

Utilizing Local Fuels in Isolated and Inaccessible Areas of the Irkutsk Region

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Abstract — Decentralized energy supply areas in the Irkutsk region rely on expensive autonomous diesel power plants for electricity supply and low- to medium-capacity boiler houses for heat supply. A common problem for these areas is untimely delivery and high cost of fuel. A possible solution may be the use of local fuels that do not require costly transportation. An analysis is made to assess the cost-effectiveness of substituting imported diesel fuel used for power generation for local oil and liquefied natural gas, as well as replacing the heat supply fuels with local fuel chips. The study shows that the cost of fuel is the key factor that affects the efficiency of an energy source in isolated and inaccessible areas. Therefore, switching to local fuels is a highly cost-effective option for existing energy sources. By replacing diesel fuel with oil in nine settlements of the Katangsky district, the subsidies to the Irkutsk region can be cut by RUB 95.6 million annually. The conversion of diesel power plants to liquefied natural gas in six settlements of the Irkutsk region will reduce the subsidies by RUB 41.9 million annually. The study concludes that, given the small population in the communities at issue, the use of wood waste for heat supply is only suitable in four settlements in the Irkutsk region. The heat sources in all these

localities are departmental, which means they are not eligible for subsidies.

Index Terms — autonomous energy sources, Irkutsk region, local fuels, oil, liquefied natural gas, wood waste.

I. INTRODUCTION

Numerous communities in the Irkutsk region are isolated from centralized power supply and face fuel supply problems due to inaccessibility and poor development of transport infrastructure. The Katangsky district receives fuel during winter either by winter roads or by water. This, however, involves seasonal delivery restrictions and additional costs for vehicle fuel. Given the distance and inaccessibility of the most remote localities, the transportation costs for fuel accounts for a significant portion, reaching 50–70%.

At the same time, the remote areas of the region can boast significant fuel resources, such as oil, natural gas, and wood waste, which makes it possible to use them for energy purposes in these territories.

The decentralized energy supply zone in the Irkutsk region relies on autonomous power sources, mainly expensive diesel power plants (DPP) [1].

Heat supply is provided from low- and medium-capacity boiler houses. Private homes normally utilize individual stove heating [2]. A common problem for such areas is untimely delivery of fuel.

Given the aforementioned problems, the use of local fuels for isolated consumers becomes highly significant as it eliminates the need for costly transportation.

This work involves assessing the cost-effectiveness of replacing the diesel fuel with local oil and liquefied natural gas (LNG), as well as substituting coal in boiler houses for

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TABLE 1. Data on Fuel Prices in the Katangsky District (as of 2023)

Locality	Diesel fuel price, RUB thousand/t	Oil price, RUB thousand/t	Share of fuel costs in annual gross revenue requirement, %
Erbogachen village	114	80	87
Preobrazhenka village			
Erema village			
Kalinina hamlet			
Podvoloshino village	112	80	65
Nepa village	108	80	51
Ika village			
Tokma village			
Bur village			

fuel chips.

II. SUBSTITUTION OF DIESEL FUEL WITH OIL

To date, more than a dozen various (large, medium, and small) oil and gas condensate fields (OGCFs) and oil fields have been explored in the Irkutsk region. The vast majority of them are completely or partially located in the Katangsky district. These are Verkhnechonskoye OGCF, the Danilovsky cluster (Danilovskoye, Severo-Danilovskoye, Yuzhno-Danilovskoye, Zapadno-Danilovskoye) OGCFs, Yarktinskoye OGCF, Ignyalinskoye OGCF, Duliminskoye OGCF, Vakunayskoye OGCF, and others. This is why the analysis of transport accessibility has revealed that the use of local oil is cost-effective only in the Katangsky district, namely in the isolated and hard-to-reach localities such as Erbogachen village, Preobrazhenka village, Erema village, Kalinina hamlet, Podvoloshino village, Nepa village, Ika village, Tokma village, Bur village, and Moga hamlet. The villages of Erbogachen, Preobrazhenka, Nepa, and Podvoloshino already use oil for heat supply from local boiler houses.

