STUDY

Market study in the context of decentralized energy supply using renewable energy technologies in selected Russian regions

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Contents

Objectives of the market study

The German Energy Agency (dena) is implementing the "German-Russian Dialogue on Energy Efficiency and Renewable Energies" with the support of the Federal Ministry for Economic Affairs and Energy (BMWi). The overall objective of this project is to sustainably improve the framework conditions for energy efficiency and renewable energy in Russia and thus to support the development of a market for energy efficiency and renewable energies.

For this purpose, dena held a workshop in Berlin in November 2017 with representatives of the BMWi, associations of the renewable energy industry, companies and representatives of Russian regions. The main goal here was to assess potential cooperation between Russian regions and German companies in the field of renewable energies. A market that struck participants as particularly interesting for any German-Russian cooperation is the expansion of renewable energies with smaller capacities (below 10 megawatts) for decentralized energy supply in remote, sparsely populated areas without access to a grid-connected energy supply (also known as isolated solutions). The method of power supply that is currently preferred in these off-grid regions, diesel generators, is costly mainly due to logistics costs for fuel transport which are heavily subsidized as a result. The use of renewable energies, in particular photovoltaics, wind power, and possibly hydroelectric power and bioenergy, could therefore be particularly economical in these regions.

In Russia the market for large and grid-based renewable energy capacities is regulated by centralized and nationwide tendering procedures and are economically advantageous due to guaranteed capacity-based tariffs for investors. During the workshop it became clear however that there is hardly any information available about the market for smaller, decentralized and off-grid capacities in remote regions and that little is known about the potential the market has and the local investment conditions.

The study at hand has been written in this context with the aim to familiarize German companies, particularly small and medium-sized enterprises (SMEs), with the economic potential that the use of off-grid renewable energies solutions (isolated solutions) have in remote regions of Russia and to identify possibilities to exploit their potential. For this, the market for electricity supply using diesel generators in off-grid areas of Russia has been analyzed in five regions and an assessment of the business opportunities for renewable energies has been carried out. PV and wind power hybrid solutions were in the focus of the analysis, with small hydropower, geothermal energy and biomass utilization being of secondary importance.

Executive summary

The Russian energy system has, since its inception, been defined by centralized structures with conventional power plants that are to a large extent powered by fossil fuels. Renewable energy sources, with the exception of large hydro power plants, have not played a role in the energy supply of the country. There is a myriad political, social and, arguably most important, economic reasons for this: being rich in natural resources, Russia's electricity generation has been generally cheap and prices for end-consumers have been kept low if required. Even in areas where electricity generation is relatively expensive, tariffs have been kept artificially low with the use of subsides. This is often the case in remote areas, which are the focus of this study. The combination of low generation costs and low electricity prices have historically hindered the natural development of RES. The development has also been slow because Russian grassroots movements pushing for a cleaner energy supply have not gained traction in Russia.

This is changing however, as electricity generation costs from renewable energy sources such as wind and solar is falling, and will soon be comparable to the cost of electricity production from traditional sources. Although conventional power plants are still undoubtedly the backbone of the Russian energy system, centralized PV and wind parks have started to appear more frequently. This development has been facilitated by the introduction of renewable energy legislation, most importantly the Decree 449 which introduced a tender-based support mechanism with important local requirements for the development of RES. Decree 449 has enabled wind and PV parks to feed megawatts to the national energy grid, but this is not the focus of this report. The focus here, was on how renewable energy sources, specifically wind and PV, can be a reliable and affordable energy source for regions which are not connected to the central or a local grid. According to different estimations, up to 60 to 70% of Russian territory, which has a population of 22-25 million people, is not connected to the central Russian grid, the UPS, and at least 10 million people are also not connected to a local grid. Decentralized energy generation sources in Russia are traditionally powered by diesel generators of all sizes. Today, the energy supply situation in these areas faces two major challenges:

1. the generators are often several decades old, meaning that their fuel-use is inefficient and that their operations and maintenance costs keep rising;

2. transporting fuel (and supplies more generally) to remote areas is often very expensive, leading to higher generation costs than the Russian average. The inherent advantage of RES such as wind and PV is that there is no need for a constant supply of fuel for operation and that with the need to upgrade / modernize the existing energy systems in remote areas represents an opportunity for using RE technologies to complement or even to replace the diesel generators in the long-run.

This report examines the energy supply situation in remote areas, describes business cases for distributed RE usage and assesses the challenges and chances for the future deployment of RES. Having examined 5 regions, including isolated territories in the Far East as well as regions with centralized grids but where not all of the territory is covered, the consensus is that RES are economical today in areas where diesel costs are high. The following points, however, should be taken into consideration when developing such projects: while low operating expenses work in favor of RES during the exploitation phase of a power plant, the relatively high capital expenditure (CAPEX) that is required to build RE installations is a challenge for the so-called "guaranteeing suppliers", which are state-owned and sometimes private utilities with the mandate to secure energy supply in remote regions. These utilities often struggle to meet the high initial capital requirements alone and as a result seek to install the largest amount of RE capacity possible instead of building the best technical RE solutions, which could include storage and modern energy management systems, which would be more economically attractive in the long-run. Due to the shortage of investment capital, the RE share of hybrid diesel-RE systems remains relatively low for now and RE are mostly used to complement old fuel-based capacity instead of replacing old energy systems with modern ones, including new and efficient fuel-based generators, energy storage, RE and intelligent energy management systems. Overcoming this CAPEX challenge is therefore an important factor when estimating the future market size of RE in remote areas. Transport is also a general issue for all items that are brought to these areas, so the logistics to build RE installations needs to be planned more thoroughly than would be the case in areas with a better transportation infrastructure. Existing installations have shown that RE installations that are built in isolated territories with extreme climatic conditions, as in Sakha Yakutia and Kamchatka, need to be carefully designed to be able to withstand extreme weather conditions.

The study demonstrates that in remote regions, that are not connected to the grid, as well as in the case of RES power supply to remote consumers in central Russia and Siberia, economically viable business cases can rarely be developed using diesel prices alone. In such regions, logistics, albeit difficult at times, not always represent a big challenge as is the case in isolated territories. Hence, diesel costs and electricity generation costs are lower.

At the same time, RES can become attractive for customers that suffer from a combination of high end-user - prices and an unreliable energy supply, ensuring reliable and safe energy supply together with diesel power plants. Simultaneously, the existing mechanism supporting the implementation of RES projects for isolated systems, as well as for remote consumers, are insufficient, which explains the small number of implemented projects and the longer payback period compared to the projects implemented under the support measures.

The possibility to use energy service contracts also opens additional opportunities for RES. It is advisable to improve the existing regulatory framework in Russia, by providing for the formation of support measures for RES projects in isolated energy systems and for the supply of energy to remote consumers, and by supporting the manufacturing of relevant technologies. Development and implementation of appropriate RES technologies and professional education play a key role in the use of RES potential in these remote and isolated areas of Russia.

Сводное Резюме (Executive Summary)

Российская энергетическая система, с момента своего создания, была сформирована как централизованная структура с традиционными электростанциями, работающими на ископаемом топливе и природном газе. Возобновляемые источники энергии, за исключением крупных гидроэлектростанций, не играли роли в энергоснабжении страны. Для этого существует множество политических, социальных и экономических причин (которые, возможно, играют самую важную роль): будучи богатой природными ресурсами страной, производство электроэнергии в России в целом можно считать не дорогим, при этом цены для конечных потребителей сохраняются искусственно заниженными. Даже в тех районах, где производство электроэнергии является относительно дорогостоящим, тарифы искусственно удерживаются на низком уровне за счет применения субсидий. Такая ситуация чаще всего имеет место на удаленных территориях, которые и являются целью настоящего исследования. Сочетание низких затрат на производство и низких цен на электроэнергию исторически препятствовало естественному развитию ВИЭ. Развитие также было медленным, потому что общественные движения, продвигающие идеи «чистого» производства электроэнергии, не получили поддержки в России.

Однако ситуация меняется, так как стоимость производство электроэнергии из возобновляемых источников, таких как ветер и солнце, падает, и скоро будет сопоставимо со стоимостью производства электроэнергии традиционными источниками генерации. Хотя обычные электростанции, несомненно, являются основой российской энергетической системы, солнечные и ветровые парки в централизованной энергосистеме стали появляться чаще. Этому способствовала разработка и введение в действие государственного законодательства о возобновляемых источниках энергии, в котором наиболее важным является Постановление Правительства Российской Федерации от 28 мая 2013 года №449 «О механизме стимулирования использования возобновляемых источников энергии на оптовом рынке электрической энергии и мощности», которое ввело механизм поддержки развития ВИЭ на основе тендера с важными требованиями по локализации для развития ВИЭ. Постановление Правительства РФ №449 позволило ветровым и солнечным электростанциям передавать мегаватты электроэнергии в Единую Энергетическую Систему (ЕЭС) России, но не это является предметом настоящего доклада. Основное внимание здесь будет уделено тому, как возобновляемые источники энергии, в частности ветер и солнце, могут стать надежным и доступным источником энергии для регионов, которые не подключены к центральной или локальной сети. По разным оценкам, от 60 до 70% российской территории, на которой проживает 22-25 миллионов человек, не подключены к Единой Энергетической Системе, ЕЭС России, и ещё не менее 10 миллионов человек не подключены к местным энергетическим сетям. В качестве источников децентрализованного энергоснабжения традиционно используются дизельные генераторы всех типов. Сегодня ситуация с энергоснабжением в этих районах характеризуется двумя основными проблемами:

1. Срок службы генераторов составляет несколько десятилетий, что означает неэффективное использование ими топлива и постоянный рост эксплуатационных ремонтных расходов;

2. Транспортировка топлива (и вообще его поставка) в отдаленные районы часто обходится очень дорого, что приводит к более высоким затратам на производство электроэнергии, чем в среднем по России. Неотъемлемым преимуществом ВИЭ, таких как ветер и солнце, является то, что происходит сильное снижение объемов завозного топлива для работы генераторов, и что при необходимости замены/модернизации существующих энергетических систем в отдаленных районах, они могут быть легко дополнены ВИЭ и даже заменены на ВИЭ и оставаться рентабельными в долгосрочной перспективе.

В этом докладе анализируется ситуация с энергоснабжением в отдаленных районах, описываются бизнес-модели децентрализованного использования возобновляемых источников энергии, а также оцениваются проблемы и возможности их будущего развертывания в этих районах. Исследовав 5 регионов, включая изолированные территории на Дальнем Востоке, а также регионы с имеющимися централизованными сетями, но не покрывающими всю их территорию, мы пришли к выводу, что ВИЭ будут экономически выгодны в тех районах, где стоимость дизельного топлива высока. Однако при разработке таких проектов следует учитывать следующие моменты: в то время как низкие эксплуатационные расходы работают в пользу ВИЭ на этапе эксплуатации электростанции, относительно высокие капитальные затраты CAPEX), необходимые для ввода оборудования ВИЭ, являются проблемой для так называемых «гарантирующих поставщиков» - государственных и частных коммунальных предприятий с полномочиями по энергоснабжению отдаленных регионов. Этим «гарантирующим поставщикам» обычно тяжело нести необходимые капитальные затраты в одиночку. Как результат, они часто предпочитают установить стандартные большие системы ВИЭ (такие как крупные СЭС от «Хевел») вместо того, чтобы внедрять инновационные технические решения на базе накопителей энергии, которые более выгодны экономически в длительной перспективе. Из-за нехватки инвестиционного капитала, доля ВИЭ в гибридных системах ДИЗЕЛЬ-ВИЭ остается относительно низкой, так как ВИЭ в основном используются только для дополнения старых энергетических систем вместо замены их на современные энергосистемы, включающие в себя новые и эффективные топливные генераторы, системы хранения энергии, ВИЭ и интеллектуальные системы управления энергией. Поэтому при оценке рынка ВИЭ в отдаленных районах очень важно учитывать необходимость преодоления этой проблемы инвестиционных капитальных затрат. Транспорт также является общей проблемой для всего, что доставляется в эти районы, поэтому логистика при монтаже установок ВИЭ должна планироваться более тщательно, чем это было бы в районах с лучшей транспортной инфраструктурой. Опыт эксплуатации установок ВИЭ, смонтированных в районах с экстремальными климатическими условиями, таких как Республика Саха (Якутия) и Камчатка, показал, что они должны быть тщательно спроектированы для того, чтобы выдерживать экстремальные погодные условия.

Исследование показывает, что в отдаленных регионах, которые не подключены к сетям, а также при энергоснабжении посредством ВИЭ удаленных потребителей центральной части России и Сибири экономически жизнеспособные бизнес-модели редко могут развиваться на основе учета одних только цен на дизельное топливо. В таких регионах логистика, хотя порой и сложная, не всегда представляет такую большую проблему, как на изолированных территориях. Таким образом, затраты на дизельное топливо и производство электроэнергии ниже. При этом, ВИЭ могут стать привлекательными для тех потребителей, которые страдают от сочетания высоких цен для конечных пользователей и ненадежного энергоснабжения, обеспечивая совместно с дизельными станциями надежное и безопасное энергоснабжение. Использование механизма энергосервисных контрактов также открывает дополнительные возможности для ВИЭ. При этом действующих механизмов поддержки реализации проектов с использованием ВИЭ для изолированных систем, а также для удаленных потребителей недостаточно, этим объясняется небольшое количество реализованных проектов и больший по сравнению с проектами, реализующимися в рамках мер поддержки, срок их окупаемости. Целесообразно совершенствовать существующую в России нормативно-правовую базу, предусмотрев формирование мер поддержки проектов ВИЭ, реализуемых в изолированных энергорайонах и для энергообеспечения удаленных потребителей, а также поддержку производства соответствующих технологий. Разработка и внедрение соответствующих технологий ВИЭ и профессиональное обучение играют ключевую роль в использовании потенциала ВИЭ на этих отдаленных и изолированных территориях России.

1 Introduction to energy supply in remote areas in Russia

This study is about the potential for RE in remote areas in Russia which are not necessarily the same as isolated territories. For an area to be considered remote a number of criteria can be used: low population density, distance to urban centeres and the maturity of the infrastructure connecting the area to the rest of a country. In the context of this study remoteness is defined as: a missing connection to a centralized electricity grid based on fossil fuels. This narrow definition limits the focus to the isolated territories in the Arctic north, Siberia and the Far East of the Russian Federation. While these territories and their specific challenges are also included in this study, other regions that are not connected to a main grid and use diesel generators for power generation are included to present a wide range of application fields for renewable energy technologies in Russia.

1.1 History and overview

With a surface area of 17.1 million square km, Russia is the largest country in the world. The country is a federal state and therefore divided into parts, with the 8 federal districts (Russian sources include the Crimea as an additional, separate district) being the first sub-governmental division [1]. Each one has an administrative center and includes smaller subjects of the Russian Federation – republics, oblasts (regions around bigger cities which are the “capitals” of the oblasts), krais (regions, also with own “capitals”), autonomous regions, cities of federal importance (Saint-Petersburg, Moscow and Sevastopol) and one autonomous oblast (Jewish Autonomous Region). Looking at a map of Russian it becomes clear, that the closer regions are located to Europe and Southern Russian borders, the smaller and more densely populated they become. The average Russian population density is 8.58 people/km2, with the highest population density in Moscow – 4,894.31 people/km2. In Krasnodar the indicator is 73.80 people/km2 while, in the Republic of Sakha (Yakutia) it is 0.31 people/km^2.

For many reasons, including climate conditions, the historical, political and economic development of the Russian power grid has been varied. In 1920, the Soviet government launched the “GOELRO plan” which aimed to raise the electrification rate in the country [26]. The plan was successfully executed and in 1935 the largest part of the RSFSR (Russian Soviet Federative Socialist Republic) territory was electrified. However, it has always been a challenge to supply every corner of the country with electricity and even nowadays there are regions in Russia which still have no connection to the central power grid, the Unified Power System of Russia (United Power System) (UPS). As a result, it is necessary to use decentralized energy generations, which are often diesel generators.

According to different estimations, 60 to 70% of the Russian territory which is inhabited by 22-25 million people, is not connected to the UPS [31] [33] which is illustrated in Figure 1:

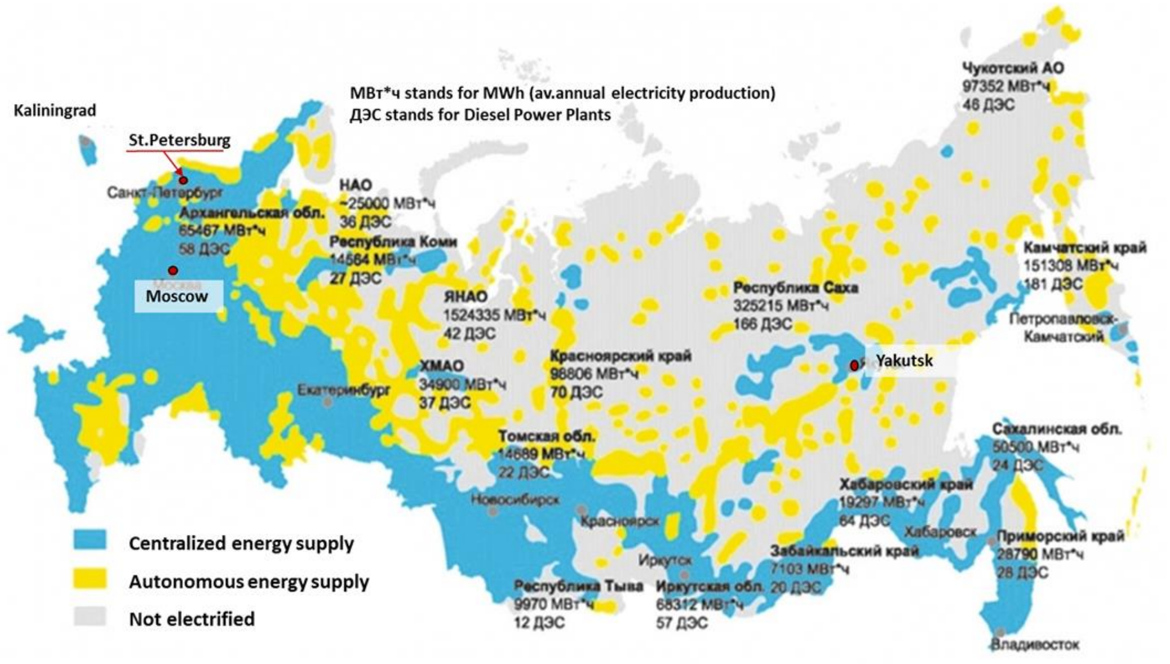

Figure 1 Map of the modern electrification of Russia; source: Elistarov, 2016 [38], based on Fortov & Popel', 2011 [44]

Although a large share of the settlements located outside the UPS area use local electricity grids operated by regional grid companies and are included in small-scale electricity systems, there are still between 10 and 20 million people living in settlements with a population of mostly between 200-300 people, whose electricity needs are traditionally covered by diesel and petrol generators of different sizes. These generating units represent a perspective market for PV, wind and hybrid diesel/RES generation solutions [33] [40]. Most of these settlements are found in the Far East, Siberia and districts of the Far North. However, going beyond these so-called "isolated territories", there are also 30% of farms and 20% of gardening communities all over Russia, including the European regions and the most developed areas close to Saint-Petersburg and Moscow, that are also not connected to the centralized electricity grid system [35], meaning that the remote areas also exist in developed and highly populated Russian regions. Simultaneously, 50% of all Russian regions are estimated to be energy-deficient, which means that they do not receive enough energy [32]. For example, only around 50% of big settlements in Russia are gasified, while in rural areas the gasification rate does not exceed 35%.

Also, outside the northern isolated territories, there are thousands of small villages in Russia which have no access to electricity grids, even though some of them are located relatively close to big cities and the UPS. One example is a developing and growing village Podberyoza (rus. Подберёза) in the Novgorod oblast (European part of Russia) which has a brand-new road but lacks electricity supply, so inhabitants have to use private diesel generators [36].

1.2 Energy and supply in remote areas

70% of the Far East is disconnected from the UPS and in Sakhalin and Kamchatka, roughly 90% of electricity is generated from liquid fuels [34]. There are more than 900 autonomous diesel power stations of different capacity in these two regions alone [34]. According to some estimations, the number of diesel-based generating facilities in the remote areas all over Russia exceeds 50,000 with an overall installed capacity of 500 MW.

Annually they use more than 1 million tons of diesel to generate 2.54 billion kWh [38][43]. The overall Russian off-grid installed electrical capacity (including diesel, coal, gas, RES based) is around 7.76 GW [39] while the installed capacity of autonomous (private) PV generation, according to Anton Usachev, the head of the non-commercial Association of Solar Energy of Russia, reaches 6 MW [42]. Annually, the Far North region, the Far East and Siberia receive around 5 million tons of all types of liquid fuel (including diesel but also mazut[1] and petrol for transport needs) and 2 million tons of coal [37] from other parts of the country to cover the electricity demand and fuel-needs for transport, this is also called the "northern delivery[2]". The government's budget has allocated hundreds of billions of rubles annually to supply these regions with fuel for energy generation needs. The price of fuel usually doubles after being delivered to these regions due to high logistical costs.

In the northern remote areas, that are disconnected from the UPS or a local electricity grid, costs for electricity are the highest and vary between 35-220 RUB/kWh (0.44 – 2.9 EUR/kWh) reaching even 600 RUB/kWh (8 EUR/kWh) in very extreme cases: for instance, according to the Decree of the State Committee for Pricing Policy of the Republic of Sakha (Yakutia) N 225 of December 28th 2018, which approved establishment of the electricity tariffs generated by "Sakhaenergo" (see chapter 2.1 for more details) for 2019, the village of Suchchino is reported to have a single-rate electricity tariff of 660,55 RUB/kWh (8.8 EUR/kWh) [137]. Nevertheless, consumers living in these areas are not the only ones that carry those costs: all energy related expenditures are split and averaged between local energy supply companies, regional budgets and other consumer groups. This is called cross-subsidization, meaning that consumer groups with low generation costs indirectly finance the higher generation costs so that consumers based in remote areas do not have to pay the "real" generation costs for electricity, far from it. Although electricity tariffs for the population in these areas often differ from the average tariffs of the region, residential customers always pay the lowest price in comparison to other consumers, such as industrial consumers and SMEs. In order to make electricity prices affordable for final customers, the state pays annual subsidies of around 65 billion RUB (866.9 million EUR) to compensate the regional electricity supply companies for the difference between the economically appropriate electricity price based on "real" generation costs and the end price for consumers [37].

Due to the low population density in these regions it would usually be economically unprofitable to develop the centralized grid and/or to build large power plants far from the UPS. Instead, it is deemed to be more effective to construct local electricity stations powered traditionally by imported or locally extracted primary energy sources (liquid fuels, gas, coal) or, this a more recent development of the last approx. 5 years to use renewable energy sources. For the remote regions, using renewable energy sources and replacement/complement of expensive imported diesel fuel is generally economically justified although RE installations in some remote areas may have to be adapted to extreme weather conditions and can therefore not be considered "standard" RE solutions. Still, the cost of fuel saved can cover investment costs and ensure the full payback of the investment. Depending on the size and type of the hybrid PV-diesel system, the average price of 1 kWh generated by a hybrid system in remote areas is sometimes estimated to vary between 7 and 15 RUB (0.09 – 0.20 EUR) which is significantly cheaper than diesel electricity [40]. However, based on the research and calculations done for this report these estimations seem to be very optimistic at least for the selected target regions. The results of our calculations would rather be in line with research done by the Russian Presidential Academy of national Economy and Public administration, RANEPA [41] : in a paper published in 2018,

[1] Mazut or heavy fuel oil of a very dark colour, received at the first step of crude oil refinery. According to Volker Quaschning, emissions from natural gas combustion are 0.2 kg/kWh, (…) of diesel is 0.27, and of mazut is 0.28.

[2] A centralized delivery of the most important goods including food and petroleum products to the Far East, Northern Siberia and the Far North and some Northern parts of the European territory of Russia. The Northern Delivery usually last between June and November when water ways are free from ice.

RANEPA gives estimates for LCOE for different PV applications. According to RANEPA, the LCOE of community solar PV plants could vary between 0.09 and 0.72 EUR/ kWh whereby the high-end accounts for carbon capture and compression but no costs of storage and transportation.

With regards to the market, size estimations differ. According to Anton Usachev, an overall market size for PV energy in remote Russian areas is estimated to be around 500 MW [40].

1.3 Legal and regulatory framework for off-grid energy supply

The power supply in the isolated energy zones is carried out in accordance with the existing regulatory and legal framework, which specifies the electricity sale procedure of energy generating facilities in territories that are not connected to the United Power System (UPS).

1. **Government Decree No. 1178** from December 29, 2011 defines pricing specific aspects in regional energy systems disconnected from the UPS of Russia [108].

The decree defines the tariffs for energy and power capacity, as well as transmission payments of this energy in disconnected from the UPS regional energy systems. The energy tariffs and tariffs for energy transmission are set according to the special guidelines and methodology, approved by the Federal Antimonopoly Service of Russia. The decree also states, that the local regulatory body of each region should be designed to fit the region's peculiarities and that energy systems may set various tariffs:

- differentiated by 4 voltage levels: ≤0.4 kV (e.g. 150 V; 220 V); 1-20 kV (1, 6, 10, 20 kV); only 35 kV and more than 110 kV;
- differentiated by two voltage levels (electric grid facilities with a voltage ≤35 kV and ≥35 kV);
- without differentiation by voltage levels;
- differentiated by consumption and/or by groups of consumers determined by the authorized executive bodies of the region.

The chosen tariffs, in accordance to the aforementioned list, are combined with other factors and tariff categories, which, at the end, seriously influence the end consumer energy price. This is especially relevant for non-residential consumers (e.g. industry). The different prices influenced by these tariff groups are presented in Table 4, Table 6, Table 8, and Table 10 of this report.

It is important to note that based on the methodological guidelines for the calculation of regulated tariffs and prices for electricity in the retail market, approved by the Federal Tariff Service of Russia of August 6, 2004 No. 20-e / 2, there are 4 tariff groups of consumers distinguished in the Russian Federation:

- Basic consumers - consumers with a required need of ≥20 MW of power capacity per month3 Those are usually large enterprises which purchase energy only from energy producers who are not a part of the wholesale market.
- Population (residential consumers);
- Other consumers (not included into categories 1, 2 or 4);

[3] In Russia prices/tariffs for electricity often include payments for used capacity (kW/MW) along with payments for consumed power (kWh/MWh). Often, consumers are divided into categories depending on the maximal capacity they purchase and on loads they have (especially is this important for industrial consumers).

- Organizations that provide electric power transmission services and acquire it in order to compensate losses in power grids owned by these organizations on the right of ownership or on other legal grounds.

Decree 1178 also regulates the following electricity tariffs for consumers[4]:

- single rate tariffs which includes the full cost of delivery of 1 kWh, taking into account the unit cost of capacity;
- single rate tariff differentiated by 2- and 3-day time zones (day and night & peak, semi-peak and night zones). This tariff includes the full cost of delivery of 1 kWh taking into account the unit cost of capacity;
- three-rate tariff applied since January 1, 2013, which includes consumption rates/ kWh and capacity rates/kW paid by the consumer in the billing period. The major difference between a three-rate tariff and a single-rate tariff is that a single rate tariff includes only payments for electrical power and a consumer shall conclude an additional contract with a grid company and pay it for energy transmission services. At the same time, a three-rate tariff already includes cost of electricity, price for power capacity (load) and payments for energy transmission. It means, that a consumer does not have to conclude a contract with a grid operator in case it pays according to a three-rate tariff.

Consumers with the maximal power of their energy receivers is up to 670 kW are able to choose from the mentioned above tariffs themselves, whereas all other consumers with higher maximum receivers' capacity use the three-rate tariff only.

Local regulatory authorities have the right not to set a three-rate electricity tariff in technologically isolated energy systems. In regional energy systems disconnected from the UPS, the three-rate energy tariff delivered to customers in retail markets is not set.

If the regulatory body does not prescribe a three-rate electricity tariff in technologically isolated (out of UPS) areas consumers of the retail market, select the tariff from the following 2 variants:

- single-rate tariff, which includes the total cost of delivery of 1 kWh, taking into account the cost of capacity;
- single-rate tariff differentiated by 2- and 3-day time zones, which includes the full cost of delivery of 1 kWh, taking into account the cost of capacity.
- the Federal Antimonopoly Service approves the intervals of the tariff zones of the day by month of the calendar year.

2. The **Decree of the Government of the Russian Federation No. 854** from December 27, 2004 [109], approves the rules of operational dispatch management in the electric power industry. According to these rules, operational dispatch control in power systems (both UPS of Russia and regional energy systems disconnected from the UPS) is carried out by means of centralized management of interrelated technological modes of operation of electric power facilities and consumers' power-receiving installations. These modes together form the electricity regimes of the respective power systems. (Hereinafter - electric power grid management regime).

[4] Only for non-residential consumers and **groups which are not equated to population** active on the retail markets of the non-prise zones and isolated areas as well as territories disconnected from UPS. **Groups, equated to population**: the category includes many consumers such as non-profit horticultural/agricultural communities; prisons; entities and individuals purchasing electricity with an aim to use it for household needs (military units, settlements); religious organizations

Operational and dispatching management of the energy systems (both UPS and regional energy systems disconnected from the UPS) is led by a centralized regulator. For the UPS, the regulatory body is the system operator of UPS (System Operator of the Unified Power System – "SO UPS"). For regional (local) energy systems, which are disconnected from the Russian UPS, this role is played by relevant operational branches of "SO UPS".

The system operator of regional energy systems disconnected from the UPS determines the structure of dispatch centers, including their levels and hierarchy in the area of its' dispatch responsibility. At the same time, dispatch centers defined as higher level dispatch centers cover operational zones that include the operational zones of other dispatch centers and are subordinate to higher level dispatch centers.

3. **Federal Law No. 35-FZ** from March 26, 2003, "On Electric Power Industry" [110] established a mechanism of support for the production of electric energy based on the use of renewable energy sources in isolated power systems, which prescribes long-term tariffs for RES-based electricity for the payback period and guarantees the mandatory purchase of the entire amount of electricity generated by renewable energy by the power system

4. When it is described how prices and tariffs in Russia are formed and function, it is important to distinguish between the different rules of how they are regulated on a higher level of the wholesale electricity market of Russia. The territory of the country is divided into 4 zones, (see Figure 2), each of them has specific rules of price formation:

- Price zones (first and second): prices for the consumers on the wholesale market and the retail market (except for residential consumers) are non-regulated
- Non-price zone (covering different territories of Russia but having the same rules): prices and tariffs for all consumers are regulated
- Isolated energy systems: prices and tariffs for all consumers are regulated

Electricity tariffs for residential consumers and groups equated to population[5] are always regulated, regardless of which zone they belong to.

The figure below illustrates different prize zones of the wholesale market existing in Russia with the highlighted target regions.

[5] **Groups, equated to population**: the category includes many consumers such as non-profit horticultural/agricultural communities; prisons; entities and individuals purchasing electricity with an aim to use it for household needs (military units, settlements); religious organizations

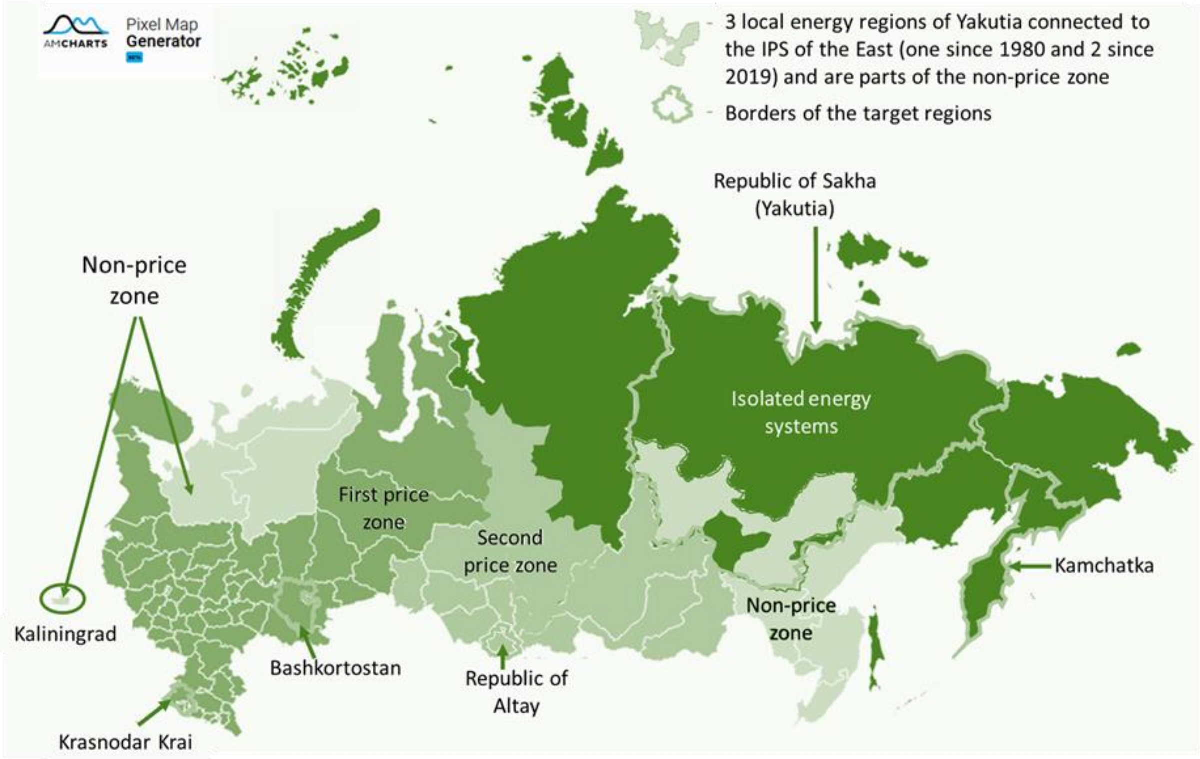

Figure 2 Prize, non-prize zones and isolated areas of the wholesale electricity market of Russia, target regions highlighted; source: eclareon 2019, based on Ernst & Young, 2018 [163]

5. Government Decree No. 442 from May 4, 2012 [111]: this document regulates the rules of electric energy sales in isolated energy zones. The sale procedure of electrical energy produced by qualified RES generating facilities is illustrated by Figure 3. The parameters of tariff regulation are presented in Table 1.

In accordance with this decree, generating facilities located in regional energy systems disconnected from the UPS sell energy at regulated tariffs to a "guaranteeing supplier" (retail company) that operates in the system. The dispatching office of the technologically isolated regional energy system forms an hourly generation schedule of retail market participants a day in advance. The schedule includes planned hourly electric energy (capacity) production of:

- qualified generating facilities based on renewable energy
- generating facilities with the lowest cost of produced electrical energy (capacity)

This rule is implemented under conditions of ensuring the reliability and safety of the electricity system. Thus, in 2012, the regulatory framework determined the priority of renewable energy generation in the power supply structure.

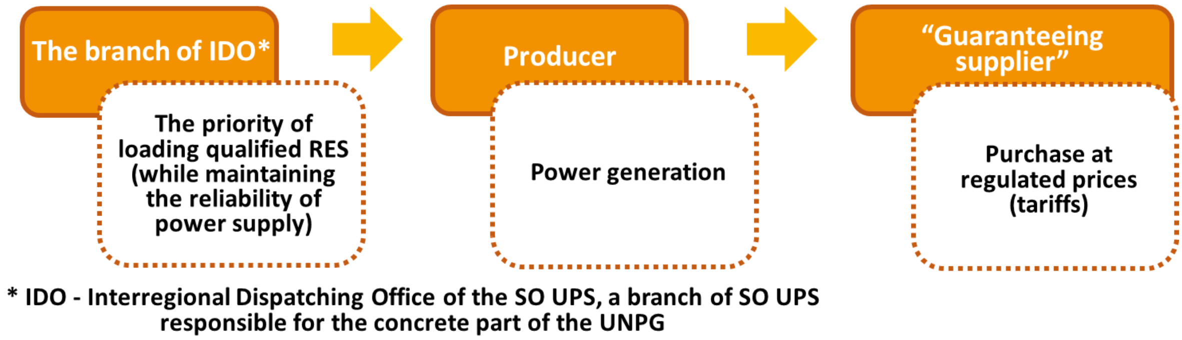

Figure 3 The procedure for the sale of electricity produced by qualified generating facilities in energy systems disconnected from the UPS; source: Barkin O.G. [112]

Tariff regulation parameter	Territories and power systems disconnected from the UPS
Basic rate of return	According to the results of the tender
Investment capital repayment period	According to the results of the tender
Limits for capital expenditures	According to the results of the tender
Limits for operating costs	Not set
The requirement for minimum capacity factor	Not set
Localization requirement (application of a reduction of the penalty factor to investment capital)	Not set

Table 1 Terms of return of investment capital, provided for by measures of support in tariff regulation in relation to qualification objects of renewable energy; source: Barkin O.G. [112]

The same resolution addresses the issue of setting tariffs for various groups of consumers.

For residential consumers (population) and groups, equated to population, the electricity tariff is set at regulated prices, regardless of the price zone or the location of the settlement, even in the isolated power system [111].

For other groups of consumers, active in price zones, the tariff (price) is set at unregulated prices within the limits of marginal unregulated prices [111]. The unregulated price is influenced by various market factors of the wholesale market: the price may vary significantly from month to month (the effect of the magnitude of demand, the cost of fuel, the repair of transmission lines, etc.). The final price consists of the following components: the price of electrical energy (capacity) on the wholesale market (58% of the end price), the tariff for power transmission (40%) and other components (less than 2%).

Price for non-residential consumers also differs depending on:

- the voltage level (high ≥110 kV; first medium of 35 kV; Second medium 1-20 kV and low ≤0.4 kV)
- belonging to one of six price categories that are calculated by the guaranteeing suppliers and are a type of "energy tariffs" for enterprises [111]. Price categories depend on many factors and the scheme of defining a price category is relatively complicated. The following price categories can be distinguished:

- First price category means, that a consumer pays for electricity once a month and consumed energy is defined in accordance to the electricity meter readings
- Second price category means, that energy consumption is separated in accordance to one of the two variants: two-day zones/double day time tariff (day and night) and three-day zones consumption (day, night and peak zone)
- Third price category: not only electrical energy but also generating capacity is applied for payment.
- Fourth category: price includes electrical energy, capacity AND energy transmission
- Fifth: same as the third but with an ahead planning
- Sixth: Same, as the forth, but with a forward planning

Simultaneously, there are 3 groups of consumers, differentiated by their maximum load corresponding to the simultaneous use of energy receivers (maximum power of energy receivers):

- those with a maximal load ≤670 kW
- those with a load between 670 kW and 10 MW and
- those with loads ≥10 MW

Consumers with loads below 670 kW are able to choose any of the six price categories; all other consumers can choose only from third-sixth price category. Those consumers are all non-residential ones, small, medium or large enterprises.

