Universe Scientific Publishing

ORIGINAL ARTICLE

# Small-scale Distributed Power Generation Development in the Siberian Regions: Evaluation of Efficiency

**V.M. Markova**[1], **V. N. Churashev**[1]

[1] Institute Of Economics and Industrial Engineering SB RAS Ave. Ac. Lavrentiev, 17, Novosibirsk, 630090, Russia

***Abstract:*** It is shown that topical issue is the solution of problems of enhancement of structure electro and heat generations in the Russian regions, including through synchronization of schemes electro and heat supplies. It causes the necessity of integration to municipal level power engineering into development plans for large power industry that causes gain of a role of the distributed power engineering (including the cogeneration installations). The carried-out serial calculations for comparative assessment of a row of technologies of the small-scale distributed power generation in the Novosibirsk and Kemerovo regions allowed to select the perspective directions of diversification of energetic branch.

***Keywords:*** Small-scale distributed power generation; cogeneration; schemes of power industry and heat supply development; energy efficiency; siberian region

## 1. Introduction

Due to the revision of energy consumption growth rates, lack of available investment resources and the long payback period of large-scale power units there is a relevant question of finding of an optimum combination and balancing of large generation objects and low and medium power distributive sources.

The increased role of distributed energy makes it possible to reduce the cost of generation and network complex development by adding new capacities with smaller increments depending on the actual dynamics and location of demand (which reduces the risks of investment deadening due to the better adaptability of distributed energy to real demand and reducing the consequences of forecasting errors). The actual realization of the distributed energy potential depends on the economic competitiveness of specific projects in specific regions compared to alternatives (modernization or construction of centralized generation capacity or network infrastructure). In the present study an attempt is made to assess the benefits of distributed energy development for the two Siberian regions - Novosibirsk and Kemerovo.

## 2. Materials and methods

The majority of cities in Russia are traditionally supplied through electro-and heating systems from power plants and high power boiler houses. The similar trend in an energy sector is technologically and historically developed in connection with the manifestation the so-called economies of scale, which are inherent only in large stations with large installed capacity. But large generation facilities have disadvantages: low capacity utilization factor of installed capacity of power plants - 52%, low quality of power supply, the high frequency of the emergency shutdowns, the high degree of depreciation of power generating and network equipment, large volumes of pollutant emissions and thermal discharges


doi: 10.18686/mmf.v2i2.1095

from large sources. The increasing demands for energy security of regions as a whole, and separate local hosts.

Many experts believe that Russian “large” power industry has reached a limits of effectiveness (destruction of scale effect due to increasing complexity of power plants and their managements, growth of network losses, difficulty of control for individual demand etc.), resulting in the growth of tariffs for electric and heat power, and also observed the dominance of the energy production problems over optimization of its consumption[1-4].

Economic crises in 2009 and 2014 have shown that orientation toward the development of “large” power did not produce desired results. In the General scheme-2030 (General`naya Shema) has planned input of large power objects with a total power of 39.5 GW through period 2010-2015, but in fact less than 25 GW were put into operation[1,2].

Small distributed power – generating facilities with a capacity less than 25 MW, located in the vicinity of the user with the ability to use energy storage systems and Smart Grid technologies.

In addition to traditional energy sources (coal, oil, gas, etc.) it can be used alternative renewable sources (wind and solar generators).

The advantages of cogeneration heat power plant compared to large CHP the following: the absence of costs for the construction of high voltage transmission lines (power lines); the elimination of energy losses during transmission; uninterrupted supply of consumers with quality electric power. Consumer acquires energy independence from power failures and accidents in heat supply systems; the possibility of obtaining a profit in direction of electricity in the centralized power grid. The high investment attractiveness of small generation is caused by relatively low level of initial investments, a fast commissioning possibility, consumer control (table 1).

| | |
|---|---|
| Prerequisites | Tariff increase<br>Decline in the quality of supply centralized energy<br>Difficulties or lack of technical capability to connect to electric grids and increasing in the cost of connection<br>"Preferential fuel" (associated gas, sawmill and agricultural waste)<br>Demand of electric and thermal energy |
| Obstacles | Unformed legislation<br>Additional technical coordination and need of compliance to standards<br>Possible counteraction from the generation companies<br>The need for the purchase of fuel and increasing prices<br>Relatively long-term investments<br>The lack of a structured development plan and account in strategic documents |
| Advantages | Energy production in close proximity from consumption<br>Lower costs of electricity and heat (part of network’s component)<br>Reliability of power supply, prevention of emergencies<br>Improvement of quality of energy<br>Ability to meet local energy demand<br>Increase in efficiency (cogeneration)<br>Low environmental pressure |

**Table 1.** Small-scale power generation: prerequisites, obstacles, advantages

There are three main reasons for slow development of distributed energy. The first is technological. Russian power industry mainly used imported technologies, and the transition to domestic, even if the development requires skills and time. Second – financial. High interest rates, unfavorable market conditions also affect the decline in business activity in this area. And the third aspect – organizational: lack of developed legal and regulatory framework and budgetary arrangements and tools for implementation of pilot projects in the area of the small-scale distributed energy are insufficiently fulfilled.

