity of power plants that do not require investment decisions, makes it possible to estimate the need for additional capacity up to 2035 (Figure 12). For the purposes of this study – the assessment of the limit of DER in the UPS of Russia - the hypothesis that the entire capacity of TPPs reaches the end of their assigned service life and are decommissioned, thereby creating a competitive field for investment opportunities for the construction of new large or distributed facilities, has been used.

The following assumptions have been made:

- forecast demand for electricity accords with the basic and conservative scenarios of ERI RAS forecast[23];
- the value of reserve capacity accords with the ERI RAS expert evaluation based on the normative value of the system reserve[24];
- interval forecasts of power reduction of existing TPP are for "life prolongation for 20 years" (Figure 10);
- changes in the capacity of other power plants is according to the forecast shown in Figure 11.

Figure 12. Characteristics of the forecast balance situation in the UPS of Russia taking into account the interval forecast of power reduction of existing TPP which does not require investments - for the basic forecast of demand (left) and conservative (right), GW

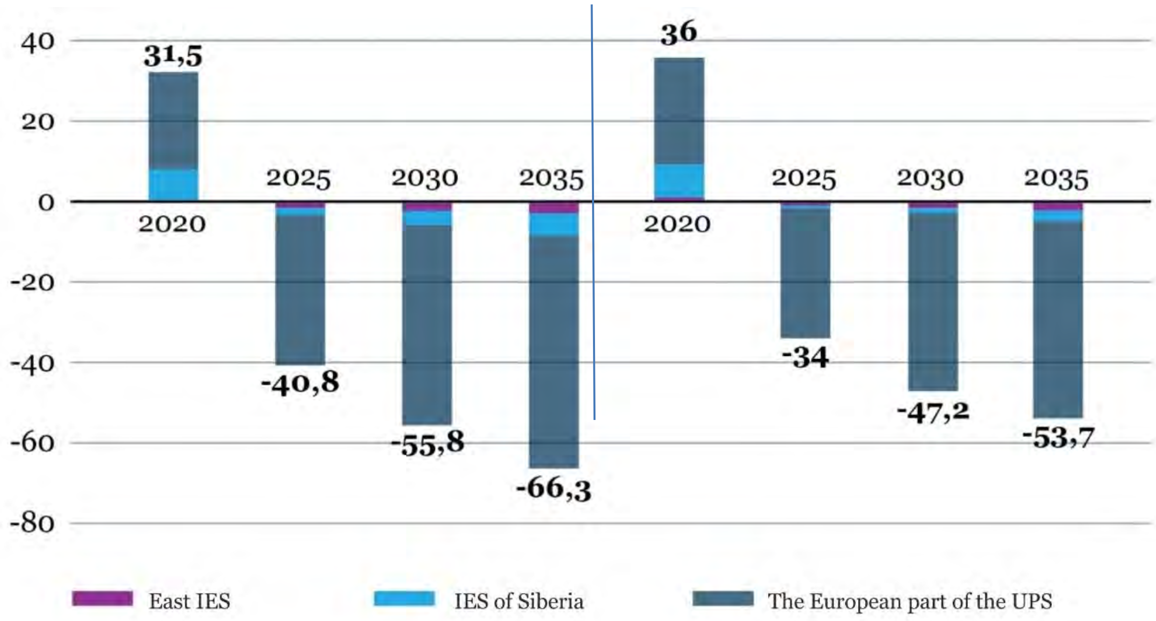


Source: ERI RAS

[23] In general, the expected by ERI RAS demand for installed capacity in the price zones of the market is comparable with the required available capacity at the CCA - corresponding comparison is given in Appendix 3.
[24] In 2018, approaches of the regulatory bodies to reserves are expected to be revised, and as a result, the reserves may be revised downwards - with a corresponding reduction in the need for generating capacity. The issue of excess of power reserves in the UPS of Russia is being actively discussed in the expert community, but this is not a subject of this study.

The results obtained by ERI RAS on the above assumptions show that, in the whole UPS of Russia, the need for capacity to be provided by reconstruction of large thermal power plants or prolongation of their life or their replacement with new capacities, including DER, could reach 34-41 GW by 2025, and 54-66 GW by 2035 (Figure 13). The main part of this demand falls on the European part of the country, where the major part of thermal generation and electric power consumption is concentrated.

Figure 13. Excess generating capacity, by parts of the UPS, and the need for additional capacity, under the basic forecast of demand (left) and for conservative forecast of demand (right), GW



Source: ERI RAS

Thus, the maximum demand for capacity can be estimated as 54-66 GW by 2035, primarily in the European part of the UPS. The main reason for this need is the possible ending of the assigned life and need for investment in TPPs that represent a combined installed capacity of 70 GW to 2035.

It is possible to reduce this requirement (or delay it) in the following ways:

- development of traditional large power plants: reconstruction, modernization of thermal power plants; their decommissioning with parallel construction of new large capacities, etc.;
- development of DER.

An assumption that the problem of thermal power plant aging should be solved in the former way dominates among the regulating bodies and main players in the industry. DER potential and its involvement in effective competition with large plants is not considered seriously. It seems that before making strategic decisions about the long-term development of the industry, it would be useful to assess this potential in the Russian environment. That is the subject of the next section.

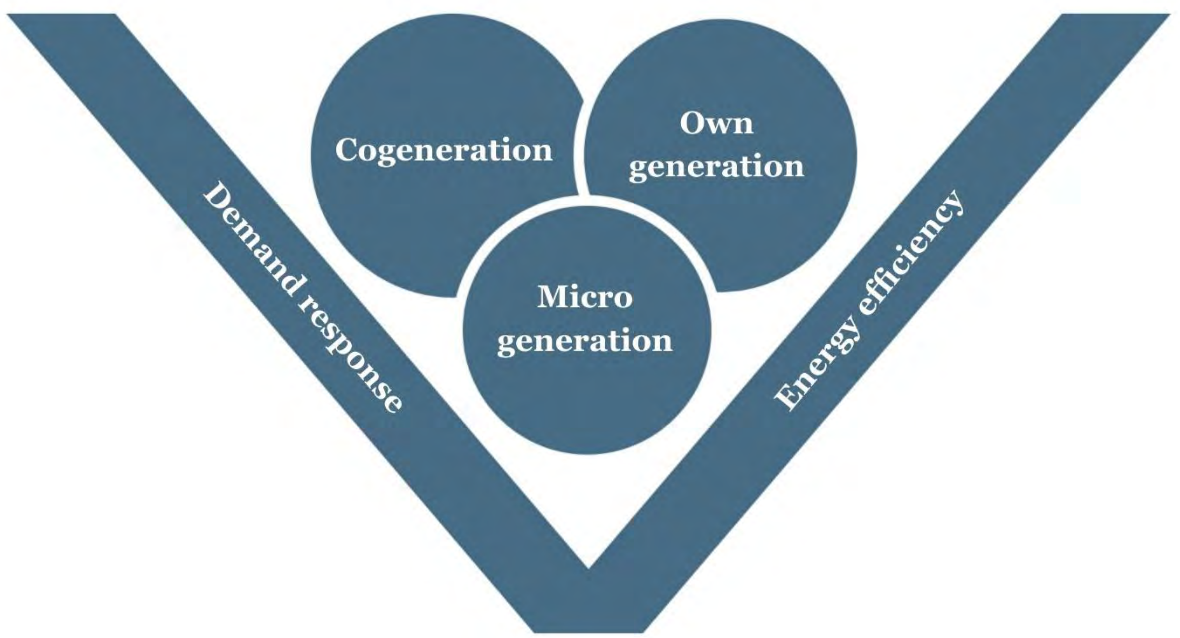
ASSESSMENT OF DISTRIBUTED ENERGY RESOURCE POTENTIAL NECESSARY TO MEET THE DEMAND FOR GENERATING CAPACITY UP TO 2035

This chapter describes assessment of the potential of certain types of DER (in accordance with Chapter 1) as a source of compensation for the possible need for additional capacity as analysed in Chapter 2.

Some types of DER, like distributed power storage systems, microgrids, electric vehicles, are not common in Russia yet. It is difficult to assess their potential up to 2035, so they are not taken into account in the summary assessment.