Electricity supply to the settlements of the region is provided from autonomous diesel power plants operating on imported diesel fuel. Over the past years, the Katangsky district has experienced regular interruptions in the electricity supply due to a lack of operating capacity and a pre-emergency state of diesel power plants. A common problem is untimely delivery of fuel due to poor transport infrastructure and the seasonal nature of cargo delivery.

Delivery of fuel to diesel power plants involves a complex transportation system relying on winter road. Oil for boiler houses is supplied from the Verkhnechonskoye OGCF, which is one of the largest in Eastern Siberia. Currently, OJSC Verkhnechonskneftegaz supplies nearly one thousand tons of oil annually to the Katangsky district.

Data on prices for oil and diesel fuel, as well as the share of fuel costs in the annual gross revenue requirement of the power generating company for power supply to the communities in question are presented in Table 1 (according to data from the Minutes of Meetings of the Board of Tariff Service of the Irkutsk Region).

The data in Table 1 show that the key component in an economically justified electricity tariff is the cost of fuel. The higher the installed capacity of the energy source, the higher the share of fuel costs. The lower the installed capacity, the higher the share of maintenance costs. Since the cost of fuel increases significantly due to the high cost of transportation, it is necessary to explore methods for minimizing the fuel component in the cost of energy. This can be achieved by increasing the efficiency of power plants and using local fuels (especially in the northern parts of the Irkutsk region, where colossal hydrocarbon reserves are concentrated). Figure 1 shows the values of diesel fuel prices (under existing conditions) and oil prices (after replacing the equipment of existing diesel power plants with new diesel generator sets running on oil, which entails an increase in efficiency, depreciation and tax deductions) which are required to achieve the same value of the

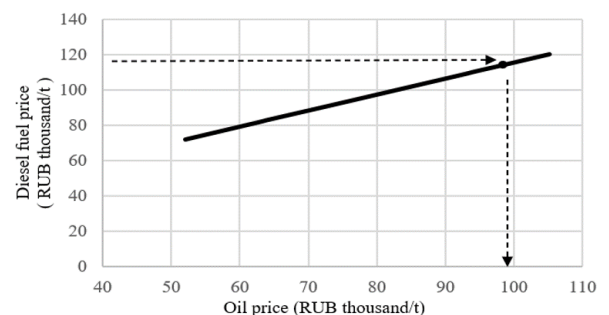


Fig. 1. Condition for equal economic efficiency of oil and diesel fuel for autonomous power plan

levelized cost of electricity. If the levelized cost of electricity is equal, the price of diesel fuel is higher than the price of oil. As the levelized cost increases, the price of oil rises slightly faster than that of diesel fuel. Based on the current cost of diesel fuel in Erbogachen village of RUB 114 thousand/t, it is evident that the use of oil will be economically feasible when its price is less than RUB 98.5 thousand/t.

A classic diesel generator cannot use crude oil as fuel. A conventional internal combustion engine is designed so that for the normal operation of all its components it requires fuel with certain parameters. The focus, therefore, is not on replacing fuel at existing diesel power plants, but on replacing diesel power plant units with new oil-fired diesel generator sets. Power plants running on oil and fuel oil require mandatory preliminary fuel preparation. To ensure this, a fuel preparation container is provided in the fuel system. The main task of which is to ensure fuel purification from water and mechanical impurities and supply it to the circulation modules.

The estimates obtained are presented in Table 2. It is established that when replacing existing diesel power plant units with oil-fired diesel generator sets, the economically justified tariff for Erbogachen village, Preobrazhenka village, Erema village, and Kalinina hamlet will decrease by RUB 10.59/kWh. This will reduce the annual subsidies allocated to cover lost income by resource-supply organizations in the Irkutsk region by RUB 85.65 million annually. Economically justified tariff in Podvoloshino village will decrease by RUB 10.44/kWh, resulting in an annual reduction in subsidies by RUB 9.03 million/year. The economic effect of converting energy sources to oil in the villages of Nepa, Ika, Tokma, and Bur is insignificant. This is due to the small share of fuel costs in the annual gross revenue requirement compared to other localities under consideration. Reduced costs for cheaper local fuel and increased efficiency are offset by significant

depreciation and tax deductions.