Abroad important strategic documents on development of distributed generation have been accepted since

2004-2005 in EU countries (The directive 2004/8/EU from 2/11/2004 "About development of a cogeneration on the basis of useful heat in the domestic energy market"), the USA (California. The development plan for the Distributed generation), Australia (The program for reforming of power industry of Australia)[2].

In Russia the active attention to this subject has begun since 2009, a year later has been founded the technological platform "The Small-scale Distributed Energy"[5,6] that has allowed to set a new vector of development of distributed generation. Since 2013 the Ministry of Energy of the Russian Federation has defined the distributed generation as one of the priority directions of energy development, was formed the working group on intellectual energy, and in the same year was created non-profit partnership "Distributed generation", and in 2015 in the framework of the National technology initiative was formed a working group EnergyNET.

There is no standard accounting of a small distributed generation power in Russia now. According to one data the distributed generation share in an energy balance is estimated at 1.4%, the capacity – about 3 GW, on others, taking into account the renewable energy sources various installations, total the capacity is 7.7 GW, and when accounting installations of the industrial enterprises - to 17 GW[2,5,7]. By different estimates in power industry of the Russian Federation more than 50 thousand objects of the small distributed generation (among them about 1,5 thousand objects are mini-combined heat and power plant) function and their number continues to increase. Total capacity of all operating renewable energy sources (wind, solar, geothermal installations) doesn't exceed 155 MW, about 300 more MW make micro and mini-hydroelectric power station. About 70% of the small power plants capacity and the renewable energy units are located in a regions Russian Asian part, which haven't centralized power supply. At the same time the share of small generation (up to 30 MW) in the total capacity of thermal power plant is from 1% in the Central Federal District to 14% in the Far Eastern Federal District[5,7].

But also in a zone of the centralized power supply consumers have interest in diversification electro-and heat supplies. Power plants of small and medium power were widely adopted for the last ten years enough in megalopolises and the large cities, both at the industrial enterprises, and in the sphere of municipal power supply. Prospects for development of small generation are connected also with such areas as: mobile consumers (transport, construction, logging, geological exploration, tourism, hunting, agriculture, emergency and rescue services, household consumers, etc.); households, cottages (reserve and "additional" power supply); regions where there is a local fuel: peat, biofuel (agriculture), waste.

Till 2010-2011 the development of small generation was not paid enough attention in strategic documents and was implemented according to the "residual" principle: in Russian Energy strategy-2030 (Energeticheskaya strategiya) a development indicator was set - a share of the distributed generation of 15% in electricity generation on thermal power plants. The General scheme provided for the input of capacities of the distributed generation in basic (3.1 GW) and maximum options (5.9 GW)[2].

In new versions of these documents (in the Energy strategy-2035 and in the General scheme) it is supposed to increase the total power of the small distributed generation to 50 GW at decrease in the reconsidered volumes of inputs of large stations from 173 to 123 GW in the long term till 2030. It is planned to increase a share of renewable energy resources to 5 GW [2].

Many scientific organizations note also the importance of development and integration of the small-scale distributed power generation for several decades[3,12,13,14,15]. The general conclusion - small-scale distributed energy has the market niche in power supply for the period up to 2030-2035 along with development of "large" generation and this niche is quite significant.

It is more difficult to determine the place of small-scale distributed power generation in the heat supply development. Since the beginning of the Russian market reforms of the 1990th years the industry of heat supply usually was considered as necessary, but secondary to the electro generation. Only recently understanding of her key role in national economy has come. The heat-and-power engineering has the largest reserves and the prospects of development: by an energy equivalent, one and a half times more than the electricity supply, and three-four times more in total expenses of consumers – the population and the enterprises.

The heat production in central district heating systems of the Russian Federation is about 1300-1500 million Gcal per year. Today 528 thermal power plants (from them 332 general use and 253 industrial enterprises) produce about 570 million Gcal of thermal energy per year or 38-40% of a district heating total volume. The rest of a heat is delivered from 70 thousand municipal boiler houses with an average power of 8 Gcal/h and with an average efficiency of 75%. At the same time it was repeatedly noted that thermal sources have a significant surplus of power, so the boiler houses capacity utilization factor is 18% on average, combined heat and power plant – 31%[13, 14].

By estimates of the Ministry of Energy of the Russian Federation the heat supply from thermal power plants for 20 years (from 1992 to 2012) decreased by 1.5 times due to the reduction of the industrial thermal load of thermal power plants and substitution them by boiler houses, which reduced the total share of cogeneration output[13, 14].