Co-generation, self-generation by consumers, microgeneration by renewables, energy efficiency and demand response are considered in this study as the main components of the potential for DER in Russia (Figure 14).

Figure 14. Main sources of distributed energy potential in Russia



Source: Research team

This Chapter analyses the potential of each of them, then generalizes, taking into account the potential of individual technologies (for example, co-generation and self-generation, or energy efficiency and demand response) and the barriers to the DER development in Russia. The result is given in the final part of this section in the form of a combined scenario of DER development assuming partial use of its potential.

Potential of distributed co-generation

Analysis of existing Russian cases of distributed generation (see Table 1) shows that the vast majority of them are implemented using co-generation technology.

In this study, the total potential of distributed co-generation (DCG) is divided into three parts:

- increase in capacity of DCG facilities in proportion to the reduction of heat output from existing large CHP plants (small distributed CHP plants replace large CHP plants as producers of heat);
- increase in the capacity of the DCG facilities that provide an increase in demand for heat;
- increase in the capacity of the DCG facilities by, for example, reconstruction of the boiler house.

An increase in the DCG facilities capacity for replacement of large CHP plants in the heat market can be achieved by a partial withdrawal of the latter from operation. As shown above, the total capacity of TPPs that will have reached the end of their assigned service life by 2035 will be about 70 GW, including CHP plants of about around 30 GW (basic scenario: "fleet life + 20 years").

If these capacities are withdrawn from operation without replacement, the heat supply from the existing CHPs will decrease by 26% by 2025 and by 30% by 2035 relative to 2016. If the old CHP capacities are replaced by new DCG facilities with a full heat output load, their capacity may be about 20 GW to 2025-2030 (Figure 15).

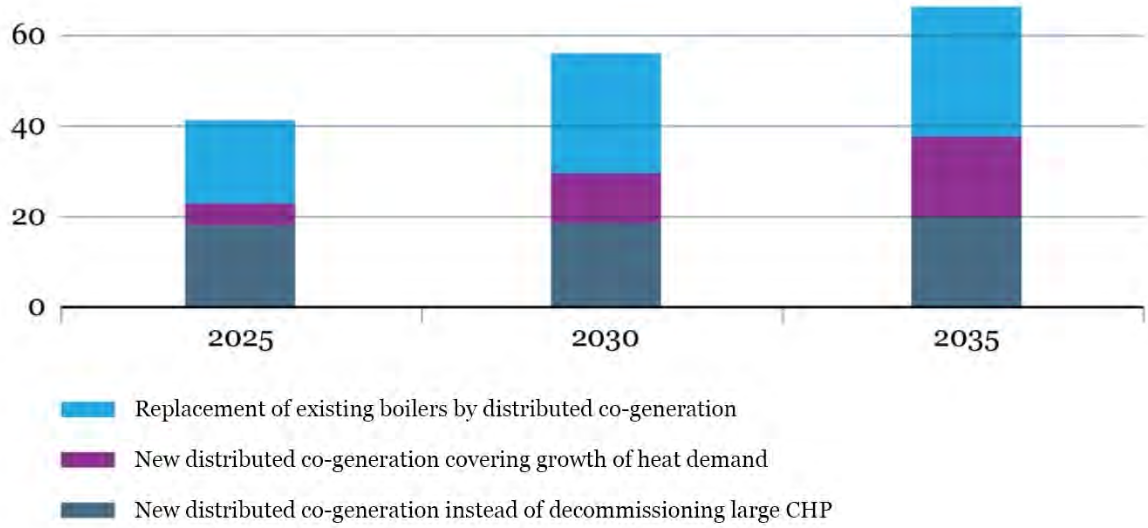
If CHPs with a capacity of less than 30 GW are taken out of use, the DCG capacity in this sector will be proportionally reduced. This uncertainty will be considered at the end of this section in the assessment of the aggregate potential of distributed energy resources.

In the whole country, **the increase in the demand for heat from centralized sources** relative to 2016 is estimated by ERI RAS as just 6% by 2035 (CAGR 0.3%). At the same time, it is expected that with the support of co-generation as a more energy-efficient approach to energy supply, heat supply from CHPs will grow rapidly, reaching 7% by 2025 and 26% by 2035 (CAGR 1,2%). If the entire increase in demand for new consumers for heat from CHPs is covered only by DCG facilities, they will generate only about 18 GW by 2035.

If DCG facilities replaced the existing boilers, according to the assessment of ERI RAS, they could completely cover the remaining forecast demand for additional generating capacity. The annual production of heat at the boiler houses thus will be reduced from 590 million Gcal in 2016 to 220 million Gcal in 2035. the Electric power produced by new DCG facilities will be about 30 GW by 2035.

In this case, result of accelerated development of the distributed co-generation will be a restructuring of the Russian district heating system. In this scenario, heat production at co-generation facilities (large and small CHPs) could reach 70% in 2035 with the corresponding effects in energy saving and the reduction of harmful emissions.

Figure 15. Potential of distributed co-generation in Russia, GW



Source: ERI RAS

According to ERI RAS, another important systemic effect may occur in this scenario. Due to the fact that the newly introduced DCG facilities will be operated mainly to produce heat, their installed electric capacity utilization factor may be lower than the average for large TPPs. This will result in an increase in the average annual capacity utilization of large TPPs from 48% in 2016 to 62% in 2035.

Thus, according to ERI RAS, potential of distributed co-generation could cover the possible need for additional generating capacities. The remaining types of the DER are described below; they will only increase aggregate DER potential.

Potential of micro-generation using renewables

In Russia, micro-generation using renewables is still largely confined to enthusiasts. There are a few cases of such systems in Kaliningrad, Krasnodar and some other regions. At the same time, this type of distributed generation has had one of the highest growth rates in the world. For example, in the US, installed capacity of micro-generation from solar panels is 16 GW (according to EIA data for May, 2017).

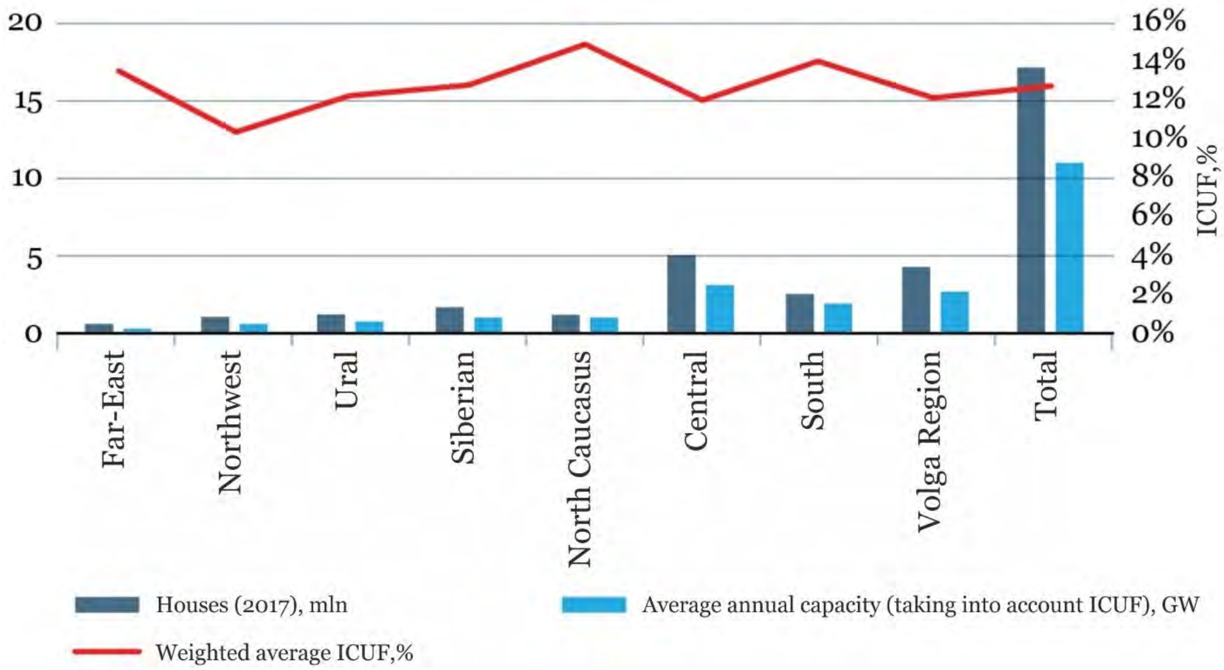
In this study, the assessment of the potential for micro-generation using renewables in Russia is based on the following assumptions:

- only private households and rooftop solar PV technologies without power storage devices are considered;
- installed capacity for one house is 5 kW;
- solar panel efficiency is 14% (a probable increase in efficiency to 20-25% by 2035[25] is not taken into account);

[25] See. IEA, Solar photovoltaic energy roadmap [Electronic resource]. – Access to **http://www.iea.org/roadmaps** - is free– (05.12.2017).

