The Need to Digitalize the Potentially Productive Fuel and Energy Balance in the Western Economic Zone of the Sakha Republic (Yakutia)

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Abstract. The article presents and justifies the development of a digital potentially productive fuel and energy balance of the Sakha Republic (Yakutia) in the context of settlements in the conditions of digital transformation of the economy. The problems traditional FEB regions creation are identified and the advantages of implementing a digital FEB of the region in the efficiency, complexity of analysis and forecasting in the long term are justified. The main stages of its development are proposed and the expected results are justified. As a result of the study, recommendations for its practical development and effective application are presented, taking into account operational current management and response, as well as realistic forecasting in the long term.

1. Introduction
Establishment of a science-based system for the efficient production and consumption of fuel and energy resources (FER) taking into account their supply between adjacent territories, economic zones and regions for the long-term integrated development of the Sakha Republic (Yakutia) is a priority task in the context of the digital transformation of the economy, providing for the specifics and peculiarities of the operation of the fuel and energy complex enterprises in the Far North.
Development of digital systems through the introduction of innovative digital technologies at the enterprises of fuel and energy complex, including the prospects for digitalization of power, heat, oil, gas and coal industry of the Sakha Republic (Yakutia), which in coming years will create an opportunity for the creation of digital fuel and energy balance of the Northern region in the context of each locality.

The digital FEB of the Sakha Republic (Yakutia) will enable the efficient formation, operational management and strategic planning (analysis, modelling, forecasting) of the prospects for the development of the TEB, including the sustainable supply of high-quality fuel and energy resources.

The research object is physical and cost volumes of production and consumption of fuel and energy resources in the Western economic zone of the Sakha Republic (Yakutia), and the research subject is the process of drawing up the basic FEB in terms of areas and main consumer groups in the Western economic zone (WEZ) of the Sakha Republic (Yakutia).

The aim of the research work was to determine the long-term effectiveness of the digital FEB of the Sakha Republic (Yakutia) in terms of human settlements in physical and value indicators in the context of digital economy.

In this work, the following tasks of the study have been carried out sequentially:
- Production and consumption of fuel and energy resources in the WEZ are considered;
- The necessity of developing a promising FEB in software is revealed and the advantage of compiling a digital FEB in the long term is determined;
- Existing problems are identified and ways of development of digital FEB are suggested;

2. Research methods and methodology

At present, in the context of the digital transformation of economic sectors, a new methodological approach is being proposed to create a digital fuel and energy balance which is based on traditional FEB development methodology in regions and country.

The novelty of the proposed methodology is to justify the effectiveness of creating the proposed digital FEB in the context of settlements of the Sakha Republic (Yakutia) in software, where the use of digital information technologies can help us to forecast a long-term period. This digital FEB is with operational management and can analyze a huge database, in connection with changes in conditions, interrelated processes and phenomena in the energy systems of the region.

Using the digital FEB will give us an opportunity to conduct a comprehensive assessment of the potential in fuel and energy resources (FER), industrial and labour capacity, efficiency of placing of productive forces of energy and economy, as well as the efficiency of production and consumption in the future.

It will be possible to develop a forecast digital consolidated FEB of the Sakha Republic (Yakutia) for a very long term (up to 100 years) with various options and scenarios for its development in the context of municipalities and settlements. And there will also be a real opportunity for operational and current management and regulation of the processes of providing consumers with fuel and energy resources on the basis of developed software using modern digital information technologies.

The works of specialists and scientists on the development of a methodology for the formation of FEB regions are of great importance for improving and timely development of more effective and comprehensive solutions (Petrov, 2005), (Petrov et al, 2010), (Elyakova et al, 2020).

3. Results and discussion

In the justification of the republic FEB digitalization, first of all, an analysis of the production and consumption of energy resources (electric and thermal energy as secondary energy carriers) was conducted. Also fuels (coal, crude oil, gas condensate for their production as primary energy) in natural and value indicators in the context of settlements and major groups of power consumers of each region the Western economic zone for the period of 2012-2019 years were estimated.

This article provides an example of only analyzing the volume of production and consumption of electric energy, although heat supply and fuel supply as boiler fuel were investigated. Electricity
supply to consumers of seven districts which included in the Western Economic Zone of the Sakha Republic (Yakutia) is carried out by three cascades of hydroelectric power plants operating in the Mirninsky district of the republic through electric high-voltage power lines.