An obstacle to active promotion of cogeneration in the regions is the lack of a proper institutional basis and financial support for its development, both from the federal center and from administrations of territorial subjects of the Russian Federation. Cogeneration units regarding heat are objects of municipal power energy interests, and regarding an electric power – objects of regional and federal interests. As a result there is no uniform center of responsibility. Undoubtedly, the fact that former orientation to developing only of schemes and programs of a power industry development without interconnection with forecasting of heat supply at the municipal level is wrong.

Development of power infrastructure, formation of a kind of municipal fuel and energy cluster, has to begin with assessment of prospects of economic development of the territory, the forecast of a power consumption, heat consumption and fuel, balances of electric energy and power. If the municipal power energy in a legislative order had the corresponding status which would allow it to define investment process on the basis of regional programs, then according to experts it wouldn't be necessary to build so many the generating capacities[2].

Now development of objects of the small-scale distributed power generation is complicated in many respects due to the lack of adequate legislative support. Among a huge number of various normative legal acts regulating energy sector in general, only a few have the relevant articles about small-scale distributed power generation. Often this definition refers to renewable energy facilities or small power generation plants act as border cut-off for consideration

There is no doubt that in the future the role of the small power can be greatly strengthened and its legal support can be implemented through amendments to existing legislation or through the adoption of a separate Federal law on small-scale power generation.

A necessary condition for large-scale development of the domestic small-scale distributed power generation is existence of various effective technologies. The set of technologies of the distributed generation of energy covers installation capacity of 25 MW, including both traditional and non-traditional and renewable sources of energy such as:

• Combustion power plants on hydrocarbon fuels (oil, gas, solid fuel, including biomass, coal, municipal solid waste) to produce electric and thermal energy.

• Turbines (wind turbines) and small hydropower plants, widely used in small distributed systems of supply.

• Solar energy converted to electrical installations in photovoltaic and the solar power plants, and heat in the solar heat supply stations.

• Heat pump installations, which uses low-grade heat.

• Nuclear power station of low power.

• Fuel cells

One of the most promising solutions may be converting boiler-houses into mini combined heat power plant (CHPP). Currently on the market are a large number of units of different types, suitable for this: reciprocating engine gas plant (GEP), gas turbine plant (GTP) and gas combined cycle plant (CCGT). These settings vary considerably in terms of efficiency and power bands respectively have different ratio of electric and heat power and different value of the fuel utilization factors.

Advantage of the cogeneration plants is that transformation of energy into them happens due to use of waste heat which is usually simply lost. Practically any boiler house can be converted into mini-combined heat and power plant by adding existing boilers to gas turbines or gas piston engines.

Depending on the sales volumes of electricity and heat, there are the following options of reconstruction of boiler houses on the basis of the innovative solution:

- in boiler steam pressure turbine in the bypass switchgear of the boiler, ensuring the realization of excessive steam pressure. A ratio of electricity generation and heat power of 10-20% to 90-80%. Basically provide own needs of a boiler houses without commercial realization of the electric power;

- reconstruction of boiler house with replacement of a boiler for steam turbine mini power plant while preserving or increasing the heating capacity and superstructure steam turbine, with boilers adapted to work on local fuels;

- complete replacement of boiler equipment by the cogeneration installations, with the drive from by internal combustion engines or microturbines for generating gas (synthesis gas, biogas or pyrolysis gas), at the same time the ratio of electric and thermal power of 1 to 2 or more when post-combustion gas or other fuel in the recovery boiler. The use of prior gasification of the fuel provides a significant reduction in environmental loads and a possibility of building in areas of dense urban development;

- use in boilers pre-prepared pulverized coal delivery and storage in closed containers, which reduces the area of the coal storage and ash disposal areas, and accordingly reduce the area of the boiler.

The realization of these innovative priorities is complicated due to the difficulties in providing domestic power technologies and the equipment. If Russian turbines /blocks prevail in large-scale power engineering, then small-scale power generation market was almost completely captured by foreign producers (GE, Alstom, Siemens, CATERPILLAR, etc.). The majority of import energy units characterized by higher electrical efficiency[7- 9].

As promising directions for reducing heat losses and utilizing thermal emissions with waste gases, it is possible to distinguish such technologies as: centrifugal-bubbling devices, absorption bromide-lithium machines (refrigerators and heat pumps), steam compression heat pumps.

The project of the waste burning plant assuming environmentally friendly burning of household garbage can become one of the directions of increase in efficiency of development of energy. The similar plant will allow to replace a number of boiler houses (with a capacity of up to 15 Gcal/h), to reduce consumption of organic fuel (specific consumption for the production of Gcal is 15-18% higher) and methane emissions.

