Feasibility of Energy Sector Development and Optimization Program of the Republic of Sakha (Yakutia)

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Abstract. This paper is a feasibility study of the long-term program for the development and optimization of local energy in the Republic of Sakha (Yakutia). It sets the primary goals and objectives of research, which is to reliably supply high-quality electricity to isolated settlements, to reduce subsidies the local energy providers need, and to renew the fixed assets. The paper overviews the state of the art in the Republic’s energy sector and compares different versions of the local energy optimization program from the standpoint of feasibility. The authors conclude on the prospects of implementing the presented program.

1. Introduction
Global economic and energy trends today indicate that energy reliability, security, efficiency, and environmental issues are the crucial factors [1-3]. On the other hand, boosting their performance in terms of these factors is a strategic effort that seeks to make the economy more energy- and cost-efficient, which will make the product more competitive both inside the country and in the global market [4-6].

In Russia, there are 69 regional energy systems that comprise 7 integrated systems: Center, East, Siberia, the Urals, Mid-Volga, South, and Northwest. Vostok is an integrated energy system that covers the entire northeast of Russia. Republic of Sakha (Yakutia) alone occupies 3 million 84 thousand square kilometers and is a part of the system; three quarters of the region are on permafrost. This makes it difficult to supply energy to the northern parts of the region, where mining is on the rise [7]. This is why investment in energy is an urgent matter [8].

2. Research goals, objectives, and subject matter
Today, the Republic of Sakha’s largest investment projects in power engineering are:

1. Construction of Yakutskaya GRES-2 (RAO Energy Systems of the East, RusHydro);
2. Construction of Kankunskaia GES (RusHydro);
3. Construction of a CHPP (RAO Energy Systems of the East);
4. A floating nuclear plant (Rosatom);
5. Construction of mini CHPPs and modular energy facilities.
The problem of the Republic’s decentralized and isolated energy system was discussed as part of the agenda for the State Council Presidium Meeting No. Пр-2288 dd. May 03, 2015; the meeting resolutions included an order to draft a *Long-Term Local Energy Optimization Program* (LEOP).

LEOP sets the following key objectives:

1. providing high-quality reliable power supply to remote settlements;
2. Reducing the subsidies to the local electric power industry in the Republic of Sakha (Yakutia);
3. Upgrading the fixed assets that are in poor condition.

The third objective is covered in detail in [9]. Research based on mathematical models of power generation equipment wear and tear [10] has shown that unless urgent action is taken to repair and restore the fixed assets of Yakutia’s power grids, there is a 95% chance none of the 110-kV substations will still be functional in 2023.

The first objective is outstandingly complicated and requires detailed analysis. Scientific foundations for handling it are laid in [11-13].

Thus, the goal and primary objective hereof is to study the feasibility of the local energy optimization program to find how to reduce cross-subsidizing in the Republic’s energy sector.

3. Research results

The previous local energy optimization program for Yakutia was drafted for 2012–2017 and set forth the following objectives:

- reduce environmental emissions;
- improve the quality and reliability of power supply;
- fulfill what is prerequisite to cutting the costs of importing and using diesel fuel in electricity generation;
- provide localized electricity and heat generation by constructing low-power CHPPs;
- reduce technological losses in the grids.

Given that Yakutia’s only supplier, PAO Yakutskanergo, uses the same pricing across the Republic, the South Yakut, Central, and Western power districts effectively subsidize their Northern counterpart. Cross-subsidies totaled 6,803 million rubles in 2017. This made it urgent to project the funding necessary to eliminate cross-subsidizing of local energy consumers in Yakutia.

For each generating facility, the current LEOP considers several retrofitting options:

- replacement with diesel-fired units;
- replacement with oil-fired units;
- replacement with gas-fired units (mainline gas or liquefied hydrocarbon gas);
- use of renewable energy (wind and solar farms) [14-16];
- assigning a generating facility to the backup set and using power transmission lines only;
- establishment of regional power systems, power consolidation and advancement of the power grid complex [18].

Analysis of these options has produced a list and schedule of actions that must be taken at local generating facilities while reporting the indicators that describe the technological and cost effectiveness [19, 20]. The new LEOP considers five alternatives:

Alternative 1: Increased backup. Determine the installed capacity of generating facilities as is conventional: the installed capacity must be 1% to 150% of the peak consumer load.