Due to the low capacity of the 110 kV transmission line, a high percentage of electricity losses is observed for the three Vilyui group of districts, which leads to its shortage, and the need for further and final implementation of the 220 kV Suntar-Nyurba power line construction project remains relevant, especially in connection with the transition of private housing stock to electric heating.

An estimate of the volume of electricity production is given in Table 1.

Table 1. Electricity consumption in the regions of the Western Economic Zone of the Sakha Republic (Yakutia), million kWh

| Consumers                | 2012  | 2013  | 2014  | 2015  | 2016  | 2019  | 2019/2012, % | Share, % |
|--------------------------|-------|-------|-------|-------|-------|-------|--------------|----------|
| TOTAL                    | 1699  | 1572  | 1901  | 2319  | 2548  | 1514  | 89           | 100      |
| Mirninsky district       | 1233  | 1082  | 1324  | 1591  | 1762  | 933   | 76           | 59       |
| Lensky district          | 132   | 139   | 173   | 229   | 326   | 177   | 134          | 18       |
| Olekminsky district      | 125   | 123   | 146   | 230   | 142   | 76    | 61           | 8        |
| Suntar district          | 86    | 96    | 113   | 123   | 130   | 144   | 168          | 7        |
| Nyurbinsky district      | 62    | 72    | 82    | 82    | 87    | 112   | 182          | 5        |
| Vilyuysky district       | 30    | 31    | 32    | 34    | 35    | 36    | 121          | 2        |
| Verkhnevilyuysky district| 23    | 24    | 24    | 24    | 24    | 35    | 152          | 1        |

As can be seen from the results of the table, the lowest rates of reduction in electricity consumption with their highest share (59%) are observed in the Mirninsky district up to 24%. This indicator is associated with a reduction in the demand of a large industrial consumer such as PJSC AK “ALROSA”.

The analysis of electricity consumption in the Western Economic Zone of the Sakha Republic (Yakutia) in natural and cost indicators, as well as the average level of electricity tariffs in the context of each district is given in Table 2.

Table 2. Analysis of electricity consumption in the Western Economic Zone of the Sakha Republic (Yakutia).

| Consumers                          | 2012 volume kWh | revenue million rubles | tariff Rub/kWh | 2019 volume kWh | revenue million rubles with VAT | tariff Rub/kWh | 2019/2012 volume % | revenue % | tariff % |
|------------------------------------|------------------|------------------------|---------------|------------------|--------------------------------|---------------|---------------------|-----------|---------|
| the Western Economic Zone          | 1695             | 6507                   | 3.84          | 1514             | 6749                          | 4.28          | 89                  | 104       | 111     |
| Mirninsky district                 | 1233             | 4875                   | 3.96          | 932,8            | 4786,10                       | 4.28          | 76                  | 98        | 108     |
| Verkhnevilyuysky district          | 23               | 71                     | 3.08          | 35,2             | 3,125                         | 3.125         | 153                 | 186       | 101     |
There is an increase in consumption volumes in natural and value indicators, which is growing very significantly in five districts except Mirninsky and Olekminsky. This indicates an increase in demand for electric energy, associated with the expansion of the housing stock and industrial and social facilities.

The analysis of electricity consumption in the Western Economic Zone of the Sakha Republic (Yakutia) on the example of the Lensky district which is the center of oil and natural gas production in the context of the main consumer groups is shown in Table 3.

**Table 3.** Analysis of electricity consumption in the Lensky district of the Western Economic Zone of the Sakha Republic (Yakutia).