In this work we have tried to evaluate by comparative efficiency of introduction of a number of power technologies and traditional power stations for regional system (Novosibirsk and Kemerovo regions). For these purposes the mesolevel model tools is developed and used in Institute of Economics and Industrial Engineering SB RAS[10].

It seems to us that the widely used method of evaluating investment projects based on the cash flows analysis does not provide an opportunity to capture the systemic effect of mass introduction of small-scale distributed power generation. Models of macrolevel allow to form reference points and tendencies of development only at the level of the industry and due to the large aggregation of information they do not sufficiently take into account the technological and regional features of the use of the estimated power plants.

A model of the regional fuel and energy complex was used as a model tool. This model is an optimization, balance type, in a quasi-dynamic formulation, with continuous variables. The model consists of four blocks and functional. The first block includes the primary energy resources production, the import and export of energy resources and the change of stocks. The second block describes the transformation of some energy resources into others, it determines the fuel balance of electricity and heat power. The third block reflects the final consumption of energy in various sectors of the economy and types of economic activity. In the fourth block calculation of the economic indicators characterizing development of fuel and energy complex of the region is made (for example, the required volume of investment, volume of installation and construction works, products volume, number occupied and the wages fund, the amount of contributions to budgets of various levels, etc.).

The optimality criterion of the fuel and energy complex development can be taken as minimization of total reduced costs, and maximization of profit. The following types of energy resources are distinguished in the model: energy coals (stone, brown and anthracite); natural and associated gas; heating oil; motor fuel, other types of fuel (peat, shale, firewood, sawdust, etc.), as well as electrical and thermal energy. Description of the interchangeability of traditional and new energy technologies is given on the basis of technological methods, expressed in economic variables (disposal and input of production capacities, inputs and outputs, etc.). Possible fuel suppliers from outside the region are considered in detail. As options for external power supply, transmission of electricity through power lines from the other regions is considered.

The mesolevel model allows to study reaction of regional energy industry structure to input of new ways of generation. From positions of regional effectiveness assessment of scales of distribution of technologies in the region, competitiveness of technologies various combinations, energy resources overall savings in the region is carried out when using new technologies in comparison with traditional technologies.

The reporting data on the volume of energy resources production and consumption, the cost characteristics of 2012-2014 are used for calculations. 2030 was considered as the boundary of the forecast period.

Assessment of perspective scales of development of power of the region was carried out with a support on expected volumes of consumption of energy resources. As a reference point for the expected level of energy consumption till 2030 the scenario assuming use of innovative sources of growth due to realization of competitive advantages of the Russian economy as in traditional branches (power, transport, the agrarian sector), and in new knowledge-intensive sectors and economy of knowledge has been chosen.

Formation of technologies set was carried out as taking into account world trends in development of power and on the basis of expert data[11,12]. The critical analysis of modern foreign and domestic literature sources, strategic documents has allowed to form a new technologies list having real prospects to introduction in regions of Siberia. At selection of technologies we were guided by the following criteria: increase in efficiency of energy resources use/production (primarily heat energy), a possibility of realization of technologies in the Siberian regions, presence of potential investors and inclusion in strategic power documents.

The effectiveness of various technological ways and scenarios was estimated on several indicators: to a fuel capacity factor, total fuel consumption (including to reduction of fuel consumption in comparison with traditional installations) and to total resulted costs (and including only on capital investments). The calculation was carried out at basic prices without inflation.

In order to quantify the extent of implementation of effective innovative technologies the rational from the standpoint of a regional system, then a series of calculations according to the following algorithm are carried out: considered in isolation separate technology substituting for energy in the full or partial amount of the traditional methods, and determined a regional system response to provide this new method using indicators of functionality, total fuel consumption and the fuel utilization factor.

# 3. Results. Opportunities and prospects for small generation and other innovative technologies in Siberian regions

The lack of full statistical information on the Siberian Federal District doesn't allow to carry out reliable calculations for assessment of prospects of small generation. This circumstance has forced us to pass from consideration macrolevel to mesolevel. In work we carry out calculations for two Siberian regions which are qualitatively differing on structure of economy and scales of development of power. Assessment of a niche of small-scale power generation was carried out for the Novosibirsk region (with diversified economy) and the Kemerovo region (pronounced industrial and raw economy).

The Novosibirsk region is positioned as one of the most dynamically developing territorial subjects of the Russian Federation with diversified structure of economy and with orientation toward an innovative development path. Unlike many other subjects of Siberian Federal District in economy of the Novosibirsk region there are no large power-consuming industries. There are no large energy-intensive industries in the economy of the Novosibirsk region. The energy intensity of GRP in the Novosibirsk region is 1.7 times lower than the average for Russia and 3 times lower than the average for the Siberian Federal District.

In the region structure of fuel consumption coal makes 57%, natural gas – 23% and oil products – about 19%. Among consumers the largest part is occupied by power plants – 44% and boiler units – 17%; in which structure of fuel usage about 80% are the share of coal. Such structure of consumption of fuel in economy and power of region has been preserved for a long time.