For all nine localities at issue, it is recommended to replace diesel power plants with oil-fired diesel generator sets. Reliable power supply to consumers will be ensured even in the populated areas where the economic effect of such a replacement is insignificant.

III. REPLACING DIESEL FUEL WITH NATURAL GAS

One of the alternative options for supplying fuel to autonomous electric sources in isolated and hard-to-reach areas in the Irkutsk region may be the use of natural gas. Switching to natural gas can be accomplished in two possible ways:

1) by using pipeline natural gas through connection to the section of the Power of Siberia - 1 gas pipeline from the Kovykta gas condensate field (GCF), passing through the territory of the Irkutsk region;

2) by supplying LNG to consumers by road or by water.

The use of natural gas is cost-effective not only for diesel power plants, but also for boiler houses that use liquefied hydrocarbon gas (LHG), or oil and fuel oil as fuel. Boiler houses in the territories at issue do not utilize LHG, and oil is used only in the Katangsky district. Although natural gas is less competitive than coal and wood fuel, from the standpoint of logistics and environmental factors, it seems appropriate to consider the use of a single fuel at energy sources in one locality.

1. Use of pipeline natural gas

The section of the Power of Siberia - 1 gas pipeline in the Irkutsk region passes through the territory of the Zhigalovsky, Kazachinsko-Lensky, Kirensky, and Mamsko-Chuysky districts. To connect populated areas in isolated and inaccessible parts of the Irkutsk region, located in close proximity to the gas pipeline route, it is necessary to construct gas distribution stations (GDS). Given the relatively small population in such localities and

TABLE 2. Data on Electricity Supply Costs After Replacing Diesel Fuel with Oil

Locality	Capital costs, RUB million	Current economically justified tariff, RUB/kWh	Economically justified tariff after switching to oil, RUB/kWh	Subsidy reduction, RUB million/year
Erbogachen village Preobrazhenka village	400	39.39	28.80	85.65
Erema village Kalinina hamlet				
Podvoloshino village	60	45.27	34.83	9.03
Nepa village Ika village Tokma village Bur village	160	55.18	53.92	0.89

their dispersion throughout the territory, the construction of gas distribution stations is unfeasible for them.

The Program for the Development of Gas Supply and Expansion of Gas Infrastructure in the Irkutsk Region for the period of 2021–2025 includes plans to transition the cities of Ust-Kut and Kirensk to natural gas and construct a gas branch pipeline to the Magistralny urban-type settlement, Sedankina hamlet, Ulkan urban-type settlement, Yukhta hamlet, and Tarasovo village. There are also plans to construct the Magistralny gas distribution station. These localities are currently connected to a centralized power supply. According to the plans, both their population and heat supply sources will transition to gas, which will be provided through the local distribution gas pipelines. A study on the possibility of extending inter-settlement gas pipelines in the future to connect the isolated inaccessible communities has revealed that all of them are located no less than 100 km from the ones mentioned in the Program. Consequently, the use of pipeline natural gas in isolated and hard-to-reach areas of the Irkutsk region is unpromising.

2. Use of liquefied natural gas

Liquefied natural gas (LNG) has become widespread in the industrial and domestic sectors. First of all, this type of fuel is in demand in regions located far from main gas pipelines. Delivery of LNG by road is carried out, if necessary, in small quantities to local consumers at distances of up to 500 km.

Under the domestic classification established by GOST 19433-88, LNG is categorized as hazardous material classified as a second-class danger [3]. In this regard, all safety measures must be provided.

Transportation of LNG by road is regulated by the rules for the international carriage of dangerous goods by road (ADR), as well as the rules for the transportation of

dangerous goods by road, which are approved by Order of the Ministry of Transport of the Russian Federation No. 73 of 08.08.1995 [4]. ADR specifies the requirements for the equipment and configuration of vehicles transporting dangerous goods. All vehicles, including cars and trailers, are required to undergo a technical inspection 2 times a year, receive a diagnostic card with a conclusion on the vehicles' safety for use. The driver must obtain a certificate of approval for transporting dangerous goods. The Department of State Road Supervision approves the transportation route. The transportation of LNG in tankers requires a special permit. The procedure for issuing the permit was approved by Order of the Ministry of Transport of the Russian Federation No. 179 dated July 4, 2011, "On approval of the Procedure for issuing a special permit for the movement of a vehicle transporting dangerous goods on roads" [5].