| Consumers                | 2017 | 2018 | 2019 | 2019/2017 |
|--------------------------|------|------|------|-----------|
|                          | volu| reven| tari| volu| reven| tari| volu| reven| tari| volu| reven| tari|
|                          | me | me | ff | me | me | ff | me | me | ff | me | me | ff |
|                          | thou| thou| Rub| thou| thou| Rub| thou| thou| Rub| thou| thou| Rub|
|                          | and| and| / k| and| and| / k| and| and| / k| and| and| / k|
|                          | kWh| kWh| wh | kWh| kWh| wh | kWh| kWh| wh | kWh| kWh| wh |
| Populati                | 52| 17| 3,3| 56| 17| 3,2| 59| 19| 3,2| 12| 12| 128|
| on, total               | 5268| 1716| 74| 5620| 17853| 9| 5954| 19026| 9| 122| 157| 128|
| The budget, total      | 10| 4| 4,0| 91| 3842| 8| 93| 5075| 0| 9| 90| 101| 113|
| Housing and utilities   | 2768| 1069| 81| 2387| 10032| 4| 2172| 11750| 6| 5,4| 98| 102| 104|
| infrastructure          | 3| 169| 47| 2387| 10032| 4| 2172| 11750| 6| 5,4| 98| 102| 104|
| Others                  | 2357| 8473| 33| 5177| 21062| 97| 4| 8676| 43316| 0| 5,0| 174| 168| 97|
| TOTAL                   | 2357| 8473| 33| 5177| 21062| 97| 4| 8676| 43316| 0| 5,0| 174| 168| 97|
| Lensk                   | 3577| 1183| 56| 3693| 12161| 1| 3,3| 3787| 12794| 3| 3,4| 114| 153| 134|
| Populati                | 3577| 1183| 56| 3693| 12161| 1| 3,3| 3787| 12794| 3| 3,4| 114| 153| 134|
| on, total               | 3577| 1183| 56| 3693| 12161| 1| 3,3| 3787| 12794| 3| 3,4| 114| 153| 134|
| The                     | 6738| 2688| 40| 5695| 23921| 4,2| 5661| 30637| 5,4| 94| 107| 114|
In this way, a database was established with large sets of data for the development of future digital Republic FEB in general and in the context of settlements in the economic zones, for example, the collection and analysis of thermal energy production of 508 boilers and the power consumption of the whole population, budget organizations, municipal utilities and major industrial consumers was conducted in the Western economic zone, in seven Western districts of the Republic.

During the research work, the problems of creating a large data on the collection and analysis of production and consumption volumes, balance sheet of fuel and energy resources were identified, as well as its processing and analysis in further, assess the potential and forecast energy balance of the Republic in the context of settlements. In this regard, the advantage of creating a digital perspective FEB of the republic is justified:

- it is possible to develop and manage the FEB of the region in the long term only by creating software for the formation, management, analysis, planning and forecasting in the form of a digital FEB;
- operational management of FEB, the ability to change operational data array and its processing machinery, which will allow making digital and analytical data every day to analyze, model and predict changes in the volume of production and energy resources consumption by enterprises and major groups of consumers in settlements;
- evaluate the efficiency of fuel and energy use, analyze and forecast the prices of fuel and energy resources and determine the possibility of substitution with alternative and renewable resources.

Thus, it is expedient and effective to create a software product for drawing up a digital long-term FEB of the republic for municipalities in the context of settlements on the basis of:

- natural and value indicators of fuel and energy resources and their delivery to each locality;
- input-output model, using economic-mathematical models;
- indicators of energy intensity of consumers and energy capacity of production;
- indicators of reliability of power supply and their qualities.

The development of the digital fuel and energy balance of the Republic of Sakha (Yakutia), as part of the applied software package for mathematical modeling and forecasting of the fuel and energy sector for the formation, management and effective use of fuel and energy resources of the Republic of Sakha (Yakutia) for the period up to 2023-2050. It includes several interrelated stages taking into account quantitative and cost estimates (table 4).  

|                | 3  | 9  | 4  | 12 | 2  | 4  | 9  | 4  | 5  | 4  |
|----------------|----|----|----|----|----|----|----|----|----|----|
| Housing and utilities infrastructure | 2302 | 8926 | 39 | 1858 | 78512 | 42 | 1667 | 90741 | 5,4 | 95 | 98 | 104 |
| Others         | 2150 | 7707 | 36 | 4124 | 16626 | 40 | 7027 | 34673 | 4,9 | 203 | 194 | 96  |
| TOTAL          | 2805 | 1005 | 36 | 4736 | 18867 | 42 | 1304 | 59605 | 4,6 | 143 | 156 | 109 |

### Table 4

|                | 3  | 9  | 4  | 12 | 2  | 4  | 9  | 4  | 5  | 4  |
|----------------|----|----|----|----|----|----|----|----|----|----|
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Table 4. Stages of formation of the digital fuel and energy balance of the Sakha Republic (Yakutia).