6. The Russian Governmental **Decree No. 47 from January 23, 2015**, “On Amendments to Certain Acts of the Government of the Russian Federation promoting the Use of Renewable Energy in the Retail Electricity Markets” [113] determines supporting mechanisms in the retail electricity market for renewable energy based on biogas, biomass, landfill gas, and other renewable energy sources including wind and solar. The resolution introduces the procedure and long-term limiting parameters of tariff regulation for supporting renewable energy generating facilities. For RES investments into projects under the Decree 47, the rate of return on investment capital (ROI) is set at 12% and payback period for investment capital is set at max. 15 years. Capital and operating costs for the production of electric energy for qualified renewable energy generating facilities are set not exceeding the capital and operating costs limits. The capital and operating costs limits are listed in the Order of the Government of Russian Federation No. 1472-p of July 21st 2015 in Appendixes 5 and 6 (until 2020) [139]. The table below illustrates some of these limits.

For the RES projects, realized under the Decree 47 in technologically isolated areas disconnected from the UPS, there are no CAPEX and OPEX limits, neither there are return or investments payback limitations. The projects are tendered, the most important “winning” condition is bringing the local energy prices down as a result of a RES project.

Type of energy generating object	2019	2020
Some limits for CAPEX, RUB/kW (EUR/kW)		
Wind power plants up to 25 MW total capacity	109,561 (1,461)	109,451 (1,459)
PV power plants up to 0.5 MW capacity	110,525 (1,474)	108,315 (1,444)
PV power plants, capacity between 0.5 and 25 MW	105,262 (1,403)	103,157 (1,375)
Biogas power plants (landfill gas), capacity between 1 and 5 MW	98,000 (1,307)	98,000 (1,307)
Some limits for OPEX, RUB/kW/year (EUR/kW)		
Wind power plants up to 25 MW total capacity	1,927 (25.7)	1,999 (26.6)
PV power plants, capacity up to 25 MW	2,777 (37)	2,880 (38.4)
Biogas power plants (landfill gas) capacity between 1 and 5 MW	17,150 (228.7)	17,150 (228.7)

Table 2 Some limits for CAPEX and OPEX for RES power plants constructed within the framework of the Decree 47; source: Order of the Government of Russian Federation No. 1472-p [139]

7. These limits are also prescribed by the Russian **Government Decree No. 1** from January 8th 2009, (rev. from 15.05.2018) for a longer period (limits are presented until year 2024) [114]. Due to a relatively small size of regional retail electricity markets and high CAPEX and OPEX limits, local administration has to increase the end customer tariffs in order to provide a required investments payback rate. However, considering the whole process of price formation, consumers' tariffs are unlikely to grow by more than 0.4%. Still, enabling of the Decree 47 is rather complicated and needs additional efforts from local governments, therefore, they are usually not hurrying with implementation of this legislative act.

8. Decree of the Government of the Russian Federation **No. 961** from September 23, 2016 [140], "On the procedure for granting subsidies from the federal budget for state support of technological connection of generating facilities using renewable energy sources" regulates the state support to stations operating on renewable energy sources (RES - solar, wind power plants, small hydroelectric power stations) and peat with an installed capacity up to 25 MW . Subsidies will be up to 70% of the cost of technical connection of generating unit to the grid but not exceeding 15 million rubles (200 thousand EUR) for each generating object.

The purpose of the law is to create legal, economic and organizational bases for stimulating energy saving and increasing energy efficiency, and its action extends to activities related to the use of energy resources.

The development and implementation of municipal programs in the field of energy conservation and energy efficiency enhancement refers the competence of local authorities in the field of energy conservation and energy efficiency. Regional, municipal programs in the field of energy conservation and energy efficiency should include an increase in the number of facilities using secondary energy resources and/or renewable energy sources as energy sources.

9. **Decree of the Government of the Russian Federation No 610** of May 23, 2017 "On Amendments to the Qualification Rules for a Generating Facility Functioning on the Basis of Using Renewable Energy Sources" [141] defines the basic principles and qualification criteria.

NP "Market Council" carries out the qualification of generating facilities and maintains their registry.

Generating facilities operating on the basis of renewable energy sources must meet the following requirements in order to be recognized as qualified ones:

- it generates energy from RES or combines RES with other types of fuel (e.g. with a diesel genset)
- it is in operation (not being repaired or decommissioned)
- it is connected to the power grid
- for participants in retail markets, the generating facility is equipped with metering devices which meet the requirements of the “Basic Operating Principles of Retail Electricity Markets”, approved by the Government of the Russian Federation on May 4, 2012 No. 442 [111]
- the generating facility is included into the “Scheme and program of Perspective Development of Electric power industry” of the concrete region, where this RES facility is located

Currently, 54 solar installations, 9 wind installations, 10 small hydropower plants and 4 biogas-installations in Russia are qualified according to the abovementioned criteria.

10. In 2018, the **Federal Law No. 261** from November 23rd 2009 "On energy saving and on increasing energy efficiency and on introducing amendments to certain legislative acts of the Russian Federation" came into force as amended on 08.03.2018 [118].

The purpose of the law is to create legal, economic and organizational basis for stimulating energy saving and increasing energy efficiency. The development and implementation of municipal programs in the field of energy conservation and energy efficiency enhancement refers the competence of local authorities. Regional programs in the field of energy conservation and energy efficiency should target increase in the number of facilities using renewable energy sources.

Federal Law No. 261 can be used (and is used for PV-diesel and wind-diesel projects in remote northern regions) as the basis for contracts between a local municipal company and an investor. In these contracts, fuel saving through the use of renewable energy sources and other technologies are the basis for recouping investments and generating income. The investor receives a payback in the amount of the cash value of the fuel saved in RUB/liter. When concluding these contracts, the localization of equipment production and conclusion of a tariff agreement are not required. Profitability for the investor in this case is not limited, but the long-term tariff risk (which mainly corresponds to inflation) remains with the municipal company.

11. December 27, 2016, a meeting of the Council of State " On the environmental development of the Russian Federation in the interests of future generations"[116] resulted in the President of Russia approving the **List of Instructions No. p-140 GS** from January 24th 2017. The document stipulates the development of microgeneration using renewable energy sources when formulating strategic planning documents and comprehensive action plan of the government of the Russian Federation for 2017-2025 [116].

12. In pursuance of the instructions list, on February 10th 2017, the government of the Russian Federation issued a relevant order to the executive authorities [117].

On July 19th 2017, the Ministry of Energy of the Russian Federation prepared **an Action Plan to stimulate the development of generating facilities based on renewable energy sources with an installed capacity of up to 15 kW.** The plan provides for amendments to the legislation on electric power industry. It establishes the basic principles of contractual relations between private owners of micro-generating units based on renewable energy sources and electric energy market participants (guaranteeing suppliers and grid companies). The main goal of the implementation plan is to simplify the procedure for RE micro-generating facilities and to enable their owners to sell surplus electricity generated to public grid. In 2017, the Ministry of Finance developed amendments to the tax code related to microgeneration. The ministry proposed exempting the owners of micro renewable energy power plants from income taxes if they sell the surplus electricity generated by no more than 30,000 RUB (400 EUR) from January 1st to December 31st annually [119].

In pursuance of the Action Plan, the Ministry of Energy prepared a draft Federal law "On Amendments to the Federal Law on Electric Power Industry" targeting development of microgeneration. On October 15, 2018, the commission on legislative activities approved a draft law of the legal regulation of electricity generation by microgeneration facilities [120]. On November 6th 2018, the Government of the Russian Federation sent a draft law on the regulation of electricity production by micro-generating facilities to the state Duma[6] [123].

The draft law introduces the following concepts and criteria for facilities, as well as criteria for classifying generating facilities as micro-generating ones:

- A micro-generating facility is based on the renewable energy source, with an installed capacity not exceeding 15 kW and is used by private consumers to produce electricity to cover the electricity demand of their personal household and/or their small production)
- A micro-generation facility supplies with energy a private house only. Apartment houses are excluded from the law.
- The procedure for technological connection of facilities to electric grid is established by the government of the Russian Federation;
- Prosumers become participants of the retail market only and are empowered to sell energy on the retail market.

All legal owners of micro-generating facilities ("prosumer") sell their electricity in retail markets in accordance with procedures established by retail markets basic principles. The sale of electric energy by citizens owning micro-generating facilities is not considered being a business activity.

It is mandatory for guaranteeing suppliers to conclude power purchase agreements with owners of micro-generating facilities in the area of guaranteeing supplier's activity. To conclude the agreement, a prosumer shall contact a guaranteeing supplier directly. The prices for electricity produced by microgeneration objects are determined in accordance with procedures, established by the basic provisions of retail markets functioning and not exceeding prices for electrical energy and power purchased by guaranteeing suppliers on the wholesale market. Currently, the average price for 1 kWh on the wholesale market is around 2 RUB/kWh (0.02 EUR/kWh) [143], in 2018, this price was fluctuating around 1.5 RUB/kWh (0.02 EUR/kWh) [142].

In cases established by the main provisions of retail markets functioning, grid companies are obliged to compensate grid losses, primarily through a purchase of electricity produced by qualified RES- or peat- based power generating facilities.

On August 21st 2019, a Resolution of the Government of Russia N 1853-r has been sent out for consideration to Duma. The Resolution amends the Tax Code of Russia with regard to the taxation of income from the sale of electricity by RES microgeneration owners. It is suggested that the owners will be exempt from income tax

[6] The State Duma – The Federal Assembly of the Russian Federation

in case of selling any electricity amount to the grid operators. The benefit is planned to be valid until January 1st 2029.

1.4 Off-grid renewable energy projects

Given the absence of specific legislation for grid connected smaller installations (the law for installations <15 kW is currently prepared but not yet enacted, see above), the Russian RE market is divided between large centralized MW installations that are mainly built based on the public tender mechanism of Decree 449 and smaller off-grid installations with common sizes between hundreds of watt and kW. By and large two off-grid (or weak grid) market segments can be distinguished in Russia:

1. Autonomous installations of mostly holiday houses. The famous Russian “datcha” settlements are oftentimes not connected to the grid. These private houses are often supplied by small diesel gensets but RE solutions, mostly solar PV, play an increasingly important role for these settlements. The installation is a pure private business between an installer and a private customer. In this small niche market economic considerations play a role as well but are not as dominant in other market segments. These installations are often built in the surroundings of urban centres such as Moscow or St. Petersburg.

2. RE installations that are built in remote areas which are defined by low population densities and difficult supply logistics. Traditionally, electricity in these areas has been generated with diesel powered gensets whose fuel supply is very expensive. Many of these gensets need to be modernized. RE installations in remote areas range from solar powered lighthouse signals with some 100 Watts to MW installations which complement the traditional fossil-fuel based energy supply of larger settlements. Installations require mostly the cooperation with a so-called “guaranteeing supplier” who are public utilities with the mandate to ensure energy supply of remote areas. Economic considerations play a role as the guaranteeing supplier are motivated to decrease the often very high costs for energy supply in remote areas. Examples for installations are the PV installation in the Batagai settlement in the Republic of Sakha Yakutia (see chapter 2.1.5) and the wind installation in Ust Kamchatsk (see chapter 2.2.4). Such installations are in the focus of this study.

1.5 Selection of regions

For this study the following 10 regions were pre-selected:

Nr.	Region	Which application areas are there for diesel power?	Flying time from Moscow	Electricity consumers groups in numbers > 15 €cent p. kW/h?	Are programs for the promotion of renewable energy sources available?	Have pilot projects for renewable energy sources been implemented?
1	Sakha (Yakutia)	The only source of energy in Northern territory is the diesel power for all types of residential, municipal and industrial consumers.	6	Energy companies, local municipal communities	Modernization program to upgrade diesel stations with renewable energy courses	12 off-grid PV powerplants in operation
2	Kamchatka	The only source of energy in Northern territory is the diesel power for all types of residential, municipal and industrial consumers.	9	Energy companies, local municipal communities, fish processing companies	Kamchatka Energy supply development program includes wind energy, small hydro and geothermal energy development	Grid connected only: geothermal power plants, wind parks
3	Sakhalin	Kamchatka municipalities, energy companies, fish processing companies, tourism areas.	9	Energy companies, local municipal communities, fish processing companies	No Regional Program	Existing grid connected wind park only
4	Irkutsk	Metallurgy companies, remote consumers, villages	5	Metallurgy Companies	No Regional Program	No
5	Tatarstan	Industrial clusters	1,5	Techno parks, Industrial Parks	No Regional Program	Small hydro systems
6	Bashkortostan	Municipalities and tourism areas	2	Remote villages, Mountain Tourism places	No Regional Program	5-10 MW Solar parks under 449 law, small hydro power plants
7	Altai	Municipalities, local electric grid companies	5	Municipal and Energy companies	No Regional Program	Support of solar on-grid and off-grid systems, including large PV parks
8	Primorye	Northern territory is a zone of decentralized energy supply. The only source of energy there is the	7,5	Energy companies, local municipal communities, all in-	No Regional Program	Wind Park project is staring

Nr.	Region	Which application areas are there for diesel power?	Flying time from Moscow	Electricity consumers groups in numbers > 15 €cent p. kW/h?	Are programs for the promotion of renewable energy sources available?	Have pilot projects for renewable energy sources been implemented?
		diesel power for all types of residential, municipal and industrial consumers.		dustrial companies in the North part of Primorye		
9	Magadan	East and North part are zones of decentralized energy supply. The only source of energy there is the diesel power for all types of residential, municipal and industrial consumers. Diesel station serve as energy supply to all metallurgical industry in the region.	8	Municipalities and industrial companies in the North and East of the region	No Regional Program	No
10	Chukotka	Used by Energy companies as primary and reserve sources. In addition, the consumers are metallurgical and coal extracting mining companies	9	Municipalities and industrial companies of the region	No Regional Program	Grid connected wind park project under construction

Table 3 Target regions, long list; source: eclareon

In order to cover as much diversity a possible in regards to remote regions in terms of geographical distribution, type of supplied customers etc. the following five regions were finally selected for in-depth research:

1. Sakha (Yakutia)
2. Kamchatka
3. Republic of Altai
4. Bashkortostan
5. Krasnodar Krai

Although there is no standard definition when a remote region is also an isolated territory, Sakha Yakutia and Kamchatka would be classified based on population density and climatic conditions as isolated territories whereas the other 3 target regions would not be regarded as isolated as a whole despite the fact there are areas where off-grid energy supply play a role.

1.6 Financing and profitability analysis of renewable energy business models

An important objective of this report is to identify viable business models for the deployment of RE in remote areas in Russia and business cases that can act as role model. Existing installations were selected and have been analysed in more detail using a profitability analysis that evaluates the economic performance of RE installations. An installation is economically viable if the sum of the discounted net benefits (benefits minus costs) is positive, payback of the investment can be assured during the lifetime of the project and if the economic internal rate of return (IRR) equals or exceeds the discount rate. A standard equity discount rate used in economic analyses of projects in Russia is estimated to target a minimum of 12% and a payback period of less than 8 years. The calculations took these values as orientation points into consideration but, in order to show what it takes to create a viable business case, may have deviated from these reference values.

An Excel based discounted cash flow analysis (DCF) was used for the profitability analyses. The DCF methodology is used to evaluate a project using the concept of the time value of money. All future cash flows are estimated and discounted to give their present values. The net present value (NPV) is the sum of all positive and negative cash flows' present values including the initial investment. The NPV allows a comparison of investments with different durations and cash flow profiles over their lifetime at the present point in time. Besides NPV, the internal rate of return (IRR) for both the equity and the entire project were calculated as well as the amortization period for the invested capital. These parameters give investors an indication of the attractiveness of an investment. Another key parameter calculated is the levelized cost of electricity (LCOE) which makes it possible to compare power plants of different generation and cost structures. Finally, ratios such as the debt service coverage ratio (DSCR) and loan life cycle coverage ratio (LLCR) provide information about whether the project's cash flows suffice to reimburse the debt invested in a project.

The regional business cases presented in this study always refer to one "real" project already installed in every target region. These "real" projects do however not necessarily represent best practice cases: The projects were often amongst the first RES projects realized in their respective region which means that their realization took place at the beginning of a learning curve, not at the end of it. For example, the case of the installation in Severny, Bashkortostan, is presented in this report since it was one of the very few existing off grid installations in the region for which data could be researched. However, the installation ceased soon to generate electricity for technical reasons so it is far from being a best practice case. As such it rather represents an illustrative example of the difficulties that early RE projects have been facing in Russia.

Having researched and assessed the profitability analysis of these projects in different regions, a number of general findings about the challenges that the development of RE faces in remote areas can already be summarized here. It is well known that most RES are often characterized by relatively high initial investment costs that can be, during the lifetime of an RE power plant, repaid by substantially lower expenses required during the years of operation. Speaking in financial terms, initial capital expenditures (CAPEX) are relatively high and operational expenditures (OPEX) are relatively low for RES. The opposite is true for conventional power plants. Although financing may also play a role during operations, the costs that drive the financial expenditures (FINEX) are usually the ones associated with the initial investment (CAPEX) which is paid back during the lifetime of a project - this is illustrated in the following graph (Figure 4):

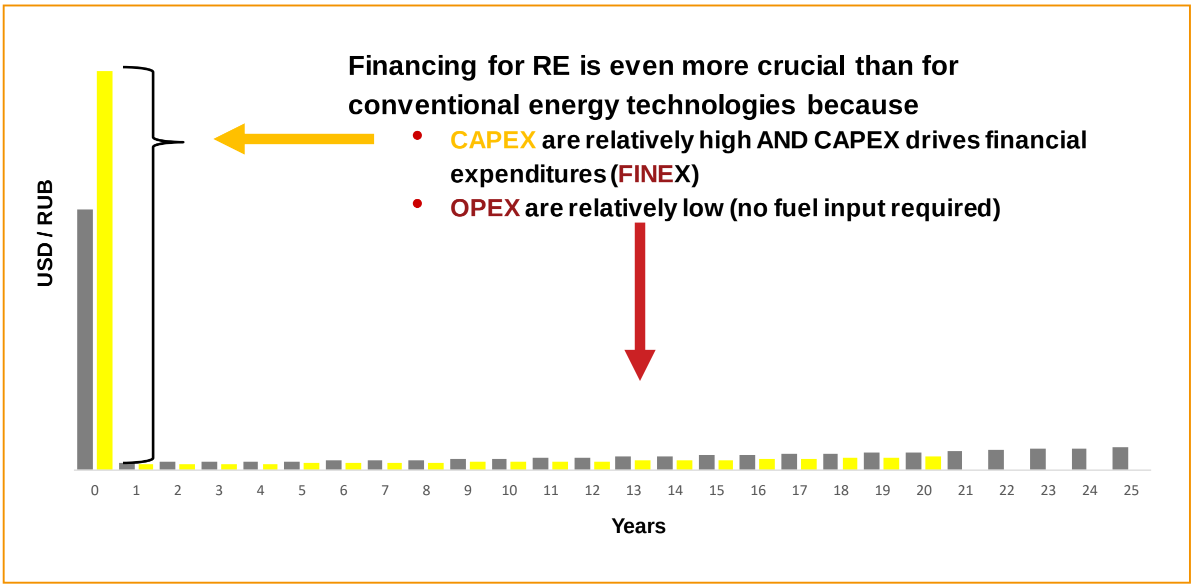

Figure 4 CAPEX, OPEX and FINEX for RES (yellow) and conventional energy sources (grey); source: eclareon, 2018

The need for upfront capital to finance RE in Russia was found to be problematic because the (mostly public) energy companies responsible for the renovation and creation of energy generation capacities in remote areas often lack financial resources to finance high initial investments. In Russia, as described in this report, there is a system of cross subsidies which means that certain consumer groups which live in an area where generation costs are relatively low cross finance other consumer groups which otherwise would have to pay very high electricity prices. Consumers in remote areas usually belong to the latter group. However, these subsidies are targeted to finance operational costs, typically diesel fuel, and not initial investments.

2 Detailed analysis of target regions

Having presented information that is generally true for all remote regions in the first section of this report, the 5 targeted regions selected for this report will now be examined in more detail. The common feature for all of them is the usage of diesel for energy generation in areas that are not connected to a centralized grid. Apart from this, the regions were selected in such a way that not only the potential for off grid RES in "typical" isolated territories such as the Sakha Yakutia and Kamchatka could be examined but also the potential of regions with some off grid areas which however do not represent the same climatic and logistic challenges as can be found in the isolated territories.

Regions differ in terms of their natural RE potential and the most attractive RE source Figure 5 illustrates potential of different renewable energy sources in Russia and shows the target regions examined in this study.

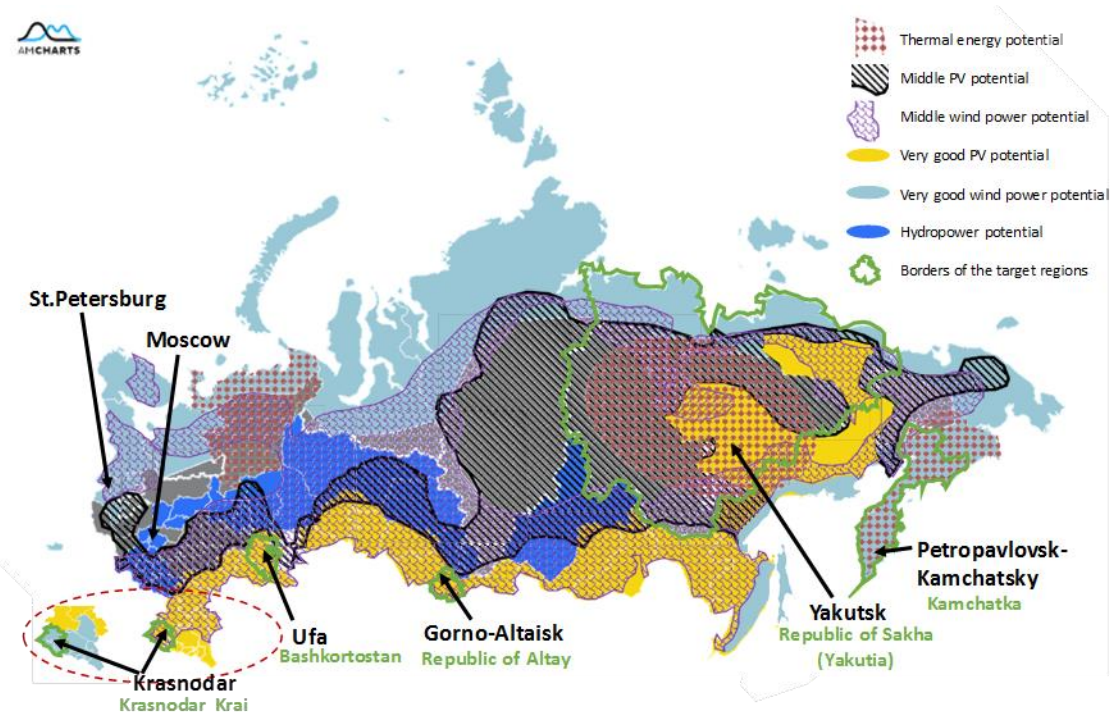

Figure 5 Map of renewable energy potentials in Russia and highlighted target regions of the study; source: eclareon 2019, generated with amCharts Pixel Map, based on Renewable Energy Maps, [161], NIPOM, 2018 [162]

2.1 Sakha (Yakutia)

The Sakha Republic, also simply referred to as Yakutia, is located in north-east Siberia and is a part of the Far East Federal District. It is the largest Russian region, covering 3.1 million km^2 [1][2]. More than 40% of the territory is located beyond the Arctic Circle. Depending on the latitude, the Polar Nights and Polar Days have different length: while in the coastal areas in the very north of Yakutia there is absolutely no sun for 3 months a year and a 24-hours sunshine also for 3 months, in more southern regions these periods are shorter. Yakutia's territory is known for its high temperature variability: rising up to $+40^0$ C in summer and falling to -60^0 C in winter [3]. 964.3 thousand people inhabit the region, of which 311.7 thousand live in Yakutsk, the regional capital city, so the population density is 0.31 people/km^2 which is one of the lowest in Russia [4] [5].

Figure 6 Map of Russia, Yakutia highlighted; source: eclareon 2019, generated with amCharts Pixel Map

Yakutia is Russia's richest region regarding natural resource deposits of all types. The main branches of the regional economy are: mining of diamonds, gold, oil, natural gas and coal [1]. Yakutian subsoils contain 82% of overall Russian diamond deposits; 61% of uranium; 82% of antimony; 40% of coal; 28% of tin; 8% of quick silver and many other types of natural resources including gas, oil, silver, zinc.

2.1.1 Current energy supply situation and renewable energy potential

Yakutia is located in one of the so-called non-prize market zones of Russia which means that the electricity market is still more regulated than this is the case in the price zones. In addition, Yakutia has "true" isolated territories, meaning that major part of the region has no connection to the UPS.

The regional energy system is divided into two energy zones including 4 distinct energy regions [10]:

- 3 regions that do have a centralized energy system (Central, Southern and Western)
- The northern region that is supplied by decentralized energy systems

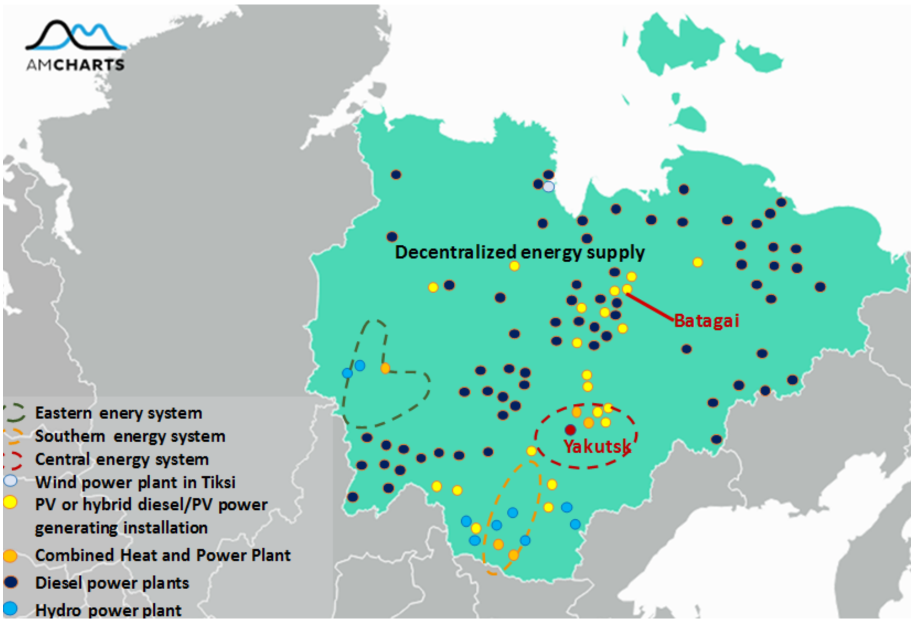

Figure 7 Current status of the electricity sector of Sakha Republic (Yakutia); source: eclareon 2019, generated with amCharts Pixel Map, based on Ministry of Economy of Sakha Republic (Yakutia), 2006 [8], RusHydro [148] and WWF Russia [55]

The three centralized energy systems include Yakutsk, they cover 36% of the territory and supply ca. 85% of the region's population with electricity. More than 50% of Yakutia's population lives within the parameters of the central energy system, while the southern and eastern energy systems cover the needs of large mining companies operating there. Major energy generation in the centralized system is ensured by the four largest power plants: one CHPP, fueled by natural gas, and three HPPs [11]. To supply parts of the South Yakutia energy region with electricity, "Yakutskenergo", the dominating regional energy company, purchases some of the needed energy from the wholesale market of the second price zone. The decentralized zone covers as much as 2,2 million km^2 (64% of the territory) with 15% of the region's population inhabiting it. Electricity generation and supply is secured by a large number of local power plants which supply settlements and mining sites.

Since January 2019, the centralized and eastern energy systems are connected to the UPS, however remaining territories (southern energy system and decentralized energy supply areas in the north) still have no grid at all or local isolated grid nets, which have no connection to the UPS. The connection to the UPS costed FSK EES 19 billion RUB (253 million EUR[7]) for 750 km of 220-V power transmission lines and 2 large backhaul substations [100]. It is unlikely that the company expands the grid further into the region in the nearest future, as that would definitely cost much more and mean complicated technical solutions.

The major reasons for connection of the two energy zones to the UPS were [100]:

- Dependence of the most densely inhabited territories from the 4 major power plants and therefore, poor quality of electricity. In case of any emergency situations or problems at any of the three HPPs or a Yakutian CHPP, people suffered from power outages.

[7] Here and further in the document – OANDA exchange rate for February 17th 2019, 1EUR=74.8552 RUB

- Majority of large combined heat and power plants in the region work on gas, which is delivered to the region by only three pipelines. Again, in case of emergency or any leakages in pipes, there is a danger of serious fuel shortage.

The energy system of Yakutia has the following three major stakeholder groups:

1. Power generating companies

- major power generating company is PJS “Yakutskenergo” (owned by “RusHydro”)
- other important power producers are: JSC “Far Eastern Generating Company” (DVGK) (owned by RusHydro); PJS “Alrosa”; JSC “Surgutneftegas”; JSC “Sakhaenergo” (owned by “Yakutskenergo”).

In 2016, these companies generated 95.7% of the region’s electricity.

2. Power sales companies (suppliers): “Yakutskenergo” and “Sakhaenergo” are the main suppliers in the region. There are no independent power sales companies due to peculiarities of the regional electricity sectors’ status (unlike regions located in price and non-price zones, where electricity from the wholesale market is purchased by grid companies, in isolated regions like Yakutia, it is sold to guaranteeing suppliers. It is common in these areas is that a guaranteeing supplier is simultaneously a generating company and energy transmitting (grid) company. It is yet unclear, how that may change after January 2019.

3. Power grid companies

- PJS “Yakutskenergo” manages 74% of the overall power grids’ length, mostly focusing on areas with centralized grid connection
- JSC “Sakhaenergo” and PJS “FSK EES” manage practically equal shares of the grid, about 7% each, “Sakhaenergo” works with decentralized territories and manages energy generation and distribution in areas disconnected from the major grids of Yakutian energy systems.
- JSC “DVGK”, JSC “Surgutneftegas”, JSC “Far Eastern Energy Management Company” managing remained grids

According to calculations of eclareon[8] based on the “Scheme and Program of the development of energy sector in the Republic of Sakha (Yakutia) for 2018-2022” [10], In 2017, the total installed generating capacity in Yakutia overstepped 3,100 MW. More than 200 MW of this capacity belongs to autonomous generating facilities in the decentralized electricity zone.

[8] In the document “Scheme and Programme of the development of energy sector in the Republic of Sakha (Yakutia) for 2018-2022”, there is no data concerning the total installed power capacity of diesel power plants in 2017, but there is data concerning installed power capacity of other energy sources for 2017. We estimate, that the installed diesel power capacity increased by ca. 10% similarly to the development of diesel-based power capacity in the previous year.

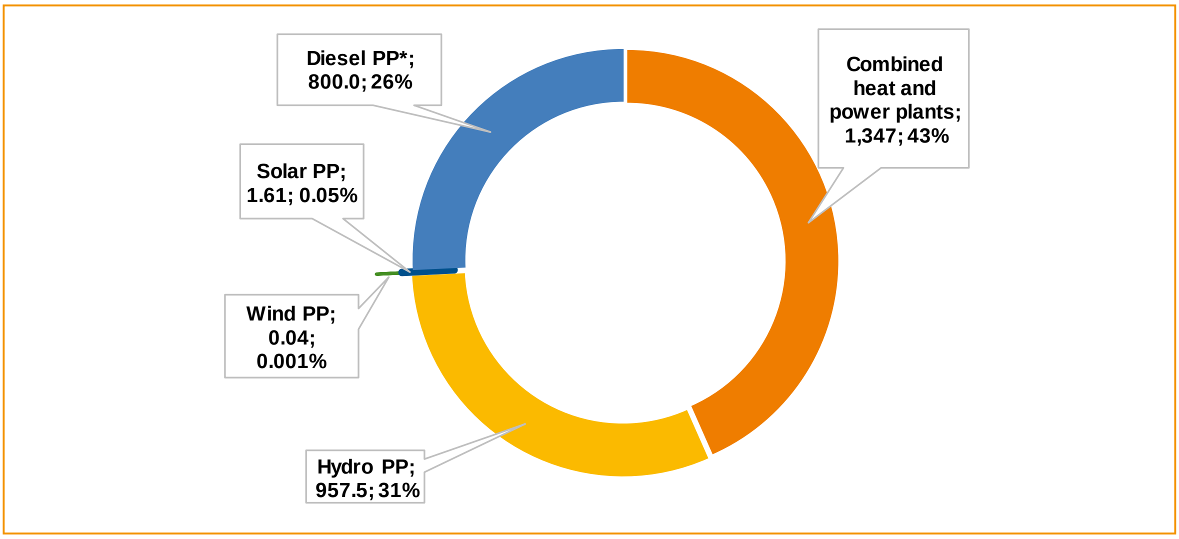

Figure 8 Structure of the installed capacity by type of power plant in Yakutia in 2017, *-estimations of eclareon based on the initial data; source: Head of the Sakha Republic (Yakutia), 2018 [10]

Figure 8 presents information on types of power plants in Yakutia in 2017. The largest part referred to combined heat and power plants (like Yakutian CHPP and CHPP-2) (40.3%), of which 47% are gas powered and 46% run on coal. A bit more than one third of the generation capacity comes from hydro power plants (largest are Viliuyskaya HPP-3 and Viliui HPP Kaskade) and a bit less than a third – from diesel power plants. The region is the country's absolute leader in terms of diesel power plants number, there are more than 600 DPPs of various size, 152 belong to "Yakutskenergo" (of which 136 are integrated into the power net of JSC "Sakhaenergo", subsidiary of PJS "Yakutskenergo"). "Sakhaenergo" manages about 200 MW of DPPs, "Yakutskenergo" – about 96 MW. More than 240 MW of diesel generation belongs to other companies, mainly, mining companies, having own generation and combining mining activities and energy generation activities (e.g. "Gazprom Burenije", "Burenergo" etc.) [144]. Renewable energy sources (excluding hydro) only accounted for little more than 0.05% of installed capacity. However, a growing trend regarding the usage of RES for electricity generation in Yakutia can be observed: the capacity of solar power plants installed in the region within one year increased by 9% in 2017 [10]. Whether this positive trend is sustainable will depend on a number of factors such as the increasing awareness for RE solutions among political and industrial decision makers, the development of diesel prices and the costs for RE solutions. Moreover, the performance of the recently built RE installations such as the 1 MW power plant in Batagai will play their role for the future development of RE in the region.

9,327 million kWh of electricity was generated in 2016. 86.9% of this was generated by power plants located in the 3 centralized energy zones and the remaining volume was produced in the decentralized zone. The overall per capita electricity consumption in Yakutia in 2016 was 9,030 kWh/capita and this indicator has been growing consistently for the last few years. Electricity consumption in 2016 was 8,693.7 million kWh, the largest share (about 30%) of electricity in Yakutia is consumed by the mining industry (see Figure 9), 22% by other industries, including manufacturing, and only roughly 10% by private households, which is less than the electricity losses for the region [10].

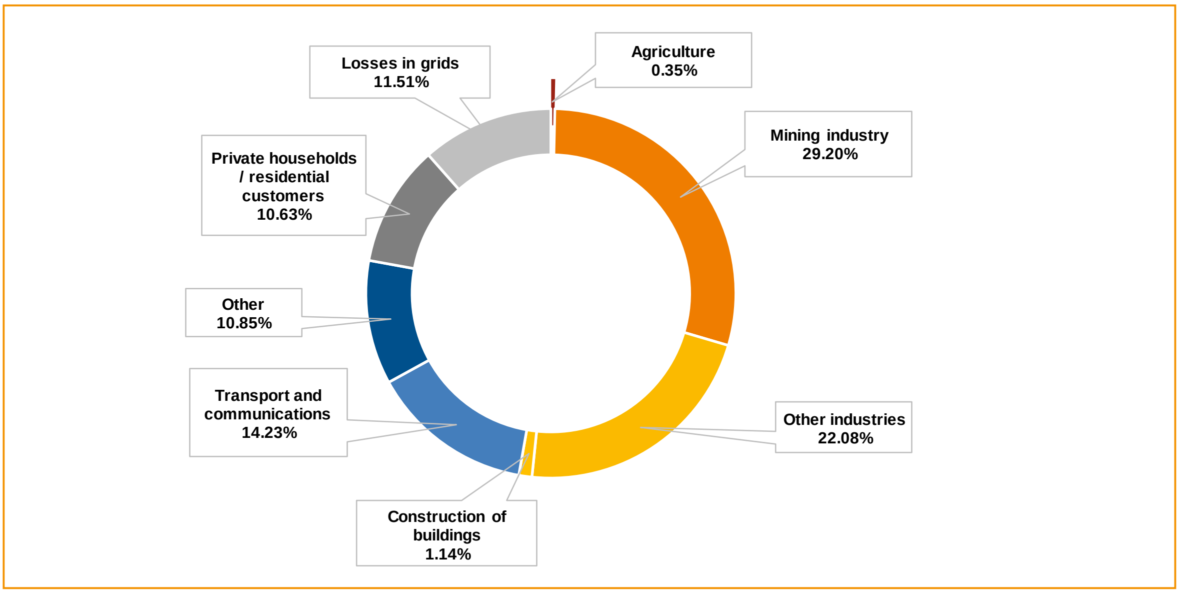

Figure 9 Electricity consumption in Yakutia by type of consumer, %, 2016; source: Head of the Sakha Republic (Yakutia), 2018 [10]

Due to territorial and climatic conditions, including extreme temperatures and Arctic nights, electricity consumption in the region increases especially (up to 3 times the rate of summer consumption) during winter across all consumer groups. This increased demand is mainly driven by longer periods of illumination and the increased use of heat pumps.

Consumer groups are different in off-grid communities where almost all electricity is consumed by residential customers and the public sector. The primary fuel source for heating purposes in all settlements apart from Yakutsk is diesel, with the secondary fuel source being wood and coal.

Off-grid settlements with an average load of 700-800 kW are estimated to be big in terms of energy consumption. For them, morning and evening peak loads are rather low: the evening peak, from 6-8 pm, is usually 15% higher than the night load. In small villages the difference between the morning/evening peak loads and night consumption can reach 30%, which puts additional pressure on the power generating facilities in these areas.

Yakutia has solar resources of up to 1,100 kWh/m^2/year of irradiation in the very southern part and between 700-840 kWh/m^2/year in the northern part [164]. A systematic use of solar PV generation facilities in Yakutia started in 2012, with the construction of the first 60 kW solar PV installation in village of Batamay, followed by a 30-kW array in the village of Yuchyugey. Nowadays, there are 21 solar PV installations in the region with an overall capacity of 1.61 MW [10], 6 of which are fully autonomous and are combined with storage systems [145]. The average diesel savings per each 50 kW of installed PV in Yakutia fluctuates around 15 tons/year [9]. In 2017, RES energy facilities (not including private non-registered facilities) generated 1.07 million kWh [144], which has led to the overall fuel savings of nearly 300 tons, equivalent to about 13 million RUB (173.4 thousand EUR) [11] [145] . According to calculations, based on the average fuel savings, maximal diesel savings through functioning of the mentioned 21 PV installations can be as high as 480 tons annually. The most famous of the current existing PV installations in the region is the SPP in Batagai, which has been included in the Guinness Book of Records as the most northern SPP in the world. It is also the largest SPP in Yakutia, with an installed capacity of 1 MW and a net annual energy production of approx. 1,375 kWh [13].