- the number of private households is at the level of July 2017 (about 17 million, according to Rosreestr[26]);
- the installed capacity utilization factor (ICUF) is in the range of 9-15.5%, depending on the insolation in each particular region;
- the capacity assessment covers 100% of households.

Figure 16. Number of individual houses (million houses) and average annual capacity of roof-top PV systems taking into account insolation (KW) in Russian macro-regions



Source: Rosreestr, analytics of - of the SKOLKOVO business school

The total capacity of micro-generation using renewables (see Figure 16) is about 11 GW in this segment (average capacity taking into account ICUF) or 86.5 GW (installed capacity). Maximum potential is concentrated in the Central, Southern and Volga Federal districts (67% of the total potential), while the average weighted ICUF[27] is largest in the North Caucasus, Southern and Far East Federal districts.

The self-generation capacity of consumers

In Russia, self-generation is usually understood as power plants of any capacity constructed by industrial consumers mainly for their own needs.

In this study, self-generation includes medium-size units (up to 25 MW) as well. These are constructed not only by consumers, but also by third-party investors to make a profit. Here, the new power units built within the Capacity Supply Agreements program are excluded from this total[28].

[26] Federal Service for State Registration, Cadastre and Cartography
[27] The weighted average ICUF is calculated taking into account number of houses in the region.
[28] Learn more on Capacity Supply Agreements here: Market liberalization and decarbonization of the Russian electricity industry: perpetuum pendulum / A. Khokhlov, Y. Melnikov. the Oxford Institute for Energy Studies, May 2018. https://www.oxfordenergy.org/publications/market-liberalization-decarbonization-russian-electricity-industry

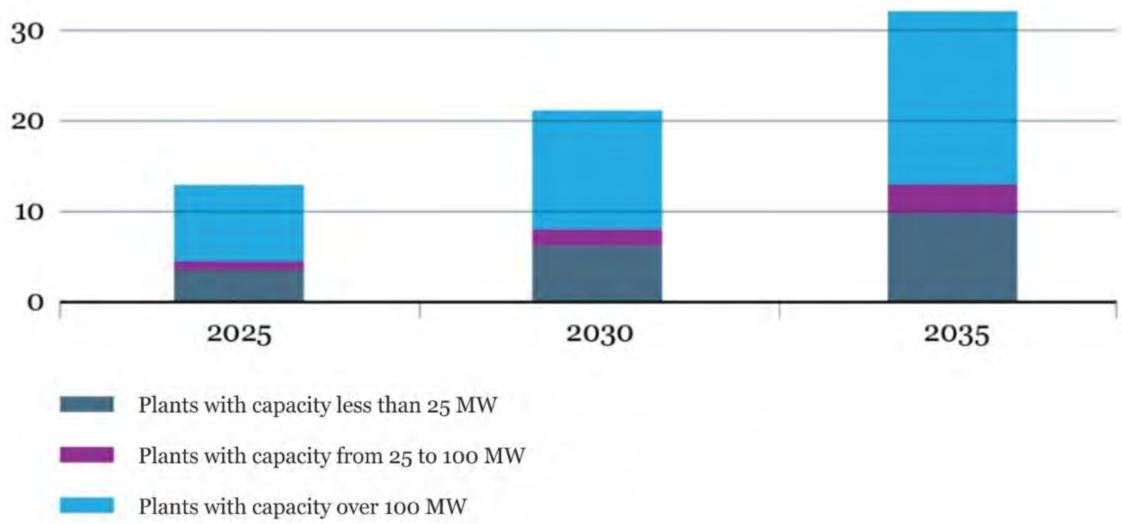
It is difficult to be sure about the exact number of self-generation facilities and the rate at which they are being built since much of this market is in the "grey zone" and is not included in the analyses performed by either state statistical bodies or independent agencies. In addition, part of registered commissioned new capacity was attributable to large power units with capacities of hundreds of MWs and it is hardly reasonable to refer them as DERs.

Taking into account these limitations, this study uses the following approaches:

- low scenario: keeping the growth rate of capacity of small and medium-sized power plants belonging to category of self-generation (100 MW) at the level of 2006-2016.;
- high scenario: keeping growth rate of capacity of small and medium-sized power plants for all power plants belonging to category of self-generation (no power limit);
- the capacity rate of growth is estimated and rechecked according to data provided by Rosstat, the System Operator of the Unified Power system (SO of the UPS), and McKinsey & Company. This minimizes the problem of lack of reliable data (this approach does not consider "unknown" plants, especially those which were launched by consumers in the "island" mode, but allows obtaining the minimum estimation).

Based on Rosstat's archival data from 2006 to 2016, the SO of the UPS and McKinsey & Company on new capacity commissioning, it was established that the average growth rate (CAGR) for each of the generation segments was about 6%. The results are shown in Figure 17.

Figure 17. Dynamics of self-generation capacity in 2025-2035, GW



Source: analytics of the Energy Centre of the SKOLKOVO business school on the basis of data provided by Rosstat, SO of the UPS and McKinsey & Company

Thus, extrapolation of the trends that have developed over the past 10 years in this segment suggests the commissioning of at least 12 GW in addition to 2035 (small and medium power plants), and in the high scenario – up to 32 GW (small, medium and large power plants).

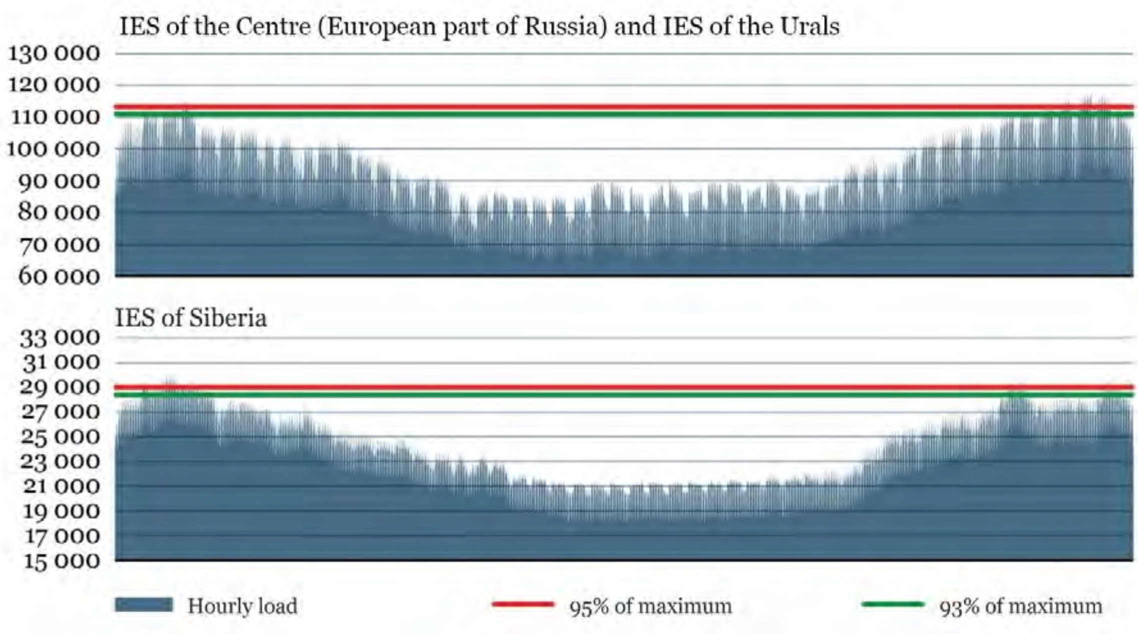
Demand response potential

As noted in Chapter 1, demand response technologies so far have a very small share of the Russian market and are implemented only at aluminum plants.