| Stages | Content | Expected result |
|--------|---------|-----------------|
| I      | 1.1. Establishment of the FEB Database for the Republic of Sakha (Yakutia) on the basis of software for the period 2019 for municipalities and settlements (in quantitative and value indicators) in the software product. | Demonstration of the main FEB indicators for the Republic of Sakha (Yakutia) by municipalities and settlements of the Republic of Sakha (Yakutia) (in quantitative and value indicators) for 2019 |
|        | 1.2. Development of software architecture for the formation, management and effective use of fuel and energy resources of the Republic of Sakha (Yakutia) for municipalities and settlements. | Creation of essential tool for shaping the planning and implementation of the development strategy of the fuel and energy sector of the Republic of Sakha (Yakutia) |
| II     | 2. Development of application software for the basic and prospective FEB of the Republic of Sakha (Yakutia) for the municipal bodies and settlements (in physical and value indicators) in order to form, manage and effectively use fuel and energy resources until 2030 and with a perspective until 2050. | Establishment of a basic FEB. Evaluation the effectiveness of the basic FEB of the Republic of Sakha (Yakutia) for municipalities and settlements for 2019 (in quantitative and value indicators) based on the established software product |
|        | 2.1. User interface creation for the software | |
|        | 2.2. Creating a client-server interaction for synchronization with remote companies | |
|        | 2.3. Development of data formats for software implementation | |
|        | 2.4. Construction an analytical software core | |
| III    | 3.1. Establishment of the FEB Database for the Republic of Sakha (Yakutia) on the basis of software for the period 2019 for municipalities and settlements (in quantitative and value indicators) in the software product. | |
|        | 3.2. Integrated analysis of production and consumption efficiency of FER Republic of Sakha (Yakutia) for | |
municipalities and settlements for the period of 2019 (in quantitative and value indicators), based on the developed software-based database:

3.1. Analysis and evaluation of the efficiency of production and consumption of electric energy
3.2. Analysis and evaluation of the efficiency of heat energy production and consumption
3.5. Analysis and evaluation of the efficiency of production and consumption of fuel resources (boiler and furnace fuel)
3.6. Analysis and evaluation of the efficiency of fuel and energy supply from outside the Republic of Sakha (Yakutia)
3.7. Comprehensive assessment of the production and consumption efficiency of fuel and energy resources by municipalities and settlements of the Republic of Sakha (Yakutia)

4. Development of effective scenarios for the production and consumption of FER of the Republic of Sakha (Yakutia) by municipalities and settlements in 2050 (in quantitative and value indicators), taking into account the resource and production potential of FER on the basis of the created software:

4.1. Development scenarios of FEC and performance evaluation of major investment projects of Sakha (Yakutia) in conjunction with the neighbouring area up to 2025 and further till 2050 based on the software
4.2. Forecast of energy demand and prices in the world energy markets of EAS and Asia-Pacific region
4.3. Forecast assessment of GRP energy intensity in adjacent

1. Growth of socio-economic, energy, environmental and budgetary efficiency of the development scenarios of the FEB of the Northern energy area.
2. Implementation of measures for energy saving, modernization and technical re-equipment of energy facilities, replacement and reconstruction of heat networks, construction of new power lines and power plants will reduce the loss of heat and electricity.
3. Events envisaged in the scenarios of development of fuel and energy complex of the Republic will allow to increase the energy efficiency of thermal power plants and boiler plants by reducing specific fuel consumption released by power plants and boiler houses.
4.4. Scenarios for efficient production and consumption of electric energy, taking into account the prospects for the development of small-scale energy:
- optimization of diesel power plants;
- application of low-power thermal power plants on coal from local producers;
- use of renewable energy sources (Solar power plants);
- use of renewable energy sources (Wind power plants (wind power plant in Tiksi)).

4.5. Scenarios of efficient production and consumption of thermal energy, taking into account the prospects for the development of municipal energy:
- modernization of public utilities;
- assessment of the possible scale of development of small-scale coal-fired thermal power plants of local producers
- efficiency of conversion to electric heating of consumers of the Republic of Sakha (Yakutia)

4.6. Scenarios of efficient production and consumption of fuel resources (boiler and furnace fuel) taking into account the prospects of development of the enterprise of the coal and oil and gas industry:
- the field “Nadezhdinskoye” (JSC "Zyryansky coal mine»);
- the field “Dzhebariki-hay” (branch of JSC HC “Yakutugol”);
- the field "Kharbalakhskiy" (JSC “Telen”);
- the field "Belogorskaya" (LLC “Sangarskiy coal mine”);
- the field “Kularskoe” and Uyandinskoe”;

electric and heat energy.