Wind power has started to develop, albeit slowly, as well: the wind park at Bykovskiy cape has a capacity of 40 kW and one much larger wind power park is currently built in Tiksi. Tiksi is located in the arctic zone of the region and is one of the most northern cities of Yakutia. In Tiksi, the polar night lasts from middle November until the end of January, which means, that about 3 months it is completely dark there. Combined with the very good wind power potential, this fact makes Tiksi and similar coastal settlements of Yakutia the most suitable for wind energy projects. Tixi's wind park with an installed capacity of 900 kW started its operation in November 2018 [14]. According to estimations made by the wind park engineers, this wind power plant will help to save between 450 and 500 tons of diesel annually. It is supposed to decrease the demand for diesel in Tiksi area by roughly 20% and supply the settlement with electricity. The wind park is a joint project between RusHydro and the Japanese NEDO corporation. The project also has R&D related aspects regarding testing the functionality of wind turbines in extremal climatic conditions (wind in this area can reach speeds of 60 m/sec and temperatures may be lower than -60^0 C). The project is mostly financed by the Japanese corporation NEDO [12]. Japan is planning to participate further in similar RES oriented projects in the region. All current RES generating facilities are managed by RusHydro through their regional subsidiary Yakutskenergo.

PV is mostly compatible with diesel on the off-grid market, where it may expand without additional subsidization. The size of RES in this market is assumed to vary according to the following scenarios:

- approximately 8 MW for 117 remote off-grid settlements (50 to 400 inhabitants in each) with no DPPs' modernization and no solar power management systems such as fuel saving controllers
- approximately 16 MW for 117 remote off-grid settlements (50 to 400 inhabitants in each) with no DPPs' modernization but with solar power management systems due to serious diesel equipment deterioration and the impossibility of successful RES facility operations in current conditions.
- more than 30 MW for 117 remote off-grid settlements in case of introduction of energy storage; with serious storage systems and 70-80 MW SPPs, DPPs can be completely switched off in the spring and summer months.

This off-grid market is assumed to be 4 to 5 times smaller for wind than for PV because only the Yakutia's Arctic coastal areas offer favorable conditions for wind parks.

RES projects in Yakutia have been experimental to date and have not been a priority because RE sources are new and have not yet been able to guarantee a stable power supply as well as having capacity limits and not being 100% reliable. Nowadays, in typical RES projects, the capacity of wind or PV power generation reaches no more than 20% of the overall needed capacity, or 10% of the DPP's nominal installed capacity. The project in Tiksi, for example, has several parts: installed capacity of a new DPP is 3 MW, overall capacity of the three wind turbines is 1 MW combined with an energy storage. In the end, all three parts should work in parallel.

In addition to the new RE hybrid solutions, it should be mentioned that there are small-scale RES solutions used by hunters and nomads, however, are not very common in Yakutia. The common fact about RES for remote areas in Yakutia is that they ultimately lower electricity prices. Transportation costs for diesel and big distances between the settlements make off-grid remote areas of Yakutia very perspective for PV projects.

2.1.2 Electricity tariffs and costs

As mentioned above, Yakutia is located in the regulated tariffs zone, which means that the electricity tariffs are established by the local government. “Sakhaenergo” bears the costs of power energy generation and distribution in off-grid areas. However, sine 2019, the two energy zones which got connected to the UPS can purchase power from the wholesale market and are now included into the non-price zone. That means, that price of energy purchased by “Yakutskenergo” from the wholesale market falls under other regulations and may change each day and even hour depending on the energy generation costs of the purchased on the wholesale market power [100].

Yakutia is among the regions with the highest electricity prices. Tariffs for the population vary depending on the group of consumers (night/day tariff; tariffs for people in rural and urban areas; tariffs for people with/without electric stoves). In 2019, tariffs for private customers for the main tariff groups are [21]:

- rural population, night tariff 2.74 RUB/kWh (0.04 EUR/kWh) – day tariff 4.23 RUB/kWh (0.06 EUR/kWh)
- urban population (households with gas stoves9), night tariff 3.91 RUB/kWh (0.05 EUR/kWh) – day tariff 6-03 RUB/kWh (0.08 EUR/kWh)
- single rate tariff (no differentiation by daytime or voltage) rural population 4.20 RUB/kWh (0.06 EUR/kWh) – urban population 5.99 RUB/kWh (0.08 EUR/kWh)

Yakutia has the fourth highest electricity tariffs among Russian regions [17]. However, these tariffs do not reflect the real generation costs due to strong subsidization. Moreover, there is a small difference in electricity tariffs for end consumers in the grid connected settlements and off-grid remote areas, although the real electricity price w/o subsidies would have to be much higher: according to research for this report, the electricity costs for production, distribution and sale were on average as high as 10 RUB/kWh (0.13 EUR/kWh) in 2018, which means that 41%-58.7% of the electricity price for the end customer is subsidized. In some settlements, the costs are even higher and reach several dozen rubles.

All off grid settlements seriously rely on diesel power plants which work on imported fuel. Liquid fuels, including diesel, are imported to the region on an annual basis, there are several ways [138]:

- Arctic (marine) way, navigation period is only 30-45 days/a between August and September
- Railways, which is weakly developed in the region, there are just some more than 165 km of railways in the region
- River ways, available for 4-4.5 months. This way supplies up to 30% of total annual diesel supply
- Automobile way, available only in winter periods. Vehicles pick up the fuel from airports or coastal areas where the marine ways end and deliver it to the settlements. There is a visible lack of automobile technique and usually owners of such vehicles in each settlement are monopolists, able to drive the price for 1 liter higher in order to gain profit. This way of transportation is the rarest one.

In 2016, 136 DPPs belonging to “Sakhaenergo” consumed over 670 tons of diesel [147] , while the total volume of diesel used for electricity generating targets in Yakutia by all power plants in 2017 reached 111,568 tons [144]. Average fuel consumption per 1 kWh is 340-500grams of diesel, reaching 800 and even 1,000

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[9] **Here and further**. In Russia, there are different residential tariffs for households with gas and electric stoves. People owning an electric stove instead of a gas one pay 30% lower tariff that the ones cooking on gas. It is assumed, that households cooking with electricity stoves or having electric heating systems consume much more electricity and therefore have a right to get a state support (subsidies) making their energy tariffs lower.

grams for old and inefficient diesel generators and costs of fuel form up to 60% of the end electricity price. Simultaneously, in 2019, price for 1 ton of diesel overstepped 60,000 RUB (800 EUR) and reached 105,000 RUB (1,400 EUR) for some arctic areas [146]. Therefore, costs of 1 kWh for remote energy systems (also called economically justified prices in some sources) in 2016 reached on average 36 RUB/kWh (0.48 EUR/kWh) [20], while the same economically justified price for centralized isolated energy systems of Yakutia only reached 6.6 RUB/kWh (0.08 EUR/kWh) [37]. In 2019, this average price is supposed to reach 40 RUB/kWh due to the further rise of diesel prices. In regions that are particularly isolated from railways, grids and big settlements, the price of diesel generated kWh can reach up to 100 or even 200 RUB (1.3 – 2.66 EUR/kWh) [22]. More than 90% of diesel imported to the region is used for energy generation targets.

In order to make electricity prices affordable for companies, they get cross-subsidization, driving the price per 1 kWh down. In 2017, electricity prices for industrial consumers on the retail market in Yakutia reached 10 RUB/kWh and on average were 7-8 RUB/kWh (0.09 – 0.10 EUR/kWh) [125]. In the second half of 2017, the electricity tariff for entities dropped drastically and were 4 RUB/kWh (0.05 EUR/kWh) in 2017 [46]. Simultaneously, electricity tariffs in other Russian regions kept growing, which also nurtured cross-subsidization in Yakutia. According to some calculations, each kWh consumed by industrial consumers of Yakutia bears on average 2.48 RUB (0.03 EUR/kWh) of cross-subsidies for diesel [45] (or simply diesel subsidies).

Type of voltage / type of tariff	High voltage (110 kV and higher)	Middle first voltage (35 kV)	Middle second voltage (20-1 kV)	Low voltage (0,4 kV and less)
Single rate tariff, 2/2 of 2018, RUB/kWh (EUR/kWh) with VAT[10], electricity for non-residential consumers disconnected from the UPS, sold by “Yakutskenergo”				
Tariff	10.76 (0.14)	11.22 (0.15)	11.78 (0.16)	11.87 (0.16)
Subsidy for tariff's levelling	5.49 (0.07)	5.76 (0.08)	6.07 (0.08)	6.013 (0.08)
Single rate tariff incl. Subsidy	**4.29 (0.06)**	**4.42 (0.06)**	**4.55 (0.06)**	**4.62 (0.06)**
Double-rate tariff, 2/2 of 2018, RUB/kWh (EUR/kWh) with VAT				
Night tariff	8.92 (0.12)	9.29 (0.12)	9.77 (0.13)	9.83 (0.13)
Subsidy for tariff's levelling	5.49 (0.07)	5.76 (0.08)	6.07 (0.08)	6.13 (0.08)
Night time tariff incl. Subsidy	**2.43 (0.03)**	**2.50 (0.03)**	**2.60 (0.03)**	**2.60 (0.03)**
Day tariff	11.59 (0.15)	12.08 (0.16)	12.64 (0.17)	12.77 (0.17)
Subsidy for tariff's levelling	5.49 (0.07)	4.76 (0.06)	6.07 (0.08)	6.13 (0.08)
Day time tariff incl. Subsidy	**5.11 (0.07)**	**5.29 (0.07)**	**5.46 (0.07)**	**5.53 (0.07)**
Some electricity tariffs for 2019 for energy, generated by “Sakhaenergo” and purchased by “Yakutskenergo” according to the purchase agreements. No voltage level differentiation, RUB/kWh (EUR/kWh) with VAT				
Single rate tariff for settlement Yuren, Verkhnevilyuyskiy region	600.45 (8.01)			
Single rate tariff for settlement Toyon-Ora of Hangalas municipal district	228.40 (3.05)			
Single rate tariff for settlement Sayylyk Ust-Janski ulus municipal district	80.21 (1.07)			

[10] VAT in 2018 = 18%; VAT since 2019 = 20%

Average price for all decentralized settlements served by "Sakhaenergo"	40-80 (0.53 – 1.07)
Electricity tariffs (prices) in 2019, RUB/kWh (EUR/kWh) with VAT, electricity for non-residential consumers disconnected from the UPS, sold by "Yakutskenergo"	
Single rate tariff (economically justifies price)	84 (1.12)
Subsidy for tariff's levelling	78.37 (1.05)
Single rate tariff incl. Subsidy	**5.63 (0.08)**

Table 4 Some tariffs for the retail market's consumers (except from population) of the electricity provided by "Yakutskenergo" and energy price purchased by "Yakutskenergo" from "Sakhaenergo" according to the sales contracts ; source: Yakutskenergo, 2018 [21], Sakhaenergo, 2019 [137], Yakutskenergo, 2019 [151]

Such high tariffs in the category "electricity tariffs for energy, generated by "Sakhaenergo" and purchased by "Yakutskenergo" are basically economically justified energy prices for isolated (remote) areas of Yakutia, which may be extremely high due to high costs of diesel, diesel transportation and OPEX (many DPPs are several dozen years old and need regular reparations). However, end consumers purchase energy for more or less affordable prices: "Sakhaenergo" sells energy to "Yakutskenergo" for these economically justified prices, then "Yakutskenergo" sells energy to the end consumers. All losses of guaranteeing suppliers and difference between the economically justified and end consumer price are compensated with the help of subsidies: "Yakutskenergo bears the price difference, then it gets money back from the local government as a direct subsidy. The local budget allocates around 7 billion RUB (approx. 93 million EUR) of subsides annually to cover the difference between the real electricity price and tariffs paid for by the end customer (basically cross-subsidization) and the sum is growing annually [18]. These subsidies are re-financed by funds from the federal budget [19]. As an example, subsidies for non-residential consumers take 93% of the real energy price (Table 4). On average, up to 65% expenditures in energy supply payments in Yakutia come from local budgets.

As mentioned above, since 2019, two more regional energy systems of Yakutia got connected to the UPS, which means, that the largest power plants located in these zones (s.a. Yakutian CHPP and CHPP-2, Viliuyskaya HPP) will now deliver energy not directly to the regional consumers, but to the wholesale market through the UPS grids. Simultaneously, "Yakutskenergo" will purchase electricity from the same wholesale market according to the wholesale market prices changing every hour. This is supposed to drive prices in the southern, central and eastern energy systems of Yakutia down due to lower costs of energy transmission and lower costs of energy generation [149]. Unlike prices formation earlier, when these energy systems referred to "technologically isolated energy systems" and the price was fixed, now prices obey the rules of the non-price zone and wholesale market prices will change monthly. As connection to the UPS is costly, these expenses should be reflected in the price for transmission services and split between users of the new grid. Residential consumers will still be subsidized, while large industrial consumers will pay for energy transmission services, as they also consume energy from the wholesale market and this will allow to refund money spent on the connection to UPS [100]. A representative of the tariff committee of Yakutia stated, that now it would be especially important for non-residential consumers to keep their hourly consumption in line with the planned one, because deviation will cause extra expenditures.

2.1.3 Extreme cases of high electricity costs in Yakutia

In Yakutia, there are some extreme cases of energy generating costs: there are 7 settlements where electricity generating costs overstep 200 RUB/kWh (2 EUR/kWh) and 2 settlements for which this value is higher than 600 RUB/kWh (8 EUR/kWh) [137]. According to the Decree of the State Committee for Pricing Policy of the Republic of Sakha (Yakutia) N 225 of December 28th 2018, which approved establishment of the electricity tariffs for the energy generated by "Sakhaenergo" and sold to "Yakutskenergo", the highest tariffs in 2019 were the following:

- Suchchino settlement, located in the North-Eastern part of Yakutia 60 km from the larger settlement, electricity costs for 2019 are 660 RUB/kWh (9.25 EUR/kWh), this settlement is located in a remote area difficult to be reached by any type of transport. The DPP located there is operated by "Sakhaenergo" and generates power for 57 inhabitants.
- Electricity demand of settlement Jyuren, where cost of 1 kWh is 600.45 RUB (8.41 EUR), is covered by a small DPP and a PV system of 3 kW installed capacity with an energy storage system.
- Troitsk settlement, located on the crossing of the Lena and Oijokma rivers in Southern Yakutia. Although being close to the three energy regions of Yakutia, this settlement refers to the areas with autonomous energy supply, a local DPP with an installed capacity of less than 1 MW is run by "Sakhaenergo" and supplies 327 people with electricity. There the generating costs are 275.5 RUB/kWh (3-86 EUR/kWh).
- Village Verkhnaya Amga on the banks of the Amga river southern from Yakutsk. The settlement is served by a DPP of "Sakhaenergo", generating electricity for 253.42 RUB/kWh (3.55 EUR/kWh). However, in summer, the 27 inhabitants get energy exclusively from a local PV station with an installed capacity of 36 kW with a lead-carbon storage system constructed in 2016.
- Toyon-Ary settlement, inhabited by 170 people, located on an island in the Lena river about 100 km from Yakutsk, also has a hybrid diesel-PV station with a PV part of 20 kW capacity, 2 diesel genset 30 kW each and 96 kWh. While usual diesel consumption without PV part fluctuates around 170 kg/day, with a PV part this volume drops to 60 kg/day which results into savings of 2.93 tons of diesel per annum. Electricity generating costs are 228.4 RUB/kWh (3.20 EUR/kWh).
- Village Tinnaja, 46 inhabitants, supplied by a 70 kW DPP of "Sakhaenergo" and having electricity generating costs 223.93 RUB/kWh (3.14 EUR/kWh).
- Innyuakh village on the banks of the Lena river close to the Southern border of Yakutia also has high electricity costs – 220.32 RUB/kWh (3.08 EUR/kWh). 103 people live in the settlement and their electricity demand is covered by a local DPP and, since 2016, by a 20 kW PV power station. A PV part helps to save about 0.15 tons of diesel per year.

Three of six mentioned settlements have PV-based generating facilities. These costs are taken from a document prepared by "Sakhaenergo", it is however not specified there, whether the mentioned energy costs are a result of only diesel-based generation, or if the investments into PV systems are also included into these costs and amortization of the PV equipment is the reason driving electricity costs up. It is more likely, that these costs are made up of only diesel-related expenses (incl. DPP maintenance costs).

2.1.4 Regional business environment & specific legal and regulatory framework for energy supply

Stakeholders participating in any project targeting the construction and implementation of any new power generating facility differ depending on the peculiarities of the project and exact region of implementation (whether it is an on- or off-grid project). Nevertheless, there exists a common scheme of relations between various stakeholders which can be considered the backbone of the process (see Figure 10)

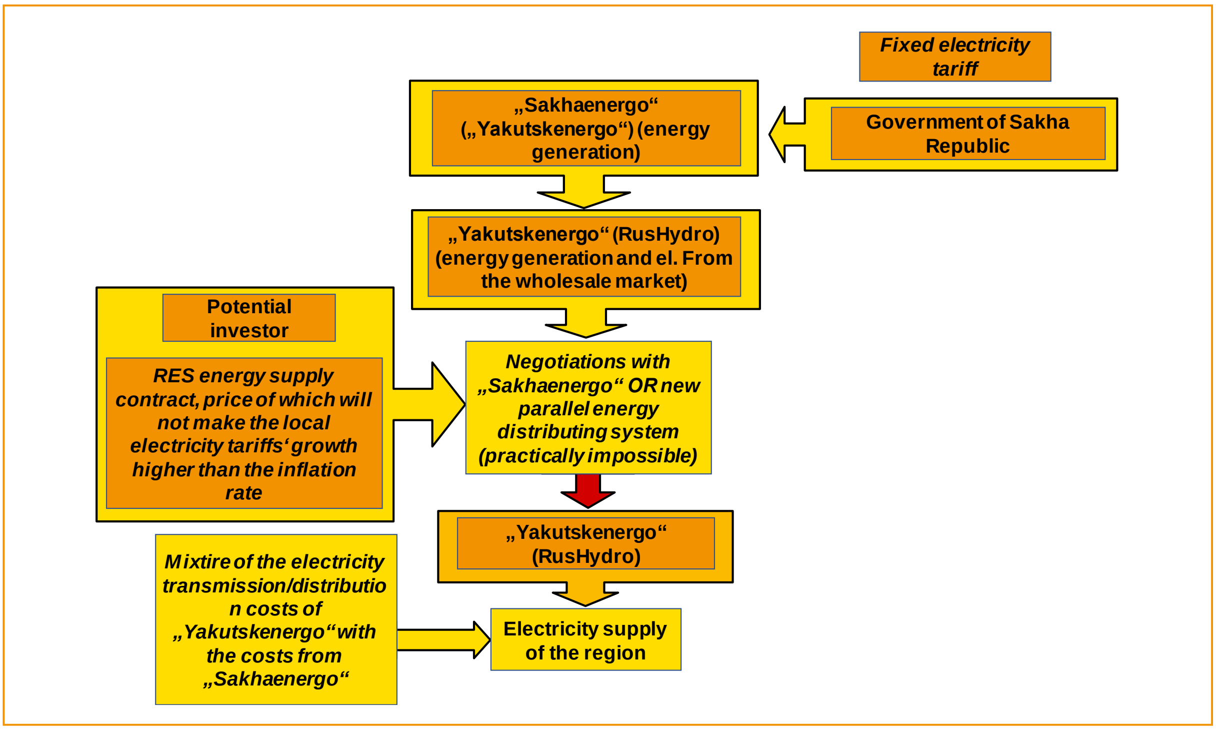

Figure 10 A common scheme of relations between different stakeholders while implementing a new project; source: Eurosolar Russia Research, 2018

In 2016, there were 675 diesel generators and turbines of power plants of different sizes, with a large share of them being old and requiring much maintenance, resulting in low efficiency overall [10]. The equipment is supposed to be replaced or renovated within the next 10 years, but this plan has not been formalized and accepted by the local government yet. Currently diesel infrastructure is not being replaced with more energy efficient equipment or RES on a large scale due to scarce financial sources of "Sakhaenergo": in 2016 and 2015 the net profit of the corporation was negative and only became positive and equal in 2017 with 13,315 thousand RUB (177,586 EUR) [7]. Simultaneously, there is also a lack of supporting mechanisms. There is an unofficial plan to build 120 diesel/PV hybrid power plants in Yakutia in the near future, but this plan has not been formalized yet and there is no regional decree enabling and enforcing such a program. The region would also need special funding from the federal budget to achieve this.

In present conditions, about 2% of the overall diesel-based capacity is being replaced per annum and usually it refers to equipment in a critical condition, which is most often replaced with modern diesel generators, such as the Chinese and Russian YAMZ[11] 50-150 kW diesel generators. In case an area needs a new power generating facility, a new DPP is normally built close to an old one to get the fastest and cheapest connection to the existing heat and power grid.

Currently, there are no specific support schemes for RES development in Yakutia. However, some schemes could be developed in the near future due to the rising popularity of RES and the plans of RAO EES of the East and RusHydro to increase RES based capacity of the Far East up to 146 MW.

Yakutia falls within the scope of the core RES oriented laws, listed in section 0 of the report. Nowadays, Decree 47 is not enabled in Yakutia due to a number of reasons and are not strengthened by the local decrees. Among the reasons why the Decree 47 is not enforced are:

- Decree 47 does not contain directions to develop RES in isolated areas. It is not clear, how RES projects should be developed in such areas;
- The principles of holding regional competitions for the selection of renewable energy facilities aimed to work for the retail electricity market are not formed and described in the decree;
- There is contradiction between Decree 47 and higher level's Decree 1178 "Regarding regulated tariffs" that stipulates how tariffs in the Far East are calculated. Basically, Decree 1178 does not contain a norm to include RES costs from Decree 47. So, it is unclear, how the tariffs for RES-based power plants working on the retail energy market should be set.

Additionally, there is a local law 1380-3 N 313-V "About the Renewable Energy Sources of Republic of Sakha (Yakutia)" of November 27, 2014 and with changes from February 28, 2017. The major points of the law are [23]:

- Definition for technologically isolated (remote) power system: a technologically isolated territorial electric and power system, which has an installed capacity of not more than 25 MW;
- Definition of the necessity of legislative, economic and organizational stimulation of energy efficiency and decline of the negative impact on the environment with the help of increase of the RES and peat combustion shares in energy generation;
- Definition of the roles of state institutions and municipalities in the process of RES development.
- Mentioning of the necessity of supporting mechanisms' development: creation of the feed-in tariff/ "green tariff", stimulation of investment inflows, creation of tax incentives for RES developers, creation of comfortable conditions for investors in RES, etc.;
- Among others, creation of the special fund to provide financial support to RES development. The roles of sources for the fund's creation are: savings from the replacement of conventional energy sources with RES; budget money of the Sakha Republic; part of the federal budget money received from the Russian budget for the aim of regional programs of energy efficiency and RES development;
- Allocation of lands for construction of RES power plants.

[11] Rus. ЯМЗ – Ярославский Моторный Завод – Jaroslawl Engine Factory, supplies major Russian vehicle producers (e.g. GAS group and some military organizations)

The law is one of the first steps towards regional RES support, although the mentioned fund has not been created yet and the law does not provide any details about the concrete mechanism of the support schemes such as land allocation and “green tariffs”.

2.1.5 Regional specific business case

The largest SPP of Yakutia is renowned for being the world’s largest solar power plant located in the Arctic Circle. The SPP is located in the Batagai urban settlement[12], which has a population of 3,676 (for 2017) people inhabiting 150 private houses and 1,700 apartments. Batagai is located in the permafrost areas, the average temperature of the coldest month (January) is -41.8^0 C, while the lowest temperature can reach -60^0 C. For half the year the sun sets at around 2 p.m. The transport connection to the settlement is only possible in winter, when the Jana river and the near lying swamps are frozen [24]. Therefore, during warmer seasons, the settlement gets fuel by air transport, which increases electricity prices for end-consumers by up to 35 RUB/kWh (0.46 EUR/kWh), should there be no subsidies available [24]. End-consumers pay on average around 5 RUB/ kWh (0.06 EUR/kWh) and gap of 30 RUB/ kWh (0.40 EUR/kWh) is subsidized.

Before the solar power plant in Batagai was built in 2015, the existing diesel power plant owned by “Sakhaenergo” had been in operation for 30 years and was outdated despite being the only electricity source in the area. The DPP consists of 12 diesel generators with an installed capacity of 11 MW. The single units are switched on and off when necessary. Average annual diesel consumption reached 6,000 tons and annual electricity generation amounted to 23,200 MWh. Winter consumption is roughly three times higher than summer consumption. For instance, in 2012, the peak load in winter reached 5.18 MW and the peak load in summer was 2 MW. The new solar plant has been integrated into the existing power supply system of the village and, combined with the DPP, leads to an average specific fuel consumption’s savings of 28 grams/kWh which ends up into between 250 and 300 tons of diesel saved annually [25].

The CAPEX of the solar power plant amounted to approx. 200 million RUB (2.66 million EUR) and is expected to function for at least 25 years which means that the solar power plant will remunerate itself 4 times within the period should it be successful [26]. This power plant was a joint project of RAO EES of the Far East and Yakutian government and is a part of the RAO EES of the Far East’s program to implement RES into local energy systems. The PV modules of the solar power plant were produced by a Chinese company Suntech Power.

2.1.6 Business model description

The PV diesel hybrid installation of Batagai, which serves residential customers is used as an emblematic business model for the region. In this model diesel savings represent the revenues of the PV installation and the power consumer, investor and plant operator are the same entity. In this business there is one central player, Sakhaenergo, assuming the roles of equity investor, borrower, operator, EPC contractor, O&M services and grid operator.

Some of these activities are realized in conjunction with the local off-grid communities which are powered by diesel generators and the regional government, finance may be partially provided by banks or the government but the key role of Sakhanergo is undisputed. As state-owned company Sakhaenergo is moreover also

[12] Rus. Поселок городского типа – a city-like settlement, between a town and a big village.

bound to procure from Russian manufacturers when possible. In case of project development, specific steps need to be undertaken to develop the PV array. These steps are presented in Figure 11 below. The scheme includes actors needed for each step and duration of the process.

The overall duration of the project's implementation is usually about 1.5 years for a solar power plant, 2.5 years for a wind park. It includes the following steps:

Before starting the project, it is necessary to negotiate with local authorities, local distribution grid companies and ministries responsible for permits (e.g. Ministry of Housing and Public Utilities). These negotiations take about 2 weeks; the process can however last longer. Delays may occur due to the poor communication between different agencies, ministries and administration departments, one has to address each utility separately and sometimes several approaches are needed before the necessary reply is received. Moreover, although the power plant's connection to the grid is in step 5 of the project's flow, negotiations with a grid company (for most of the territory it is Sakhaenergo) should be completed before the project starts. This is essential because of the "technical conditions" requested by the grid company: it is important to discuss the connection voltage and specifications of the transformer, agree on the capacity of the RES power site for its compatibility with an existing DPP and discuss other operational and connection peculiarities.

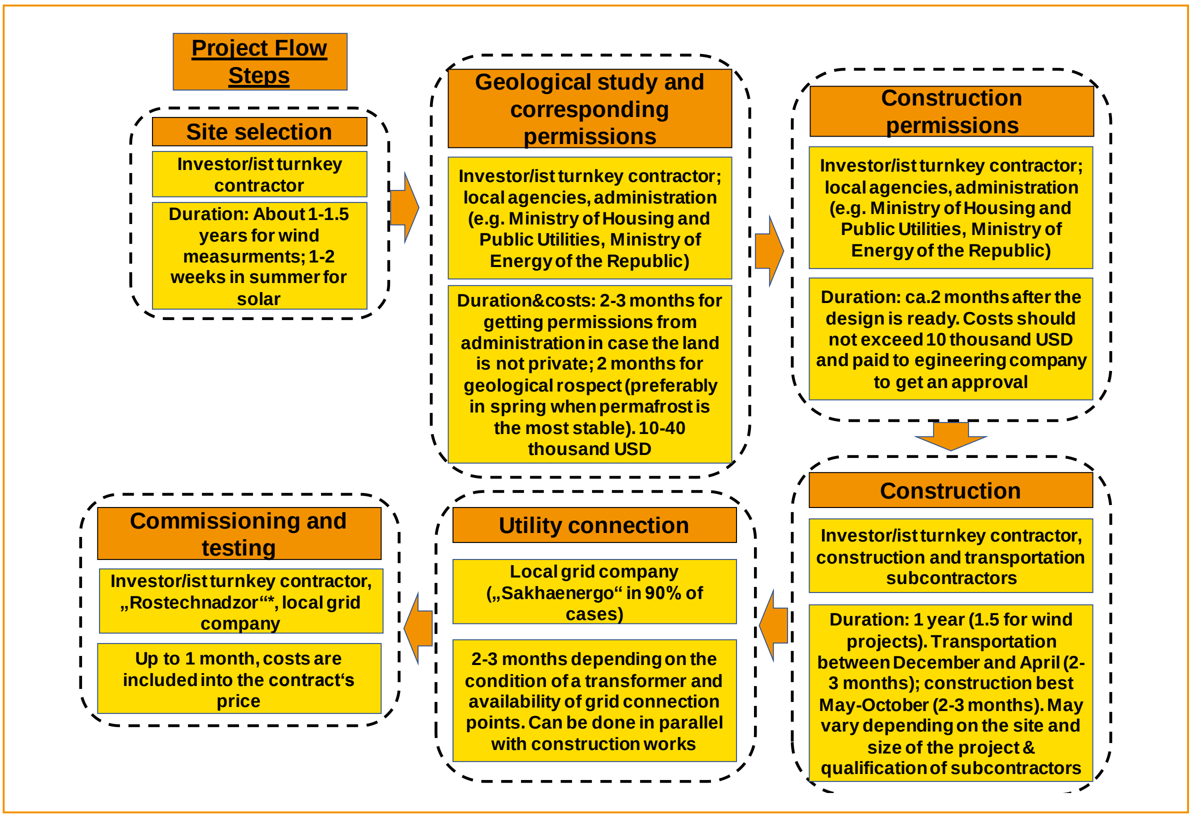

Figure 11 Scheme of the project's flow; source: based on the research completed by eclareon and partners of the project

It is important to take into consideration that, due to climate conditions, there is only a short period between May and October which is suitable for construction. In case the works are not completed within this period, construction has to be put on hold for months. Additionally, transportation of equipment is possible only in the winter period between December and April when the roads are frozen and between June and September when the equipment can be transported using waterways rivers are not frozen.

2.1.7 Profitability analysis (inputs, outputs, scenarios, sensitivities)

In the following, an exemplary profitability analysis for a 1MW PV project, based on diesel power savings is presented. The reference model for this business case is the 1MW installation in the village of Batagai. The known input data was partially updated due to the fact that the plant was already constructed in 2015.

The results of the calculations show that the payback period for the equity investment is about 10 years and that the equity IRR is > 20%. These results suggest that the realization of a project such as Batagai is economically viable. It needs to be noted that the models used in this report calculate the payback period using the time value of money concept. This means that future cash flows are discounted with a discount rate. This concept is based on the assumption that money available now is worth more than the identical sum in the future due to a potential earning potential of money. In simple terms this would mean that 10 RUB in the future are worth less than 10 RUB earned today. In our calculation, equity cash flows are discounted with a certain rate (e.g. 10%). Practitioners often do not use the time value of money but the nominal value which means that 10 RUB today are worth as much as 10 RUB in a year from now. If this concept were applied instead of the time value of money concept the calculated payback period would be shorter.

The input parameters, main assumptions and results of the calculated base case scenario of the profitability analysis are summarized in the following figure:

PV System			
Project Duration		Years	20
PV System Size		kWp	1.000,00
PV Battery Capacity		kWh	-
Total System Cost		RUB	156.000.000
Global Horizontal Irradiation		kWh/qm/a	1.000
Performance Factor		%	80%
Degradation		% p.a.	1%
Total Battery Replacement Costs		RUB	-

Financing			
Debt (Gearing)	60%	RUB	93.600.000
Loan Tenor		Years	8
Grace period		Years	1
Debt Interest Rate		%	10%
Initial Equity		RUB	66.100.895
Additional Equity		RUB	1.449.486
Discount Rate		%	10%
Longterm Inflation Rate		%	4%

System Operation		
Aplied Yield	kWh/kWp/a	800
Average Yearly Generation	kWh/a	724.541
Self-Consumption Rate	%	95%
Genset efficiency	kWh/ltr	2,50
Average Replaced Diesel Consumptior	ltr/year	275.326
Diesel Price (1st Ops Year)	RUB/ltr	69,67
Diesel Price Escalation	% p.a.	10%
Fixed Operation Costs	RUB p.a.	2.340.000
Longterm Insurance Costs	% p.a.	-

Results		
Net-Present Value	RUB	161.024.859
Project IRR	%	18,8%
Equity IRR	%	21,7%
Payback Period	Years	10,14
LCOE (no subsidy)	RUB/kWh	30,91
Min DSCR**	x	0,85 x
Min LLCR***	x	1,32 x

* LCOE: Levelized Cost of Electricity
** DSCR: Debt Service Coverage Ratio
*** LLCR: Loan Life Coverage Ratio

Figure 12 Project Overview – Batagai 1 MW diesel PV hybrid; source: eclareon calculations, based on input data researched by EUROSOLAR Russia, 2018

The cash flows from the perspective of an equity investor are shown in the next graph:

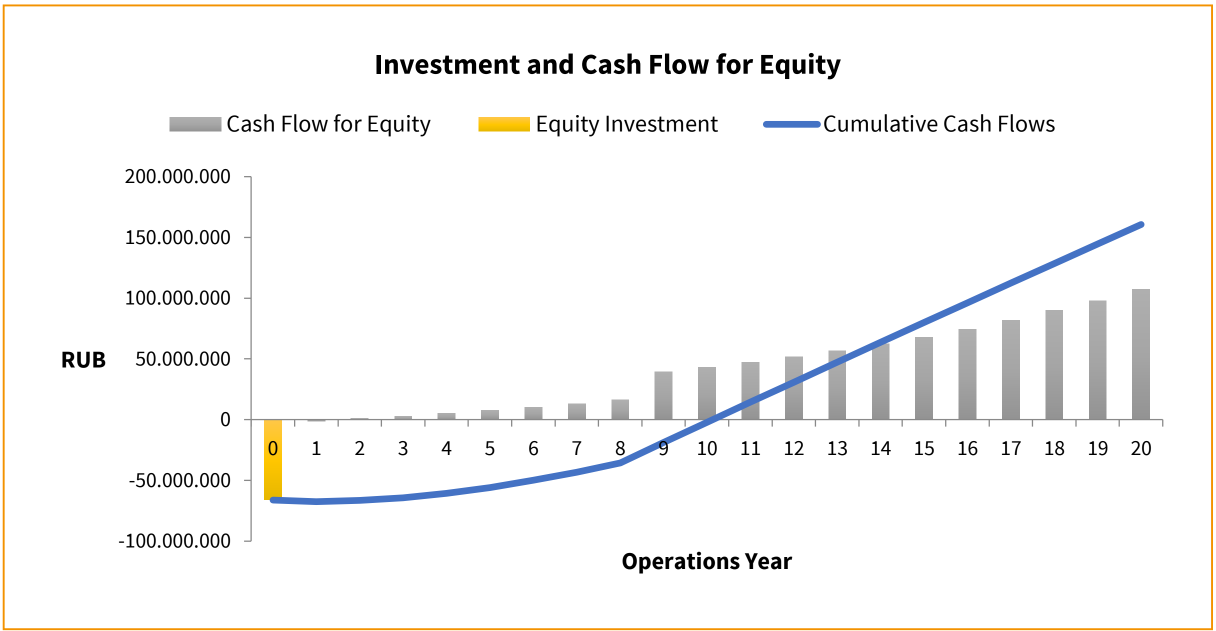

Figure 13 Equity Cash Flow – Batagai 1 MW diesel PV hybrid; source: eclareon calculations, based on input data researched by EUROSOLAR Russia, 2018

As can be seen, the cash flow available to pay back the equity investment is low in years 1-8 when cash flows are primarily used to pay back debt which accounts for 60% of the overall investment. After all debt has been paid back after year 8 the cash-flow available for the equity investor increases. The cash flow available for equity also increases year by year based on the assumption that the diesel that is replaced by solar power is becoming more expensive every year. Under the chosen financing conditions (loan tenor of 8 years with a 1-year grace period), the diesel savings are sufficient to repay the loan. Additional equity may however be re-quired after year 1 in order to operate the plant. The equity is paid back after approx. 10 years. In the graph this is illustrated by the blue line crossing the horizontal x-axis.

The next figure shows the development of revenues, debt service and the operations costs over time. O&M costs are escalated with the RUB inflation rate, since the revenues (diesel purchases) are also in RUB and it is assumed that O&M will be contracted and paid in RUB as well. As long as the red-shaded area in the graph covers the bars which represent debt service (interest and repayment of the principal) and O&M costs, the cash flows of the project suffices to cover these costs. Debt service is no longer needed from year 9 onwards given the loan tenor of 8 years.

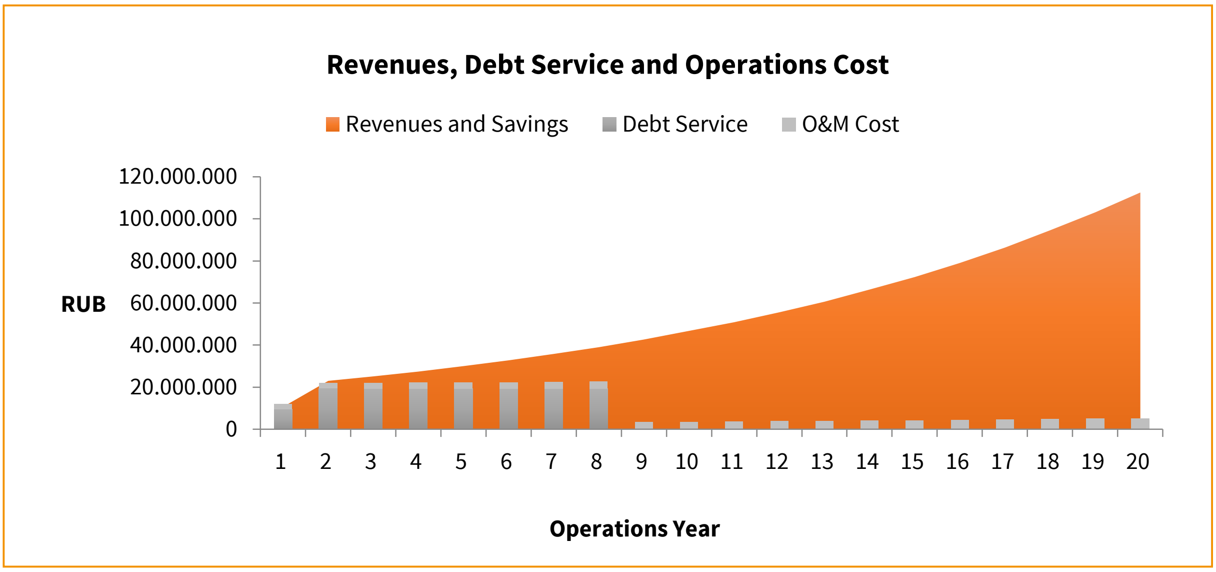

Figure 14 Project Cash Flows – Batagai 1 MW diesel PV hybrid; source: eclareon calculations, based on input data researched by EUROSOLAR Russia, 2018

The following sensitivities show how the payback period for the equity (amortization) and the equity IRR would change if some key input parameters were modified. The results of the base case scenario with an equity payback period of 10.1 years and an equity IRR of 22% are shown in rectangles of each graph.