Alternative 2: Moderate backup. Installed power of new generating facilities depends on the feasibility of installing similar units (2 in operation and 4 for backup): the installed capacity must be about 2% of the peak consumer load.

Alternative 3: Grids. Consider the efficient designs for laying electrical grids to remote settlements. Actions at generating facilities in the remaining municipalities are taken based on the most efficient Alternative 1 or Alternative 2 solution.

Alternative 4: Heavy use of renewable energy. Determine the installed capacity of generating facilities as is conventional: the installed capacity must be 1% to 150% of the peak consumer load.
This alternative also implies renewable energy facilities, commissioning which will reduce the electricity prices [21].

Alternative 5: Grids and renewable energy. This alternative uses the high-performance RE projects from the third alternative and implies reconstructing the generating facilities currently disconnected from the energy systems, similarly to the fourth alternative [22].

Table 1 compares the LEO alternatives without taking into account compensating the excessive prices for the users of centralized energy systems.

**Table 1.** Local Energy Optimization Program: comparison of the alternatives.

| Post-program specifications | Alternative 1 | Alternative 2 | Alternative 3 | Alternative 4 | Alternative 5 |
|-----------------------------|--------------|--------------|--------------|--------------|--------------|
| Installed capacity of the newly commissioned generating facilities, MW | 109 | 81 | 82 | 146 | 127 |
| Total investment in 2018 prices exclusive of VAT, billion rubles: | | | | | |
| exclusive of VAT | 13 | 12 | 30 | 21 | 37 |
| p/p with VAT | 21 | 19 | 44 | 33 | 56 |
| Total effect (reduction in cross-subsidizing) attained by the LEOp over 2018-2040 in 2018 prices, billion rubles. | 22 | 23 | 37 | 25 | 39 |
| Ratio of total effect over 2018-2040 to capital investment in 2018 prices, exclusive of VAT | 1.67 | 1.88 | 1.25 | 1.2 | 1.05 |
| Reduction in the minimum cost-effective electricity prices provided the LEOp is carried out in full: | | | | | |
| % rubles/kW·h, no LEOp | 13.9 | 14.4 | 16.0 | 17.3 | 18.8 |
| rubles/kW·h, full LEOp | 58.9 | 58.9 | 58.9 | 58.9 | 58.9 |
| 50.4 | 49.5 | 48.7 | 47.8* | |
| Total subsidies for investment and cross-subsidizing of local power supplies over 2018-2040 in 2018 prices, billions of rubles. | 161 | 159 | 163 | 166 | 168 |
| Electricity generation efficiency of AO Sakhaenergo after LEOp is complete, % | 34 | 34 | 34** | 39 | 39** |
| Reduction in the annual imports of diesel fuel for local electricity generation | | | | | |
| % thousand rubles, no LEOp | 44 | 44 | 50 | 58 | 63 |
| thousand rubles, full LEOp | 100 | 100 | 100 | 100 | 100 |
| 56 | 56 | 50 | 42 | 37 |

*+ 10% consumers connected to ES Magadanenergo, Yakutskenergo
**+ loads of the major thermal and hydroelectric power plants operated by Magadanenergo and Yakutskenergo

The chart below visualizes some of the technical indicators, see Figure 1.
The first column of the chart (Figure 1a) makes it clear that Alternative 4 will boost the installed capacity the most, as this alternative implies constructing additional renewable energy facilities. The second column (Figure 1b) shows a considerable reduction in diesel fuel imports by 58% and 63% for Alternatives 4 and 5, respectively, as these two emphasize renewable energy. The third column (Figure 1c) shows the total economic effect of carrying out the program in 2018-2040; the best alternatives are 3 and 5. However, the third alternative implies constructing grids to isolated settlements in Far North; as such, it is more complicated and expensive than Alternative 5, which relies on renewable energy.

All the alternatives are aimed at reducing the economically sound electricity tariffs while reducing the subsidies to the local generation facilities.

4. Conclusions
To conclude, we’d like to note that any alternative will considerably reduce cross-subsidizing of local electricity generation in the Republic of Sakha (Yakutia). Technically and economically, the best option is Alternative 5, which is also the eco-friendliest scenario for the northern districts. All the alternatives imply increased oil consumption by AO Sakhaenergo’s facilities. AO Sakhaneftegazbyt’s infrastructure and backups will require an upgrade. Upgrade will cost approximately 203 million rubles in 2018 prices exclusive of VAT. These costs are not included in the LEOP and require further clarification.

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