The main limitation of the LNG use for isolated and hard-to-reach consumers is the categorization of delivery roads, which must correspond to at least category IV (2 lanes of 3–3.25 m each, with a shoulder of 1.5–2 m). However, even category IV roads do not fully correspond to the safety of LNG transportation. This category is characterized by a low-quality coating, which can make it challenging to move along them, especially in the autumn and spring. Such roads are often closed to heavy vehicles. This is because the movement of heavy vehicles leads to rapid and serious destruction of the road surface [6]. In addition, restrictions on the category of roads are also related to the dimensions of gas carriers. The roads in most of the settlements under consideration are unpaved (or winter roads) and belong to category V, i.e. mostly country roads [5].

LNG can be delivered by river. An analysis of this option indicates that the localities that may be potentially promising for the use of LNG are: Yuzhny settlement,

TABLE 3. List and Characteristics of Diesel Power Plants in Isolated and Hard-To-Reach Localities of the Irkutsk Region, which are Recommended for the Use of LNG (as of 2023)

Municipal district	Locality	Population as of 01.01.2022, people	Diesel fuel consumption, t/year	Diesel fuel price, RUB thousand/t
Bratsky	Yuzhny settlement	93	25	77
	Naratay settlement	305	242.6	81
	Karakhun settlement	516	319	81
	Ozerny settlement	570	645.7	81
Ust-Udinsky	Atalanka village	189	506.1	104
	Podvolochno village	229		
	Anosovo village	461		
	Klyuchi hamlet	86		

TABLE 4. Electricity Supply Costs After Replacing Diesel Fuel with LNG

Municipal district	Locality	Current economically justified tariff, RUB/kWh	Economically justified tariff after switching to LNG, RUB/kWh	Subsidy reduction RUB million/ye
Bratsky	Yuzhny settlement	13.47	185.60	-8.7
	Naratay settlement	25.06	24.58	0.5
	Karakhun settlement	25.2	26.04	-1.0
	Ozerny settlement	21.94	17.88	12.3
Ust-Udinsky	Atalanka village	36.94	21.07	29.1
	Podvolochnoe village			
	Anosovo village			
	Klyuchi hamlet			

Naratay settlement, Karakhun settlement, and Ozerny settlement in the Bratsky district and Atalanka village, Podvolochnoe village, Anosovo village, and Klyuchi hamlet in the Ust-Udinsky district. Initial data on these localities are presented in Table 3.

The economic efficiency of converting diesel power plants to LNG in eight isolated inaccessible localities in the Irkutsk region is detailed in Table 4. The studies indicate that the conversion to LNG is effective in Naratay and Ozerny settlements of the Bratsky district and all four communities in the Ust-Udinsky district at a cost of LNG of RUB 30 thousand/t (including storage, transportation, and other payments). After the conversion of diesel power plants to LNG in the Yuzhny and Karakhun settlements in the Bratsky district, the economically justified tariff for electricity increases. Therefore, this conversion is inappropriate.

Figure 2 shows the prices for diesel fuel (under current conditions) and for LNG (when converting diesel power plants to LNG), which are required to achieve the same value of the levelized cost of electricity. As seen in the Figure, with an equal value of the levelized cost of electricity in the Ust-Udinsky district, the price of diesel fuel is higher than the price of LNG. As the levelized cost

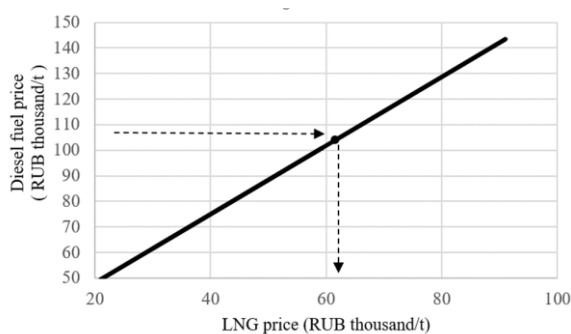


Fig. 2. Condition for equal economic efficiency of LNG and diesel fuel when used by autonomous power plants.

increases, the price of LNG rises slightly faster than that of diesel fuel. We can conclude that at the current diesel cost of RUB 104 thousand/t, the use of LNG will be effective at its cost below RUB 61 thousand/t.