Balances of power of the Novosibirsk power supply system are superfluous, but proceeding from economic criteria obtaining power from Kazakhstan and interfacing power supply systems of UES (OES) of Siberia is expedient (totally about 300 MW). Power supply of consumers of the Novosibirsk region is carried out by six power plants, with a total installed capacity of 3014.5 MW. The main part of regional generating capacities is located in Novosibirsk having surplus of power, from where it is transmitted over long distances to the dispersed consumers. So, the western areas of the Novosibirsk region (more than 80% of the territory) receive about 95% of the electric power of the Novosibirsk power center over extended electric grids. All this causes high power losses.

The existing condition of system of heat supply of the city of Novosibirsk and other settlements of area differs little from an overall picture across Russia, keeping a number of unresolved problems: high total thermal losses taking into account the distributed networks, large depreciation of fixed assets and insufficient level of capital investments in modernization. However, due to sufficiently large agglomeration point (Novosibirsk with the adjacent cities) a research of problems of heat supply of the region should be divided for the Novosibirsk agglomeration and other rural areas.

There are about 1 thousand boiler houses and 5 thermal power plants in the region. In Novosibirsk the centralized heat supply captured about 86% of the territory, development of heat power is carried out by 4 combined heat and power plants and more than 200 boiler houses. In the heat supply system of the city, there are separate small departmental boiler houses (about 150 units) and large local boiler houses. In regions of the area the generation of heat energy is predominantly carried out in small-capacity boiler houses.

In the declared need to expand cogeneration, no one of the strategic regional documents specifies the construction of a mini-CHPP. In the developed heat supply schemes in Novosibirsk and other cities the majority of new boiler houses during the period till 2031 is planned to input on gas. At the same time the small-scale power generation of the Novosibirsk region presented now by a large number of small boiler houses. And they can be reconstructed and modernized in such a way that due to development of mini-combined heat and power plant will be able to satisfy all needs of regional consumers for padding volumes of electric and thermal energy. The boiler houses potential which are using gas and having the prospect of transfer to cogeneration objects, specified in table 2.

| Type | In agglomeration | In municipal districts |
|---|---|---|
| gas turbine plant (GTP) | 1350 | 150 |
| gas combined cycle plant (CCGT) | 2556 | 281 |
| reciprocating engine gas plant (GEP) | 351 | 93 |

**Table 2.** Gas boiler houses potential which are having transfer to cogeneration objects in the Novosibirsk region, MW

From the data in Table 3 it can be seen that about 90% of the boiler houses, perspective for transfer to the cogeneration mode, are located in the territory of agglomeration. At the same time, about 60% of the boiler houses can be converted into mini-CHPP to gas combined cycle plant, 30% - to gas turbine plant and 10% - to reciprocating engine gas plant

In the region, there are practically no alternative energy facilities operating on renewable energy sources, although there are prerequisites for the development of such sources.

As a guideline for the projected electricity and heat consumption levels, we used several program documents. Taking into account the planned activities of the energy saving program, no significant increase in heat consumption is expected. Its possible growth is largely related to the projected inputs of housing and shopping center areas.

Under the conditions of development of economy of area accepted in a task as a result of the carried-out calculations the inefficiency of the direction with orientation to development of a traditional power engineering which assumed construction of new CHPP by 2030 was shown at once: on the fuel utilization factor and to the given expenses it significantly lost to the direction providing introduction of new power technologies (table 3)

| | Large power generation development | Own generation stabilization | Small scale disturbed power generation development |
|---|---|---|---|
| Fuel utilization factor,% | 75.1 (92.7%) | 78.7 (97.2%) | 81.0 |
| Total cost, bln rubl | 53.5 (106.4%) | 51.0 (101.4%) | 50.3 |
| Fuel consumption, bln tce | 13.4 (104.7%) | 12.3 (96.1%) | 12.8 |
| Electric generation, bln. kWh | 18.2 (98.9%) | 13.8 (75%) | 18.4 |
| Electric energy Import, bln kWh | 1.3 (118.2%) | 5.7 (518.2%) | 1.1 |
| Share of small scale power generation (in electric production) | 0% | 0% | 26.3% |

**Table 3**. Perspective indicators of power engineering in the Novosibirsk region by variants (to % small scale power generation variant)

The direction without the own generation development is characterized by lower fuel consumption, which allows achieving a higher level fuel utilization factor. However it means increasing import of the electric power to 5-6 billion kWh. Due to the decrease in the region’s self-sufficiency power supply and tariff increase in case of aggravation of the competition in the wholesale market of united energy system of Siberia arise the electric power.