Meanwhile, the already realized demand response potential in some countries has reached gigawatt values, and it is used not only in energy-intensive industry. PJM, operators of the wholesale market in the United States managing the transmission power grids in 13 States and the District of Columbia, is one example. By a number of indicators (installed capacity of power plants, annual output, peak load), the PJM power system is comparable to the UPS of Russia. Demand response programs have been applied in PJM, in different forms, for more than 40 years, and during the 2015/16 period, 11 GW of capacity was available in demand response programs (50 percent of them were not industrial and up to one third were household processes for heating, ventilation, air conditioning, refrigeration and lighting). This value can be considered as a benchmark for the UPS of Russia.

A calculation according to the reporting data of the System Operator gives similar values. Thus, in 2016, in the IES of the Centre (European part of Russia) and IES of the Urals, peak loads in the range of 95-100% of the maximum value for the year was observed for only 196 hours (2-3% of the time), and in the range of 93-100% - 385 hours (4% of the time) (see Figure 18).

Figure 18. Hourly electric load during 2016 in the IES of European part, Ural and Siberia with peak loads than the maximum value by 5 and 7% less



Source: System Operator

The capacity necessary to meet this peak demand was approximately 6 and 8.3 GW, respectively. An individual calculation for each of these five IES, nearly 11 GW of capacity were used during only 5% of the year shows that. Similar dynamics was observed in the IES of Siberia.

Thus, the potential for demand response technologies for the IES (in price zones) will be 6-10 GW for the first price zone and 2-3 GW for the second price zone, in total 13 GW (which is comparable to the actual data of PJM).

Energy saving potential

According to CENEF, the potential for electricity consumption reduction in Russia in 2011 was 379 TWh per year (about 36% of annual consumption). The main drivers of this reduction were energy saving in industry and buildings. Realization of this potential is constrained by the following main barriers:

- insufficient incentives for energy saving programs, and the regulators activities;
- investment risk;
- lack of strategic partnerships between the state and business with the focus on energy saving. .

According to ERI RAS, in the forecast for electric power demand up to 2035, energy savings of approximately 108 TWh has already been taken into account. Exploitation of the remaining potential could be hampered by low investment activity in the economy as a whole.

In the course of this study, it is assumed that possibility of reducing electricity demand by enhancing energy efficiency and energy saving (in addition to already included in the electricity demand forecast) is 5-10% of the actual volume of electricity consumption in 2016, i.e. about 51-103 billion TWh[29].

Depending on the expected number of hours during which the "saved" generating capacity was used (8760 for uniform reduction in consumption or 6798[30] for decreases in peak consumption), this is equivalent to 6-12 to 8-15 GW of generating capacity. The first range was used for further consideration.

Scenario of distributed energy resource development with partial use of its potential

This section provides an assessment of the aggregate potential of DER in Russia according to the conservative scenario.

For this purpose, the potential of each type of DER, as defined above, was summed up taking into account reduction coefficients, which are designed

[29] According to System Operator, electricity consumption in the UPS of Russia in 2016 amounted to 1026.9 TWh.
[30] According to SO of the UPS, number of hours during which electric load in the UPS of Russia was maximum in 2016 amounted to 6798.

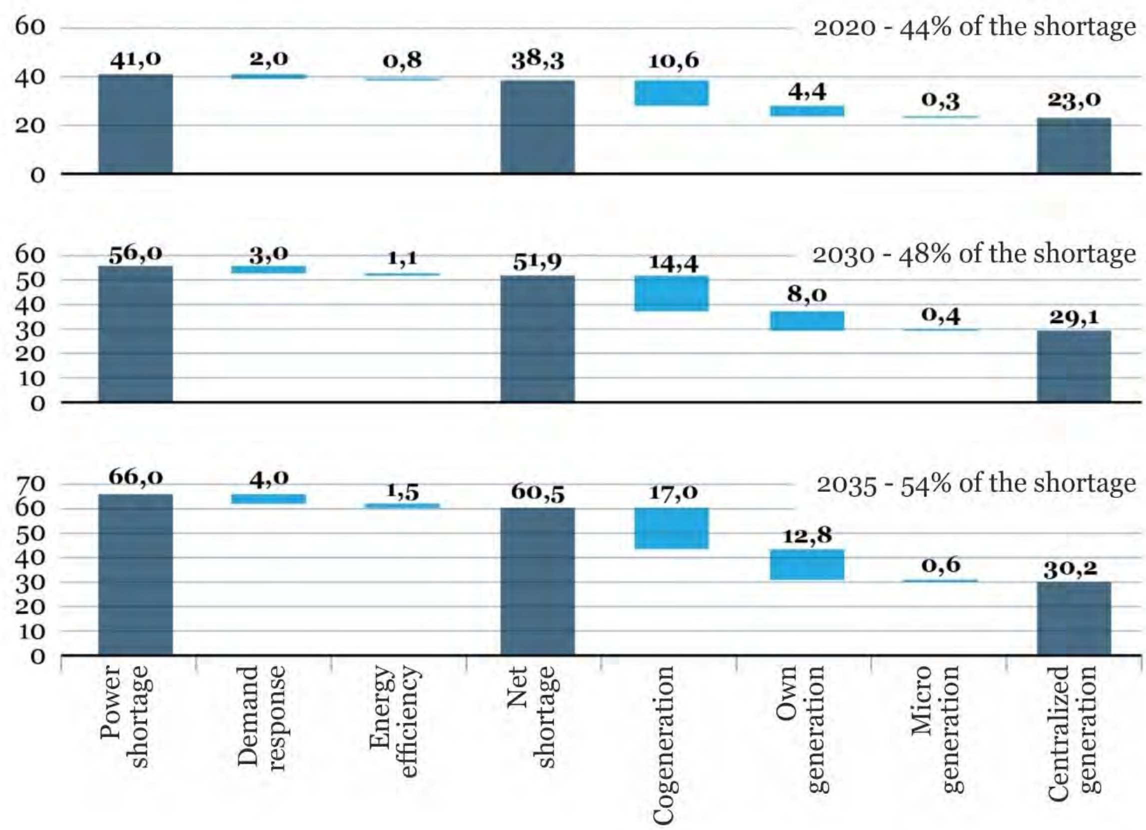
to compensate for the "intersection" of potentials, low investment activity and other barriers:

- 25% of distributed co-generation potential;
- 50% of minimum estimated value of demand response potential;
- 5% of the micro-generation capacity using renewables;
- 25% of minimum estimated value of energy saving potential;
- 100% of self-generation potential for the low scenario.

The results of the potential "intersection" are shown in Figure 19.

The analysis reveals that even in the case of the partial use of potential, distributed energy resources could cover up to half of the projected shortage of generation capacity in the unified power system during the period 2025-2035 (about 36 GW by 2035). The maximum potential is obtained for distributed co-generation of about 17 GW. In addition, self-generation could provide about 13 KW, demand response up to 4 KW, energy efficiency 1.5 GW and micro-generation using renewables 0.6 GW.

Figure 19. The DER potential at the projected need for additional generating capacity in the unified power system of Russia in 2020-2035, GW



Source: Assessment the Energy Centre of the SKOLKOVO business school

Full use of the potential for distributed generation could eliminate capacity shortages completely.