The "Specific Yield" sensitivity shows how the equity payback period and the equity IRR would change if the same installation were installed in an area with different solar irradiation. When the specific yield increases, meaning if there is more irradiation available at a specific place that can be converted into electricity, the equity IRR increases and the payback period decreases. The respective values can be found when moving from left to right on the horizontal axis that shows different yield values. In the base case the global tilted irradiation was at 1.000 kWh/kW/pa. The fact that not all of this irradiation can be converted into electricity is accounted for by the performance factor that is set to 80%. The base case therefore assumes an applied yield of 800 kWh/kWp/a that can be converted into electricity. If this value were higher, for instance at 1.000 kWh/kWp/a, equity payback could already be reached after approx. 8 years and the equity IRR would increase to approx. 27%.

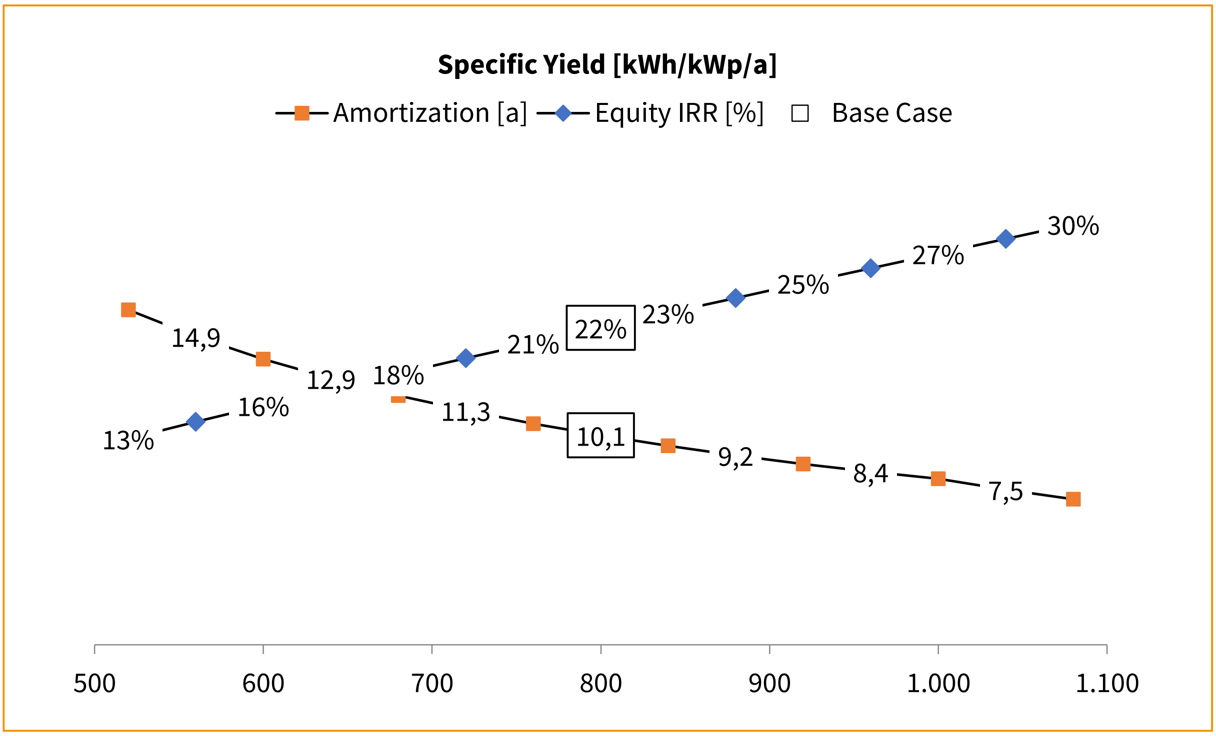

Figure 15 Specific Yield Sensitivity – Batagai 1 MW diesel PV hybrid; source: eclareon calculations, based on input data researched by EUROSOLAR Russia, 2018

Another sensitive factor is of course the system price. This is illustrated in the next figure. The base case values are again shown in rectangles. In this case, the payback period increases when the system price is higher than in the base case calculation. The researched price per kWp for the Batagai installation was at 156.000 RUB/ kWp (approx. 2.500€ at 2015 conversion rates). This price may seem rather high for a 1MW PV system without storage. However, it needs to be reminded, that the systems described in this report are no standard solutions as they may be found in other regions. The installations in isolated territories need to be designed in such a way that they can withstand harsh weather conditions. Another factor that can explain a rather high prices is that the installation of PV and other RES in Russia is a rather recent phenomenon which means that actors did not yet have the chance to accumulate years of experience. However, once projects become more standard and more experience is accumulated, costs may go down. What this means for an equity investor can for example be seen when looking at the results for the payback period and the equity IRR if the system price were assumed to be at 140.000 RUB/kWp: in that case, payback would decrease to approx. 9 years and equity IRR would increase to approx. 24%.

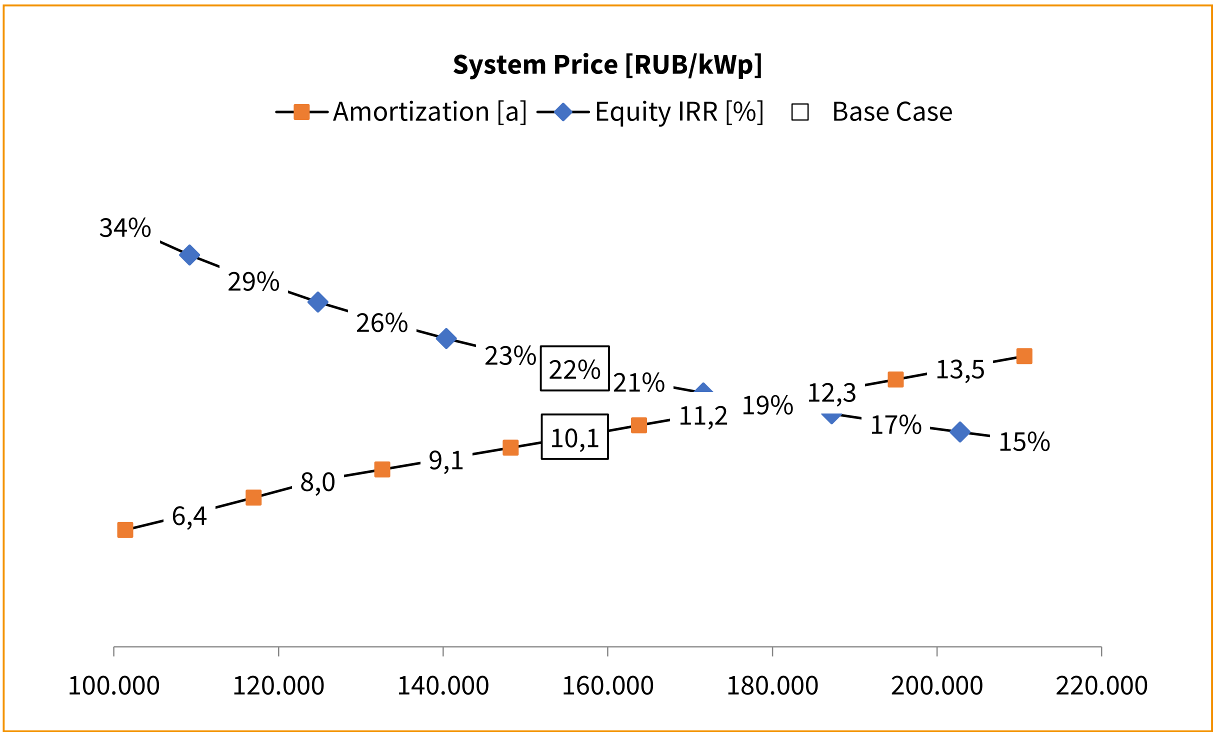

Figure 16 System Price Sensitivity – Batagai 1 MW diesel PV hybrid; source: eclareon calculations, based on input data researched by EUROSOLAR Russia, 2018

Moreover, the diesel price today and its development over time play an important role for the business case. This is shown in the following two graphs.

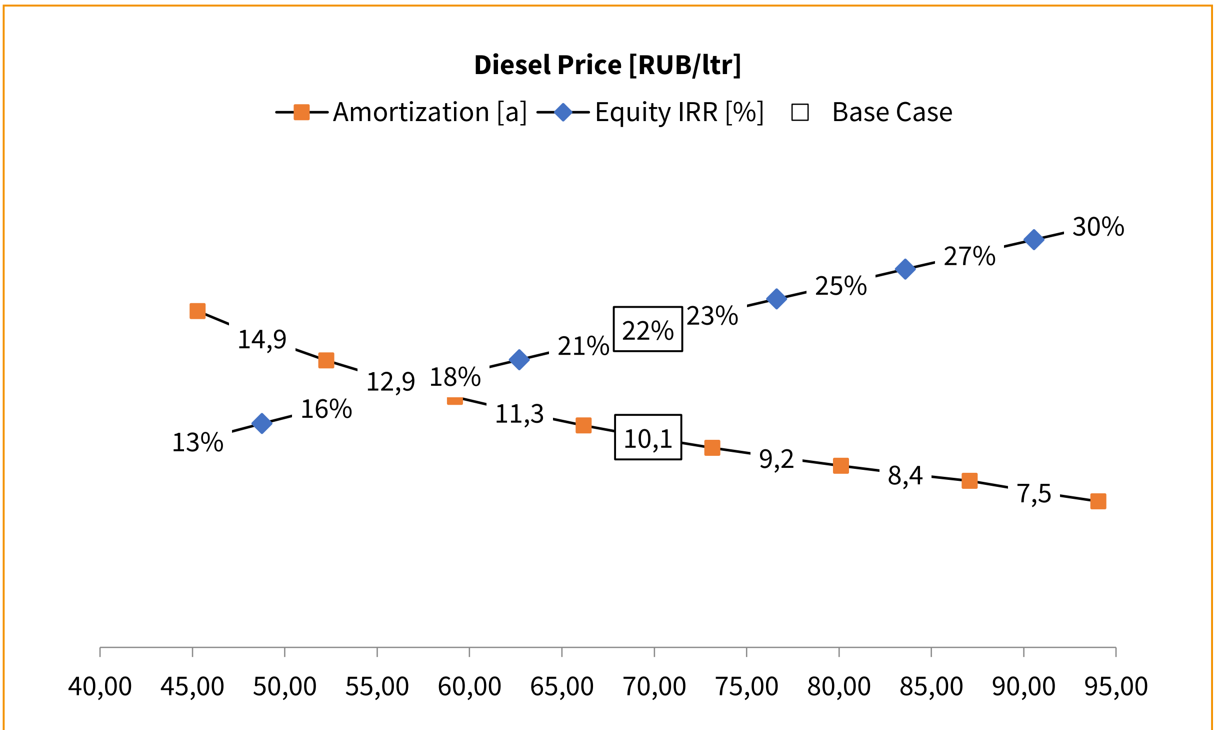

Figure 17 Diesel Price Batagai 1 MW diesel PV hybrid; source: eclareon calculations, based on input data researched by EUROSOLAR Russia, 2018

The diesel price in the base case was assumed to be at nearly 70 RUB/ liter. These costs are relatively high compared to standard pump prices in Russia. This higher price is explained by the challenging logistics when it comes to bringing and storing diesel to an isolated territory. The higher the diesel costs the better the PV business case from the perspective of an investor. As mentioned in the text, RES were installed in remote areas with the motivation to bring down electricity supply costs which are defined primarily by high diesel costs. The big advantage of PV is that there are hardly any logistic costs for transportation and storage during operation. If the base case assumption were changed, the graph of the diesel price sensitivity (Figure 17) shows that, with a diesel price higher than 70 RUB/ liter, the payback period goes down while the equity IRR goes up. At a location with even more challenging logistical conditions than Batagai, diesel could for instance cost 85 RUB/ liter which would lead to a payback period of approx. 8 years and an equity IRR of approx. 26%.

Another sensitivity that has an impact on the key results of a business case is the future development of diesel prices. An investment is paid back over time which means that it is necessary to estimate how certain critical parameters will develop over time. Future diesel prices are not assumed to stay as they are today. The annual diesel price escalation in the model was assumed to be at +10%. If this rate were higher the payback period and the IRR for the equity would change accordingly: an annual diesel cost increase of 12% would decrease the payback period to less than 10 years and increase the equity IRR to 24%. However, it can of course also be assumed that the diesel prices escalation is lower than in the base case. If that were the case, the payback would increase and the IRR decrease. E.g. if the price escalated only by 6% p.a., equity payback would increase to approx. 13 years and equity IRR would be at approx. 16%.

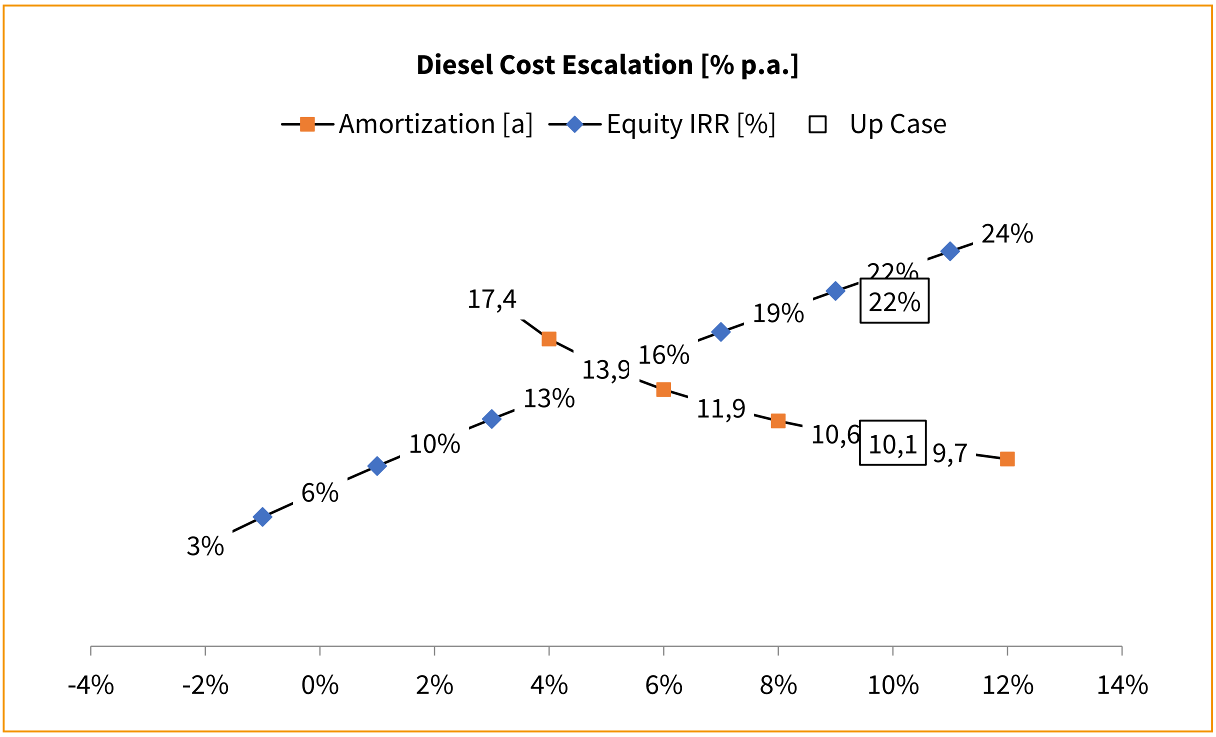

Figure 18 Diesel Cost Escalation Batagai 1 MW diesel PV hybrid; source: eclareon calculations, based on input data researched by EUROSOLAR Russia, 2018

2.1.8 Potential for cooperation/business opportunities and recommendations

The RES market in the region is at a nascent state and there are both pros and cons for the perspective of RE deployment in the dece0ntralized energy areas of Sakha Yakutia.

Positive factors:

- In Yakutia, many remote settlements are cut from the grid and need alternative energy sources. Although the two energy regions of Yakutia are now connected to the United Grid of the East, which is a part of UPS, remaining territory will remain isolated for years to come. It is hard to predict when the decentralized energy region of Yakutia (northern energy region) will be connected to any grid;
- Due to the fact, that large industrial energy consumers will bear the costs of UPS expansion and pay more for energy transition services, it is likely that their energy bills increase within the nearest time. This may become a strong encouragement to found an own generation facility and avoid paying high transmission fees (same as similar consumer groups make in other regions). PV-diesel/wind hybrid systems are a suitable solution;
- Currently existing DPPs are mostly outdated and most of them will need to be replaced or at least updated to satisfy additional capacity in the next 10 years. This could at least be partially done by using RES. The older the diesel generators, the smaller the installable PV capacity is, assuming that no further technical upgrades are done (fuel save controllers etc.);
- Diesel costs are showing a rising trend, which is driving diesel-based electricity prices up further and is leading to the growth of subsidization and cross-subsidization in order to keep the prices low for the end customer. Energy supply companies also have a motivation to develop RES, as the difference between the real electricity costs and the price a consumer pays is significant, even in regard to commercial and industrial consumers which pay higher prices than private households;
- RAO EES of the East and RusHydro have announced ambitious plans to deploy RES in Yakutia. This will attract more investments in the region and will most likely push local policy makers towards creating additional support schemes and legislative frameworks to make PV and wind development in Yakutia more feasible;
- Yakutia is a region rich in natural resources, with both existing and planned mining sites supplying the region’s electricity needs. RES could serve as a form of relief for mining companies, which usually operate in remote areas. These solutions could reduce the operational costs of extraction, leading to lower final good costs and an increase of the net profit;
- The majority of settlements in Yakutia have poor transport communications, as some villages can only be reached by air transport for half a year. For these settlements, diesel costs are even higher due to transportation costs and there is the additional risk of blackouts when diesel is not delivered on time. RES would at least partially decrease this dependence;
- From an economic perspective, high diesel costs make the payback of PV investments possible.

2.1.9 Risks and barriers

- Logistics are a challenge: access to the region is difficult because of the geographical location, meaning that there is only a short timeframe to construct RE plants due to climate conditions;
- The climate conditions make wind and PV solutions a fringe energy source. A new supplier who has no experience in such severe and cold climate conditions (e.g. in Canada, Alaska etc.) must take this into consideration;

- Typical PV business cases in the region are ones where settlements are currently supplied by diesel and upgraded with solar PV; in these cases, diesel remains the main energy source, and PV only supplies max. 10- 20% of the electricity;
- There is no significant RES market in the region and foreign entities need to care about marketing, logistics and search for partners on site themselves;
- In theory, the maximum cumulated market size or the upgrading of remote villages would be 80MW (with storage technology, modern switching technology etc.). The more realistic market size (spread over the next 5-10 years) is 8-30 MW, annual 2 – 6 MW. The larger the RE share in the hybrid solution the more up-front CAPEX investments are needed to upgrade diesel generators and introduce modern control technologies etc. It is doubtful that the central player Sakhaenergo is willing and/or able to pay more than the minimum required CAPEX. So, the Batagai technical solution could be considered a role model;
- The current Russian subsidy systems (cross-subsidies and direct subsidies) are designed and targeted to reduce operating costs (OPEX), resulting in high diesel costs. However, there are no direct investment subsidies that would reduce the high initial CAPEX needs;
- The largest existing PV installation is Batagai, with a 1 MW installation. Batagai also has a population of [45] approx. 3,500 people, most of the other off-grid villages are smaller, hence 1 MW projects will remain an exception and the bulk of the projects will be most likely smaller despite other official annulments;
- Despite the plans announced, there are currently no plans as to when and which village will be upgraded with PV;
- Regional and federal RE (Decree 47) laws have been put in place but have proven to be rather ineffective. Decree 47 has to be implemented by all Russian regions before its directives are applicable to the region. In Yakutia, this decree has not yet been implemented into the legislative framework, so the decree does not work in the region yet;
- In order to take part in the diesel upgrade projects you need to be in touch with Sakhaenergo; you can usually only do business when you are in personal contact with them. If you are not well connected there is no real chance of doing business with them;
- There is a lack of motivation among local administration representatives to encourage and speed up the permits needed for a project;
- Conflicts of interest between different branches of local administration. For example, there might be different opinions about the same issue from the side of representatives of municipal and federal levels, however such conflicts are often thinly veiled;
- Scarcity of qualified workforce and subcontractors. Since the market of RES oriented maintenance and services is just beginning to develop, most of the players have lack of experience in this field;
- There is an intrinsic lack of support, initiative and understanding from energy suppliers and grid companies. These companies have poor motivation to work with independent energy producers although their ideas and projects result in saving fuel. One of the main reasons for this is the pricing strategy of Sakhaenergo, where low energy production costs drive down electricity tariffs resulting in less profits for the company. The reliability of energy supply from new RES-based energy sites is often uncertain in these regions and therefore a major barrier to entry.

The RE market in Yakutia was launched with a number of pilot projects because using renewable energy sources, especially solar PV, makes sense from an ecological and from an economic point of view. However, the market is still rather small today and it is unclear when it will be exploited on a larger scale. Moreover, the role of state-owned Sakhaenergo is central and their decision processes are not transparent. As a consequence, opportunities for German PV/RE companies are limited, especially for small and medium sized companies. Those who want to invest in business development activities in Yakutia must approach key stakeholders themselves and this challenging and time costly.

2.2 Kamchatka

Kamchatka Krai, or simply Kamchatka, is located in the very east of Russia and is a part of the Far East Federal District. Kamchatka lies on the peninsula and on surrounding islands (such as Comandor, Verhoturov, Karaginsky) and covers a territory of 464,300 km^2 [47]. In 2018 the population of Kamchatka was 315,000 people, of which 181,000 live in the capital city of the region, Petropavlovsk-Kamchatsky, 78% of the total regional population lives in urban areas [48]. The density of the population in Kamchatsky Krai is 0.68 people/km^2 which is much lower than the average Russian population density. The population is unevenly distributed across the territory, with most of people living in the southern part of the peninsula, in the coastal areas and the big cities where the population density varies between 0.02 and 586 people/km^2. Kamchatka is well known for its natural beauty, virgin nature, the Valley of Geysers, its rich biodiversity and marine treasures. Only roughly 10% of the territory of Kamchatka is developed and used. Kamchatka has a continental climate with maritime climate features. The average temperature in winter is -6.4 C^0 with the lowest winter temperatures in the very northern settlements (it can go down to -57 C^0). The summer temperatures usually do not go over +22 C^0 [49]. The territory of the region is vulnerable to cyclones, earthquakes and strong winds. A first geothermal power plant was still built in the USSR in 1966 and it is still the most important energy source for the Southern part of Kamchatka [50].

Figure 19 Kamchatka Krai region; source: eclareon 2019, generated with amCharts Pixel Map

2.2.1 Current energy supply situation and renewable energy potential

Being disconnected from the UPS and from transit transregional high voltage grids, Kamchatka is an isolated territory. As a result, Kamchatka's electricity market is a part of a non-price zone and refers to the isolated energy areas, which means that the region is totally disconnected from the UPS and from transregional high voltage grids.

The energy market in Kamchatka is divided into one central regional energy system and 13 additional isolated energy systems or energy zones, which are disconnected from each other and from the central energy system [46]. The largest is the central regional energy system which includes the two largest CHPPs and some cities including the regional capital city, Petropavlovsk-Kamchatsky. Only this energy system includes grids with the voltages between 110 and 220 kV. Apart from the 13 medium-sized energy systems, there is a number of smaller systems covering only one settlement and consisting of a power generating facility and locally stretched low voltage grids. Some of the power plants and two energy systems are presented in Figure below.

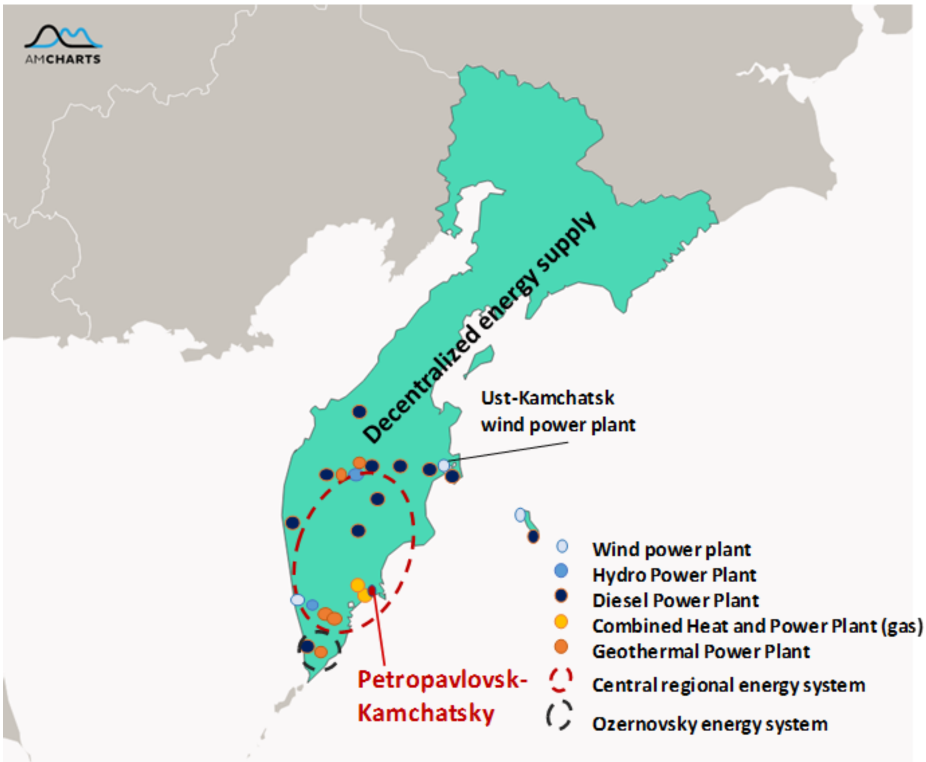

Figure 20 Electricity sector in Kamchatka, location of some power plants and energy systems; source: eclareon 2019, generated with amCharts Pixel Map, based on Orlov, 2008 [52] and WWF Russia, 2017 [55]

The central regional energy system is located in the southern part of Kamchatka, it supplies the majority of the population and covers more than 80% of the total annual electricity consumption in Kamchatka. Power generation consists of the two largest regional combined heat and power plants (CHPP-1 -204 MW of installed capacity and CHPP-2 - 160 MW), two GPPs, a hydropower plant, a diesel power plant having a function of a backup reserve power source and a wind park located in the settlement of Oktyabrski.

Subsidiaries of RusHydro dominate the energy value chain of the region. Most of the regional companies are active in all segments of the energy value chain, generation, transport and distribution. In 2017, there were more than 15 companies responsible for electricity transportation and supply, among them the largest were:

The public joint stock company “Kamchatskenergo” is the major energy supplier (guaranteeing supplier) of the region and the major energy producer for the capital city. The company also operates the central electricity grids. It is a subsidiary of RAO EES of the East (RusHydro structure). “Kamchatskenergo” operates more than half of the region’s power generating facilities and they are also responsible for the energy generation of more than 50% of the off-grid remote communities. Grids of the central power system are managed by PJSC “Kamchatskenergo”; grids of 35 kV are managed by JSC “Southern Power Grids of Kamchatka” and “Pauzhet HPP”; lower voltage grids are managed by JSC “Koryakenergo” [51].

- The joint stock company “Southern Power Grids of Kamchatka” (100% owned by “Kamchatskenergo” and part of the RAO EES of the East) is a power producer, guaranteeing power supplier and distributer. The company operates beyond the borders of the central energy system, it owns and operates around 10% of the total regional installed power capacity (namely, 20 large DPPs, a small HPP and a hybrid gas-diesel power plant) and 813 km of power grids.
- JSC “Pauzhet HPP” (part of RusHydro group) operates hydro power plants in the central energy system and supplies consumers (has a status of a guaranteeing supplier)
- PJSC “KamGEK” (Kamchtsky Gas Energy Complex) (RusHydro group) is responsible for constructing gas power plants and hydro power plants and operating HPPs. Currently it operates 45,4 MW of HPPs (more than 95% of the total hydropower capacity installed in Kamchatka).
- JSC “Koryakenergo” is an independent company owned by regional authorities and private stakeholders, and has the status “guaranteeing supplier” because it produces, sells and distributes electricity and heat in 17 settlements of Kamchatka. The company operates about one third of DPPs in the north of Kamchatka.

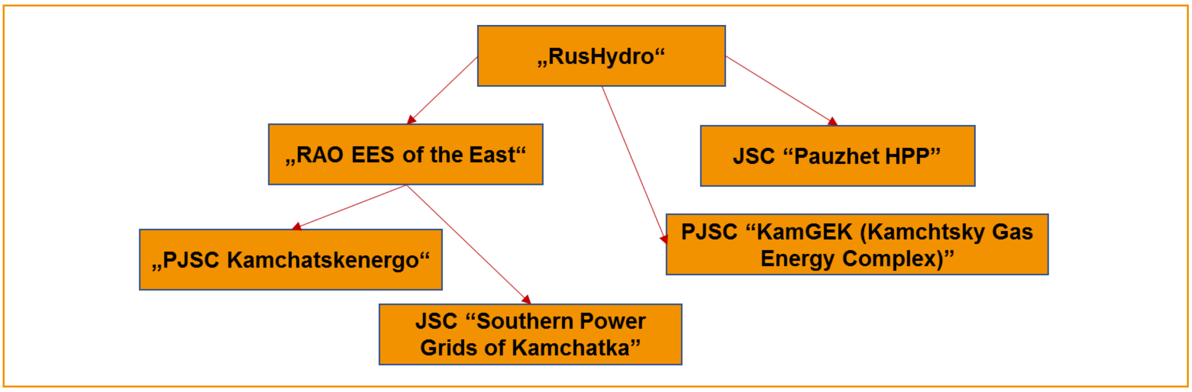

Figure 21 A scheme of relationships between the largest energy companies of Kamchatka; source: based on the research completed by eclareon and IP Kekelidze

Additionally, there are some companies which are responsible only for energy production. For example, JSC “Geotherm” (RusHydro group) operates 2 GPPs with an overall capacity of 62 MW, which is more than 80% of the overall installed geothermal capacity in Kamchatka. Simultaneously, there exists a number of companies which are responsible for energy generation and distribution in very small areas – isolated energy systems of Kamchatka, for instance, JSC “Ossora” in Ossorsky isolated energy system and “Kolhoz “Udarnik” Ltd. In Karaginsky isolated energy system.

In 2017, the overall total installed capacity in Kamchatka was 648.8 MW of which 483.15 MW belong to the central energy system. The major share of installed capacity refers to combined heat and power plants (powered mainly by gas), 24% is taken by diesel generation and more than 10% are geothermal based power plants. The power sector of Kamchatka has a relatively high share of renewable energy sources in its energy mix, represented by geothermal power, wind and small hydropower (together nearly 20%). The overall structure of Kamchatka’s installed power capacity is shown in Figure 22. The volume of total installed power capacity has been growing for the last few years, mainly because of new RES based installations (mainly hydro) capacity and some new, more efficient, generating facilities on existing DPPs.

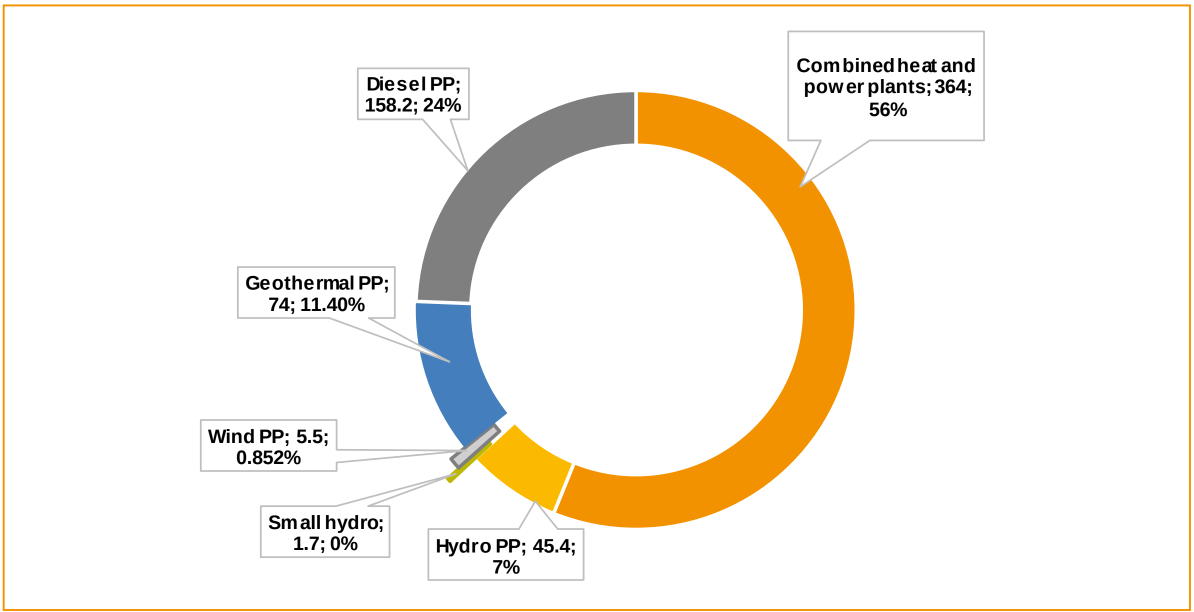

Figure 22 Structure of the installed capacity by type of power plant in Kamchatka in 2017 (in MW and %); source: Ministry of Housing and Construction and Energy Sector of Kamchatka, 2018 [51]

The energy balance in Kamchatka is such that it has enough power generating capacity to fully cover the consumption of the region.

Specification	Central regional energy system, number of PPs	Isolated energy systems (all remaining territory) number of PPs	Owner/operator	Installed capacity in total
Power plants ≥ 5WM (all fuel types)	5	6	"Kamchatskenergo"; "Piskunov Kamchatka power grids"; "Geotherm"; "Pauzhet HPP"; "KamGEK"; "Koryakenergo"; "Southern Power Grids of Kamchatka"	514.47
Diesel PPs 0,1-6 MW		38	Other owners	≈100
Diesel gensets <200 kW		290	Local municipalities	≈40

Table 5 Number, capacity and major owners of power generating facilities in Kamchatka; source: Ministry of Housing and Construction and Energy Sector of Kamchatka, 2018 [51], WWF Russia, 2017 [55]

In 1993, Kamchatka's government and Ministry of Energy decided to decrease the dependence of the region from imported fuel by connecting gas pipelines and energy generating facilities to the settlements. Since 2000, several gas pipelines have been built, combining settlements and heat and power plants with gas deposits in the region [51]. However, this program could not be successfully completed due to a 40% drop in gas extraction in the region. In 2011, "Gazprom" launched a new gas deposit on Kamchatka and it was planned to extract about 750 million m³ annually, which should have been enough to supply the regional energy system with fuel. However, a de-facto extraction resulted into 400 million m³. Such difference happened due to an inaccurate geological model and uncertainties during exploration works [85].

100% of oil products (including diesel, petrol, mazut, etc.) and 90% of hard coal consumed in Kamchatka are imported from other Russian regions [53]. Hence, a number of boiler houses of cities and industrial consumers use gas to produce energy; CHPP-2 also works on gas having mazut as a standby fuel, CHPP-1 uses mainly gas. The overwhelming majority (about 90%) of power generating facilities in other isolated energy systems of the region work on diesel and hybrid diesel-gas, some work on geothermal power and small hydropower [51]. There are 328 DPPs of different installed capacity in the region. The structure of fuel types used by power plants in the region is presented in Figure 23.

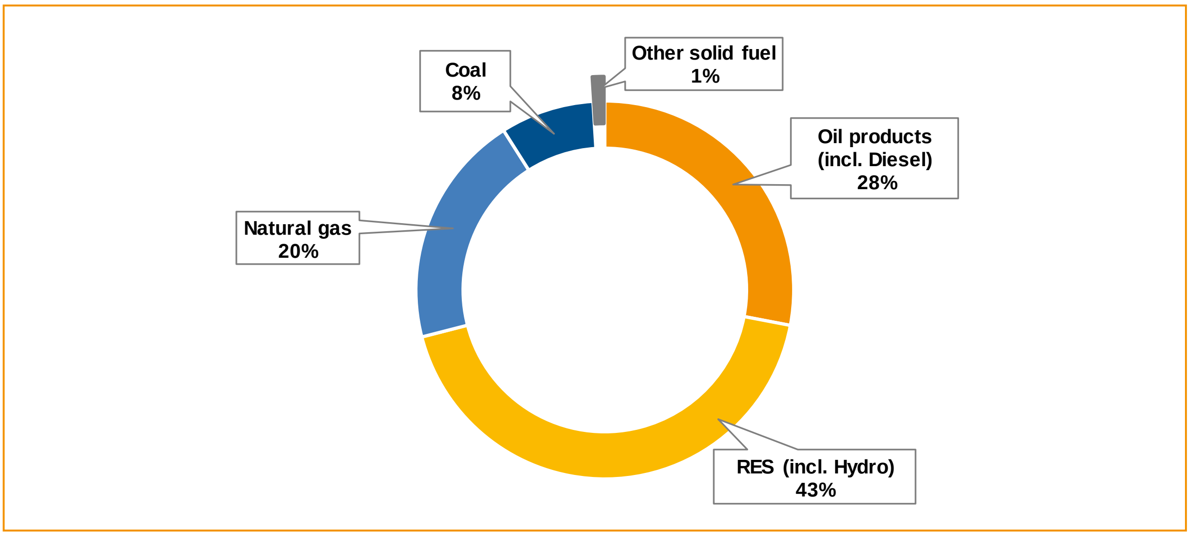

Figure 23 Correlation of fuel types at power plants in Kamchatka; source: Kamchatka Government, official web site, 2018 [53]

Energy consumption has been steadily growing for the last few years. In 2017, the average per capita energy consumption in Kamchatka was 5,570.6 kWh/capita/year [51]. Meanwhile, per capita consumption in isolated settlements is much higher and reaches 9,000 kWh/capita/year which is due to the widespread usage of cooking stoves and heating [55]. The major share of electricity consumption in the region (more than 80%) occurs in the central region; total electricity consumption in the other regions does not exceed 8% of the overall consumption; local consumers using private generation do not represent more than 7% of the overall regional consumption. There are no big power consumers outside the central energy system due to the low population density and absence of big industrial in other parts of the region.

Total electricity consumption in Kamchatka in 2017 amounted to 1,752.32 million kWh: 30% of electricity was consumed by rural and urban residential customers, 26% by the mining industry (extraction and mineral processing of precious metals, cobalt, copper and other metals; exploitation of the two gas deposits) and 20% by other industries, mainly fisheries, fish farming and the manufacturing industry. There was an 11% loss of electricity in the grids [54]. For energy consumption in rural areas, the following two main consumption patterns can be distinguished:

- Areas with peak consumption in the winter: Consumption is highest during cold months when loads are 30-50% higher than between May and August due to illumination and running of heat pumps.