The direction associated with development of small distributed generation favorably differs from two previous in more high level of self- sufficiency (import of the electric power is supposed at the level of 1.1 billion kWh), a higher fuel utilization factor and a lower value of the reduced costs. At the same time, electricity generation volumes will be achieved, as in the case of the new CHPP construction, and fuel consumption will be lower.

The share of small-scale power generation in the total capacity of the Novosibirsk region power industry can be up to 15% under favorable conditions, and 28% (26% of the demand) for electricity generation, such small-scale power development in the region will be higher than forecasted in the Russian Federation as a whole.

The direction assuming introduction of technologies to small-scale power generation is characterized by the following resultant indexes:

- in the long term up to 2030 input of mini-combined heat and power plant among which construction of reciprocating engine gas plant, installations on a wood wastage and water-coal fuel is preferable, their share in development of heat power can make 11-12%, in the electric power – 25-26%; construction of other mini-combined heat and power plants is not effective;
- the heat pumps share can make about 5%;
- input of new boiler houses on water coal fuel is effective. Their share in heat generation can reach 5,5%;
- the choice of a technological way of utilization of solid waste "Complex Regional Thermal Station" is economically inexpedient that it is possible to explain with lower coefficients of an energy output. In further calculations we assume to consider more precisely economic consequences of realization of other products (scrap of ferrous and non-ferrous metals and so forth) and changes of an environmental pressure that will increase competitiveness of its.

The Kemerovo Region is a large territorial production complex and a base for industrial development not only in Siberia, but also in the whole country in its economic potential and specializes in the production of raw materials and products of its primary processing. The region occupies the 11th place in Russia and the second place in the Siberian Federal District (SFD) for the production of industrial products. The leading roles in economy of area belong to fuel and energy complex, metallurgy and chemical branch. About 20% of export commodity turnover of Siberian Federal District fall to the share of area. The region produces 2.5% of the Russian power production, 12.3% of the SFD, taking the 3rd place in the SFD on development.

The Kemerovo region, which has a specialization in raw materials, belongs to a group of regions of the country with a high energy intensity of the economy: the specific consumption of fuel and energy resources, measured in terms of unit fuel, for GRP production is close to the average for the SFD and 42-46% higher than the average for Russia.

Providing the planned power consumption without construction of power generating capacities is possible only with a marked increase of size of import of the electric power: by 2030 the volume of deficit of electricity in the territory of the Kemerovo region can increase about 17–19 billion kW of the h (from the current level of 9-12 billion kW of the h) that can significantly reduce self-reliance level to 60–65% against the existing 75%. The similar situation taking into account the developing intense balance of energy in the wholesale market of power and the electric power of Siberia is connected with a high risk.

As the scenario was considered based on (Energy strategy-2035 and General scheme-2030) the future growth of electricity generation at the expense of input of new power units at the existing stations (Tom-Usinskaya TPP – an increase of 1350 MW) and the input units to the new heat and power plant (increase in power to 645 MW) to cover the energy deficit in the region. Such a large-scale input of power capacity will improve the electric power self-sufficiency to 82 %, however, will require significant capital investments.

On the basis of a series of calculations, which were determined by reaction of the Kemerovo power system for input of new energy technologies, we developed the innovative scenario that has a set of perspective facilities, replacing traditional generating stations. Into this set entered reciprocating engine gas plant and gas turbine plant, mini-combined heat and power plants on coal, underground gasification facilities, boiler houses using water coal fuel and methane and also steam compression thermal pump (on gas).

Apparently from table 4, input of new technologies variant surpasses basic variant in efficiency indicators and allows to save in the long term about 2 million tce annually (or more than 30 overall for the period). Fuel utilization factor in basic variant owing to lower expenses on own needs of the electric power and reduction of thermal losses in innovative variant occurs decrease in development and electro-heat power. The total savings of thermal energy can be 1.6 million Gcal for the considered forecast 15-year period. At the expense of a combination of input of new technologies the specific given expenses from 197.1 are reduced to 143.6 rub/tce.

| | base variant | | new technologies variant | |
|---|---|---|---|---|
| Indicators | 2020 | 2030 | 2020 | 2030 |
| Electricity consumption, bln kWh | 40.1 | 45.3 | 40.1 | 44.7 |
| Electricity generation, bln kWh | 33.0 | 38.2 | 32.8 | 37.6 |
| Self-sufficiency | 82.3% | 84.3% | 81.8% | 84.2% |
| Heat production, mln Gkal | 50.4 | 59.3 | 50.2 | 59.1 |
| Fuel utilization factor | 57.4% | 58.2% | 58.6% | 70.7% |
| Fuel consumption, bln tce | 40.3 | 44.8 | 40.2 | 41.6 |
| Specific total cost of fuel tonne | 207.1 | 197.1 | 161.2 | 143.6 |

**Table 4.** Indicators of power engineering in the Kemerovo region by variants, per year

In a covering of internal need for the electric power the contribution will be made by mini-combined heat and power plants (on coal and on gas). Power generation at mini-combined heat and power plant by 2030 can make 8.2 billion kWh (18.5% of the total amount of consumption). The covering of additional requirement for heat power is carried out due to increase in development, on boiler houses on water coal fuel and mini-combined heat and power plant (at the same time only at mini-combined heat and power plant the gain of development of heat power by 2030 will reach 7.0 million Gcal that will make 12% of the general need for heat power).