3. Replacing coal with biofuel

The richest forest resources on the territory of the Irkutsk region served as the basis for the technological advancement of the wood processing industry. Most enterprises, including all the largest ones such as LLC Magistral-Transit, LLC Rusforest Magistralny, LLC IND TIMBER, LLC OMFAL, LLC PLT, LLC Lesresurs, and LLC Atlant, are located in the north of the Irkutsk region (the Ust-Kutsky, Nizhneilimsky, and Kazachinsko-Lensky districts). These districts concentrate the most large-scale exploitation of forest resources. This is due to the predominance of mature and overmature forest stands, as well as the close proximity to the Baikal-Amur Railway.

An analysis of transport accessibility [7] indicates that biofuel in the form of fuel chips or pellets from all 64 isolated and inaccessible localities in the Irkutsk region can be supplied to only 20 of them. At the same time, transporting fuel with low energy density is cost-ineffective for seven communities in the Kirensky district, five communities in the Ust-Kutsky district, and one settlement each in the Ust-Udinsky, Usolsky, and Chermkhovskiy districts, in particular due to the absence of boiler houses. Table 5 shows the list of the small isolated inaccessible localities in the Irkutsk region, along with their population and the minimum distance for transporting biofuel.

Table 6 presents a list of isolated and hard-to-reach localities in the Irkutsk region, which are recommended for the use of biofuel.

LLC VitimLes operating in the Kirensky district is one of the largest wood processing enterprises in the Irkutsk

TABLE 5. Isolated and Hard-To-Reach Localities in the Irkutsk Region Where Biofuel Delivery is Possible (as of 2023)

Municipal district	Locality	Population, people	Distance, km
Kirensky	Korshunovo village	144	0
	Daryina village	5	0
	Zolotoy settlement	6	108
	Pashnya settlement	16	35
	Krasnoyarovo village	35	82
	Mironovo village	36	2
	Spoloshino village	11	105
	Vizimiy settlement	46	113
	Ust-Kirenga village	53	53
Usolsky	Oktyabrsky settlement	173	89
	Maninsk settlement	9	91
Ust-Kutsky	Tayura village	25	107
	Bobrovka settlement	23	100
	Maksimovo hamlet	11	94
	Boyarsk village	74	101
	Omoloy village	50	94
Ust-Udinsky	Anosovo village	461	67
	Klyuchi hamlet	86	54

TABLE 6. List and Characteristics of Isolated and Hard-To-Reach Localities in the Irkutsk Region Recommended for the Use of Biofuel (as of 2023)

Municipal district	Locality	Type of fuel used	Fuel consumption, t/year
Kirensky	Korshunovo village	Wood processing waste	No data
Kirensky	Daryina village	Wood processing waste	No data
Usolsky	Oktyabrsky settlement	Firewood	244
Ust-Udinsky	Anosovo village	Firewood	900
Tulunsky	Arshan settlement	Brown coal	110

region. Its plots located in Korshunova and Daryina villages can provide fuel chips or pellets to four isolated and hard-to-reach localities in the Kirensky district. The remaining three will be supplied with fuel chips or pellets from the city of Kirensk. However, the population in all nine communities is small, therefore it is recommended to continue using forestry waste in Korshunovo and Daryino villages, where they are produced and used at the boiler houses of LLC VitimLes.

Oktyabrsky settlement is located 89 km from the city of Usolye-Sibirskoye, where several forestry enterprises are situated. These include LLC Lime, LLC Usolsky Plywood Plant, LLC Technopark, and others. Currently, there is one operational boiler house, owned by a secondary school, in the Oktyabrsky settlement. This boiler house runs on wood. It is recommended to consider the possibility of replacing firewood with fuel chips supplied from the enterprises in the town of Usolye-Sibirskoye.