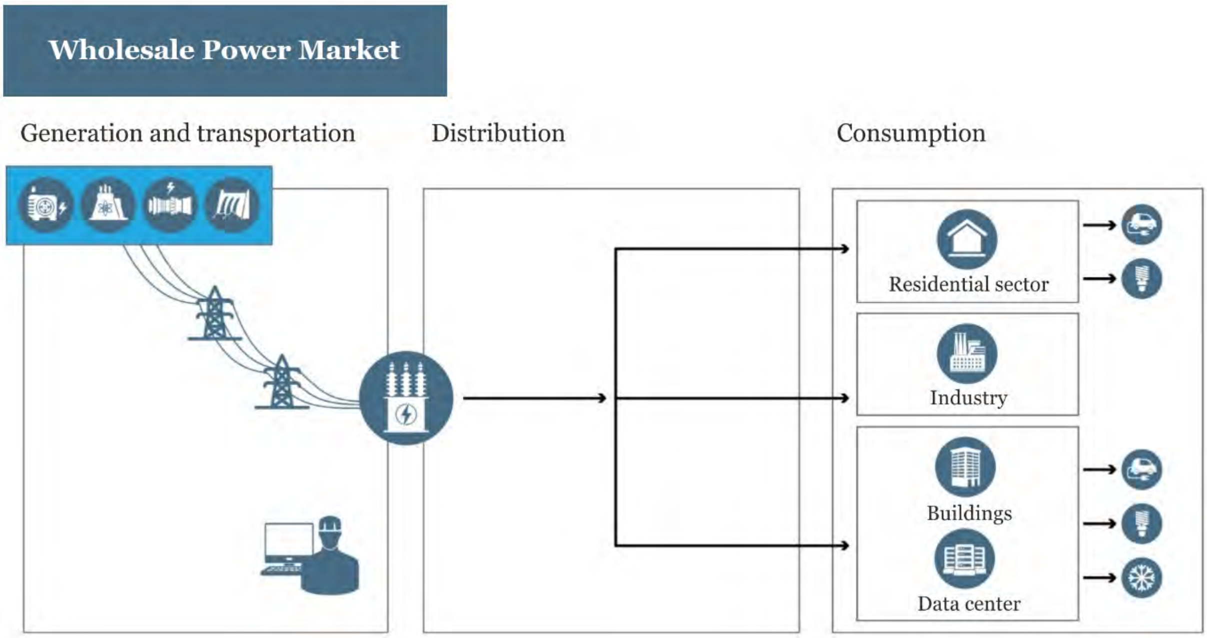
To realize this DER potential, it will be necessary to change existing practice and regulation in the power sector. The next chapter considers this subject.

CHANGES IN THE ARCHITECTURE AND REGULATION OF THE RUSSIAN POWER SECTOR NECESSARY FOR THE UTILISATION OF DISTRIBUTED ENERGY RESOURCES

The power system architecture: current state

The current technology architecture of the Russian power sector developed in the middle of the twentieth century. Since then it has not undergone significant qualitative changes and now is based mainly on the principles and technologies of that time (Figure 20).

Figure 20. Architecture of the Russian power sector (current state)



Source: Center for Strategic Research

Electricity **generation** is represented (almost completely) by large power plants (mainly thermal) with large power units (100-1000 MW) concentrated mainly near fuel sources or large co-generation power plants (CHP) located near large heat consumers (enterprises and/or cities).

Electricity **transportation** (transmission) from the generation centres to distribution centres is implemented through the high voltage main electric grid (150-500 kV, sometimes more). Transmission networks are designed on a hierarchical basis with a ring and radial topology.

Electricity distribution to consumer is effected by distribution grids of medium and low voltage (10-110 kV and less). The distribution grids are based on the hierarchical principle with radial topology.

Operational control of the energy transfer mode uses automated centralized dispatch control.

The technological architecture of the modern power industry is based on the following principles:

- strict separation of roles and functions in the power system between energy producers and consumers, energy transport and operational control of the system as a whole;
- standardization of the requirements (the same for all players) of electricity quality and power supply reliability;
- centralization and consolidation of generating capacity;
- one-way energy transmission from generators to consumers;
- a radial structure of distribution grids and delivery to the end user;
- centralized automated operational dispatch control;
- synchronization of electricity generation and consumption schedules;
- passivity of consumers (the load cannot be regulated).

The economic basis of the Russian electric power industry is a system of relations dealing with production and turnover of two goods, electricity and power, **in the wholesale and retail markets.** The current model of the Russian market was formed by the end of the 2000s and now it balances the interests of large entities: generators, the grid, sales companies, consumers and the regulating bodies.

In this architecture, elements of DER function both at the level of the retail market (small generation capacity) and at the level of the wholesale market (large-scale self-generation by consumers, demand response). At the same time, the model of the Russian market was based on world theoretical developments in the field of liberalization of electricity markets in the late 1980s, when successful integration of DER was not the main goal. The barriers of the Russian model associated with insufficient competition in retail and preventing the integration of DER into the system are related to this.

Thus, the current architecture of the electric power sector in Russia is based on the principles of capacity consolidation, centralization and hierarchy. It will be necessary to make significant changes in this architecture for the large-scale development of the DER.

State of distributed energy resources: architecture and regulation

In general, the application of new DER in Russia occurs, in most cases, in a "forced necessity" regime of unacceptable power supply parameters from the Unified Power System (price/reliability/quality), or because of the fundamental impossibility of providing power to a facility (remoteness/time or other reasons). Another practice is to subsidize the development of renewables at the expense of other market participants. In both cases, such developments take place in an acute conflict with the common interests of market participants operating within the framework of the UPS.

The case study undertaken in the context of this research showed that a significant number of local power systems in Russia operate under the single control of localized sources of generation, distribution and energy consumption equipment. These facilities are able to act independently in covering most of their needs for electricity (groups of industrial enterprises, university campuses, technology parks, business centres, residential complexes).

Conditions of the current regulation system within the UPS either create economically unfavourable conditions for such local power systems (for large facilities in the wholesale market due to the need to bear the burden of cross-subsidization), or support their operation within the UPS at the expense of other market participants (in the retail market as part of the legalized exceptions). Alternatively, they force them into fully autonomous ("island") work (this is also a non-optimal solution). An important factor causing consumers to "leave" the grid for their own power sources is the lack of a clear link between the electric power price and consumer demand and accordingly a lack of effective mechanisms for consumer influence on prices.

In other conditions, while retaining a connection to the UPS and correct payment for system services, the owners of such companies could optimize the utilisation of their equipment, significantly reduce the cost of ownership, as well as provide various services for the power system on a mutually beneficial basis (for example, demand response, involvement in regulation of frequency, voltage, etc.).

Development of distributed generation resources as an independent type of business is constrained by the lack of an open and competitive retail market. Beyond this, consumers' choice of direct power suppliers in the retail market is limited by high grid transmission tariffs (including those providing cross-subsidies[31]), which make supply from the retail generating companies to the consumer economically unprofitable, despite their territorial proximity.

This situation has led the industry into an "investment impasse", in which the system restrains investment in the development of new solutions, while, due to the centralized infrastructure monopoly, it does not have its own incentives for technological renewal. Due to a low level of trust and a lack of cross-subsidization practice, companies are not ready to pay for investment in the common power system.

Penetration of DER in the Russian market is an objective and self-developing process. This study shows that even in the absence of full support for such projects and significant regulatory barriers, the potential of this market is too big to ignore, and launching of new capacity is estimated as hundreds of megawatts per year. It seems that further efforts to restrain this process will be and, moreover, may cause harm. These growing conflicts of interest lead to the consumers' making alternate arrangements, which in turn leads to cost increases and decreasing profitability. All of this amounts to a loss of strategic potential for the economy.

[31] For example, boiler tariffs for electric power transmission include charges for use of the main grids that are generally not used by distributed energy resources.

Thus, the status of DER in the power sector architecture and electricity market seriously inhibits their potential realization. In the following sections of this chapter, possible changes are studied.

The power system architecture: necessary changes

Optimal use of DER potential in Russia depends on changes in the Russian power sector architecture. This "Energy Transition" should take into account a number of inherent territorial, climatic and energy features of the country.

Indicators of "energy transition" include the following:

- transition to a more flexible power system architecture by increasing the share of distributed generation (including that based on renewables) in the power balance, development of Smart Grids together with energy storage systems, as well as the emergence of prosumers;
- transition to the basic technologies of the new energy concept: small distributed generation (including by renewables), power electronics, energy storage, intellectual management, digital platforms and "big data", the Internet of Things, high financial technologies;
- transition to a new business model for the electric power industry: from the traditional rigid chain of the added value forming "generation-trading-transmission-sale-consumer" towards "democratization" of electric power, emergence of new market participants, flexible energy exchange;
- transformation of the electricity market regulation system: transition from support of energy producers (including renewables) and competition in the electricity market to stimulation of active consumers, integration of DER into the unified power system, transition to a "flexible market".