At the same time up to 30% of the operating boiler houses can be effectively transformed (or are replaced) to mini-combined heat and power plant with a total capacity of 850 MW. Potential of using heat pumps at power industry of the Kemerovo region is estimated within 20–30% of replacement of development of boiler houses, their share in a covering of the need for heat power can make up to 14%.

In the above-stated variant the optimal solution had included the mini-combined heat and power plants burning coal, water coal fuel and wood waste, first of all thanks to lower cost of the used fuel. As new boiler houses there was a choice of boiler houses on water coal fuel.

# 4. Conclusions

The research conducted by us have shown that though two Siberian regions significantly differ on structure of economy of the Kemerovo region with specializes in production of raw materials and production of his primary processing with high power consumption of economy, and the Novosibirsk region has diversified structure of economy of without large power-consuming industries), in both regions there is a niche for development of the small-scale distributed power generation.

Indicators of energy production for new technologies variant are given in a figure 1.

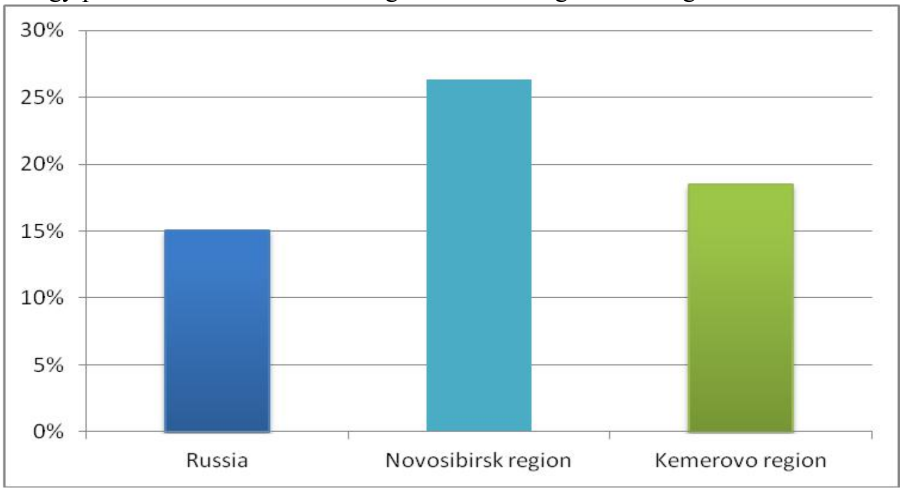


**Figure 1;** Share of small scale disturbed power in Electricity generation, 2030.

In the Novosibirsk region the priority direction is transformation of boiler rooms in mini-combined heat and power plants among which construction of reciprocating engine gas plant, power stations on wood waste and water coal fuel is preferable. Realization of this direction will allow to improve indicators the Fuel utilization factor of power of area to 79-82%, to cut down annual expenses on fuel on 2 billion rubles, to reduce losses of heat power and to increase a share of small-scale power generation in development of heat power to 30%.

For the Kemerovo region construction of mini-combined heat and power plant using coal methane and water coal fuel, underground coal gasification station and also thermal pump is preferable. Implementation of the innovative scenario in comparison with the scenario of development of traditional power will allow to raise by 2030 a fuel utilization factor from 59% to 71%, to save fuel about 2 million tce annually and to lower the specific total cost from 197.1 to 143.6 rubl / tce.

For effective development of the small-scale distributed power generation it is required to develop mechanisms of coordination of interests of the state and business at the level of the country, regions and municipal units. The state can't separate from participation in process of creation and introduction of innovations. However there shouldn't be also a total state regulation which as practice shows, often negatively is considered by other investors. In power rules and procedures – accurate, clear, long-term are necessary for successful realization of all innovative actions.

As the measures promoting wide circulation of small-scale distributed power generation have to be worked:

- the actions of industrial policy on large-scale introduction of new types of the equipment providing reduction in cost of cost of standard investment projects in power industry;

- improvement of competitive pricing to create incentives for replacement of the equipment and competitive selection of investment projects,

- obligation of joint development at the municipal level of the schemes of heat and power supply focused on development of a cogeneration,

- subsidizing of interest rates for the credits and tax benefits, including the accelerated depreciation of the new equipment and tax holidays, etc.