- Areas with peak consumption in the summer: in such areas night loads can be 2 to 3 times lower than day loads. An example would be Ust-Kamchatsk settlement, where the total installed power capacity in 8.2 MW, June loads reach 6.5 MW and January loads are only 3 MW. Peaking summer consumption happens due to summer tourism and local fish processing industry.

In 2017, the regional power system (both electricity and heat) consumed 401,213 cubic meters of gas, 266,600 tons of coal, 100,729 tons of mazut and 49,241 tons of diesel.

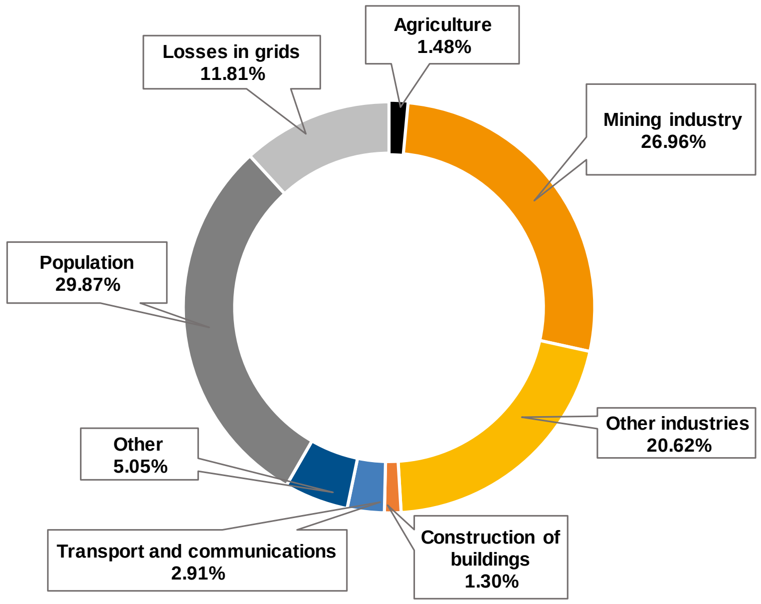

Figure 24 Electricity consumption in Kamchatka by type of consumer, %, 2017; source: Federal State Statistics Service of Russia, 2018 [54]

The Kamchatka energy sector has numerous problems for various reasons, among which are:

- Remoteness: Kamchatka is practically isolated from other regions and scarcity of transportation ways make fuel more expensive.
- High deterioration level of the power generation equipment: a large share of this equipment was installed more than 40 years ago. In 2020-2022, it is awaited that major share of this old equipment is going to break down-

At the same time, the region is already an active user of RES, as mentioned in the text above. However, there are no solar power plants in the region which are acknowledged by the Ministry of Energy of Kamchatka and included in the energy statistics. Nevertheless, there are some small-scale PV arrays, with most installed-on lighthouses and have capacities between several watts and couple of hundreds of kilowatts. The total estimated installed PV capacity in Kamchatka is below 1 MW [56].

Albeit still small as well, wind power plays a more important role in the region. The following gives an overview of wind power plants:

- Hybrid diesel-wind power plant in village Nikolskoje, consists of 2 wind turbines with an overall capacity of 550 kW and a DPP of 292 kW, built in 2013

- Wind power plant in the village Ust-Kamchatsk with an installed capacity of 275 kW (French company Vergnet as a result of an investment program PJSC Mobile Energy (part of RAO EES of the Eas" group)), built in 2014
- 3 wind turbines in Ust-Kamchatsk, 300 kW each (total installed capacity 900 kW) constructed by Japan's NEDO
- Wind power plant in settlement Oktyabrski built in 2008 with an overall installed capacity of 3,3 MW (. The wind park was a joint project of the current owner, JSC KES Piskunova – Piskunov's Kamchatka Power Grids, and Danish MICON (VESTAS) company. In 2015, this power plant generated 6,1 GWh of electricity [55].

More hybrid wind-diesel power plants are in the planning phase and to be built in 7 isolated from energy systems settlements in Kamchatka, which have no road connection to the capital city and fuel has to be delivered by marine transport, making it especially expensive. It is yet unclear, how the wind turbines will be delivered there.

With regards to their development potential, the most promising RES in the region are:

- Hydropower with an estimated energy potential of 800 MW / 50.6 billion kWh/year;
- Geothermal power with an estimated energy potential of 900 MW installed electrical capacity
- Wind power with an estimated energy potential of 1 GW / 30-36 billion kWh/year) mainly in the coastal areas of peninsula.

The potential for solar is lower than in southern Yakutia: horizontal solar radiation in southern parts of Kamchatka reaches 1,100 kWh/m^2/year in some areas but is around 900 kWh/m^2/year on average [164]. Settlements are mainly concentrated along the coasts where cloudy days are more common than sunny days. In 2015, a Czech company Ekotechnik offered to install a PV array for the local government in one of the settlements and was generally well received by the local government. The project also called for financial support from the government, which delayed the project's implementation. Currently, preparations are underway in the target settlement to install the 100 kW PV project [55].

All in all, the potential wind energy market consists of off- and an on-grid parts: The estimated size of the market inside the grid of the central energy system is 15-20 MW for wind. This capacity is best integrated in the existing power grid in the capital city, where good wind conditions are available. It will become especially important in the years after the two CHPPs will be affected by the shortage of supplies, which will lead to a switch to mazut-based energy generation. It is hard to estimate the size of the off-grid potential wind market due to scarcity of the research of wind potentials for concrete populated areas.

2.2.2 Electricity tariffs and costs

Kamchatka has the third highest electricity tariffs among the Russian regions. There is no wholesale electricity market in the region due to its disconnection from the UPS. High energy tariffs are one of the most serious problems in Kamchatka, putting much pressure on the population and burdening the regional economy. For this reason, production costs for products from Kamchatka are very high for energy intensive industries, thereby decreasing their competitiveness with similar Russian products from other regions.

Costs of electricity and heat production are very high due to a number of factors:

- nearly all fuel types need to be imported
- poor transport connection of the region with other Russian regions, due to geographical location
- no rail, road and pipeline connection to fuel extracting regions of Russia
- outdated and inefficient equipment at power plants, especially CHPP-1 and -2

Tariffs for the population differ depending on the group of consumers (night/day tariff; tariffs for people in rural and urban areas; tariffs for people with/without electrics stoves) and the power supplier. In 2018, residential electricity tariffs for the main tariff groups were 11% higher than tariffs in 2017 and resulted into [58]:

- energy sold by "Kamchatskenergo"; "Southern Power Grids of Kamchatka"; "Koryakenergo" and a number of smaller suppliers (with VAT):
  - rural population: night tariff 3.74 RUB/kWh (0.05 EUR/kWh)– day tariff 5.38 RUB/kWh (0.07 EUR/kWh)
  - urban population (households with gas stoves), night tariff 5.35 RUB/kWh (0.07 EUR/kWh) – day tariff 7.69 RUB/kWh (0.10 EUR/kWh)
  - single rate tariff (no differentiation by daytime or voltage) rural population 4,68 RUB/kWh (0.06 EUR/kWh) – urban population 6.68 RUB/kWh (0.09 EUR/kWh)
- Energy sold by "Pauzhet HPP" in Ozernovsky energy system only:
  - rural population: night tariff 2.89 RUB/kWh (0.04 EUR/kWh) – day tariff 4.16 RUB/kWh (0.05 EUR/kWh)
  - urban population (households with gas stoves), night tariff 4.13 RUB/kWh (0.05 EUR/kWh) – day tariff 5.94 RUB/kWh (0.08 EUR/kWh)
  - single rate tariff (no differentiation by daytime or voltage) rural population 3.62 RUB/kWh (EUR/kWh) – urban population 5.17 RUB/kWh (0.07 EUR/kWh)

Tariffs for non-residential consumers are calculated differently and may reach 50 RUB/kWh (0.66 EUR/kWh) for isolated settlements.

These tariffs do not reflect the real electricity price due to strong subsidization. High fuel prices and payments for transportation increase the generation costs and overstep the ceiling price levels established by the Federal Tariff Service of Russia. For example, real fuel costs in power generation are between 11 and 25 RUB/kWh (0.15 – 0.33 EUR/kWh). In 2018, the maximal electricity generation costs reached 88 RUB/kWh (1.17 EUR/kWh) [51]. On average, generation costs were 12-50 RUB/kWh (0.16 – 0.66 EUR/kWh) [59]. The difference between the true costs and end tariffs for consumers is covered by subsidies from the budget, which is, on average, 2 RUB/kWh (0.02 EUR/kWh) [51]. In 2016, total energy subsidies in the region reached 37 billion RUB (490 million EUR) which was the third biggest regional energy subsidy in the country [51]. The annual budget allocation for these targets is about 6% of the regional budget [55].

The region's gasification program aimed to decrease the costs of electricity and slow down the tariffs' growth and this target has been partly achieved in 2012-2013. Gazprom delivers gas directly to customers, including power plants [51]. Although the programs of gasification have been successfully implemented, their effect was not enough to fully resolve the problem of high electricity tariffs and has not driven the energy generation costs down to average Russian. Currently, the price of the imported natural gas sold to "Kamchatskenergo" is lower than its costs, the difference is based on cross-subsidization inside the Gazprom structure. In 2018, this gas price subsidized by Gazprom was 7,167 RUB/cubic meter (95.58 EUR) in Kamchatka, while the real price without subsidies would have been around 18,000 RUB/cubic meter (240 EUR). Without this subsidization, energy prices for electricity sold by the two CHPPs would increase and make the end customer energy tariff grow by 10% [51]. For the last few years, Gazprom's annual losses based on the gas trade with "Kamchatskenergo" has reached 4 billion RUB (53.35 million EUR).

Due to a combination of the following facts, the two CHPPs are likely to switch to mazut for energy generation one day, resulting in a drastic growth of energy generation costs:

1. Domestic extraction of natural gas will reduce by 4 times until 2030 and regions will face the problem of fuel shortages

2. There are no pipelines or suitable road and rail connections between Kamchatka and Russian gas extracting regions, so importing gas from other regions will be nearly impossible

3. Theoretically, a regasification terminal for a liquified natural gas (LNG) could be built in the region by "Gazprom" as was done in Kaliningrad (see http://www.gazprom.com/projects/kaliningrad-terminal/ for more information). In order to do this, large investments are needed, which the regional administration cannot fulfill. Moreover, that would require marine transportation of LNG which could also mean additional transportation costs.

4. CHPPs already have generators and turbines aimed at being fueled by mazut and it is likely that this existing equipment is preferable to additional investments in new facilities and solutions

In 2018, for both CHPPs of Kamchatka working on gas, the electricity cost without service payments for electricity transportation (payments to grid operators) was 5.3 RUB/kWh (0.07 EUR/kWh) , which is 2 times higher than the similar average tariff in Russia [51]. For small isolated settlements, the cost for electricity is much higher and varies between 11 and 88 RUB/kWh (0.15 – 1.17 EUR/kWh). Therefore, the cheapest electricity prices in Kamchatka is for RES-based energy: geothermal energy price is 3.05 RUB/kWh (0.04 EUR/kWh) and the hydro power energy price is 4.95 RUB/kWh (0.06 EUR/kWh) which explains the lower energy tariffs in Ozernovsky's energy system. Energy from hybrid wind-diesel power stations may be sold to the end consumer for 10-20 RUB/kWh (0.13 – 0.26 EUR/kWh), while small hydro can ensure final consumer energy prices between 2 and 15 RUB/kWh (0.02 – 0.20 EUR/kWh) [55].

RUB/kWh (EUR/kWh) with VAT	All energy systems in common	Ozernovsky energy system (hydro)	Isolated settlements, non-common situations
Urban population single rate tariff	6.68 (0.09)	5.17 (0.07)	_
Rural population single rate tariff	4.68 (0.06)	3.62 (0.05)	_
Costs of electricity generation	av. 6-15 (0.08 – 0.20)	av. 5 (0.06)	12 up to 88 (0.16 – 1.17)

Table 6 Some tariffs for energy consumers in Kamchatka and costs of electricity generation; source : WWF Russia, 2017 [55]; Ministry of Housing and Construction and Energy Sector of Kamchatka, 2018 [51]; Bashmakov & Dzedzichek, 2017 [59]; outcomes of research by eclareon and IP Kekelidze

<table>
<tr><td colspan="5">Economically justified electricity price (without subsidies), for first and second half of 2019, RUB/kWh (EUR/kWh) with VAT[13], electricity for residential and non-residential consumers in isolated energy system “Ossorsky”, only low voltage grids exist (0.4 kV and less)</td></tr>
<tr><td></td><td colspan="2">1/1 2019</td><td colspan="2">2/2 2019</td></tr>
<tr><td>Single rate tariff, urban population</td><td colspan="2">33.385 (0.45)</td><td colspan="2">49.278 (0.66)</td></tr>
<tr><td>Single rate tariff, double-day zones, urban population</td><td colspan="2">Day – 38.393 (0.51)
Night – 26.707 (0.36)</td><td colspan="2">Day – 56.670 (0.76)
Night – 39.423 (0.53)</td></tr>
<tr><td>Single rate tariff, three-day zones, urban population</td><td colspan="2">Peak – 40.062(0.53)
Semi peak – 33.385 (0.45)
Night – 26.707 (0.36)</td><td colspan="2">Peak – 59.134 (0.79)
Semi peak – 49.278 (0.66)
Night – 39.423 (0.53)</td></tr>
<tr><td>Single rate tariff, rural population</td><td colspan="2">23.369 (0.31)</td><td colspan="2">34.495 (0.46)</td></tr>
<tr><td>Single rate tariff, two-day zones, rural population</td><td colspan="2">Day – 26.875 (0.36)
Night – 18.695 (0.25)</td><td colspan="2">Day – 39.669 (0.53)
Night – 27.596 (0.37)</td></tr>
<tr><td>Single rate tariff, three-day zones, rural population</td><td colspan="2">Peak – 28.043 (0.37)
Semi peak – 23.369 (0.31)
Night – 18.695 (0.25)</td><td colspan="2">Peak – 41.349 (0.55)
Semi peak – 34.495 (0.46)
Night – 27.596 (0.37)</td></tr>
<tr><td>Single rate tariff, non-residential consumers</td><td colspan="2">27.821 (0.37)</td><td colspan="2">41.065 (0.55)</td></tr>
<tr><td>Single rate tariff, two-day zones, non-residential consumers</td><td colspan="2">Day – 22.256 (0.30)
Night – 31.994 (0.43)</td><td colspan="2">Day – 32.852 (0.44)
Night – 47.225 (0.63)</td></tr>
<tr><td>Single rate tariff, three-day zones, non-residential consumers</td><td colspan="2">Peak – 22.256 (0.30)
Semi peak – 27.821 (0.37)
Night – 33.385 (0.45)</td><td colspan="2">Peak – 32.852 (0.44)
Semi peak – 41.065 (0.55)
Night – 49.278 (0.66)</td></tr>
<tr><td colspan="5">Economically justified electricity price (without subsidies), for first and second half of 2019, RUB/kWh (EUR/kWh) with VAT in isolated energy system “Karaginski”</td></tr>
<tr><td>Electricity price</td><td colspan="2">30.692 (0.41)</td><td colspan="2">34.611 (0.46)</td></tr>
<tr><td colspan="5">Electricity tariffs (with subsidies) for the first half of 2019 for non-residential consumers in Kamchatka, incl. voltage level differentiation, RUB/kWh (EUR/kWh) with VAT</td></tr>
<tr><td>Type of voltage / type of tariff</td><td>High voltage (110 kV and higher)</td><td>Middle first voltage (35 kV)</td><td>Middle second voltage (20-1 kV)</td><td>Low voltage (0,4 kV and less)</td></tr>
<tr><td>Single rate tariff</td><td colspan="4">5.55 (0.07)</td></tr>
<tr><td>Single rate tariff, double day-zones</td><td colspan="4">Day – 6.38 (0.09)
Night – 4.44 (0.06)</td></tr>
<tr><td>Single rate tariff, three day-zones</td><td colspan="4">Peak – 6.66 (0.09)
Semi peak – 5.55 (0.07)
Night – 4.44 (0.06)</td></tr>
</table>

Table 7 Some economically justified electricity prices and end electricity tariffs (with subsidies) for energy consumers in Kamchatka; source: “Ossora”, 2018 [153], “Kolhoz “Udarnik”, 2018 [152], Government of Kamchatka, 2018 [154]

[13] VAT in 2018 = 18%; VAT since 2019 = 20%

Table 7 contains both economically justified and end consumer prices for electricity. If one compares residential energy tariffs established in the whole region (see the text above Table 6) with real electricity prices, it becomes clear, that about 80% of residential price is subsidized. Same situation is for rural consumers and non-residential consumers of the retail market, like SMEs and industrial facilities – for them, share of subsidization in the in-bill price is also about 80%. Similar to isolated energy systems in Yakutia, in Kamchatka high costs of electricity are explained by a large share of fuel expenses in energy price:

- In Ossorsky energy system, there is a DPP-12 with an installed capacity of 5 MW, generation is managed by "Ossora" Ltd. In 2019, the planed expenses for fuel take 44% (19,163 thousand RUB / 255.6 EUR) of overall planned expenses which at the end form electricity price [155]
- In Karaginsky energy system, electricity is generated also on DPP (1.7 MW) by "Kolhoz "Udarnik", in 2019, the planed expenses for fuel take 62% (15,292 thousand RUB / 203.9 EUR) of overall planned expenses which at the end form electricity price [156]

Although the residential tariffs get strongly subsidized, they are still the second highest in Russia. High energy tariffs are one of the most serious problems in Kamchatka, putting pressure on the population and oppressing the regional economy. In 2018, an average citizen of Kamchatka gave out 16.3% [86] of his salary for housing and communal services, including electricity, water, heating and gas. An average salary in Kamchatka is 33.6 thousand RUB (about 442 EUR) and everything, especially fruits, vegetables and dairy products, is much more expensive than in many other Russian regions because of high transportation costs, therefore such utility bills are putting a lot of pressure on families' budgets.

Often, consumers are not able to pay the electricity and heating bills, causing serious financial problems among energy supply companies and slowing down the development of energy systems and renovation of power plants due to a lack of free financial resources.

2.2.3 Regional business environment & specific legal and regulatory framework for energy supply

The most attractive technical RES solution in Kamchatka is seen in the construction of hybrid diesel-wind power plants. The 2 main factors which could push the development of such projects forward are: the availability of investment which is often obtained through governmental RES supporting programs and the "readiness" of a local company (power supplier/distributor/producer) to take part in such projects and support them.

There are around 330 DPPs of different sizes in the region, which usually consume 275 grams of diesel/kWh and some consuming up to 440 grams/kWh; most of them are outdated and integrated into local small-low-voltage grids (mainly, 6-10 kV). There is no centralized program aiming to replace the old power capacity and no concrete timeframe to do that. According to some estimations, the average annual DPPs' capacity replacement or/and renovation is about 2% of the total installed capacity each year which would result in new installations of 3-5 MW/year. Given that the maximum wind power that can be integrated cannot be more than of 20% of the DPPs' maximum load, or 15% of its nominal installed capacity provided that no intelligent energy management systems are installed, the annual market for wind energy in the region could be as much as 600kW to 1 MW.

Major activities inside the regional energy system are concentrated in the hands of JSC Southern Power Grids of Kamchatka (basically, meaning RAO EES of the East) which has enough human resources for such a project implementation. However, RAO EES of the East has not yet shown serious commercial interest in RES development. Moreover, the company seems to lack the financial resources to invest in RE. Therefore, it will only drive the implementation of RES projects in case of receiving additional financial resources from the federal government (as it does right now with the help of an investment program described in the next subparagraph). Nowadays, isolated settlements have surpluses in installed generation capacity (about 50%) but, at the same time, up to 70% of the equipment is not functional. It is assumed to be more economically effective to install modern energy efficient diesel power plant rather than a hybrid wind-diesel facility or small hydro [57]. There is also no motivation for the RES implementation for residential consumers, who only pay a regulated tariff regardless of the real costs of production. Moreover, a grassroots movement criticizing the use of fuel powered electricity generation for environmental reasons is not a relevant phenomenon. Hence, the parties who are motivated to develop and implement RES projects are the regional energy suppliers like Kamchatskenergo because they have to compensate for high generation costs. Therefore, for a RES project to become attractive for local companies, it has to demonstrate lower generation costs. An investor should sign an energy supply contract with Kamchatskenergo or its subsidiary Southern Power Grids of Kamchatka. This contract should include energy costs which will, in the end, make the consumer prices stay below the inflation rate.

Currently, there is a large regional investment project "implementation of energy supply of isolated areas of Kamchatsky Krai based of renewable energy sources". The main investor is RAO EES of the East. The overall project's budget is around 2 billion RUB (~27 million EUR). This project has several targets:

- Decrease of expenses for imported diesel by replacing them with wind power plants
- Reduction of electricity tariffs due to cost savings on imported diesel fuel
- Improvement of electricity and heat supply to consumers
- Improvement of the regional ecological situation

The NEDO wind park project was financed by this investment project and is the result of a memorandum between "NEDO", "Rao EES of the East" and the government of Kamchatka [53].

Kamchatka has a regional development strategy implemented by the Decree of the Government of Kamchatka № 332- (P) of 27.07.2010 with the following change from 2018: Decree № 1- (p), "Strategy of the socio-economic development of Kamchatka Krai until 2030". The document includes guidelines on the necessary steps which, at the end, will decrease energy prices in the region and make it more energy independent [60]. Two of the points of the strategy is construction of new RES-based power generating facilities (based on hydro energy, geothermal and wind energy) and construction of hybrid diesel-wind power plants in isolated settlements.

The mentioned targets are to be reached with the help of various mechanisms, including the creation of favorable economic conditions for RES development; the creation of mechanisms for the return of private investments; the development of different forms of partnerships between governmental structures and private companies and the abolishment of administrative barriers slowing down various projects, etc. According to the plan, the share of RES in the total consumption volume shall increase to more than 30%, meaning an increase of 3.5% between 2013 and 2030.

2.2.4 Regional specific business case

For Kamchatka, a hybrid diesel-wind power plant for isolated settlements was selected as business case. The installation is in the Ust-Kamchatsk settlement, where a new wind park has been combined with an old diesel power plant and integrated into the existing local power grid. The project was a part of a large investment program of PJSC Mobile Energy (part of Rao EES of the East group), mentioned in the text above (2.2.3) which aims to construct hybrid wind-diesel power plants in several isolated settlements of Kamchatka, which today rely fully on diesel-based power. The replacement shall be completed by 2020.

Ust-Kamchatsk is located on the eastern coastal area in the central part of Kamchatka, the population of the settlement is around 5,000 people. The annual power generation in the settlement fluctuates around 20,600 MWh/year. The diesel power plant supplying this settlement has 8.2 MW of total installed capacity with maximal loads in July up to 6.4 MW. Currently, the installed wind power capacity is 1.175 MW in total, while the planned total capacity is 3.4 MW. The project consists of several stages: the first stage was completed in 2013 when a French company Vergnet installed a 55-meter wind turbine with a capacity of 275 kW; the second stage was completed in 2015 by a Japanese company NEDO (Mitsui & Co. and Komaihaltec Inc.) which installed three wind turbines produced by Komaihaltec Inc. Each of these wind turbines has a capacity of 300 kW and is 41.5 m high [62]. The plan is that the total installed wind power shall go up to 3 MW (the year of a project's final is not specified in open sources). NEDO installed the turbines at its own expense, with an aim to check the equipment in extreme weather conditions, similar to the project in Tiksi (see chapter on Yakutia: p. 29).

The wind park is supposed to produce around 2 million kWh annually, which could help save 533 tons of diesel each year. Nowadays, the wind park is working in a test regime, but, according to some estimations, has already saved more than 550 tons of diesel during the period 2013-2016.

2.2.5 Business model description

In the case of a project development, specific steps need to be undertaken to develop a RE array. These steps are presented in Figure 25 below, the scheme includes actors needed for each of the step and the duration of these steps. The process of cooperation between different stakeholders while RES project development is similar to the one for Yakutia.

The overall project's duration for a wind power plant in Kamchatka is around 2 years and includes the following important steps:

Before the project starts, it is essential to approach local authorities, ministries (e.g. Ministry of Construction and Infrastructure Development) and companies responsible for the local isolated grids (in case the project is foreseen there) or Kamchatskenergo in case of a project development on the territory covered by the central regional energy system. Unlike Yakutia where most of negotiations are to be done with Yakutskenergo, in Kamchatka the partner varies depending on the concrete area of the region. The waiting time for an answer from local responsible players takes on average 2 weeks, while the overall duration to receive permits may last 2-3 months. In order to clarify all open questions that may arise during the process it is sometimes recommended to approach the ministry/administrative body/company several times. Moreover, it makes sense to approach larger companies, such as RAO EES of the East and cooperate directly with them to accelerate negotiations "top down" since subsidiary companies such as Kamchatskenergo and Southern Power Grids of Kamchatka often get directives from RAO EES directly.

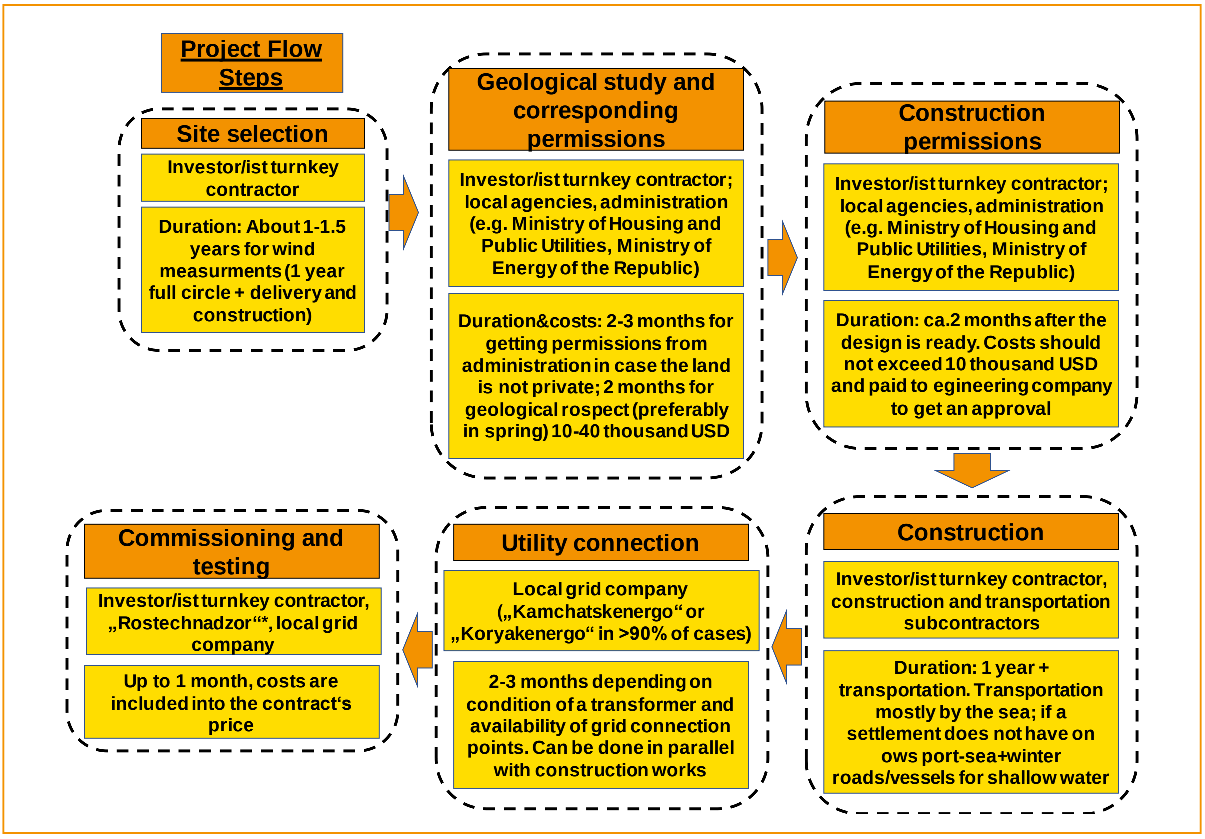

Figure 25 Scheme of the project's flow in Kamchatka; source: based on the research completed by eclareon and IP Kekelidze

There is a number of regions in Kamchatka, which are promising for the development of wind projects, but which have a very poor transport connection. For such cases, logistics should be set before the design of the project and one should consider existing variants of transport connection. For example, some equipment may be transported by sea, but in the case a settlement that has no suitable marine port, the hardware should be transported to the closest settlement with a suitable port and from there be either delivered by roads or by inland waterways. The northern part of Kamchatka lies in the permafrost zone which means that roads are in the best condition during the winter.

2.2.6 Profitability analysis (inputs, outputs, scenarios, sensitivities)

In the following, an exemplary profitability analysis for the 900 kW wind project based on diesel power savings is presented. The reference model for this business case is the installation in the village of Ust-Kamchatsk. Expected investment payback period for this project was estimated at 15 years, according to the information received by "Eurosolar" Russia from REO EES EAST GROUP. This result can according to our calculations only be achieved by assuming that some investment subsidies/ financial support was provided. This is likely given that Ust-Kamchatsk is a project with an R&D focus, not a commercial installation. Such support could have come from both Japanese and Russian sources: as mentioned previously. Given that no exact figures for the financial support could be found during our research but the 15-year payback were communicated as a fact, the financial support for the project was estimated.

It needs to be noted that the overall wind power project is actually split into 2 wind power installations: besides the three 300kW turbines installed by the Japanese company NEDO there is also an additional 300 kW wind turbine from a French manufacturer which is not part of these calculations. The main parameters and results of the base case scenario are presented in the following figure:

Wind System			
Project Duration		Years	25
Wind Generator Size		kWp	900
Battery Capacity		kWh	-
Specific System Cost		RUB/kWp	340.000
Applied investment subsidy/ support		RUB	100.000.000
Total System Cost		RUB	206.000.000
Capacity Utilization Factor		%	17%
Battery Replacement Interval		Years	-
Total Battery Replacement Costs		RUB	-
Financing			
Debt (Gearing)	20%	RUB	41.200.000
Loan Tenor		Years	10
Grace period		Years	-
Debt Interest Rate		%	11%
Initial Equity		RUB	167.255.633
Additional Equity		RUB	6.452.989
Discount Rate		%	10%
Longterm Inflation Rate		%	4%

System Operation		
Average Yearly Generation	kWh/a	1.302.058
Direct-Consumption Rate	%	80%
Genset efficiency	kWh/ltr	2,50
Average Replaced Diesel Consumpt	ltr/year	416.658
Diesel Price (1st Ops Year)	RUB/ltr	44,00
Diesel Price Escalation	% p.a.	10%
Fixed Operation Costs	RUB p.a.	4.120.000
Longterm Insurance Costs	% p.a.	-
Results		
Net-Present Value	RUB	153.612.024
Project IRR	%	15%
Equity IRR	%	15%
Payback Period	Years	15,38
LCOE (no subsidy)	RUB/kWh	32,51
Min DSCR**	x	0,07 x
Min LLCR***	x	2,98 x

* LCOE: Levelized Cost of Electricity
** DSCR: Debt Service Coverage Ratio
*** LLCR: Loan Life Coverage Ratio

Figure 26 Project Overview – Ust-Kamchatsk 900kW diesel wind hybrid; source: eclareon calculations, based on input data researched by EUROSOLAR Russia, 2018

As was also the case with the previously presented PV business case of Batagai, the specific system costs seem high but the technical solutions are not standard solutions due to the demanding climatic conditions. Diesel prices for isolated settlements were reported to be lower than in Yakutia at approx. 44 RUB/ liter (~0.58 EUR/ liter). This is not far away from pump prices that private customers would pay. The main reason for this fairly low Diesel prices in an isolated territory are the location close to the sea which reduces transportation costs. Moreover, procurement prices for the operators are lower than for private customers based on the quantities purchased (economies of scale). The Diesel costs in conjunction with an estimated investment subsidy of approx. 100 Mio. RUB and with a diesel price escalation of 10% p.a. lead to a positive NPV and a positive IRR. The payback period for the equity investor using discounted cash flows, corresponds to approx. 15 years. This payback period and the IRR show that the installation is Ust-Kamchatsk was not built based on economic considerations alone. R&D aspects for the operation of a wind power plant under harsh climatic conditions played a role as well. Moreover, the business case would improve in terms of IRR and payback period if Diesel prices were higher. This may be the case in isolated locations that are not as easily accessible by waterways as Ust-Kamchatsk.

The next figure shows that under the chosen financing conditions the project revenues suffice to pay back the equity investment over time.

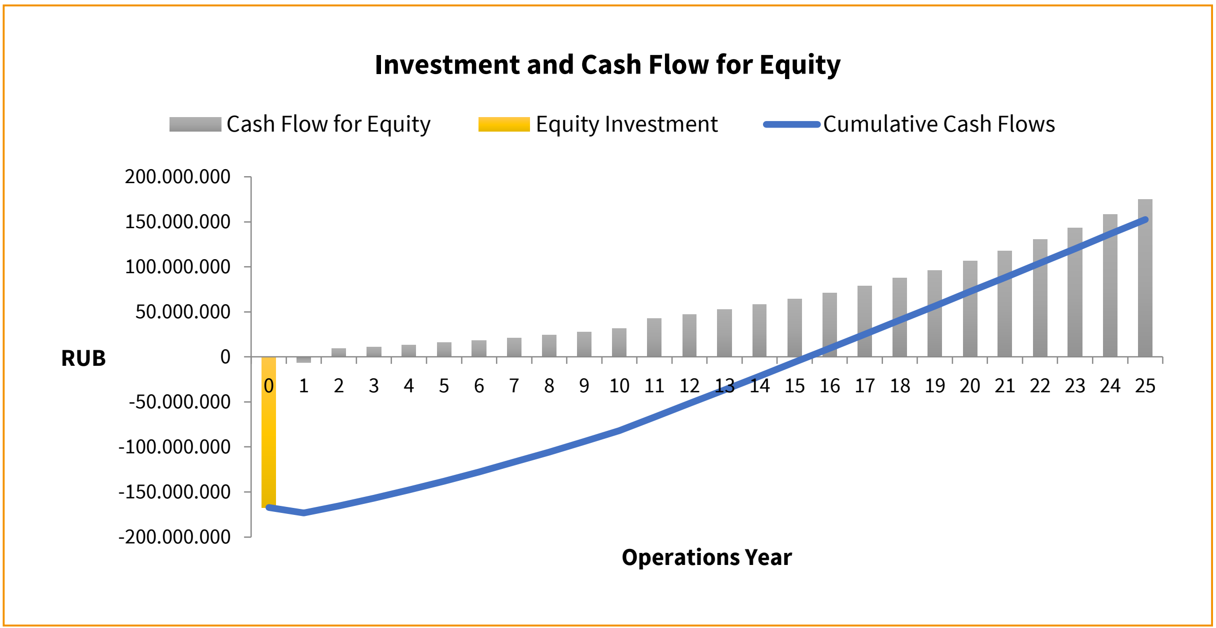

Figure 27 Equity Cash Flow – Ust-Kamchatsk 900kW diesel wind hybrid; source: eclareon calculations, based on input data researched by EUROSOLAR Russia, 2018

As can be seen, the cash flow available to pay back the equity investment increases over time. During the first 10 years cash flows are used primarily to pay back the loan. A small jump can therefore be seen in year 11 but given that only 20% of the overall investment was assumed to be financed by debt this jump is less prominent than in business cases where debt plays a more important role. Under the chosen financing conditions (loan tenor of 10 years), the diesel savings are sufficient to repay the loan. The cash flow available for equity also increases based on the assumption that the diesel that is replaced by wind power is becoming more expensive every year. Additional equity may however be required after year 1 in order to operate the plant. The equity is paid back after approx. 15 years. In the graph this is illustrated by the blue line crossing the horizontal x-axis.

The impact of a changing capacity factor which in the base case scenario is with 17% relatively low is shown in the next figure:

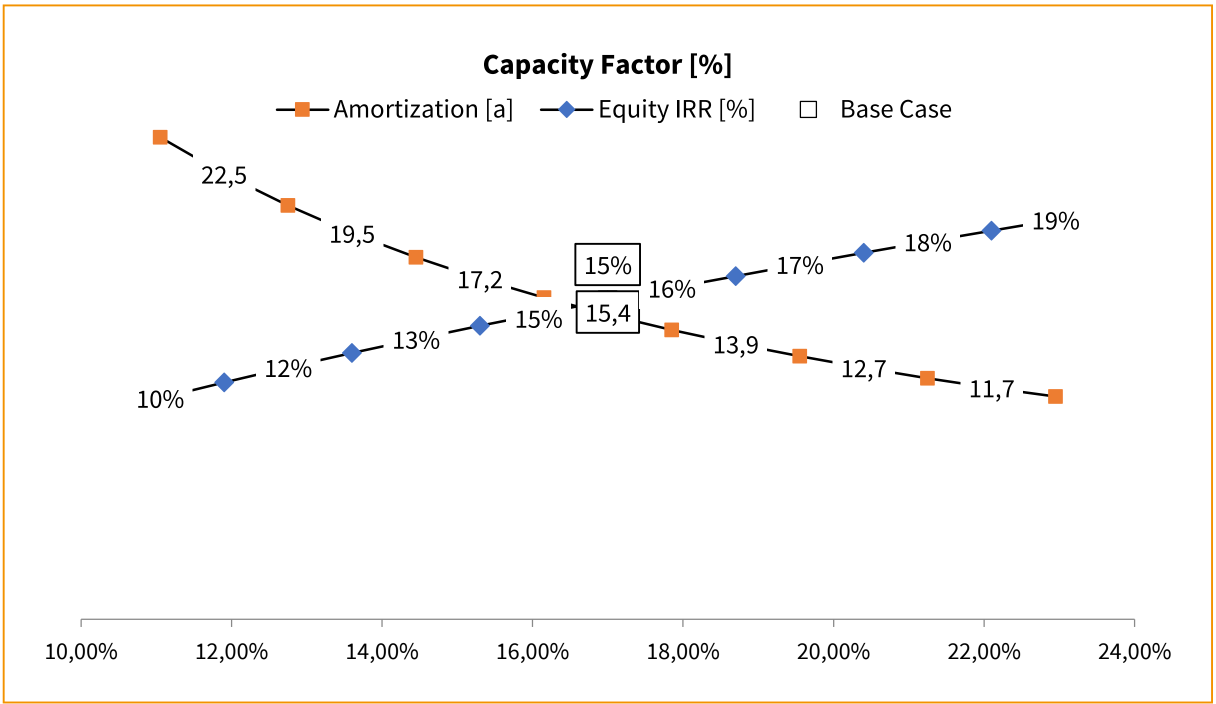

Figure 28 Capacity factor Sensitivity – Ust-Kamchatsk 900kW diesel wind hybrid; source: eclareon calculations, based on input data researched by EUROSOLAR Russia, 2018

The capacity factor, sometimes also referred to as the load factor, refers to the ratio of the generated net electricity during a certain period to the theoretical maximum of energy during the same period. There are of course seasonal differences but for standard onshore wind turbines a yearly average efficiency would rather be between 20% and 30%. But as stressed before, the installation in Ust-Kamchatsk is not standard. Interruptions of service, some forced by the harsh weather conditions some voluntary to account for R&D related aspects could have led to this rather low capacity factor. If the experience from Ust-Kamchatsk were used for future installations, it can be assumed that the capacity factor could be higher. The impact of such a higher capacity factor can be seen when moving to the right on the horizontal x axis: a capacity factor of 22% could bring the equity payback down to approx. 12 years, everything else left unchanged.