New basic concepts of the transition:

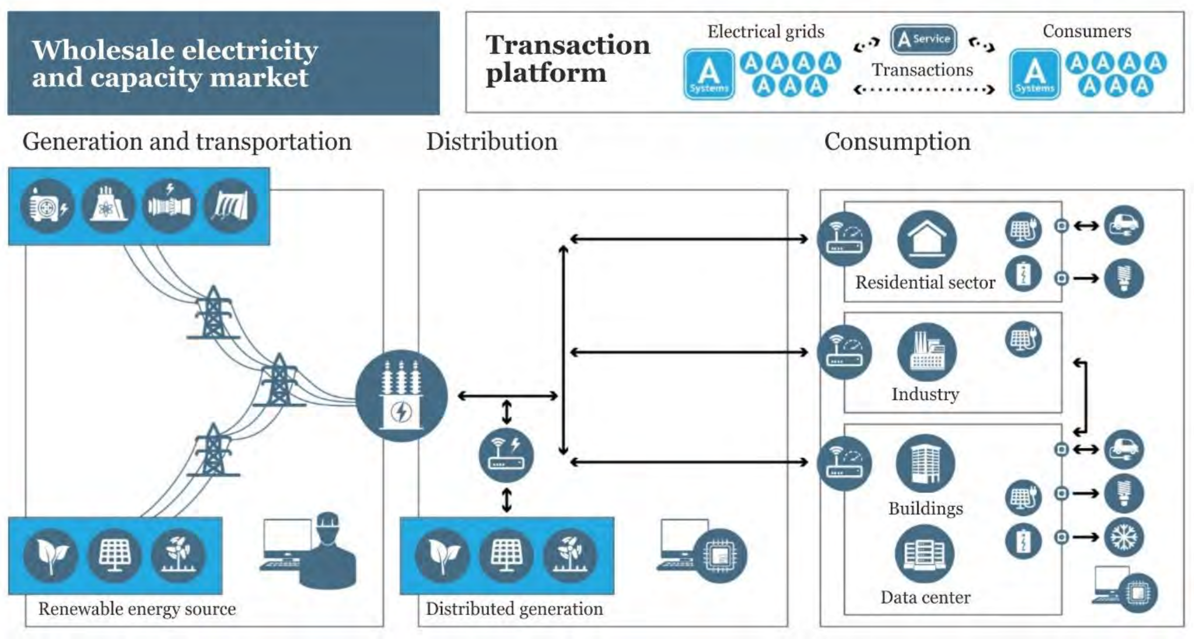
- the active consumer: a new subject for the energy industry which, in addition to the traditional function of energy consumption from third-party sources, performs the function of energy storage and generation (combination of consumption with technologies of distributed generation, distributed storage, demand response, etc.);
- Internet of Energy: this concept has several different definitions:
    - a set of electric and digital communication channels and protocols allowing the organization of automatic interaction between the players in the electric power market [32];

[32] Definition of the Energy Centre of the SKOLKOVO business school.

- an integrated dynamic network infrastructure based on standard and state-of-the-art communication protocols that connects electrical grids to the Internet and allow energy resources (produced locally, stored and sent) to be used where and when it is needed [33];
- a cybernetic physical electric power system that unites users as active consumers, and which permits free energy exchange and allows them to provide power for future use (providing sharing)[34].

Thus, to implement an "Energy Transition", the Russian power system will have to convert consumers to being "active" users of the Internet of Energy technology (Figure 21).

Figure 21. Architecture of the Russian electric power sector (target vision)



Source: Center for Strategic Research

One basis for the new technological paradigm in power generation is the end devices of consumers with controlled demand, as well as distributed generation and energy storage systems located on the consumers' side and/or in low- and medium-voltage distribution grids close to consumers.

New elements of architecture will be:

- controlled interfaces that enable the integration of active devices in the distributed power system;

[33] Definition of ARTEMIS Joint Undertaking, Project "Internet of Energy" (consortium of 38 companies from 10 European countries).
[34] Definition of Center for Strategic Research.

- “energy routers" installed at the "borders" of different scale power systems, for smart control of the electricity exchange between systems;

- control and service platforms that provide unified access to all DERs and energy routers, flexible organization of energy exchange and other services, harmony of economic relations between old and new players in the electric power industry.

In the concept developed by the Centre for Strategic Research[35], changes in the existing architecture of the Russian power sector can be carried out at the level of distribution grids by gradually transforming them into clusters of new energy. They would combine DER and integration into the common information space. In this concept, generating capacities, transmission and distribution grids, large consumers remain in the traditional paradigm for a transition period.

This transition period will last until the cumulative weight of the new clusters in the overall large power system requires free energy exchange between them.

The main principles of the new architecture will be:

- bi-directional electricity exchange in the distribution grid, technical feasibility of DER connection to the grid, complex closed-circuit topology of medium and low voltage grids, use of controlled interfaces and power flow control facilities;

- decentralized multi-agent approach to different scale power system control, ensuring reliable energy supply to consumers taking into account dynamically changing technical and economic conditions of energy exchange;

- platform organization of DER markets, energy services for consumers and infrastructure organizations, use of modern information and financial technologies.

Clusters within the new architecture will be deployed and developed simultaneously with the development of the UPS of Russia. The clusters will have electrical connections to the UPS (unidirectional and, in the future, bi-directional grids). They will partially use the network infrastructure of the UPS for power flows between geographically remote consumers and their associations. The new architecture will begin on a “bottom up” basis and will involve small distributed generation and end users of existing power systems. At the first stage, it will "capture" energy resources of relatively small capacity (10-10, 000 kW), operating at low and medium voltage (0.4-10 kV). In the next stages, development of new energy technologies and the Internet of Energy will affect the UPS of Russia at all levels, completely changing its architecture.

[35] The Project “Architecture of Internet of Energy” was approved as of December 7, 2017 by the Interdepartmental working group on development and implementation of the National technology initiative under the Presidium of the presidential Council for economic modernization and innovative development of Russia.

The regulatory regime: necessary changes

To implement the "energy transition", and to restructure the power industry's architecture, it will be necessary to make large-scale changes in legislation relating to the power industry.

The regulatory base of the market after the changes should ensure the formation of legislative conditions for development of the electric power industry in this direction. The main limitations are that the new regulatory base should:

- create new opportunities for consumers;
- ensure system efficiency (to create conditions for realization of advantages for other entities and for the system as a whole);
- "legitimize" the appearance of new entities (active consumers and prosumers, operators, microgrids and aggregators of DER, various services business), deregulate relations between them, standardize the interfaces of interaction with the UPS, and transform electricity markets.

There is also an important time limit: new regulatory documents should be developed, agreed with the main regulators of the market and issued in the form of enacted regulations (level of government resolutions, changes to Federal laws and below) by 2020-2025 (a period of possible capacity shortage in the power system).

The main obstacle to this reform is that, in the current institutional environment, the major market players and infrastructure organizations are not interested in such a transition. Retail consumers and DER remain outside the field of competitive mechanisms, and face regulatory barriers to implementing new approaches to energy supply.

In addition to this key obstacle, the following problems should also be noted:

- The lack of preparedness of state regulators and infrastructure organizations for energy market liberalization and the emergence of new types of "active consumers".
- The technological lack of preparedness of the Russian power system for the mass emergence of "active consumers" connected to the grid, and for the distribution of bi-directional and multi-directional flows of electric power.
- Obsolescent technical regulations and design standards in the power sector, their focus on outdated technologies, and a lack of practice of timely updating technical regulation standards.
- Traditionally, the Russian electric power industry has focused on ensuring high reliability and capacity, rather than on the efficiency of the system and meeting customer needs.

- Long-term and costly procedures for new entities entering the wholesale market, restrictions on use of alternative energy technologies and forms of organizational relationship;

- The extensive practice of cross-subsidizing (despite the declared principles of the need to eliminate this practice, actual volume continues to grow);

- The positioning of electricity as a special commodity with specific regulation so that many significant market parameters and related services are not structured to allow assessment by the market;

- The complexity, extent and instability of the regulatory base for the electricity sector (that results in non-transparent market operation, which further complicates market entry and increases risk).