Anosovo settlement (Ust-Udinsky district) is located 67 km from the Ust-Uda settlement, where one of the largest forestry enterprises in the Irkutsk region, CJSC Angarskiy Les, is located. Currently, the settlements of Anosovo and Oktyabrsky each have one wood-fired boiler house owned

by a secondary school. It is recommended to replace firewood with fuel chips supplied by CJSC Angarskiy Les.

Arshan settlement in Tulunsky district, is located 100 km from the city of Tulun, where several wood processing enterprises (LLC Timberkom, LLC LPK, LLC Fenix, and others) are located. These enterprises can meet the demand of the Arshan boiler house for fuel, amounting to 66 tce annually, and have a reserve. Currently, the only boiler house in the settlement runs on local brown coal. As can be seen in Figure 3, the use of fuel chips in the settlement of

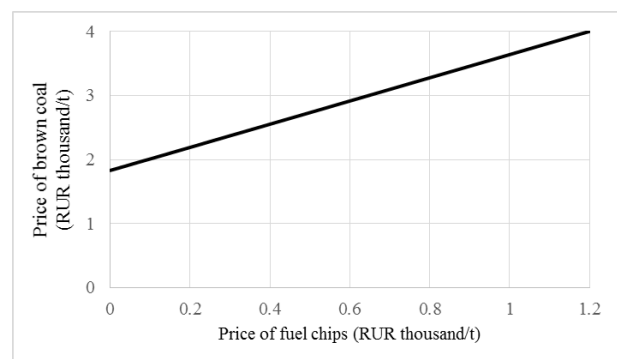


Fig. 3. Condition for equal economic efficiency of brown coal and fuel chips when used by low-capacity boiler houses.

Arshan, Tulunsky district, at the current cost of brown coal equal to RUB 1 860/t can be efficient only if the fuel chips are free and the cost of their delivery does not exceed RUB 15/t.

All boiler houses recommended for the use of fuel chips are departmental, owned by private enterprises or municipal institutions. Subsidies are not allocated to compensate for the income lost by resource-supply organizations.

IV. CONCLUSION

The primary challenge regarding energy supply to consumers in isolated and hard-to-reach areas in the Irkutsk region is underdeveloped transport infrastructure, which significantly increases fuel prices due to high transportation costs. One possible solution for fuel supply is the use of local fuels, which do not necessitate costly transportation.

A key factor in the efficiency of the energy source for isolated consumers is the cost of fuel. Therefore, converting existing energy sources to local fuels is feasible and, in many cases, cost-effective.

The Katangsky district possesses the main reserves of oil and is engaged in its production. Currently, oil is used as fuel in boiler houses in the district. An analysis of the economic efficiency of local fuels has revealed that the replacement of diesel fuel with oil in nine localities of the Katangsky district (Erbogachen village, Preobrazhenka village, Erema village, Kalinina hamlet, Podvoloshino village, Nepa village, Ika village, Tokma village, and Bur village) will reduce the subsidies to the Irkutsk region by RUB 95.6 million annually.

The use of LNG at diesel power plants as a substitute fuel is limited due to the quality of roads. The transportation of LNG, which is classified as hazardous goods, is prohibited on unpaved country roads that connect remote hard-to-reach localities with main highways. The study has examined the localities that can be supplied with LNG by water transport along the Angara river. The conversion of diesel power plants to LNG is effective in Naratay and Ozerny settlements of the Bratsky district, as well as in the villages of Atalanka, Povolochnoe, Anosovo, and Klyuchi hamlet in the Ust-Udinsky district. This transition to LNG will reduce the regional subsidies by RUB 41.9 million annually.

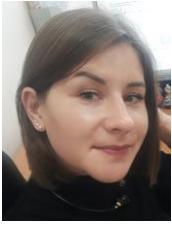
The Irkutsk region is home to numerous large wood processing companies producing a significant amount of waste that can be effectively utilized, particularly for energy generation. However, given the small population in the isolated and hard-to-reach localities at issue and, in some cases, the complete lack of social infrastructure, the use of wood waste for heat supply is advisable only in Korshunovo and Daryina villages in the Kirensky district; in Oktyabrsky settlement in the Usolsky district; and Anosovo village in the Ust-Udinsky district. The heat sources in all these localities are departmental, which means they are not eligible for subsidies.

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