The influence of the system price is shown in the next graph. Even after the application of subsidies, the applied system price is still rather high at approx. 230.000 RUB/kWp (approx. 3.700€/kWp in 2015). Standard wind turbines built in 2015 had on average total installed costs well below 2.000 EUR/kWp[14]. This means that a potential for a lower price does not seem unrealistic for future projects. If a price of 200.000 RUB/kWp were applied payback of equity would be at approx. 13 years. This can be seen in the following graph when moving to the left on the horizontal axis where system prices are displayed.

[14] IRENA “RENEWABLE POWER GENERATION COSTS IN 2018”, page 33, Total installed costs of onshore wind projects and global weighted average by year of commissioning, 1983–2018

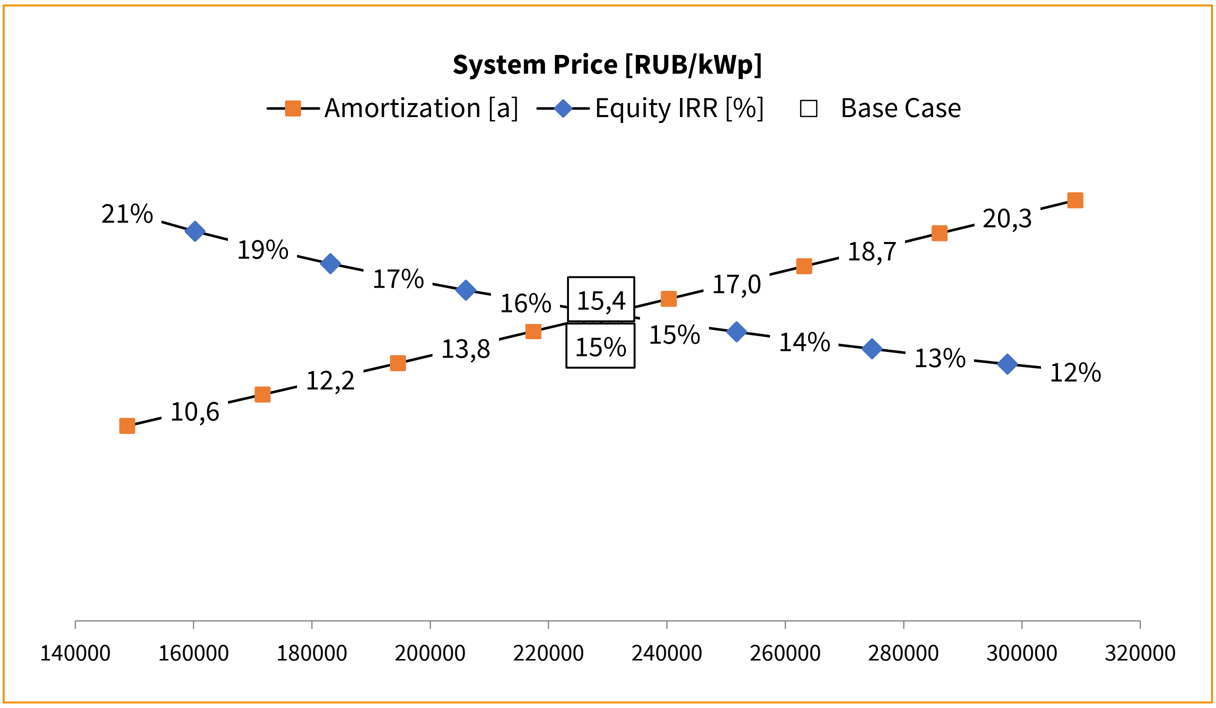

Figure 29 System Price Sensitivity – Ust-Kamchatsk 900kW diesel wind hybrid; source: eclareon calculations, based on input data researched by EUROSOLAR Russia, 2018

As shown, the capacity factor and also the system price have a strong influence on the profitability of the installation because of their strong impact on revenues and overall costs. In comparison to "standard" onshore systems that are for example used in central Europe, installation costs are very high and the capacity factor is low. The main factors affecting the cost of the project in Kamchatka (as well as in other isolated systems with a cold climate) compared to projects in the European part of the country are for example:

- Increased logistic costs due to the distance to manufacturing centres and often difficult accessibility of settlements in isolated territories
- the use of specific steel which is able to withstand extreme climatic conditions;
- electromechanical and electronic products (generators, relays, electromagnets, microcircuits, switching devices) have a suitable climatic design, which guarantees their trouble-free operation at low temperature;
- protection of wind turbine elements against icing, etc.

In addition it should be noted that the installed wind turbines KWT300 in the village Ust-Kamchatsk, are, in fact, a newly developed product, created on the basis of a serial sample specifically for work in low temperature conditions of up to minus 40°C and with a temperature of preservation of up to minus 50°C. Due to the applied technology of hermetic nacelle design, additional heating of components and mechanisms, as well as due to more precise climatic selection of lubricants, the operating temperature range of wind turbines has been significantly extended. This adaptation permitted the maintenance of the parameters of the nominal and maximum wind speeds, but at the same time to increase the power factor of wind power plants due to them working in the winter months. Thus, only a limited number of wind turbines have the appropriate characteristics to operate at low negative temperatures, which is crucial in the conditions of the Far East.

The impact of the Diesel price and the Diesel cost escalation on the amortization time and the equity IRR is shown in the following figure:

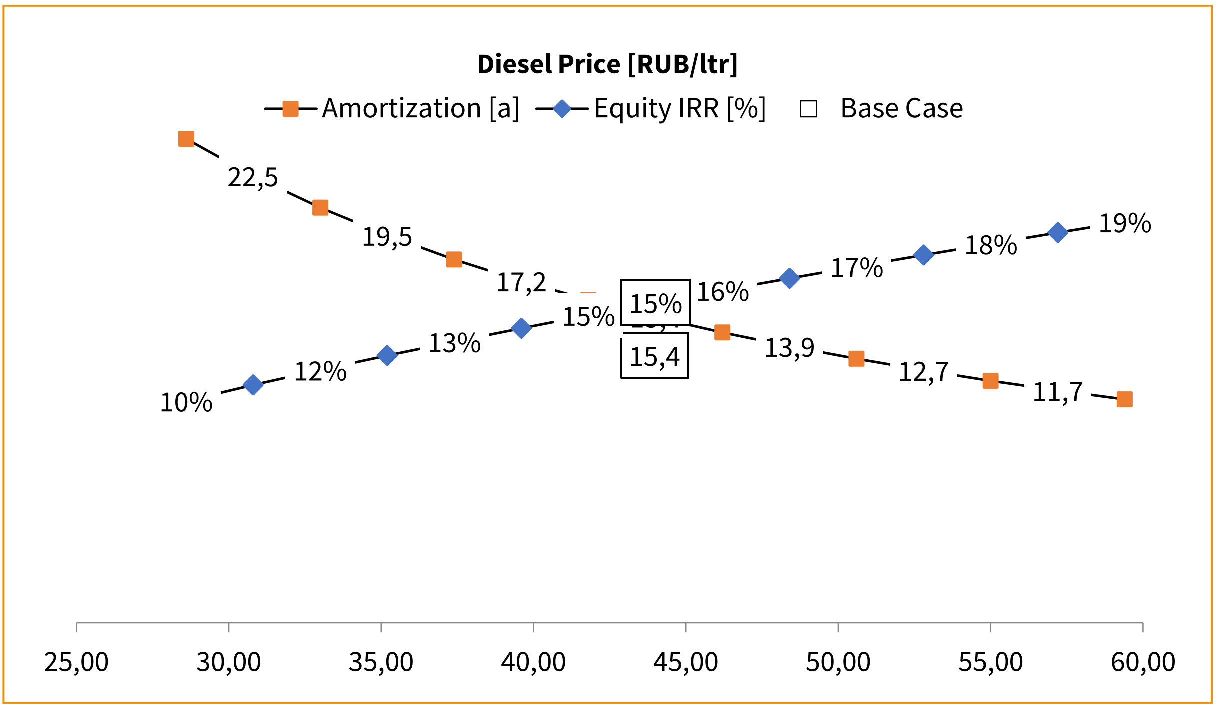

Figure 30 Diesel Price Ust-Kamchatsk 900kW diesel wind hybrid; source: eclareon calculations, based on input data researched by EUROSOLAR Russia, 2018

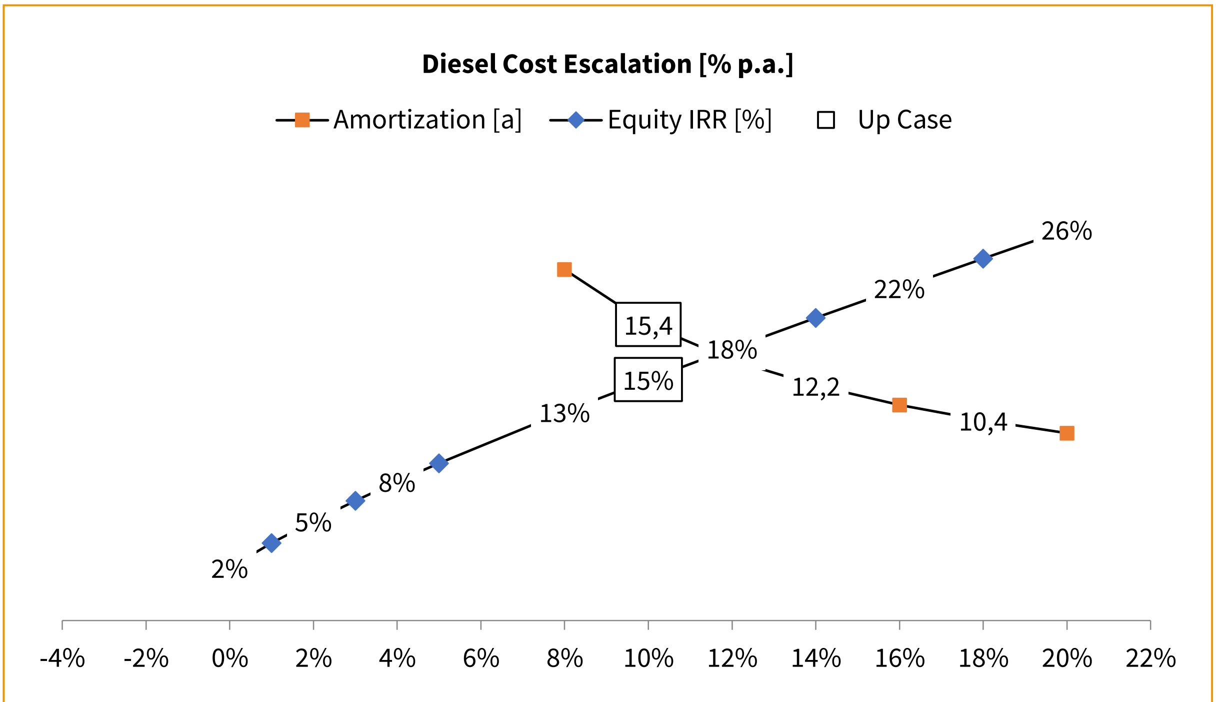

Figure 31 Diesel Price Ust-Kamchatsk 900kW diesel wind hybrid; source: eclareon calculations, based on input data researched by EUROSOLAR Russia, 2018

The diesel price in the base case was assumed to be at nearly 44 RUB/ liter. These costs are not very high compared to those in other isolated territories, e.g. in Batagai. This relatively moderate price for an isolated territory does not favor the business case: The higher the diesel costs the better the RES business case would be from the perspective of an investor. If the base case assumption were changed, the diesel price sensitivity (Figure 31) shows that, with a diesel price higher than 44 RUB/ liter, the payback period would go down while the equity IRR would go up. At a location with even more challenging logistical conditions than Ust-Kamchatsk, diesel prices could be higher and payback periods shorter.

Another sensitivity that has an impact on the key results of a business case is the future development of diesel prices. An investment is paid back over time which means that it is necessary to estimate how certain critical parameters will change over time. Future diesel prices are not assumed to stay as they are today. The annual diesel price escalation in the model was assumed to be at +10%. If this rate were higher the payback period and the IRR for the equity would change accordingly: an annual diesel costs escalation of 12% would decrease the payback period to less than 14 years and increase the equity IRR to 18%. However, it can of course also be assumed that the diesel price escalation is lower than in the base case. If that were the case, the payback would increase and the IRR decrease. E.g. if the price escalated only by 6% p.a., the equity could not be paid pack during the assumed project lifetime of 25 years.

2.2.7 Potential for cooperation/business opportunities

The RES market in the region is in a nascent state and there are both pros and cons for the prospects of RE deployment in the decentralized energy region of Kamchatka.

- The region has no centralized power grid and no connection to the UPS of Russia, all existing settlements are united by numerous different isolated energy systems with local grids of low voltages. Each of these energy systems is managed by a concrete energy supplier/grid operator. This fact makes negotiations with the local responsible actors easier and allows work on a relatively small scale, shortening the duration of negotiations.
- The region has a large coast with good wind potential, opening broad opportunities for on- and off-shore wind park development.
- Currently, gas plays a very important role in the energy supply of the region. Its high price along with “Gazprom” planning to rapidly decline gas extraction in the next few years is causing a growing shortage of gas for energy generation and increase of the fossil fuel share in energy generation. In the end, that will make electricity costs higher and increase the need in RES to reduce electricity costs using RES which are economically competitive.
- Many settlements are located in the coastal areas and most of them have fisheries and fish processing industries which drive electricity demand up in summer months. Additionally, the region attracts a lot of tourists creating extra energy demand. Being affected by rapidly growing electricity prices, small and medium size companies are likely to turn towards renewable energy sources.
- Having a large share of hydro power and geothermal, Kamchatka already has experience with the usage of RES. Therefore, the overall attitude towards wind, PV and other types of RES is already more open and positive than would be the case in many other Russian regions, hence, less work to raise awareness regarding RES is required.

- Existing diesel power plants in Kamchatka are outdated and in need of replacement/renovation. That is supposed to increase the demand and interest in small hydro, hybrid diesel-wind and diesel-PV power plants.
- Kamchatskenergo owns a majority of diesel power plants serving the needs of a bulk of isolated settlements of Kamchatka. Rising oil products' costs is motivating the company to invest in RES to decrease electricity costs.
- RAO EES of the East and regional authorities have a plan to build up to 120 MW of RES capacity in Kamchatka which means allocating financial resources and a qualified working force and know-how for the program. This is where foreign entities could contribute.

2.2.8 Risks and barriers

Along with positive factors, there are a number of difficulties which can make RES project development challenging:

- Kamchatka gets subsidies from the federal government, as well as cross-subsidies and gas prices which are subsidized by "Gazprom". It can happen that electricity prices are kept stable and that OPEX remains relatively low, even after a decline of gas volume and increase of diesel in energy generation, artificially through a further growth in subsidies. This would keep wind and PV power plants from price competitive with other energy sources.
- The climate conditions are extreme, meaning that standardized RE solutions cannot be used. The installed equipment needs be designed to withstand very low temperatures. These prerequisites make initial investment costs for wind power plants in the region extremely high.
- Due to the geographic location of the region, the transportation of equipment from Europe is very expensive. At the same time, Japan and China are much closer to the region and are interested in the regional market. European companies may however have niche knowledge regarding know-how and qualified O&M providers.
- Typical PV business cases in the region are the ones where settlements are currently supplied by diesel and are upgraded with wind. Diesel will remain the main energy source, with wind or PV will only supply max. 10- 20% of the energy due to technical reasons and difficulties in a RES power facility implementation into the existing power system of a specific settlement.
- Despite a positive attitude towards RES, knowledge about wind, PV and other RES is not yet commonplace. That means that an investor needs to conduct a research in the area before starting project's design.
- In order to get partnerships and support from the regional energy supply/grid and energy generating companies, it is essential to build relationships with these organizations, using contacts from the official company website is often not enough for successful cooperation.
- The largest energy companies in Kamchatka are managed by "RAO EES of the East" which often has enough financial resources for a potential project, but lacks the motivation to develop it. At the same time, its subsidiaries, have the motivation and but lack the money. That means that a foreign company needs to care about the largest share of investments for the project.

- Conflicts of interest between different branches of local administration. For example, there might be different opinions on the same issue from municipal and federal levels of government, however such conflicts are often thinly veiled

All in all, the RE market in Kamchatka is dominated by large hydro and geothermal power plants, owned by large companies. Markets for other RE sources have started to develop as can be seen by several completed and planned wind/hybrid diesel-wind projects. These projects are the often the result of an existing partnership between Russian and foreign companies. Due to the predicted decline of gas supply and high costs for oil products in Kamchatka, the development of RES is essential for the region. Wind is much more promising in the region than PV, however the potential for the wind market is not clearly known. This creates a possibility for foreign companies to enter the region via research activities. There are several important players in the region, offering a choice of partners for an investor, however major activities are controlled by “RAO EES of the East”, “RusHydro” and their subsidiaries. For a non-Russian company, the best way to enter the region would be to approach the targets both top-down through “RAO EES” and bottom-up through local subsidiaries.

2.3 Republic of Altai

The Altai Republic is part of the Siberian Federal District and is located in the mountains of Altai. The territory of the Republic of Altai is 92,900 km^2. The region is divided into ten municipal districts, uniting 92 rural administrations, comprising 248 settlements and the city district of Gorno-Altaisk. The climate is harsh-continental where in the winter the temperature drops to -30 C^0 while in summer it can go up to just +19 ^{0}C. According to the federal state statistics service 218,063 people inhabit the region, but only roughly one third of the population lives in urban areas - the population density is 2.3 people per 1 km^2 [102].

The territory is mainly agricultural with the main branch of agriculture being animal husbandry, particularly breeding of: red deer, sheep, horses and beef and dairy cattle. In all municipalities, enterprises process agricultural products and wild plants which are low in energy intensity and thereby electricity consumption is minimal. There are also gold mining enterprises and logging and timber processing is carried out in almost all municipalities. The competitive products in the region are: wood, lumber, cheese, oil, meat processing products, building materials, phytoproducts (teas, balsams, fees), non-ferrous metallurgy products (gold, copper, silver) [127].

Figure 32 Map of Russia, Republic of Altay highlighted; source: eclareon 2019, generated with Charts Pixel Map

2.3.1 Current energy supply situation and renewable energy potential

The Republic of Altai is located in the second price zone (the north-western territories close to the border with the Biysk power district of the Altai Krai), with the exception of the territories that are not technologically connected to the UPS of Russia and technologically isolated territorial electric power systems [128].

All power grids in the region are united in one net and these centralized power grids only cover 30% of the territory. Some areas are remote while others are barely accessible (e.g. mountainous areas), others, like the

Altay State Nature Reserve, are prohibited for grid construction Currently, there are 12 villages with no centralized power supply. Figure 33 illustrates the schematic energy system of the region and major known power plants of the region.

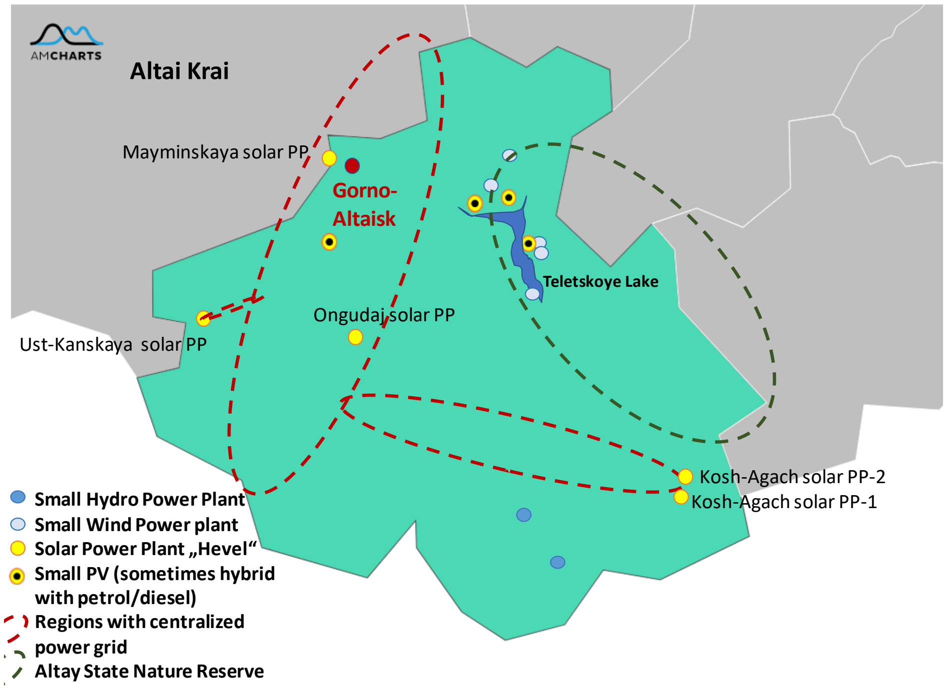

Figure 33 Largest SPPs of Republic of Altai and known location of some small off-grid energy generating; source: eclareon 2019, generated with amCharts Pixel Map, Head of Republic of Altai, 2018 [81], Gavrischenko, V.P. [82]

There are several players in the energy market of the region:

- All grids in the region are under control of ROSSETI through their local grid operator “Altaienergo”, which is a subsidiary of “Gorno-Altaisk Electrical Grids”
- Energy supply is committed by JSC “Altaienergosbyt” which is the only energy sales company in the Republic of Altai. “Altaienergosbyt” is a subsidiary of “Altaienergo” (ROSSETI group) and serves the needs of Altai Krai and the Republic of Altai.
- The only relatively large energy generating company is Hevel
- “Solar Energy” Ltd., the administration of the Chelushman rural settlement and the administration of the Saratan rural settlement of the Ulagan district of the Altai Republic are the guaranteeing suppliers of electric energy in less accessible and remote settlements of the region [129].

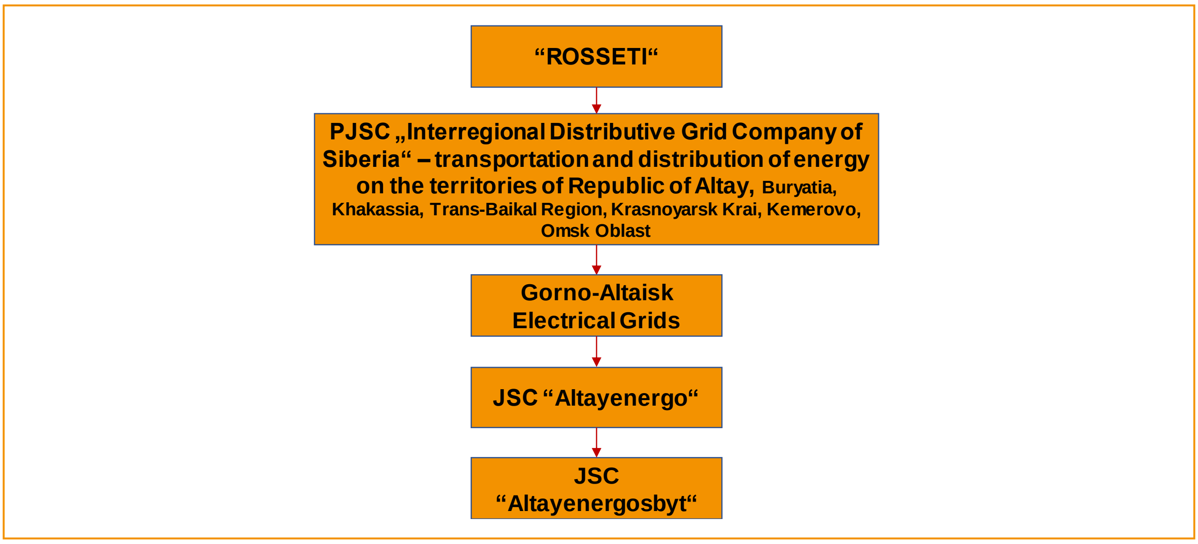

Figure 34 Scheme of the relations between major active in Republic of Altai energy companies; source: research by eclareon

Until 2015, there was no domestic generation in the Republic of Altai with the exception of ten small diesel power plants (installed capacity between 30 and 150 kW), a number of small WPPs and two small HPPs which together had an installed capacity of around 1.3 MW. There is additional RES installed off-grid capacity which supplies local consumers in natural reserves and cordons (such as hybrid wind-solar and small PV in cordons Katarash, Kamga, Chiri). Its overall volume is hard to estimate. Those energy generating facilities are still in operation and are examples of pure off-grid generation. They supply 12 remote settlements and local applications.

- The five villages isolated from the grid are located in the Turachak municipal region, where energy is generated by diesel gensets and hybrid solar-diesel power plants (PV part is small), e.g. in Yaylu village, the territory of a state nature reserve, a hybrid PP has 80 kW diesel and 20 kW PV installed capacity [78] [86]; in Artabash (also nature reserve); wind turbines in cordon Kokshi.
- Two villages in the Kosh-Agach municipal region, where energy is produced by a 30 kW diesel genset and a small HPP of 630 kW [83]
- Five villages in the Ust-Ulagan region supplied by diesel and hybrid solar-diesel power facilities and a HPP Kairu, in operation since 2002 and has 400 kW installed power capacity; cordon Bele has a hybrid petrol-wing generator (6 kW wind) [79]; cordon Chelyush is supplied by a hybrid PV-wind power plan; village Kok-Pash has a wind genset of 6 kW supplying 10 families living there with energy [80].

Power generation by these plants was only 4.4 % of the overall energy consumption in the Republic of Altai. After 2015, the situation changed with the launch of the four large SPPs: Kosh-Agach SPP-1 and SPP-2, with 5 MW capacity each, both built in 2015; Ust-Kanskaya SPP, 5 MW, launched in 2016; Mayminskaya SPP, 20 MW, opened in 2017; Ongudaj SPP, 5 MW, also launched in 2017.

The installed power capacity in the region is shown Figure 35. It is important to note that the data presented on the chart for wind and diesel and hybrid PV-diesel most likely differs slightly from the real numbers.

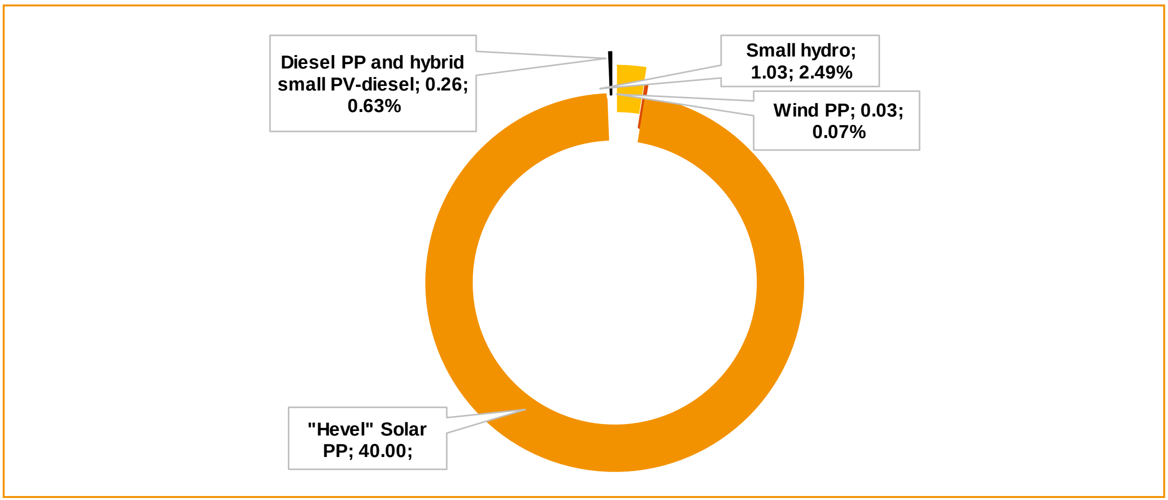

Figure 35 Structure of the installed capacity by type of power plant in Altai Republic in 2017 (in MW and %) source: Scheme and program for the development of the power industry of the Altai Republic for 2018 – 2022 [81]

All solar power plants are parts of the wholesale electricity market and are owned by the Hevel group, Russia's most renowned solar PV company. They are a module manufacturer and solar EPC company with a focus on large scale (on-grid) PV power plants mostly built on the basis of decree 449. Hevel plans to increase the total installed PV capacity in the region to up to 260 MW by 2020. The composition of existing power plants with unit installed capacity of above 1 MW is shown in Figure 36. Hevel also successfully concluded a so-called "Menza" project together with ROSSETI – a 120 kW Solar-Diesel station. This project is the first of its kind. It is based on an energy-service contract and therefore is not part of the current study. However, it will be described in further updates demonstrating such contract mechanisms in different regions of Russia.

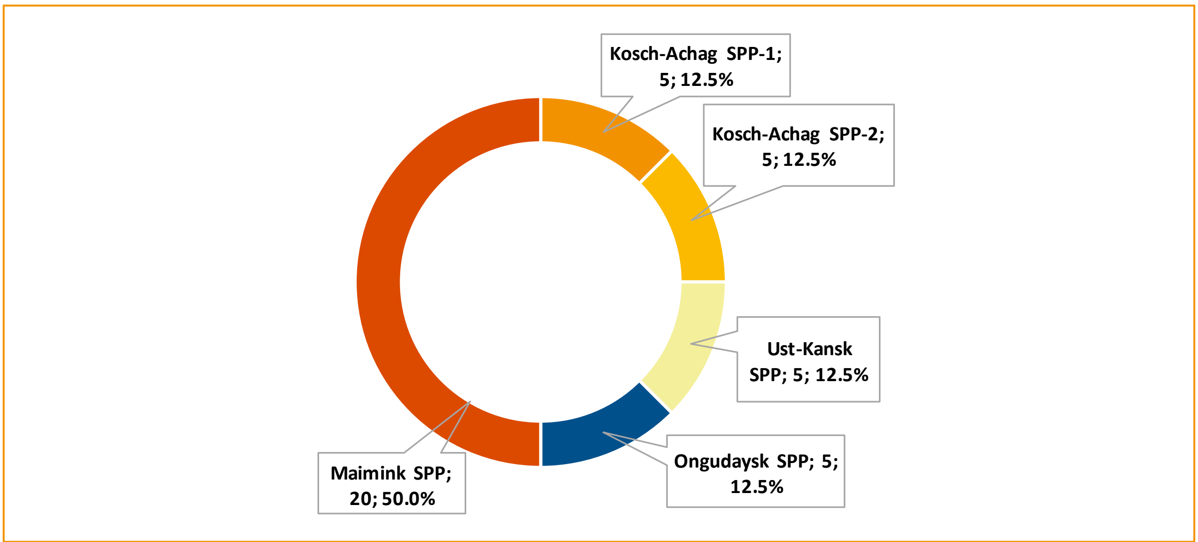

Figure 36 Structure of the installed capacity by type of power plant in Altai Republic in 2017 (in MW and %) source: Hevel, 2018 [88]

In 2017, 530.79 million kWh of electricity were consumed by the region, of which its own regional generation supplied just 23.2 million kWh or 4.37% [81]. 97% of domestic power production happened due to the five Hevel SPPs. All remaining volume of energy is imported to the region from Altai Krai. The largest consumers of electricity in the region are private households, which account for roughly 36% of electricity consumption; the second and third largest consumer groups are various industries, manufacturers and the mining industry.

Unlike other regions described in this study, where losses of energy in grids do not exceed 13% of the overall energy consumption, in the Republic of Altai losses are much higher and represent close to 20% of total consumption. This occurs because power lines of 110 kV stretch long distances from energy generating facilities located in Altai Krai until it reaches end consumers in the Republic of Altai, especially those located in southern parts of the region. The longest power lines stretch for more than 600 km from Bijsk in Altai Krai (and its big CHPPs) to Kosh-Agach region in the Republic of Altai. Figure 37 illustrates consumption of energy in the region in 2017. Energy consumption in the region is uneven throughout a year and peaks of consumption happen in winter the main reason being heating needs.

In the Republic of Altay, there are still areas which have no electricity supply at all and where it is too expensive to stretch the power grid. Simultaneously, a large part of the regional territory borders with a state nature reserve where it is prohibited to build grids. Still, these areas are often inhabited and sometimes settlements are very small, about ten households. An illustrating solution for such settlements, would be a case of Kok-Pash. The settlement is currently supplied with energy by a 6-kW wind park consisting of three small wind turbines built in 2010 and combined with an energy storage system [80]. Before 2010, energy needs of this settlement had been covered by a diesel genset and exploitation of the wind park saved about 6 tons of diesel within the first ten months [84].

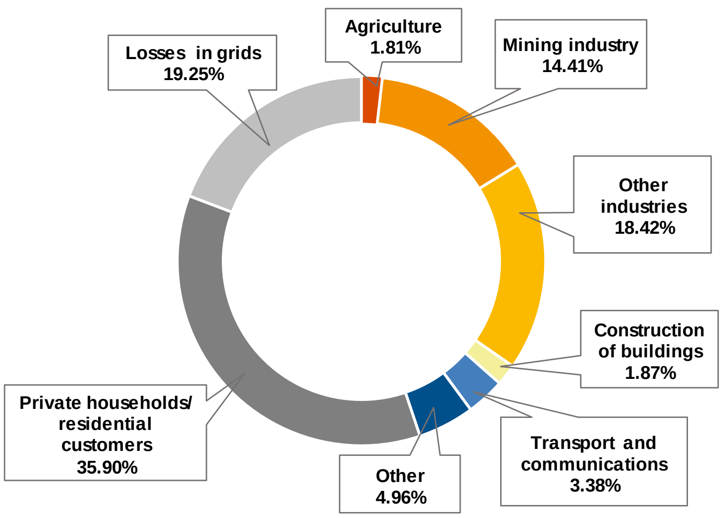

Figure 37 Electricity consumption in Altai by type of consumer, %, 2017; source: Federal State Statistics Service of Russia, 2018 [54]

The Republic of Altai has significant solar energy resources [89] with roughly 300 sunny days annually and an average annual solar irradiation of 1,200 – 1,300 kWh/m^2/year [164]. The total potential of wind energy in the Republic of Altai is about 50 billion kWh/year.

2.3.2 Electricity tariffs and costs

The Republic of Altai (its territories covered by UPS) is located in the second price zone of electricity market of Russia. However, its disconnected areas are considered isolated zones and are therefore regulated by other price formation rules.

The power grids in the region stretch unevenly throughout the territory and energy has to travel long distances until it reaches the end consumer resulting in large losses (up to one fifth of electricity). As a result, costs of energy transition and distribution in the region are especially high and seriously influence the end price for electricity.

In 2018, the Altai Republic had the eighth most expensive tariffs for electricity for private households [91], despite the fact that in 2016 the region ranked seventh [92]. Taking into account the high level of losses in the grids (19.25%), the cost of transport and distribution of electrical energy becomes prohibitive. As a result, more than two thirds of the costs that form electricity tariffs for end users are accounted to its transmission, distribution and sales within the Republic of Altai.

On the territory of the region, the state regulation of tariffs (prices), including electricity, is carried out by the tariff committee of the Altai Republic. For population and categories of consumers equated to it, the tariff for electricity is set at regulated tariffs established by the tariff committee of the Republic of Altai, within the limits of the range established by the FTS (Federal Tariff Service) of the Russian Federation.

In 1/1 of 2019, tariffs for private consumers were [157]:

- Rural population, night tariff 2.88 RUB/kWh (0.04 EUR/kWh) – day tariff 4.14 RUB/kWh (0.05 EUR/kWh)
- Urban population (households with gas stoves), night tariff 4.04 RUB/kWh (0.05 EUR/kWh) – day tariff 5.83 RUB/kWh (0.07 EUR/kWh)
- Single rate tariff (no differentiation by daytime or voltage) rural population 3.60 RUB/kWh (0.05 EUR/kWh) – urban population (households with gas stoves) 5.06 RUB/kWh (0.07 EUR/kWh)

For a group of other consumers in the price zone, which includes all organizations and entities, the tariff for electricity is set at unregulated tariffs [93]. The unregulated price is formed under the influence of market factors of the wholesale market and may change from month to month under wholesale market conditions. Table 8 presents the limit levels of nonregulated prices for electricity for January 2019 as first and second price categories:

Type of voltage / type of tariff	High voltage (110 kV and higher)	Middle first voltage (35 kV)	Middle second voltage (20-1 kV)	Low voltage (0,4 kV and less)
The first price category, RUB / kWh (EUR/kWh) (with VAT), for January 2019, non-residential consumers under 670 kW loads				
Single-rate tariff	5.72 (0.08)	6.6 (0.09)	6.77 (0.09)	7.4 (0.10)
The second price category, double day zone tariff, RUB / kWh (EUR/kWh) (with VAT), for the January 2019, non-residential consumers under 670 kW loads				
Day zone	7.73 (0.10)	8.65 (0.12)	8.78 (0.12)	9.43 (0.13)
Night zone	4.48 (0.06)	5.40 (0.07)	5.54 (0.07)	6.18 (0.08)
The second price category, three day-zones tariff, RUB / kWh (EUR/kWh) (with VAT), for January 2019, non-residential consumers under 670 kW loads				
Peak zone	9.72 (0.13)	10.64 (0.14)	10.77 (0.14)	11.42 (0.15)
Semi-peak zone	5.79 (0.08)	6.71 (0.09)	6.85 (0.09)	7.49 (0.10)
Night zone	4.48 (0.06)	5.40 (0.07)	5.54 (0.07)	6.18 (0.08)

Table 8 Tariff for electricity for other consumers in the price zone of the Republic of Altai for October 2018; source: "Altayenergosbyt" JSC, 2018 [95], Time2Save [130]

For consumers in regions with decentralized energy supply the size of payments is determined on the basis of regulated electricity prices, established by the executive authority of the state tariff regulation [96].

Electricity tariffs for companies in the second price zone may differ from tariffs in isolated areas by three to seven times. In an attempt to make the tariff payable and to level the difference in tariffs for the population in different price zones local municipalities get subsidies. In 2017, this subsidy amounted to 7.3 million RUB (95,200 EUR) [97]. In 2018, three unofficially disclosed municipalities received subsidies of 7.6 million RUB (about 102,870 EUR) [98]. Simultaneously, there is a cross-subsidization: costs associated with energy supply of the respective consumer group in the isolated zones are transferred to other consumers of the price zone. In the first half of 2018, the value of cross-subsidization amounted to 109.6 million RUB in total (about 1.4 million EUR), in the second half of 2018 it was 108.1 million RUB (about 1.45 million EUR) [99].