The most feasible approach in Russia would be the creation of a balanced power system model that could provide an optimal combination of the elements of the "new" power system and a centralized, "large", electric power system. To do this, it will be necessary to take a number of fundamental measures[36]:

- Create the regulatory conditions for the emergence of new electric power entities and implement flexible ways in which they can participate in electricity exchange. Necessary changes to the legislation of the power sector will include the following:

    - legislating for a new type of market participant ("active consumer", "active energy complex") which complies with the standard of controlled connection to the electric power system, and which is fully responsible for managing its energy supply while, at the same time, has the minimum of regulatory restrictions on its method of operation;

    - improving the rules for trading systems to help create DER markets that ensure the effective exchange of goods and services between traditional market participants and participants of a new type;

    - providing for trading and other systems that support a variety of servers, intellectual software agents and systems authorized by their owners to carry out transactions independently in accordance with the specified goals and heuristics;

    - ensuring the possibility of using technologies for coordinated control of DER and consumers, energy storage systems, load control systems ("aggregators") in order to improve their efficiency and increase their participation in Power Joint Markets, including systemic services and other functions in these markets;

[36] Expert analytical report "Digital transition in the power industry of Russia" by the Center for Strategic Research with participation of experts of the working group "EnergyNet" of the National technology initiative of Russia

  - increasing the technological and economic flexibility of requirements for the reliability and quality of the power supply, giving the consumer the ability to choose power supply conditions and facilitate cost accounting;
  - developing a method for analysing the capabilities of the "new" solutions to assess, form and implement investment programs in regulated companies (including implementing methods of investment project evaluation in respect of ownership cost throughout the life cycle of the solution).
- Review cross-subsidizing practice in the power sector in order to obtain more accurate and useful economic signals for technological renewal and energy efficiency in those areas where the best results can be achieved, including:
  - avoiding the practice of preferential technological connection to electric grids regardless of the real economic cost of the solution (since this inhibits the development of alternative, more efficient, energy supply technologies);
  - changing the structure of payment for grid services to show the payment for reserving the grid power of the connection;
  - changing the structure of payment for electric power with the exception, or minimization, of the components related to cross-subsidization, while adding components that reflect reliability and the quality of the supplied power;
  - replacing cross-subsidization of the public by industrial consumers with mechanisms of targeted social support for the needy segments of the population or with a system which limits consumption at preferential tariffs (social norm);
  - stopping further deployment of the subsidized electricity supply system in some regions at the expense of consumers in other regions (because it leads to an increase in non-efficient energy consumption in the subsidized regions which are not provided with sufficient generation capacities and infrastructure);
  - minimizing cross-subsidization in heat supply in order to increase efficiency and demand for sources that combine the generation of electricity and heat.
- To develop measures to stimulate the implementation of up-to-date, innovative solutions in the power industry, including the following:
  - development of model implementations of new power system architectures of different scale (house/building, micro-district, industrial site, settlement, city);

- changes in the technical regulation and design standards based on new technologies; changes in programs of power infrastructure development;
- transition to the practice of tariff-regulatory experiments in the heat and power industry in certain places;
- implementation of innovative solutions in the power industry with the support of infrastructure organizations;
- stimulating implementation of regional programs ("pilot" and "regular") aimed at the integrated development of the energy sector on the basis of new approaches, technologies and practices, as well as ensuring development of high-tech companies of small and medium-sized businesses.

Detailed proposals for revision of the relevant legislation are summarized in the Appendix No.4 of the Russian version of this report.

QUALITATIVE ANALYSIS OF THE ADVANTAGES AND DISADVANTAGES OF THE WIDE USE OF DISTRIBUTED ENERGY RESOURCES

Increasing the role of DER creates advantages and disadvantages for all players of the energy market and for the economy as a whole. In this study, quantitative indicators were not studied, but an attempt has been made to qualitatively assess all significant effects.

The analysis assumes the active development of DER when most of the existing barriers described in the previous Chapter have been eliminated, and the possibility of obtaining systemic effects exists for all stakeholders.

Consequences for energy users

Typical **positive effects** for energy consumers when involved in the distributed energy development as investors or owners of distributed energy resources (**active consumers**) can be divided into two groups:

1. Benefits for the power supply of the core activity (business).
2. Profit from DER business activity.

The benefits for the power supply of the core activity include:

- enhanced long-term control of reliability and the cost of energy supplied for their own needs, with reduced uncertainty;
- reduction of direct power and capacity costs (bill cost) compared to those when purchasing from the common grid (taking into account the whole price structure, including wholesale price, grid tariff for the particular class of voltage and sales allowance, and taking into account different sale tariffs by consumer groups);
- reduction of direct heat supply costs compared to the energy purchased from external suppliers;
- reduced input costs (connection fees) for new or growing consumers;
- the ability to control the reliability and quality of the electricity and heat supplied, and to adjust the quality to suit individual needs, with corresponding changes in cost;
- flexibility, increased consumer choice (between energy supply methods, suppliers, prices, etc.).

The opportunities for new business include:

- entry into the market for electricity and heat as an independent supplier of energy and related services;
- income from demand response programs;
- participation in aggregated associations of DER (virtual power plants).

Positive effects for passive consumers, those not directly involved in the development of DER:

- reduced electricity prices by shrinking the investment component when DER can lower the share of expensive and large projects in the power system that are not needed by consumers;
- reduction of electric power costs due to increased competition; emergence of independent energy suppliers and related services;
- flexibility, increased consumer choice (between suppliers, prices, etc.).

Risks and additional costs that may appear for consumers investing in DER (generation, demand response, energy efficiency, etc.): these are **active consumers**:

- a decrease in reliability and increase in the cost of supplied energy in comparison with the traditional model of energy supply from the power system due to erroneous planning, engineering, implementation of self-generation projects, including the operation phase (errors are quite likely as the energy production is a non-core business for the vast majority of consumers) ;
- the need for organizational changes: development and maintenance of appropriate competencies for the new activity;
- withdrawal of investment capital from the main activity in order to create and maintain the energy infrastructure for self-generation systems, for demand response programs and the appropriate control systems, etc.;
- high investment risks of DER projects (long payback period, etc.), sensitivity to the presence/absence of special competencies;
- small effects due to the small share of energy costs in prime cost;
- expenses for additional reservation in the event that reservation from centralized energy is not carried out (for example, at operation in "island" mode).

Risks and additional costs for passive consumers that may occur for those not directly involved in the development of DER:

- growth of the grid portion of the power cost if the existing practice of consumers "leaving" for self-generation continues, shifting part of the cost of maintaining grids to the remaining consumers;
- reduction of power supply reliability in the event of errors in the technical integration of DER into the centralized power system.

Consequences for the electricity producers

Decentralization of the electricity sector may give the power producers (if they are involved in this process) the following advantages:

- optimization of capital and investment resources, diversification of activities in different markets and pricing regimes;

- growth of profitability due to projects in distributed generation, especially co-generation with a guaranteed market;
- a strong competitive position in comparison with new investors (including consumers) as they have more special experience than other players;
- strategic export prospects for models and practices in the growing global market for DER.

Disadvantages and risks:

- risks for core business include a decline in the wholesale market, reduced demand for large capacity plants and for utilization of existing assets, as well as fewer and smaller investment projects, and reduced revenue in the wholesale market;
- increased competition with other manufacturers (including new players);
- the need to correct business models, and make organizational changes.

Consequences for electric grid companies

Benefits and positive effects:

- increasing activity in distribution grids, increasing number of connections (in particular, when new DERs do not work in "island" mode and when reservation of the "active" consumer is performed from the grid), plus a growing number of payments for connection and for reservation;
- the opportunity to develop new types of business using owned assets (for example, control services for DER), their qualitative improvement toward the Smart Grid, and development of functions inherent for Distribution System Operators (DSO);
- strategic prospects for the export of models and practices in the growing global market for distributed energy.