# References


1. Energeticheskiy byulleten'. Inertsiya elektroenergetiki [Power bulletin. Inertia power industry]. the Russian Government Analytical Centre, 05/2015, 24 p.
2. Kontseptsiya razvitiya elektroenergeticheskoy i teplosnabzhayushchey infrastruktury v Rossiyskoy Federatsii na osnove kogeneratsii i raspredelennoy energetiki [The concept of development of the electrical power and heat supplying infrastructure in the Russian Federation on the basis of a cogeneration and the distributed power]. M., APBE, 2012, URL: http://www.e-apbe.ru/library/presentations/2012_09_24_infr_dev.ppt
3. Stennikov V.A., Voropay N.I. Tsentralizovannaya i raspredelennaya generatsiya – ne al'ternativa, a integratsiya. Part 4.2. [The centralized and distributed generation – not an alternative, but integration] Innovatsionnaya elektroenergetika – 21 [Innovative power industry – 21]. M. URL: http://www.energystrategy.ru/projects/energy_21.htm
4. Livinskiy A.P. O nekotorykh aspektakh tekhnicheskoy politiki v elektro- i teploenergetike Rossii [About some aspects of technical policy in electro-and power system of Russia]. Novosti teplosnabzheniya [Heat supply news], 2010, №09 (121), http://www.ntsn.ru
5. Novoselova O.A. Malaya raspredelennaya energetika – novaya paradigma v elektroenergetike [The small-scale distributed power generation – a new paradigm in power industry]. the III Professional Forum of power traders of Russia, Moscow, on October 24-25, 2013. URL: http://nnhpe.spbstu.ru/wp-content/uploads/2015/01/Malaya_raspredelennaya_energetika.pdf
6. Kozhukhovskiy I.S., Novoselova O.A. Rol' i perspektivy deyatel'nosti TP «Malaya raspredelennaya energetika» v razvitii raspredelennoy energetiki [A role and the prospects of activity of TP "The Small-scale Distributed Power Generation" in development of the distributed power]. Materials of a round table of TP "The Small-scale Distributed Power Generation", M., on October 23, 2013 URL: http://www.reenfor.org/upload/files/f91e3e2f4c1a8d41af6dd5bc6f632429.pdf
7. Nyushloss D., Ryapin I. Development of distributive generation. Power center of Moscow School of Management Skolkovo, 2012. URL: http://nnhpe.spbstu.ru/wp-content/uploads/2015/01/Skolkovo.pdf
8. Dil'man M.D., Filippov S.P., Ionov M.S. Problemy i perspektivy ispol'zovanija kogeneracionnykh ustanovok pri rekonstrukcii sistem teplosnabzhenija [Problems and prospects of use of the cogeneration installations at reconstruction of systems of heat supply]// M., Institut ehnergeticheskikh issledovanijj RAS, 45 p.
9. Strategicheskaya programma issledovaniy tekhnologicheskaya platforma «malaya raspredelennaya energetika» [Strategic program of researches technological platform "The small-scale distributed power generation"]. M., Higher School of Economics National Research University, 2012 URL:innovation.gov.ru/sites/default/files/documents/2016/5841
10. Sistemnoe modelirovanie i analiz mezo- i mikroekonomicheskikh ob"ektov [System modeling and the analysis meso - and microeconomic objects]/ ed. V.V. Kuleshov, N.I. Suslov ; IEIE SB RAS, Novosibirsk, 2014. -488 s. URL: http://lib.ieie.nsc.ru/docs/2014/SistemModelir/.
11. Filippov S.P., Dil'man M. Perspektivy ispol'zovaniya kogeneratsionnykh ustanovok pri rekonstruktsii kotel'nykh [The prospects of use of the cogeneration installations at reconstruction of boiler rooms]. Promyshlennaya energetika [Industrial power], 2014, № 4, pp. 7-11.
12. Kozhukhovskiy I.S. Perspektivy razvitiya teplovoy energetiki [Prospects of development of thermal power]. Materialy VII ezhegodnoy konferentsii gazety Vedomosti «Rossiyskaya energetika», M. 2013.
13. Teploenergetika i tsentralizovannoe teplosnabzhenie Rossii v 2012–2013 [Power system and the centralized heat supply of Russia in 2012-2013].Minenergo RF, M., 2014, 35 p.
14. Nekrasov A.S., Sinyak Yu.V., Voronina S.A. Perspektivy razvitiya teplosnabzheniya Rossii [Prospects of development of heat supply of Russia]. Energiya: ekonomika, tekhnika, ekologiya [Energy: economy, equipment, ecology]. 2014. № 2. pp. 2-11.
15. Raspredelennaya energetika, kak vazhnoe napravlenie razvitiya sovremennoy energetiki [The distributed power as the important direction of development of modern power]. URL: http://komitet2-13.km.duma.gov.ru/Rekomendacii-po-itogam-meropriyatij/item/221570