4. The renewal of physically and morally obsolete equipment, the use of new energy-and fuel-saving technologies will significantly reduce the specific consumption of boiler and furnace fuel.
- the field “Krasnorechenskoe”;
- the field “Buolkalakhskoe”;
- the field “Aginskoe”.
- oil and gas fields including LNG production

4.7. Scenarios for effective use of FER from outside the Republic of Sakha (Yakutia)

4.8. Comprehensive assessment of the potential of the FER of the Republic of Sakha (Yakutia) based on the software:

| 4.8.1. Electricity |
|-------------------|
| 4.8.2. Thermal energy |
| 4.8.3. Natural gas |
| 4.8.4. Oil |
| 4.8.5. Coal |
| 4.8.6. Other solid fuel (including firewood for heating, solid household and industrial waste) |
| 4.8.7. Nuclear energy |
| 4.8.8. Peat (including peat fuel briquettes and semi-briquettes) |
| 4.8.9. Renewable energy sources (RES): |
| - solar power; |
| - wind power; |
| - hydroelectric power; |
| - energy from waste |
| 4.8.10. Petroleum products (including liquefied gas, automobile and aviation gasoline, kerosene, diesel fuel, heating oil, domestic heating oil, fleet fuel oil, gas turbine and motor fuel) |

5. Development of the Republic of Sakha (Yakutia) for the period up to 2030 and for the future up to 2050 for municipalities and settlements in quantitative and value indicators based on the developed software

| V |
|---|
| 5.1. Balance of secondary fuel and energy resources: |
| - balance of electrical energy; |
| - the balance of thermal energy |
| 5.2. Balance of primary fuel and energy resources (boiler house-furnace and motor fuel) |
| 5.3. Integrated fuel and energy Economic security and deficit-free balance of FER in the Republic of Sakha (Yakutia), the operational control of tactical and strategic tasks of formation, management and efficient use of fuel and energy resources of the Republic of Sakha (Yakutia) in municipalities and settlements of Sakha (Yakutia) based on the created software will allow the efficient development of the economy and fuel and energy complex of |
balance of the Republic of Sakha (Yakutia) for the period up to 2030 and for the future up to 2050

Testing of FEB-based software for the Central Energy District of the Republic of Sakha (Yakutia) with the commissioning of the software package.

Demonstration of software performance based on FEB of the Republic of Sakha (Yakutia)

4. Conclusions
The benefits of digital fuel and energy balance of the Republic are:
- it is possible to develop and manage the FEB of the region in the long term only by creating such a product in software - in the form of a digital FEB;
- where the control subjects of FEB can make digital and analytical data every day to analyze, model and predict changes in the volume of production and energy resources consumption by enterprises and major groups of consumers in settlements,
- evaluate the efficiency of fuel and energy use, analyze and forecast the prices of fuel and energy resources, and determine the possibility of replacing them with alternative and renewable resources.

Digital FEB should be like a “live” mechanism – which should react quickly and simulate various effective options for the production and consumption of fuel and energy resources when even one significant set parameter of the software is changed.

The implementation of the Digital Fuel and Energy Complex will allow a qualitatively high level and timely provision of fuel and energy services in the Republic of Sakha (Yakutia), increase the competitiveness of the industry in the domestic and global fuel and energy markets.

The introduction of digitalization technologies in the region's fuel and energy sectors will reduce the costs of energy producers and consumers, which will lead to a multicative effect for the economy and the social sphere as a whole.

5. Recommendations
1. Establish a database of FEB for the Republic of Sakha (Yakutia) in the context of municipalities and settlements for 2020.
2. Develop a software architecture for municipalities and settlements (in physical and value indicators).
3. Conduct a comprehensive assessment of the potential of fuel and energy resources and the efficiency of their production in the future.
4. Develop a model of the consolidated FEB of the Republic of Sakha (Yakutia) for the long term (up to 100 years) in the context of the municipalities and settlements on the basis of the developed software.

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