Disadvantages and risks:

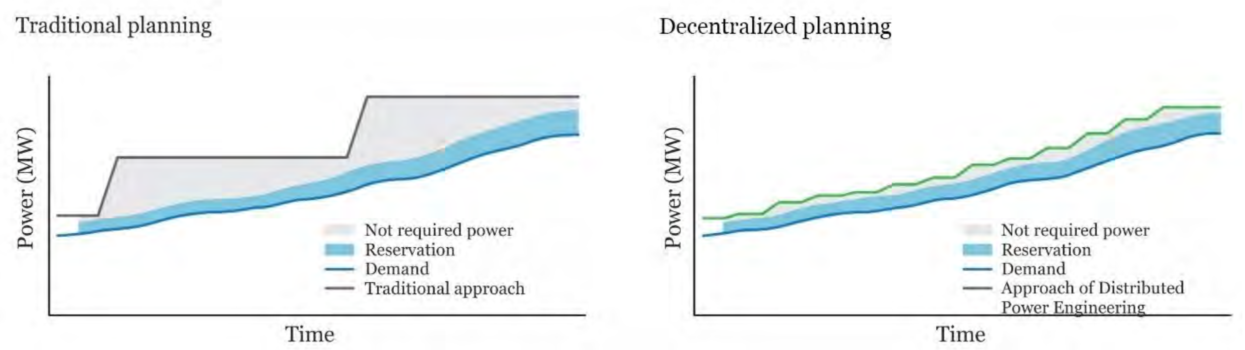
- reduction of electric power transfer via existing grids, especially transmission networks, reduction of revenue; reduction of traditional investment programs;
- technological difficulties in the integration of small generators into the system (including their impact on reliability), and the need for capital expenditure for modernization of distribution networks, protection, automation, etc.
- the need to acquire and develop new competencies.

Consequences for the power market

Benefits and positive effects of DER development:

- reduction of costs of the grid and large-scale generation development, including:
  - the ability to add new capacity in smaller increments depending on the actual demand dynamics and location (this reduces the risks of investment immobilization due to the better adaptability of DER to real demand and reduced impact of forecasting errors), as shown in Figure 22;

Figure 22. Difference in approaches to the generating capacity development in traditional planning (by means of the construction of large stations) decentralized planning



Source: SolarCity Grid Engineering

  - by rejecting the need to 'shift right on schedule' projects on construction of new facilities and/or network infrastructure, replacement of the increasing demand with demand response or energy efficiency solutions.

- improving the efficiency of generating capacity utilization due to direct connection to final consumers (for example, the utilization rate of installed capacity of industrial (owned by industrial enterprises) power plants in 2013-2014 in Russia was[37] 60.4% against the average for the UPS indicator for TPP at level 49-50%);
- equalization of the load schedule by using the technologies of demand response, facilitating control modes of the power system and equipment;
- reduction of grid electricity losses (especially in transmission grid);
- increased reliability, which includes the faster restoration of power supply after natural disasters or cyberattacks; reduced peak load in the power system;
- reduction of all-system costs by means of local value of DER and reduction of generation and grid reserves, growth of competition in the sources, expansion of consumer choice and, as a result, corresponding price reductions;

[37] Report on functioning of the UPS of Russia in 2014. / System Operator. [Electronic resource.] - Access to http://so-ups.ru/fileadmin/files/company/reports/disclosure/2015/ups_rep2014.pdf is free – (27.12.2017).

- the elimination of distortions and distorted economic signals for market participants.

Disadvantages and risks of decentralization:

- increasing complexity of the power system and market space from the point of view of scheduling, control, regulation and monitoring due to the emergence of thousands of small generators, storage devices, new services and contractors.
- changing the traditional principle of central planning and future development in the power industry.
- distribution of responsibility for reliability of power supply to consumers in the event of failures in distribution grids;
- acceleration of consumers' switch to self-generation which will shift part of the cost to the remaining consumers (in the absence of an integrated approach and disbalance of interests toward maintaining/strengthening the relevant incentives for consumers);
- the need to seriously adjust the established market model and make changes in the regulatory base.

Consequences for the Russian economy

Advantages and benefits of decentralization:

- increasing competitiveness of industrial and commercial consumers and a reduction in the financial burden on household consumers when changing the conditions of electricity supply-price, reliability and quality of supplied electricity, which would improve economic growth;
- containment of electricity and capacity tariff and price growth, cost optimization;
- reduction of GDP energy intensity, reduction of emissions due to replacement of traditional generation technologies and the development of co-generation, leading to an increase in grid efficiency;
- creation of centres of demand for innovation, multiplicative effects of investments in new technological sectors of the electric power industry, including the impetus for innovation in manufacturing industry (engineering, production of new materials), ICT;
- increasing attractiveness of the Russian electricity sector for investors.
- emergence in Russia of companies capable of developing new competencies and entering the large-scale global market for equipment and technologies.

Disadvantages and risks of energy decentralization:

- complication of the power sector as a subject of state regulation due to the multiplication of subjects and the lack of a "single centre of responsibility".

- social stress imposed by rising electricity prices, increased numbers of blackouts, and accidents;
- problems with single-industry towns located at large combined heat and power plants when those are decommissioned, as well as in coal enterprises which are technologically connected to specific power plants.

The above qualitative analysis of risks and benefits shows that distributed energy has valuable advantages for all market participants and for the Russian economy as a whole. The advantages will be manifested to different degrees in specific projects, so it is important to analyse them separately in each case.

The next chapter describes the priority actions that will help to minimize the risks of the distributed energy industry.

PRIORITY ACTIONS

This study has shown that to obtain systemic benefits from DER development for all market participants and the economy as a whole, significant changes in sector regulation and practices will be required.

There is an important time constraint: these changes in the regulatory acts will have to be made before 2020-2025. If that happens, DER can not only become a driver of the industry, but also help to solve the practical problem of replacing obsolete generating capacity. This means that we need to initiate priority action right now.

First and foremost, it is necessary to recognize DER's potential as an important element in the Russian electrical power industry's development. Despite this apparently commonplace observation, a significant proportion of the expert community and the market regulators in Russia consider decentralization as a local solution, and more a source of problems for the power sector than a catalyst for its development.

The new technological structure is already making autonomous and distributed power supply more attractive for consumers all over the world, regardless of the views of regulators, traditional power companies or consumers still within the power system. For example, the Rocky Mountain Institute (RMI), when analysing similar trends emerging in the U.S. power system, called this process a "utility death spiral". RMI encourages the latter to take a proactive approach and seek, before it's too late, new business models. In a rapidly changing world, centralized and distributed energy resources will coexist, and be connected by dynamically evolving electric grids.

Removal of barriers to DER development will mean significant changes in the existing Russian market architecture and regulatory background. It will be necessary to "legalize" the emergence of new entities in the DER market (active consumers and prosumers, microgrids and aggregators of DER, various service businesses), to remove regulations controlling their inter-relationship, to standardize interfaces for their interaction with the unified power system, and to transform electricity markets. In addition to specific proposals for changes in the existing legal base, described in detail in Chapter 4, the following recommendations emerge from this study:

For co-generation development:

- to study world practice in the field of distributed co-generation development, and to develop a strategy for this sector's development in Russia;
- to establish key performance indicators for regional leaders (governors, mayors) for the quality and reliability of heat and electricity provision for the population, and also in connection with co-generation;
- to set priorities for CHP development (including distributed co-generation) in the heat supply master-plans of cities and towns (with the obligatory elaboration of appropriate options for heat supply scheme development).

For the development of self-generation:

- to allow implementation of pilot projects in the field of self-generation in order to obtain positive effects for all power system shareholders (taking into account the changes in the regulatory acts described in Chapter 4);

- to support those pilot projects by promoting systemic effects and the sue of co-generation technology;

For the development of renewables-based micro-generation:

- to liberalize the micro-generation market as far as possible;
- to remove restrictions on the format, prices and methods of payment between market participants;

To develop demand response and energy efficiency, to stimulate the emergence and development of distributed energy storage systems:

- to test pilot demand response technologies and practices (including those for retail consumers, with the participation of demand aggregators), and the use of power storage systems;
- to raise awareness and/or0 strengthen the motivation of consumers to participate in demand response and energy efficiency programs by providing appropriate support to new participants through the rules of wholesale and retail markets.

In addition, it is recommended to ensure equal participation of projects for DER development, for the expansion and modernization of the electrical grid infrastructure, and for the construction of large-scale generators in competition in order to eliminate local power shortages (and also to include all such projects within the mechanisms of the power market).

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