2.3.3 Regional business environment & specific legal and regulatory framework for energy supply

The main off-grid consumers of electricity and heat in the region are enterprises in the housing and utilities sector. The most promising consumers of off-grid and RES-based systems are remote rural settlements and animal husbandry and woodworking enterprises. In all regions of the republic, enterprises process agricultural products and wild plants, but the share of agriculture in total energy consumption is very low at roughly 2%. A motivation for the local administrations to implement RES in off-grid areas is to reduce losses in grids as well as reduce costs needed to stretch new grids to the settlements. Investments and equipment for solar power plants in the Republic of Altay mainly come from Hevel LLC. The company LLC Solar Energy, designs, installs and maintains power plants. A local utility company operates generation facilities.

The Altai Republic is subject to the basic laws focused on the renewable energy sources listed in section 1 of the report. Currently, there are no specific schemes to support the development of renewable energy in the region. However, some schemes may appear in future due to the growing popularity of RE. The “Strategy of Social and Economic Development of the Altai Republic for the Period until 2035” contains recommendations for necessary steps that will ultimately lead to lower prices for energy carriers in the region and make it less energy-dependent by developing domestic power generation that is affordable and reliable. The document provides the following steps aimed at meeting the goal:

- further diversification of the production of RES-based electricity (PV and hydro):
- creation of an economically favourable environment for private investments into RES and supporting energy projects on terms of a public-private partnership
- modernization of existing generating equipment;
- reduction of losses in grids;
- creation of conditions for technological connection of new consumers.
- Meeting the challenges of energy development will allow the Republic of Altai to achieve the following systemic effects by 2035:
- reduction of energy shortage during winter periods
- increase of energy and environmental safety;
- easier consumer access and reliability of power supply
- reduction of power losses and improved grid efficiency

2.3.4 Regional specific business case

In 2013, the first autonomous hybrid PV-diesel system in Russia was constructed in the region – the project "Autonomous hybrid power plant in the village of Yaylu" [87]. It was implemented within the framework of a state contract of the Ministry of Education and Science of the Russian Federation to create PV pilot projects carried out under the "Federal Target Program for Research and Development in Russia for 2007-2013". The objectives of the project were: round-the-clock supply of the 200 inhabitants of the village and R&D of an autonomous hybrid system. Before this project, outages happened daily and could last from several hours to the whole night.

A hybrid installation in Yaylu has a capacity of 100 kW and is located on the territory of the Altai State Biosphere Reserve. The system was amended to compliment an outdated diesel generator and reduce diesel consumption by 50-60%. An engineering design of the system combined modern technologies and allowed to effectively distribute the load between the photovoltaic system, storage devices and diesel generators.

The Ministry of Education and Science of the Russian Federation provided major investments, while Hevel LLC co-financed the project. The project was design and constructed by Hevel, Avelar Solar Technology (part of Renova GC), Solar Energy (Altai Republic local company that installed the system) and "Ioffe Physical-Technical Institute of the Russian Academy of Sciences". Hevel owns the system, while Avelar Solar Technologies is a system operator.

The power plant is controlled automatically but there is a remote backup diesel genset that can be switched on in case of energy shortages. 30 to 40% of energy comes from a PV system, while the rest is supplied by a diesel generator. This system generates up to 1,400 kWh/kWp, which is one of the highest values in Russia. The warranty period of the power plant is 25 years.

Composition of the installation:

- photovoltaic system consists of thin-film solar modules - 60 kW;
- diesel generators with a unit capacity of 40 kW;
- energy storage;
- remote control.

The contractual relationship between key project stakeholders is illustrated by the scheme shown in Figure 38.

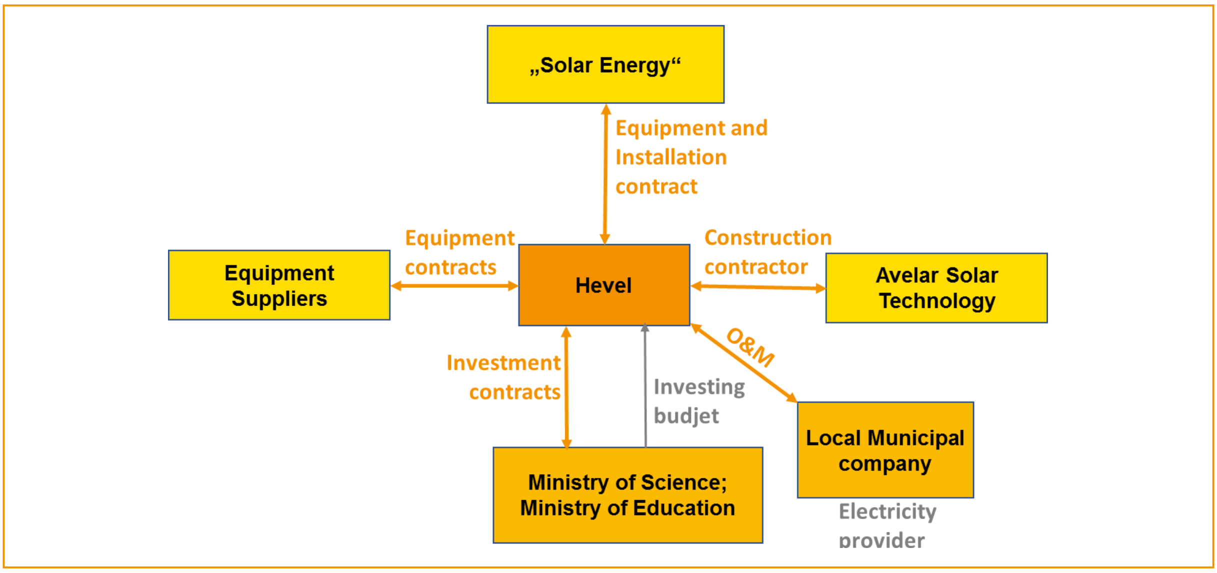

Figure 38 Scheme of relations between different stakeholders while implementing a new project; source: based on the research completed by eclareon and IP Kekelidze

For now, it is the only automated power plant of such a large size in Russia, which is able to cover the energy demand of a whole village 24 hours a day. In the Republic of Altai, a potential market for such plants is estimated to be 1-3 MW.

2.3.5 Business model description

To successfully develop a PV plant specific steps need to be undertaken. These steps are presented in Figure 39 below and include the actors needed to complete each step. The process of cooperation between different stakeholders while RES project development is described in 2.4.4. The overall duration of the project's implementation is usually about 1.5 years for a solar power plant and 2.5 years for a wind farm.

Before starting a project, it is necessary to negotiate with local authorities, the local distribution grid companies and the ministries responsible for various granting permits (e.g. Ministry of Regional Development). These negotiations usually take about two weeks; however, the process may last longer. Delays may happen due to the poor communication between different agencies, ministries and administration departments and because one has to address each unit separately and sometimes several approaches are necessary. Moreover, despite the connection of the power plant to the grid being step 5 the negotiations with the grid company (for most of the territory it is "IDGC of Siberia - Gorno-Altai Power Grids") should be completed before the project starts. This is essential because of the "technical conditions" requested by the grid company: it is important to discuss the connection voltage and specifications of the transformer, agree on the capacity of the RES power unit for its compatibility with an existing DPP and discuss other operational and connection peculiarities prior to launching a project.

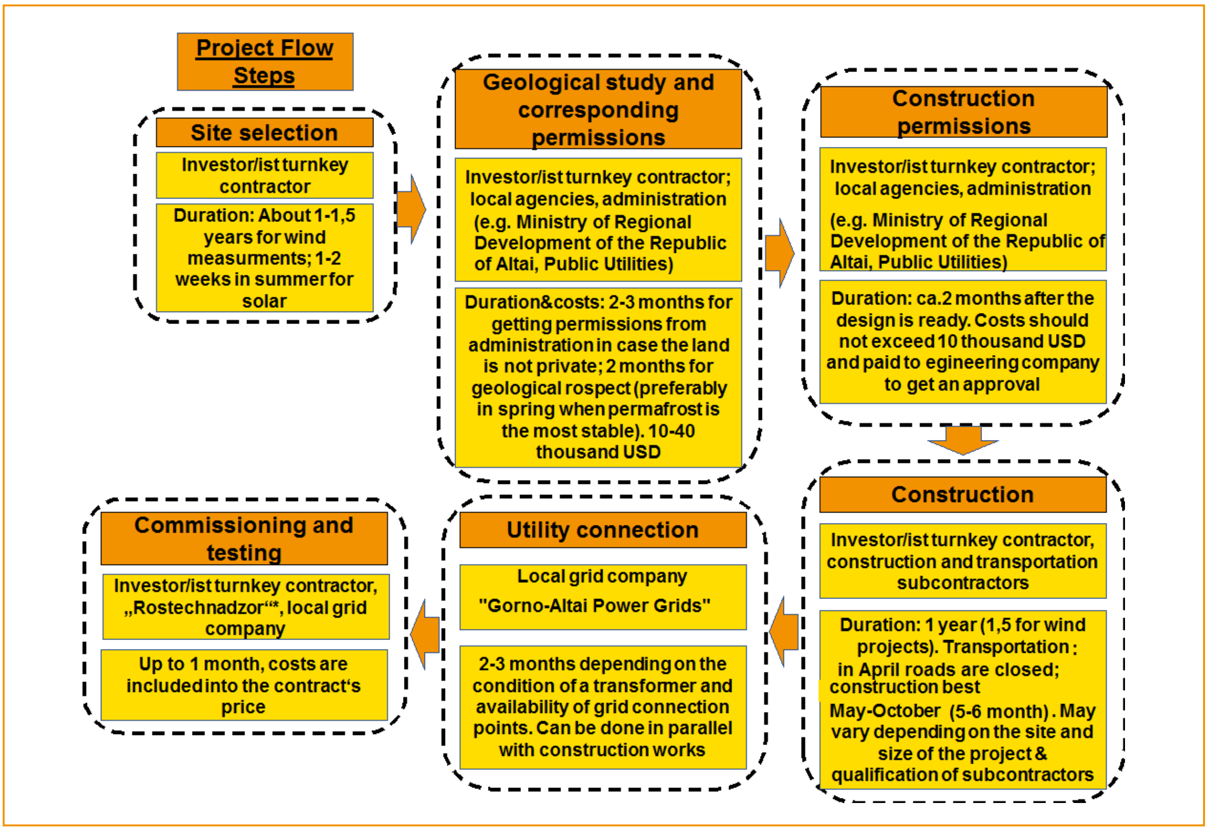

Figure 39 Scheme of the project's flow; source: based on the research completed by eclareon and partners of the project

It is important to take into consideration that due to climatic conditions, there is only a short period between May and October that is suitable for construction activities. Should a project not be completed in this period construction will have resume the following year.

2.3.6 Profitability analysis (inputs, outputs, scenarios, sensitivities)

In the following, an exemplary profitability analysis for the RES share of an autonomous hybrid power plant with battery storage in the village of Yaylu is presented. The input parameters and results of the calculated base case are shown in the following figure:

PV System			
Project Duration		Years	25
PV System Size		kWp	60,00
PV Battery Capacity		kWh	20,00
PV System Costs		RUB/kWp	118.000
Total System Cost		RUB	7.622.800
Performance Factor		%	80%
Degradation		% p.a.	1%
Battery Replacement Interval		Years	8
Total Battery Replacement Costs		RUB	757.497

System Operation		
Applied Yield	kWh/kWp/a	1.200
Average Yearly Generation	kWh/a	65.139
Self-Consumption Rate	%	90%
Genset efficiency	kWh/ltr	3,00
Average Replaced Diesel Consumpt	ltr/year	19.107
Diesel Price (1st Ops Year)	RUB/ltr	43,37
Diesel Price Escalation	% p.a.	6%
Fixed Operation Costs	RUB p.a.	114.342
Longterm Insurance Costs	% p.a.	-

Financing			
Debt (Gearing)	30%	RUB	2.286.840
Loan Tenor		Years	5
Grace period		Years	-
Debt Interest Rate		%	11%
Initial Equity		RUB	5.410.971
Additional Equity		RUB	49.716
Discount Rate		%	10%
Longterm Inflation Rate		%	4%

Results		
Net-Present Value	RUB	3.182.258
Project IRR	%	14,16%
Equity IRR	%	14,19%
Payback Period	Years	14,88
LCOE (no subsidy)	RUB/kWh	15,89
Min DSCR**	x	0,92 x
Min LLCR***	x	1,33 x

* LCOE: Levelized Cost of Electricity

** DSCR: Debt Service Coverage Ratio

*** LLCR: Loan Life Coverage Ratio

Figure 40 Project Overview – Yaylu diesel-PV hybrid with storage; source: eclareon calculations, based on input data researched by EUROSOLAR Russia, 2018

The graph shows that the installation in Yaylu is viable from a financial perspective but the payback period is rather long with less than 15 years. Battery replacement has been assumed to take place in years 9 and 17 and 25 under the assumption of declining battery prices which explains the decrease of cash flow available for equity in those years, see following figure:

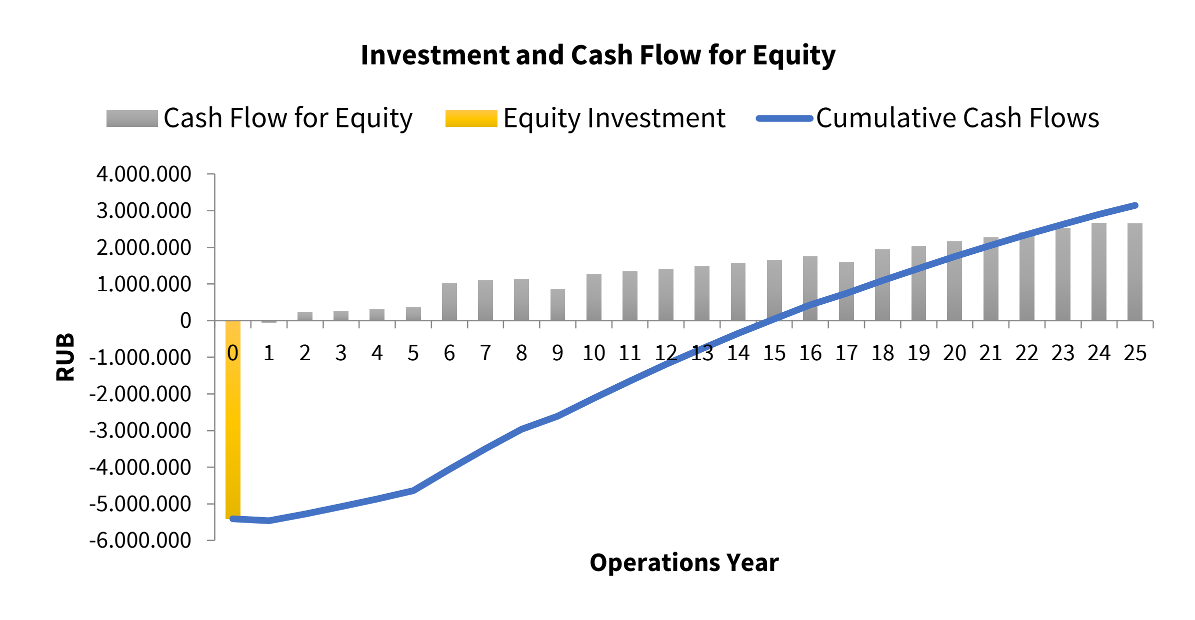

Figure 41 Equity Cash Flow – Project Overview – Yaylu diesel-PV hybrid with storage; source eclareon calculations, based on input data researched by EUROSOLAR Russia, 2018

The cash flow available for equity also increases year by year with the exception of those years when the battery is replaced. This general increase is based on the assumption that the diesel that is replaced by solar power is becoming more expensive every year. Under the chosen financing conditions (loan tenor of 5 years no grace period), the diesel savings are sufficient to repay the loan. Additional equity may however be required after year 1 in order to operate the plant. The equity is paid back after approx. 15 years. In the graph this is illustrated by the blue line crossing the horizontal x-axis.

Changes in the irradiation conditions (specific yield), the system prices as well as the diesel price have an important impact on the business case as shown in the following sensitivity analyses (the base case values are shown in rectangles):

The "Specific Yield" sensitivity shows how the equity payback period and the equity IRR would change if the same installation were installed in an area with different solar irradiation. When the specific yield increases, meaning if there is more irradiation available that can be converted into electricity, the equity IRR increases and the payback period decreases. The respective values can be found when moving from left to right on the X axis. In the base case the global tilted irradiation was at 1.500 kWh/kW/pa. The fact that not all of this irradiation can be converted into electricity is accounted for by the performance factor that is set to 80%. The base case therefore assumes 1.200 kWh/kWp/a that can be converted into electricity. If this value were higher, for instance at 1.400 kWh/kWp/a, equity payback could already be reached after approx. 12 years and the equity IRR would increase to approx. 16%.

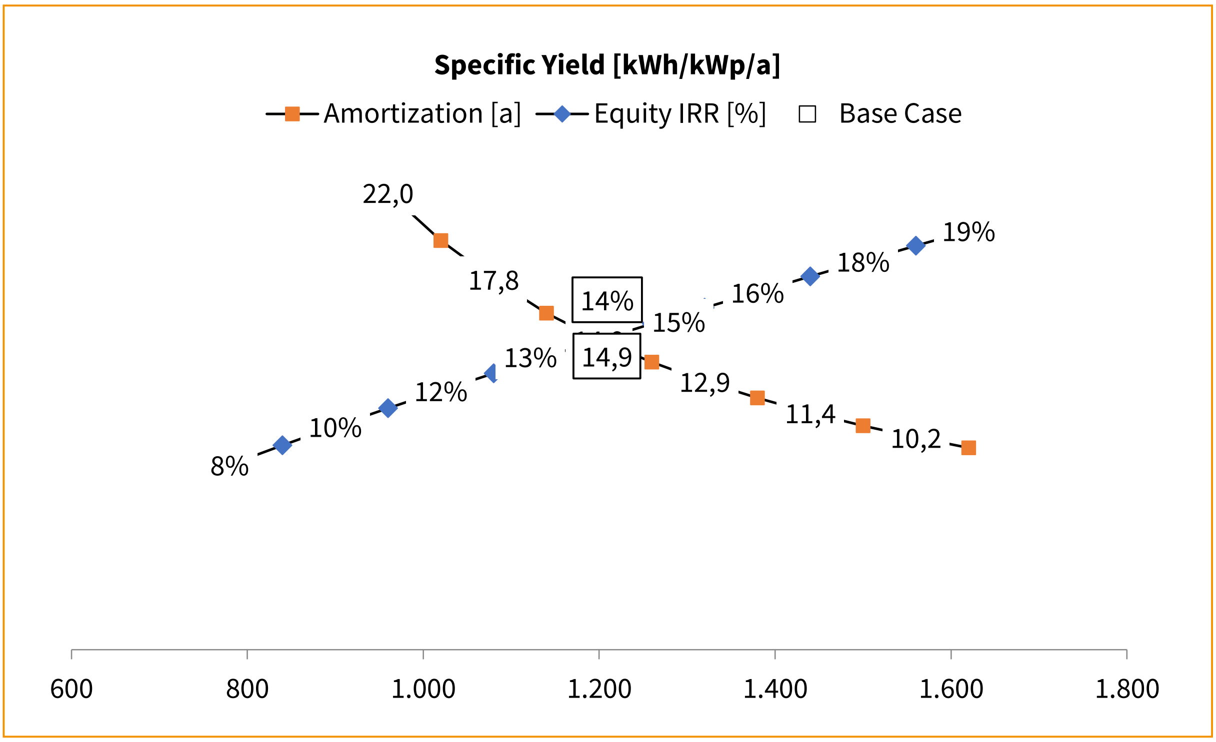

Figure 42 Specific Yield Sensitivity – Project Overview – Yaylu diesel-PV hybrid with storage; source: eclareon calculations, based on input data researched by EUROSOLAR Russia, 2018

Another sensitive factor is of course the system price. This is illustrated in the next graph. In this case, the payback period increases when the costs are higher than in the base case calculation. The researched price per kWp for the PV part of the Yaylu installation was at 118.000 RUB/ kWp (approx. 2.700€ with 2013 conversion rates). To come up with the systems price, the storage costs need to be added which were assumed to be as high as 27.140 RUB/kWh. The resulting systems price including storage is therefore as high as 127.000 RUB/kWp. These prices may seem rather high even for a small 60 kWp PV system with storage. However, it needs to be reminded, that the systems described in this report are no standard solutions but can rather be regarded as pioneering installations. A factor that can explain a rather high price is that the installation of PV and other RES in Russia is a rather recent phenomenon which means that actors did not yet have the chance to accumulate years of experience and that, as a consequence, there is room for improvement along the development of similar projects today. As projects become more standard and more experience is accumulated, costs are likely to go down. What this means for an equity investor can for example be seen when looking at the results for the payback period and the equity IRR if the system price were assumed to be at 100.000 RUB/kWp: in that case, payback would decrease to approx. 11 years and equity IRR would increase to approx. 18%. This can be seen in the following graph when moving to the left on the horizontal axis where system prices are displayed.

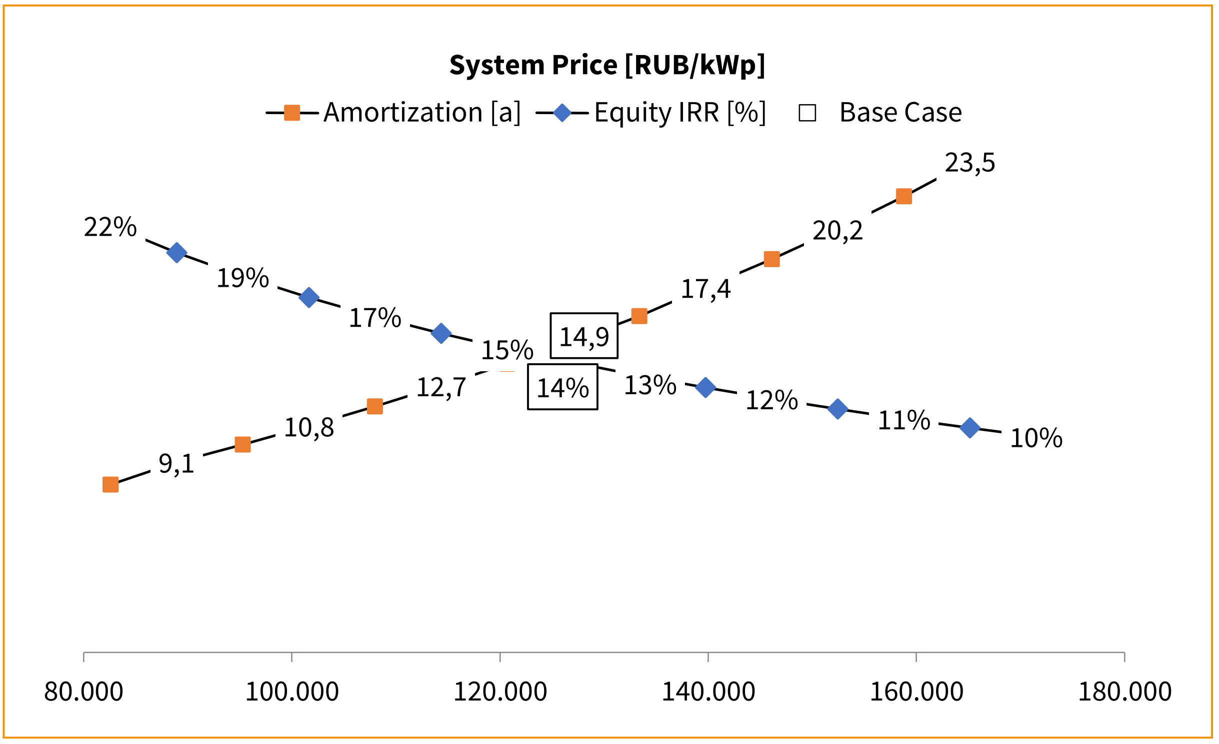

Figure 43 System Price Sensitivity – Project Overview – Yaylu diesel-PV hybrid with storage; source: eclareon calculations, based on input data researched by EUROSOLAR Russia, 2018

Moreover, the diesel price today and its development over time play an important role for the business case. This is shown in the following two graphs.

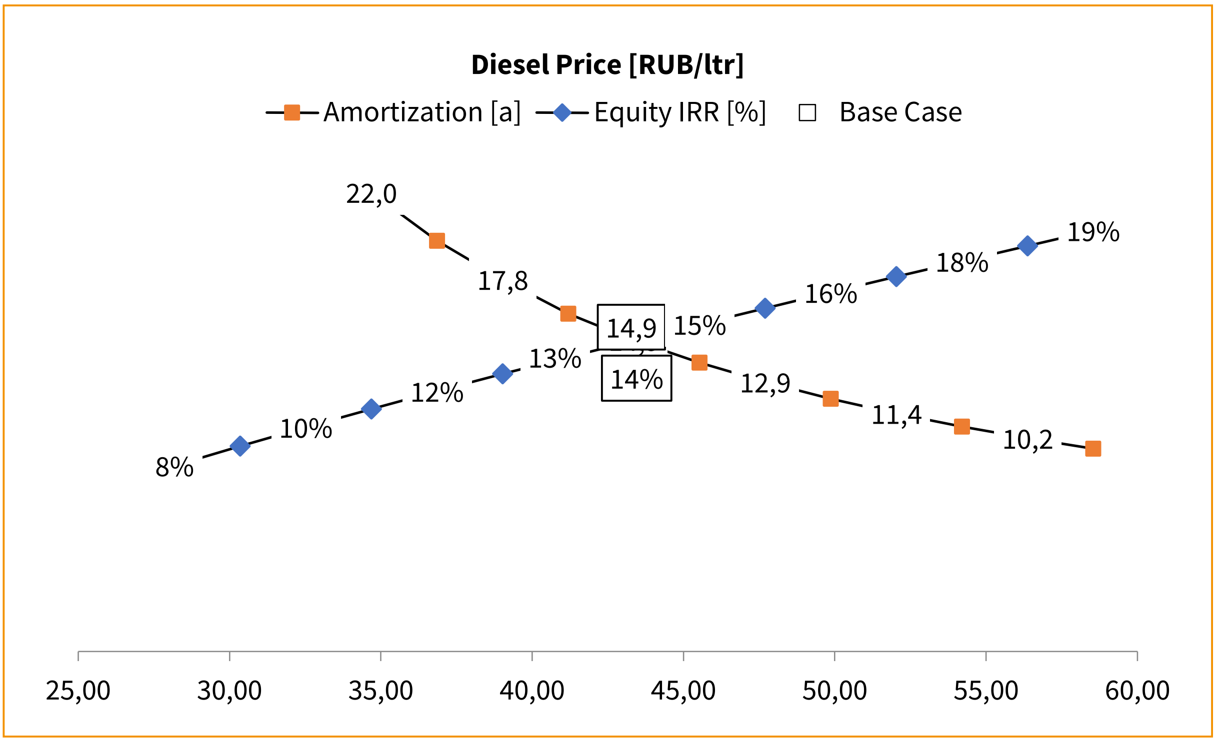

Figure 44 Diesel Price Project Overview – Yaylu diesel-PV hybrid with storage; source: eclareon calculations, based on input data researched by EUROSOLAR Russia, 2018

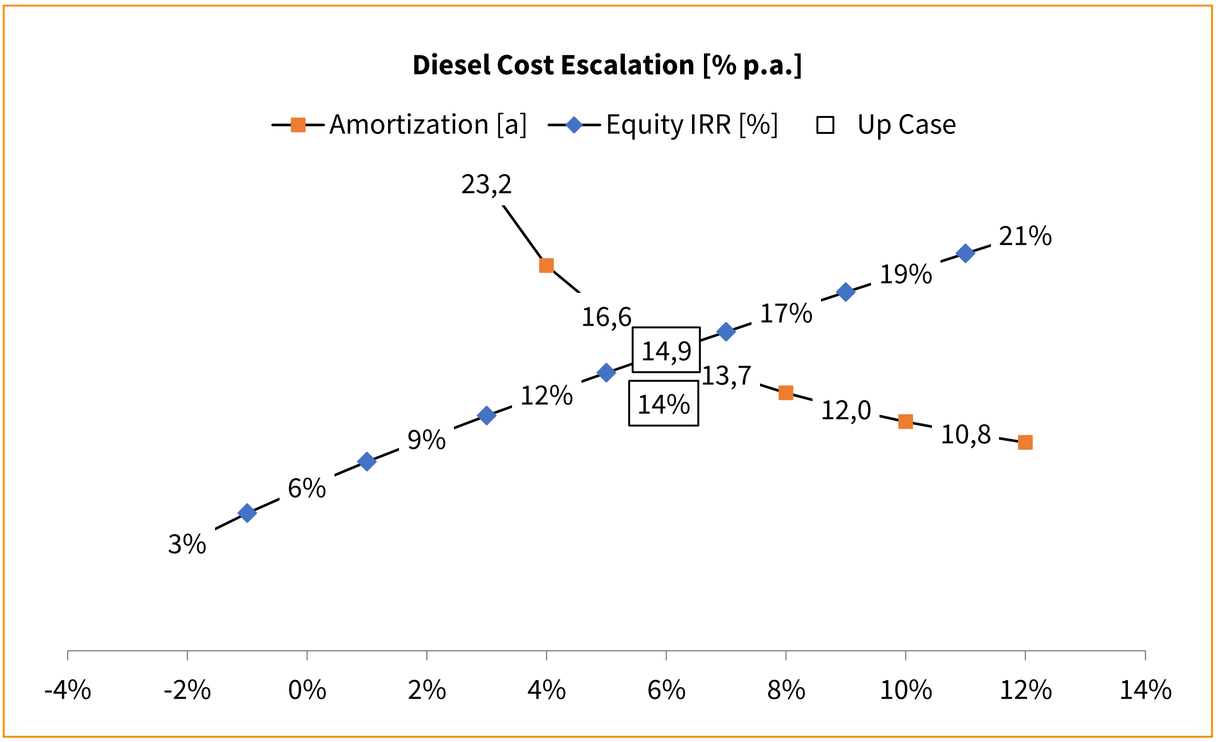

Figure 45 Diesel Cost Escalation Project Overview – Yaylu diesel-PV hybrid with storage; source: eclareon calculations, based on input data researched by EUROSOLAR Russia, 2018

The diesel price in the base case was assumed to be at approx. 43 RUB/ liter. These costs are not high compared to those in isolated territories, e.g. in Batagai. This relatively moderate price does not favor the business case: The higher the diesel costs the better the RES business case would be from the perspective of an investor. If the base case assumption were changed, the diesel price sensitivity (Figure 44) shows that, with a diesel price higher than 43 RUB/ liter, the payback period would go down while the equity IRR would go up.

Another sensitivity that has an impact on the key results of a business case is the future development of diesel prices. An investment is paid back over time which means that it is necessary to estimate how certain critical parameters will change over time. Future diesel prices are not assumed to stay as they are today. The annual diesel price escalation in the model was assumed to be at +6% for Yaylu. This is the lowest value for all business cases presented in this report: for truly isolated areas (business cases in Yakutsk and Kamchatka) increases were at 10%. For non-isolated but installations in remote areas (business cases for Altai, Bashkortostan and Krasnodar) values between 6% and 8% were chosen in order to reflect the difference in logistical challenges between the regions. If diesel costs were escalated with more than 6% p.a. in Yaylu the payback period and the IRR for the equity would change accordingly: an annual diesel costs escalation of 10% would decrease the payback period to approx. 11 years and increase the equity IRR to 19%. However, it can of course also be assumed that the diesel price escalation is lower than in the base case. If that were the case, the payback would increase and the IRR decrease.

2.3.7 Potential for cooperation/business opportunities

The RES market in the region is developing relatively quickly and there are both pros and cons for the perspective of RE deployment in the decentralized energy region of Republic of Altai:

- The Republic Altai has a good relationship with PV and small hydro power, so the overall attitude towards wind, PV and other types of RES is positive, and thus awareness raising and advertising of RES is less required;
- Electricity for mining enterprises, agriculture, tourism, recreation facilities, and social facilities in the southern regions of the country will require the further development of generating complexes based on renewable energy sources;
- The government of the Republic of Altai plans to achieve a total installed capacity of 145 MW of renewable energy by 2022, which should solve the problem of the region's energy shortage.
- There is promising potential for PV in Altai because of modern technology, the vast available land and the 300 sunny days a year the region has. As a result, centralized, decentralized and individual energy supply all have great potential.
- The total technical potential of small hydropower industry of the Altai Republic is 5.20-6 billion kWh / year. The construction of a cascade of small hydropower stations on Chuya may initiate interest in building a wind farm in this valley, to compensate for the reduction in hydropower capacity in the low-water winter season. Twelve remote settlements that are off-grid, will be isolated for years and need alternative energy sources. These settlements have high diesel costs due to transportation and the risk of blackouts is high if the diesel cannot be delivered on time - RES would partially decrease this risk. Economically, the high diesel costs make the payback of PV investments possible because there is a positive IRR and NPV;

- Existing DPPs are outdated and most of them will need to be replaced or enhanced in the next 10 years - a viable alternative could be RES. The older the diesel generators are, the smaller the installable PV capacity is, assuming that no further technical upgrades are done (fuel save controllers etc.);
- Diesel costs have been rising, driving diesel-based electricity prices up further and thereby leading to further growth of subsidization and cross-subsidization to keep the prices low for end-consumers;
- Hevel is well represented in Altai and has ambitious plans to construct 145 MW of solar based power. This will attract more investments into the region and will likely push local policy-makers towards creating legislative framework to make PV and wind in Altai more feasible;
- Both existing mining sites and planned ones need a stable electricity supply, RES could provide this stable supply for mining companies that usually operate in remote areas. Such solutions could decrease operational costs of extraction, leading to lower costs for the final goods and an increase in the net profit.

2.3.8 Risks and barriers

Despite the positive factors, there remain a number of challenges impeding the development of RES projects:

- Logistics is a challenge: access to the region is difficult and the region is located far from European borders.
- Harsh climate conditions mean that neither PV, nor wind is considered standard. A new supplier who has no prior experience in severe climate conditions (similar to Canada, Alaska etc.) needs to take this into consideration;
- There is no mature RES market in the region and foreign entities need to cooperate with Russian partners for marketing and logistics operations;
- The market size for the next 5-10 years is 1-3 MW - the larger the share of renewables in a hybrid solution, the larger upfront CAPEX is needed to upgrade existing diesel power plants and import modern control technologies;
- The current Russian subsidy system (cross-subsidies and direct subsidies) targets the reduction of operating costs, such as expensive diesel fuel, however, there are no direct investment subsidies that would reduce the high initial CAPEX needs;
- The current absence of long-term tariffs creates additional risks for investors;
- Due to geographical location of the region, transportation of equipment from Europe becomes rather expensive. At the same time, China is much closer to the borders and is interested in the regional market. European companies may however get a niche of know-how and qualified O&M providers.
- To get partnerships and support from local PV and energy companies, it is essential to develop relationships with these organizations. Using common contact information published on official company websites is often not enough to develop successful cooperation and partnerships.

2.4 Bashkortostan

The Republic of Bashkortostan (or Bashkortostan) is located in the southern part of the Ural Mountains on the border to Europe and Asia. Bashkortostan covers 142,900 km^2. With more than 4 million people living in Bashkortostan the region is the seventh largest by population density in Russia, with 28.5 people/km^2[63], and overall population. There are 21 cities and 4,532 villages in the region, however more than 60% of the population lives in cities. The continental climate of Bashkortostan gives the region a warm summer with an average July temperature of+20 C^0 and a long and cool winter with -15 C^0 in January [64]. More than 1 million people which is 27.5% of the overall population live in Ufa, the region's capital city.

Figure 46 Map of Russia, Bashkortostan highlighted; source: generated with amCharts Pixel Map

Bashkortostan is one of the leading industrial and agricultural regions of Russia; oil and gas extraction regions and also a center for chemical industry and machinery. The fuel and energy industries play a key role in the economy: they generate 70% of the region's total profit and represent 85% of its export to other regions [65].

2.4.1 Current energy supply situation and renewable energy potential

Bashkortostan is part of the UPG of Ural which again is a part of the UPS of Russia. In Bashkortostan, there are 10 power grid systems (energy systems), that are connected with the UPS and with each other. Energy consumption is highest in the central power grid. The region consumes slightly more energy than it produces: a bit more than 85% of electricity demand is supplied by the region's own energy generation capacities. Some energy is imported from the neighbouring regions: Chelyabinsk and Orenburg.

The main players of the regional energy market are the following [66]:

- One energy supplier or the “guaranteeing supplier” (default provider of electricity) – “Bashelectrosbyt” Ltd. (Electricity Supplier of Bashkortostan), subsidiary of “INTERRAO EES” (in other words, State-owned company).
- 21 energy supply companies having contracts with “Bashelectrosbyt”; among them are “MagnitEnergo”, “Energy Supply Company of RusHydro”, “Mosenergosbyt” (Moscow energy company)
- JSC “BESK” – Bashkortostan’s electricity grid company, a private corporation, managing power grids in the region and owning three further companies (see Figure 47). Currently, there are negotiations between the owners and “FSK EES” (ROSSETI group) about purchasing of “BESK” by “FSK EES”
- Several energy generating companies, the largest being “BGC” Ltd. (Bashkortostan generating company) a subsidiary of “INTERRAO EES”. The company owns 4,423.2 MW (1 Condensing power plant (working on gas), 10 CHPPs, 7 Hydropower plants and 1 wind park) of generating capacity in the region, which is 86% of overall regional installed electrical capacity; smaller companies own and manage other power plants.

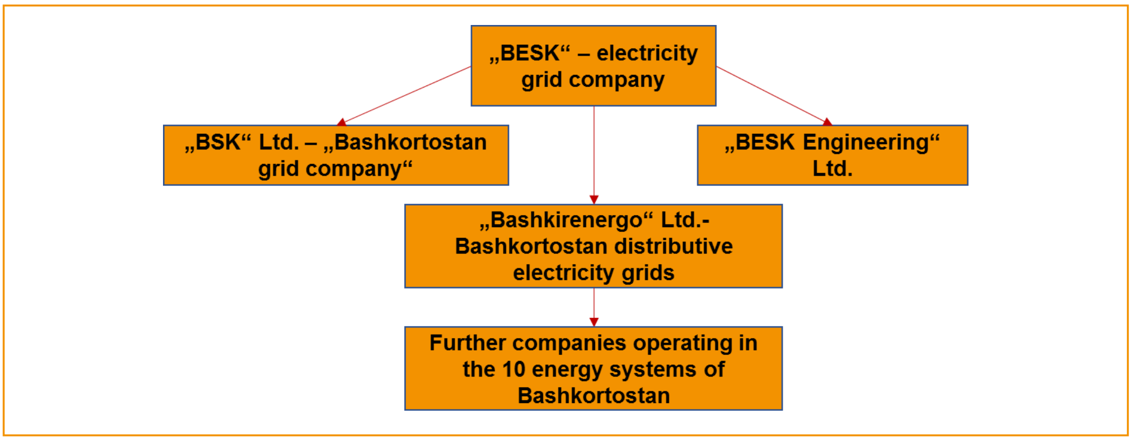

Figure 47 Organization chart of “BESK”; source: official web site of “BESK” [69]

In 2017, the overall installed electrical capacity in Bashkortostan reached 5,140.33 MW, slightly more than in 2016. The largest power plants in the region are [66]:

- Condensation Electric Power Plant Karmanovskayja (electrical installed capacity 1,821.1 MW, generates electricity only)
- Ufa’s CHPP-2 (519 MW)
- Sterlitamakskayja CHPP (320 MW)
- Ufa’s CHPP-4 (270 MW)
- Novo- Sterlitamakskayja CHPP (255 MW)
- Priufimskayja (near Ufa) CHPP (210 MW)

Figure 48 shows information about the types of power plants in 2016.More than 94% of the overall installed power capacity in the region refers to combined heat and power plants (CHPP), which are mainly powered by gas and represent more than 95% of total fuel types used at CHPPs. The share of mazut in energy generation is around 3.5% and the share of coal is less than 0.5% [67]. Hydropower plants account for 4% of the total installed capacity of the region.

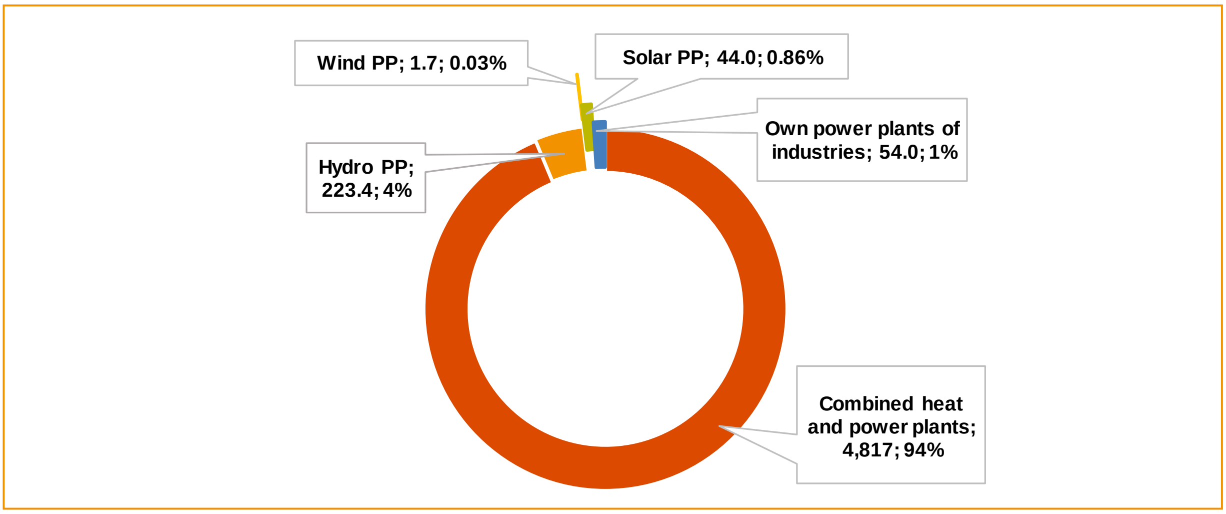

Figure 48 Structure of the installed capacity by type of power plant in Bashkortostan in 2017, in MW and %; source: Ministry of Industry and Innovation Politics of the Republic of Bashkortostan, 2019 [66]

RES (wind and PV) only have a share of less than 1% of installed capacity. Some large industrial companies, specifically the chemical industry, oil refinery and oil and gas extraction, use their own, decentralized energy generating facilities which are sometimes fueled by diesel. The installed PV capacity is mainly split between the following solar power plants: Buribajevskayja (20 MW); Isyangulovskaya (9MW); Buchul'chanskayja (partially under construction, 3 arrays of 5 MW each, one of them is located in another place than the two and is called Buchul'chanskayja-1).

All of them belong to "Avelar Solar Technology" (a subsidiary of "Hevel"). The only wind power plant "Tyupkildyi" was launched in 2002 and built by "Bashkirenergo".

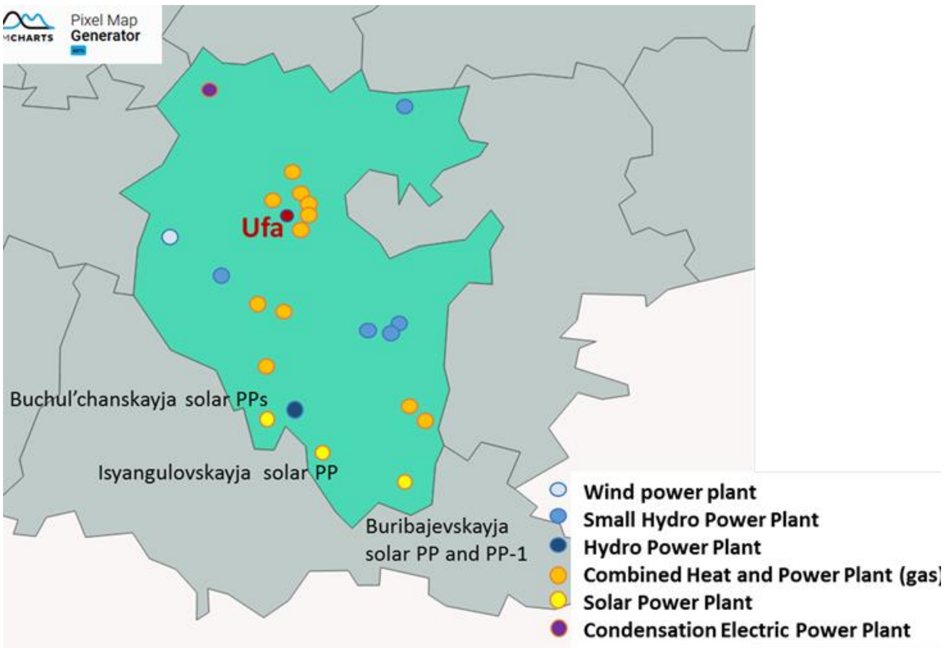

Figure 49 Largest power plants of Bashkortostan; source: eclareon 2019, generated with amCharts Pixel Map, "BGC" Ltd. [70], "Hevel"

23,799 million kWh of electricity was generated in 2017. 95.4 % of energy was generated by combined heat and power plants; RES, including hydro, generated 4.63 % of energy; the remainder was generated by industrial companies' own generation facilities. The overall per capita electricity consumption in Bashkortostan in 2017 was 6,668.7 kWh/capita [66]. The electricity consumption in 2017 was 27,234 million kWh, with the largest consumer in the region being the mining and refinery industry, which accounted for more than 60 % of the total consumption (see Figure 50). Slightly more than 6% of overall consumption refers to other industries and a similar share of energy is consumed by the transport sector and used for communication needs. 11% of the total energy consumption is attributable to private households.

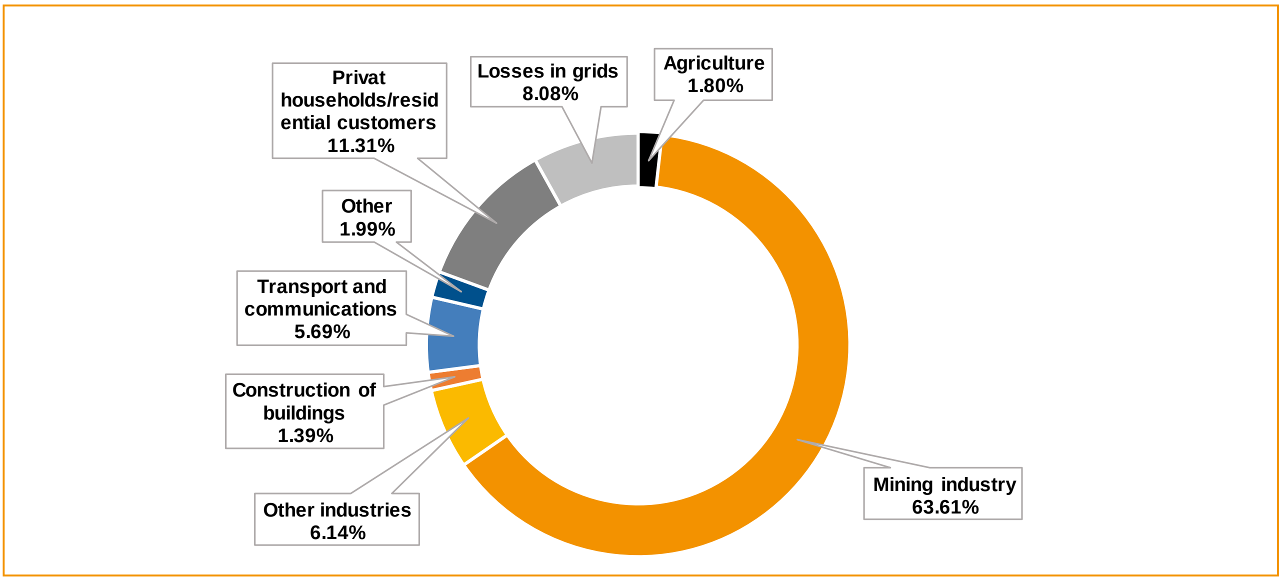

Figure 50 Electricity consumption in Bashkortostan by type of consumer, %, 2017; source: Federal State Statistics Service of Russia, 2018 [54]

The off-grid generation in the region is of little importance: the estimated off-grid RES installed capacity in Bashkortostan is around 300 kW. This capacity is formed by small private generation. Other off-grid power generators mostly work on diesel and gasoline, rarely on liquified gas. According to our research, there are about 1,400 petrol and diesel based gensets of different installed capacity (between 3 and 500 kW) owned by various regional municipalities, state organizations, energy companies and local branches of the Ministry of the Russian Federation for Civil Defence, Emergencies and Elimination of Consequences of Natural Disasters. Their total cumulative installed capacity reaches 60.7 MW. This capacity is, however, not included in the regional energy generation figures since these gensets are only used in case of emergencies.

The territory of Bashkortostan gets 1,700-2,000 hours of sunshine annually, which corresponds to 1,150 kWh/m^2/year [164]. The majority of PV projects in the region were built and operated by "Hevel". In 2018, the total cumulated installed PV capacity in the region reached 44 MW [73] and all solar power plants are integrated in the wholesale electricity market. In addition, there are 2 small hybrid projects: a hybrid power generating facility consisting of a wind turbine, PV panels, energy storage and a petrol genset with an overall capacity of 21.5 kW in the village of Severny and a 600 kW installation consisting of PV panels, a wind turbine, a petrol generator and energy storage capacity. However, both of these facilities are not functioning properly due to the failure of inverters. Moreover, in 2014, "Hevel" installed 3 kW rooftop PV panels in a child sanatorium, generating up to 3,500 kWh annually and partly covering the sanatorium's energy needs.

The market size for off-grid RES in Bashkortostan can be divided into four parts: small settlements, commercial consumers, tourism, methodological equipment. The total potential capacity needed to serve the four groups is estimated to be around 300 kW:

1. Residential sector: around 15 settlements with 3-7 households each where grids are very old and of bad quality. Energy companies do not have the right to disconnect these settlements from the grid as they are legally obliged to supply all households with electricity. At the same time, renovating and repairing existing grids is very costly, requiring investments of up to several millions RUB. Therefore, it is often more economically efficient to provide these settlements with autonomous hybrid power plants between 5- and 15-kW capacity depending on the size of the village. Currently, "Hevel" is developing a solution for the village of Starosubkhangulovo which frequently suffers from power outages (in total, about 10 days without energy annually).
2. Commercial consumers: An estimated number of 3 to 5 telecommunication equipment spots (transmission towers) need a more stable energy supply between 3 and 10 kW each.
3. Tourism: There are three large national parks and protected areas in Bashkortostan: South-Ural, Sulgan-Tash and Altyn-Solok (a center of honeybee keeping). It is forbidden to build a grid through their territories, however energy is still needed there, for instance, for mobile phones charging, lighting, payment terminals and other applications. Each of these application sites needs on average 10 kW of installed capacity.
4. Weather equipment and traffic control systems: around 7 sites in the north-east of the region and Trans-Ural region that need on average installed capacity of approx. 1 kW per site.

2.4.2 Electricity tariffs and costs

Bashkortostan is in the first price zone and is among Russian regions with relatively low electricity tariffs. In 2019, some tariffs for private customers for the main tariff groups were [158]:

- rural population, night tariff 1.71 RUB/kWh (0.02 EUR/kWh)– day tariff 2.47 RUB/kWh (0.03 EUR/kWh)
- urban population (households with gas stoves), night tariff 2.45 RUB/kWh (0.03 EUR/kWh) – day tariff 3.52 RUB/kWh (0.05 EUR/kWh)
- single rate tariff (no differentiation by daytime or voltage) rural population 2.14 RUB/kWh (0.03 EUR/kWh) – urban population 3.06 RUB/kWh (0.04 EUR/kWh)

Prices for non-residential consumers, again, differ. Due to the fact, that Bashkortostan is located in the first prize zone of the electricity market of Russia, the electricity price changes each month depending on many factors including wholesale energy and capacity price. However, there are ceiling prices, which are established by the Federal Antimonopoly Service of Russia and some of them are presented in Table 9 below.

Type of voltage / type of tariff	High voltage (110 kV and higher)	Middle first voltage (35 kV)	Middle second voltage (20-1 kV)	Low voltage (0,4 kV and less)
Ceiling electricity prices for February 2019, RUB/kWh (EUR/kWh) with VAT[15], electricity for non-residential consumers with loads under 670 kW, first price category				
Single rate tariff	4.49 (0.06)	5.34 (0.07)	5.30 (0.07)	5.86 (0.08)
Ceiling electricity prices for February 2019, RUB/kWh (EUR/kWh) with VAT, electricity for non-residential consumers with loads under 670 kW, second price category				
Double day time tariffs				
Night tariff	2.90 (0.04)	3.75 (0.05)	3.71 (0.05)	4.27 (0.06)
Day tariff	6.88 (0.09)	7.77 (0.10)	7.69 (0.10)	8.25 (0.11)
Tree day-time tariff				
Night tariff	2.90 (0.04)	3.75 (0.05)	3.71 (0.05)	4.27 (0.06)
Semi-peak zone	4.68 (0.06)	5.54 (0.07)	5.49 (0.07)	6.05 (0.08)
Peak zone	11.10 (0.15)	11.96 (0.16)	11.91 (0.16)	12.47 (0.17)

Table 9 Some ceiling prices for the retail market's consumers (non-residential consumers) of the electricity provided by "Bashelektrosbyt" in 2019; source: "Bashelektrosbyt", 2019 [159]

Other non-residential consumers which have energy receivers with the maximum capacity over 670 kW, have different energy prices which are changing every hour and in accordance to the rules of the 3rd-6th price categories (see section 1.3).

Costs of RES-based electricity in the region are higher than costs of an energy produced by large power plants fueled by gas: existing solar power plants feed electricity into the regional grid, and, according to an ex-vice Minister of the Government of Bashkortostan, Dmitry Sharonov, in 2016, 1 kWh of energy produced by "Hevel's" solar plants costed around 8 RUB [75] (approx. 0.1 EUR) which was 4 times higher than the average market price [73]. At the same time, there are opinions that the price for solar energy was even as high as 25 RUB/kWh (0.33 EUR/kWh) [75]. The dominant solar company in the region "Hevel" does not officially publish such information, so the real numbers are unknown. For various HPPs owned by "BGC" Ltd., electricity costs in 2017 varied between 2.46 and 5.86 RUB/kWh (0.03 – 0.08 EUR/kWh) which is higher than the average electricity tariff in the region. The generation company "BGC" is planning to stop the exploitation of all their small HPPs due to low economic effectiveness. The only regional wind park, also belonging to "BGC", generates electricity for an estimated cost of around 11 RUB/kWh (0.15 EUR/kWh). At the same time, the cost of energy generation by traditional CHPPs is on average 1.49 RUB/kWh (0.02 EUR/kWh) [75]. Due to the fact that the volume of electricity generated by renewable energy sources is very small and its share in the overall energy mix of the region is tiny, such high costs of energy generation do not affect the end customer price for electricity. There are no subsidies, which aim to drive the energy price down, allocated to these power plants. Based on decree 47, the local grid company BESK is legally obliged to cover up to 5% of their grid losses with RE-based electricity. Hence, the grid provider is the one who has to pay RE companies such as "Hevel".

[15] VAT in 2018 = 18%; VAT since 2019 = 20%

According to some estimations, were all electricity in the region to be produced by RES, citizens of Bashkortostan would have to pay up to 4-5 times more for their energy bills monthly. Meanwhile, were heat to be produced by RES, the bills would become 7 times more expensive than they are now, which is, at current conditions, unacceptable for the majority of the population [73].

2.4.3 Regional business environment & specific legal and regulatory framework for energy supply

With regards to solar PV there are currently no companies other than “Hevel” in the region. “Hevel” built all their PV installations using Decree 449, and signed a contract with the regional government for the construction of 44 MW of solar capacity for the wholesale electricity market [66]. Apart from “Hevel’s” projects, no other RE projects are planned in the region for the upcoming years.

In Bashkortostan, efforts were made to implement Decree 47 at the regional level: In 2017, the Government of Bashkortostan published a Decree № 124 of March 29th about the terms and conditions of the competitive processes aimed to include the RES based power generation in the retail market of Bashkortostan’s power sector. This decree created the framework for companies to develop RES power plants in the region and it provided guidance to local authorities and decision-makers. In Bashkortostan, a roadmap targeting the improvement of energy and gas infrastructure was implemented: this roadmap deals with the development of the existing electric power facilities, the construction of new generation capacities and grid related questions.

In the region, ideas to modernize existing technologies and traditional energy sources have become popular with time. For example, “BGC” Ltd. created an energy savings and energy efficiency program at its power plants for the period 2018-2022- The goal is to replace and/or renovate equipment at existing CHPPs to decrease gas consumption. As a result of this program, fuel consumption decreased by 4.91 g/kWh to 313.95 g/kWh from 2016 to 2017. The target is to reach 301.26 g/kWh of fuel consumption by the end of 2022 [73].

Some new medical assistant stations are also being planned in villages and small settlements in Bashkortostan in the next few years. These require energy and the best solution is seen to be diesel gensets due to their low CAPEX. For this aim, modern efficient diesel and petrol gensets are planned to be purchased by the local Government.

2.4.4 Regional specific business case

In 2015, a very first hybrid power plant was built in the Bashkortostan settlement Severny. This power station uses various technologies:

- grid connection
- wind turbine – 3 kW installed capacity
- PV panels – 12 kW
- petrol genset – 6.5 kW
- energy storage – 50 kWh

The overall installed capacity reached 21.5 kW. The power plant generated up to 15,000 kWh annually and was aimed to supply the settlement with energy. For this project, the local grid operator “GIP-Energo” Ltd.

was a customer and an investor. The existing grid in the area was outdated and the settlement frequently suffered from power outages. Upgrading the grid with new technology was estimated to cost about 20 million RUB (266,745 EUR), while a hybrid RES facility costed 10 times cheaper. The company tendered the project, which was finally awarded to the local RES installer "Energoengineering" Ltd. From Ufa. This company already has experience in constructing similar hybrid power stations in Bashkortostan: they have completed several residential hybrid projects for private customers with an overall capacity of 300 kW since 2015. Other project participants were the grid operator "GIP-Energo" as an initiator, the Ministry of Industry and Innovative Policy of the Republic of Bashkortostan (local executive authority office agreed to a technical solution) and "STR Alpha" Ltd. As a subcontractor.

During exploitation of the system, it occurred, that the location of PV modules was not optimal, as well as the location of a wind turbine. In case they have been located with another inclines or direction of solar panels' surface, they could have been working more effective. The village is tiny and has no own financial resources, while investments from "GIP-Energo" covered only CAPEX and did not consider maintenance of the system. Thus, sometime after the system had been launched, PV inverters broke, and as nobody could repair or exchange them, the system stopped supplying the village with electricity.

2.4.5 Business model description

For a typical hybrid project similar to the one in the Severny settlement, the following stakeholders should be involved:

- investors: local administration/municipalities; local grid operators; private investors
- owners: territorial grid operator; local administration
- engineering and distribution company/main contractor: "STR Alpha" Ltd.
- equipment delivery by: Russian/German/Korean companies
- O&M services: local grid operator/engineering company
- consumers: households, telecommunication companies, municipalities
- financial sources: local grid operator

There could be two different variants of contractual relationship between key stakeholders. The first is in case financial sources come the regional budget in accordance to the current investment program in the region. The scheme is presented below.

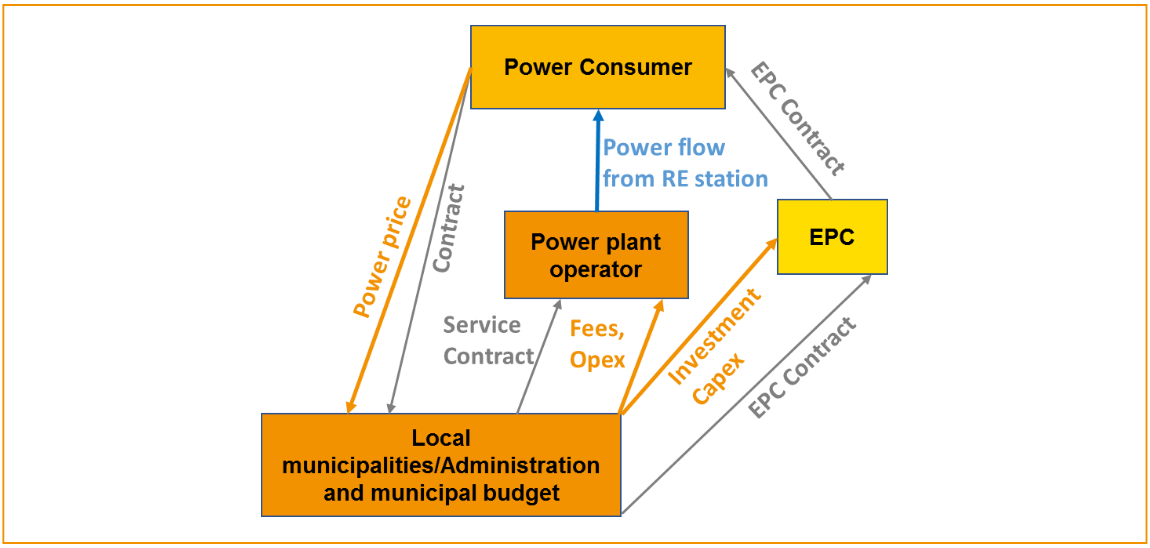

Figure 51 Hybrid power plant business model with government support; source: own research [54]

For Severny there was no additional financial support. All investments were made by the grid operator.

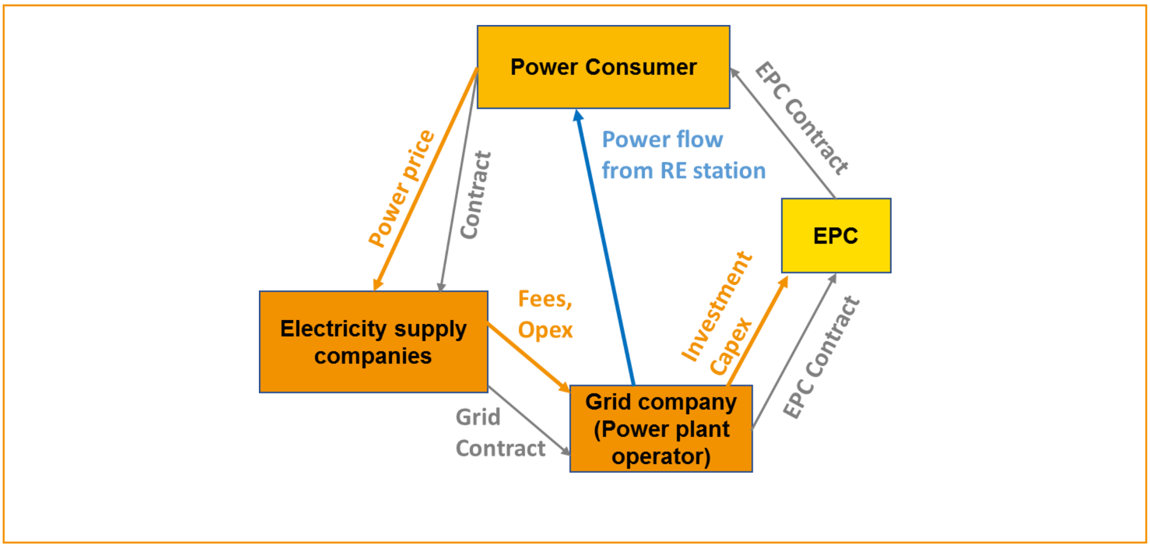

Figure 52 Severny: Hybrid power plant business model without government support; source: own research [54]

For projects similar to Severny, a scheme presented in Figure 53 below is common: The average project's duration from the first official step to the launch of the system is 3 to 12 months. In the case of Severny, this was 12 months. All processes between the start of construction and sending the station to the operation takes between 1 and 2 months.

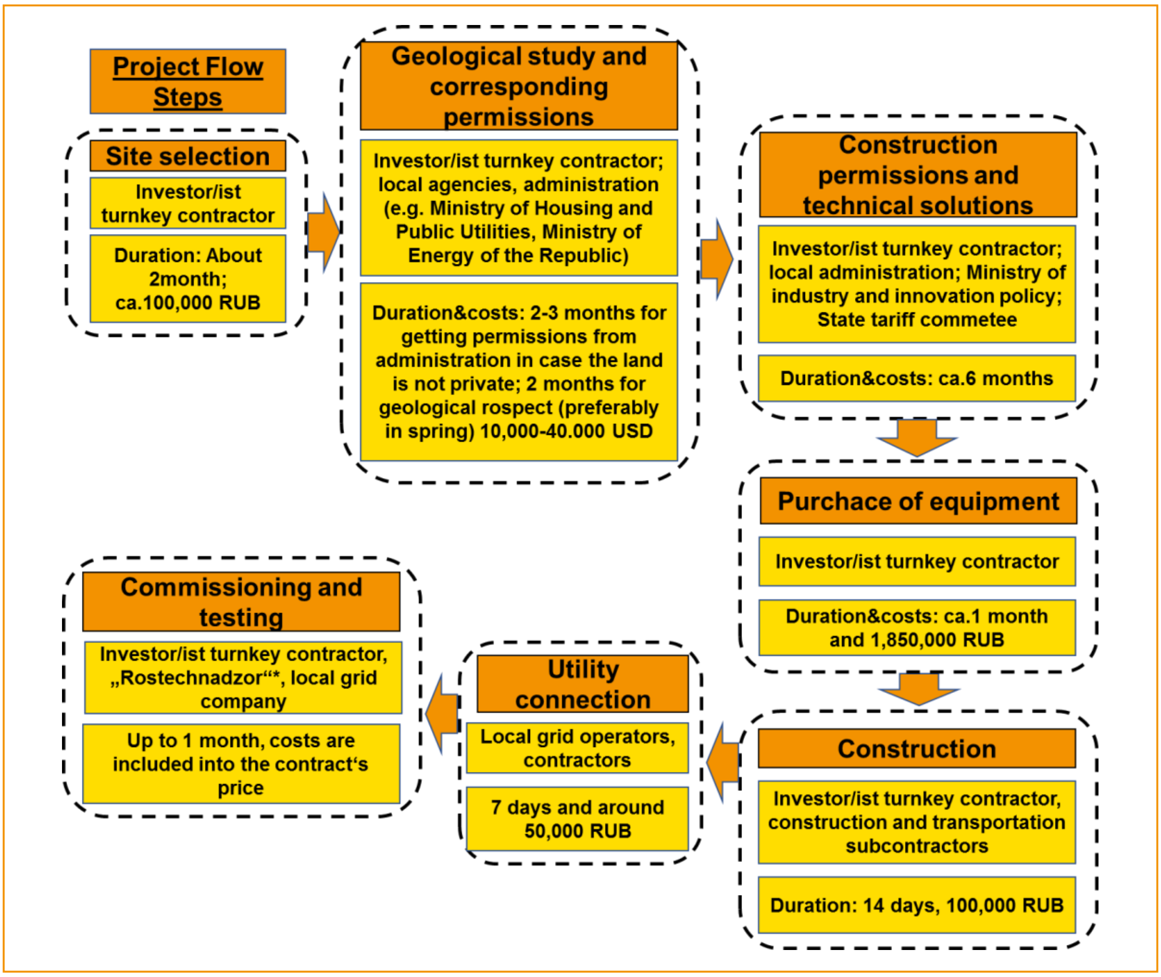

Figure 53 Project development steps; source: own research

For such projects, it is important to negotiate with the local administration and ministries in order to get all licenses and permits required, specifically a license for energy generation and ecological permissions, and an allowance to connect the power plant to the grid (in case of necessity). Before designing a project, research regarding the effect on the environment is also to be submitted.

2.4.6 Profitability analysis (inputs, outputs, scenarios, sensitivities)

In the following, an exemplary profitability analysis for the RES share of the 15 kW wind /PV/ diesel project with battery storage based is presented. The calculations refer to the RE parts of the installation only. The reference model for this business case is the installation in Severny. It needs to be noted that this case is one of the few installations in the regions for which data could be obtained. However, as described above, the real installation is not functional at the moment and could rather be seen as an installation with a lot of improvement potential for future off-grid installations in the region. The base case parameters and calculation results are shown in the following figure.

RE System: PV & Wind			
Project Duration		Years	25
Wind Generator Size		kWp	3
Wind Capacity Utilization Factor		%	10%
Wind Specific System Costs		RUB/kWp	120.000
PV Generator Size		kWp	12
PV Specific System Costs		RUB/kWp	100.000
Specific PV Generation		KWh/kWp	960
Battery Capacity		kWh	50,00
Total System Cost		RUB	2.560.000
Battery Replacement Interval		Years	-
Total Battery Replacement Costs		RUB	-

Financing			
Debt (Gearing)	30%	RUB	768.000
Loan Tenor		Years	10
Grace period		Years	-
Debt Interest Rate		%	14%
Initial Equity		RUB	1.821.405
Additional Equity		RUB	50.671
Discount Rate		%	8%
Longterm Inflation Rate		%	4%

System Operation		
Average Yearly Generation	kWh/a	13.008
Direct-Consumption Rate	%	80%
Genset efficiency	kWh/ltr	2,50
Average Replaced Diesel Consumpt	ltr/year	4.163
Diesel Price (1st Ops Year)	RUB/ltr	46
Diesel Price Escalation	% p.a.	8%
Fixed Operation Costs	RUB p.a.	51.200
Longterm Insurance Costs	% p.a.	-

Results		
Net-Present Value	RUB	823.645
Project IRR	%	11%
Equity IRR	%	11%
Payback Period	Years	19,50
LCOE (no subsidy)	RUB/kWh	26,97
Min DSCR**	x	0,65 x
Min LLCR***	x	1,37 x

* LCOE: Levelized Cost of Electricity
** DSCR: Debt Service Coverage Ratio
*** LLCR: Loan Life Coverage Ratio

Figure 54 Project Overview – Severny Diesel-PV-Wind hybrid; source: eclareon calculations, based on input data researched by EUROSOLAR Russia, 2018

Given that the installation in Severny is not located in an isolated territory system costs for both wind and solar, without the storage, are lower than the costs of the business cases in Sakha and Kamchatka. Diesel costs are also lower than in Batagai. The installation is also equipped with battery storage which increases the initial investment requirements. Debt leverage is lower (30%) and interest rates are higher based on higher perceived risk.

The graph shows that the installation in Severny could be, leaving aside the technical problems that ceased operations of the “real” project, viable from a financial perspective but only just: even assuming that the discount rate is only at 8%, equity payback takes as long as 19,5 years and this also only based on the assumption that Diesel will increase by 8% every year.

As can be seen, the cash flow available to pay back the equity investment is low in years 1-10 when cash flows are primarily used to pay back debt which accounts for 30% of the overall investment. After all debt has been paid back after year 10 the cash-flow available for the equity investor increases. The cash flow available for equity also increases year by year based on the assumption that the diesel that is replaced by solar and wind power is becoming more expensive every year. Under the chosen financing conditions (loan tenor of 10 years no grace period), the diesel savings are sufficient to repay the loan. Additional equity may however be required after year 1 in order to operate the plant. The equity is paid back after approx. 20 years. In the graph this is illustrated by the blue line crossing the horizontal x-axis.

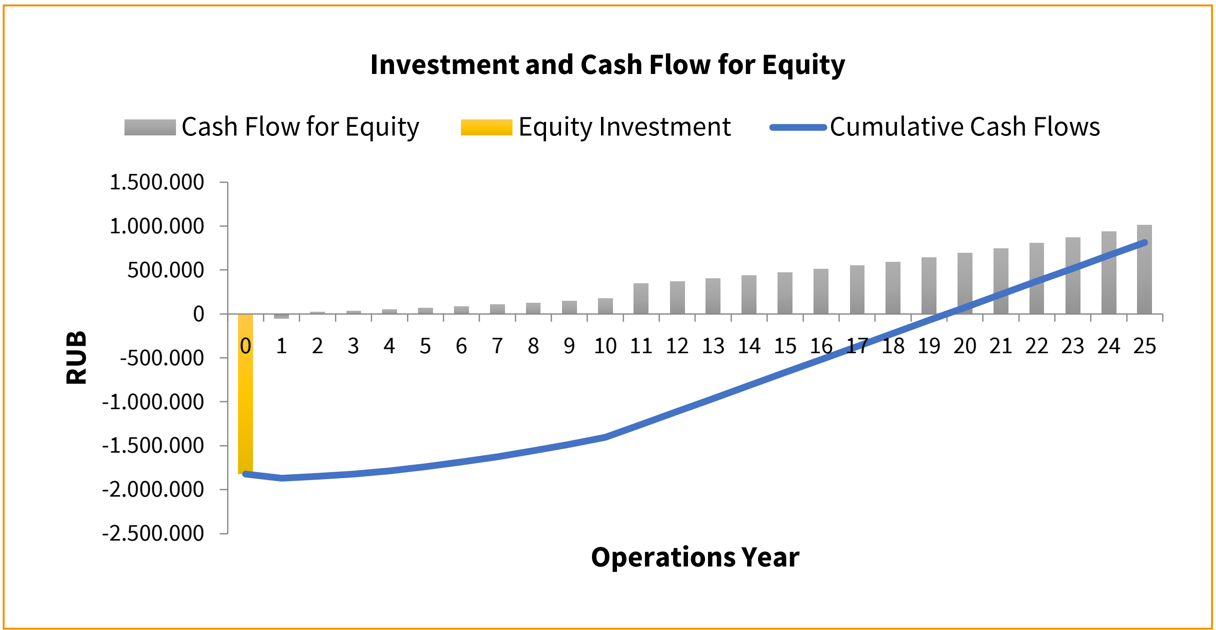

Figure 55 Equity Cash Flow – Severny Diesel-PV-Wind Hybrid; source: eclareon calculations, based on input data researched by EUROSOLAR Russia, 2018

The capacity factor, sometimes also referred to as the load factor, refers to the ratio of the generated net electricity during a certain period to the theoretical maximum of energy during the same period. There are of course seasonal differences but for standard onshore wind turbines a yearly average efficiency would rather be between 20% and 30%. But as stressed before, the wind turbine of the installation in Severny is not standard, at the moment it is not even functional. Longer periods of interrupted operations due to technical problems and/ or missing spare parts could explain this rather low capacity factor. If the experience from Severny were taken into account, we believe that the capacity factor could be higher. The impact of such a higher capacity factor of the wind turbine can be seen when moving to the right on the horizontal x axis which displays different capacity factors with base case results being shown in rectangles: a capacity factor of 22% could bring the equity payback down to approx. 15 years, everything else left unchanged.

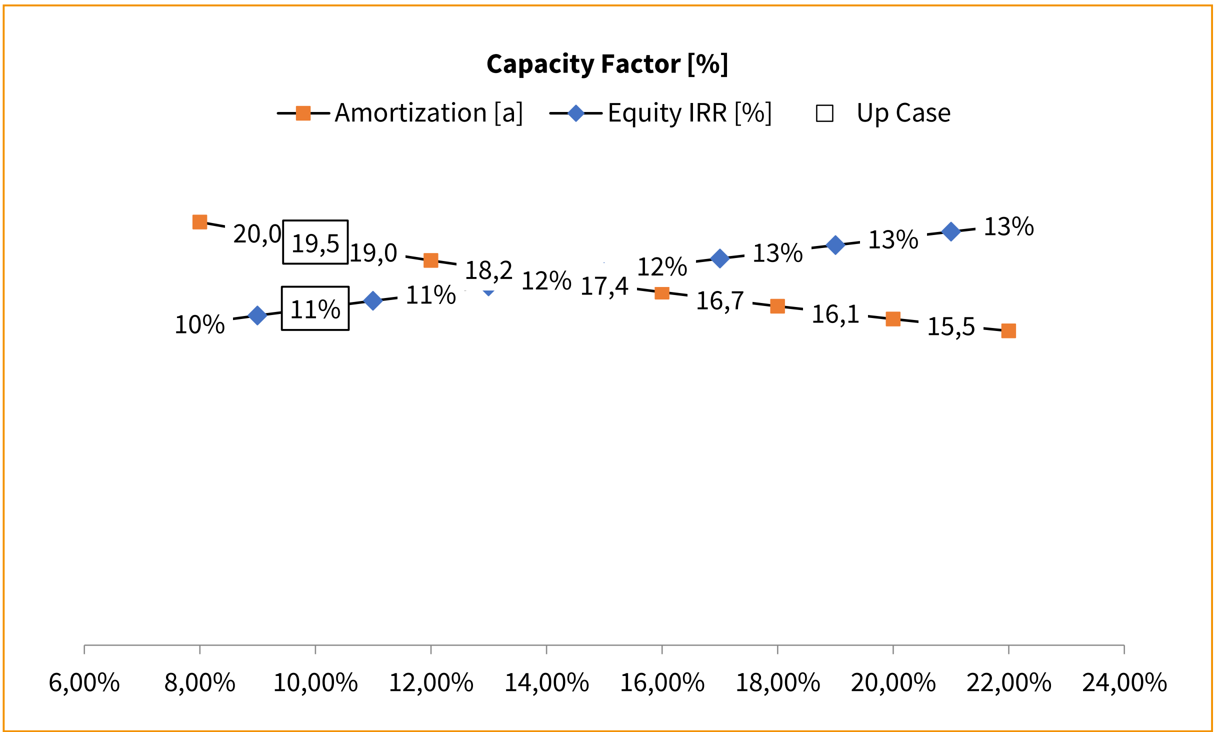

Figure 56 Capacity factor Sensitivity – Severny Diesel-PV-Wind Hybrid; source: eclareon calculations, based on input data researched by EUROSOLAR Russia, 2018

Another sensitive factor is of course the system price. This is illustrated in the next graph. The base case values are again shown in rectangles. In this case, the payback period increases when the costs are higher than in the base case calculation. The researched system price per kWp for the Severny installation including storage were high at approx. 171.000 RUB/kWp. The costs of the 50 kWh battery system assumed to be as high as 20.000 RUB/ kWh contributes substantially to the high system costs. Moreover, the fact that the installation of PV and other RES in Russia were, especially at the time when Severny was built in 2015, a rather recent phenomenon which means that actors did not yet have the chance to accumulate years of experience. However, once these very specific projects become more standard and more experience is accumulated, costs may go down and, as a consequence, payback time will be shorter and the equity IRR will be higher. This can be seen in the following graph when moving to the left on the horizontal axis where system prices are displayed.

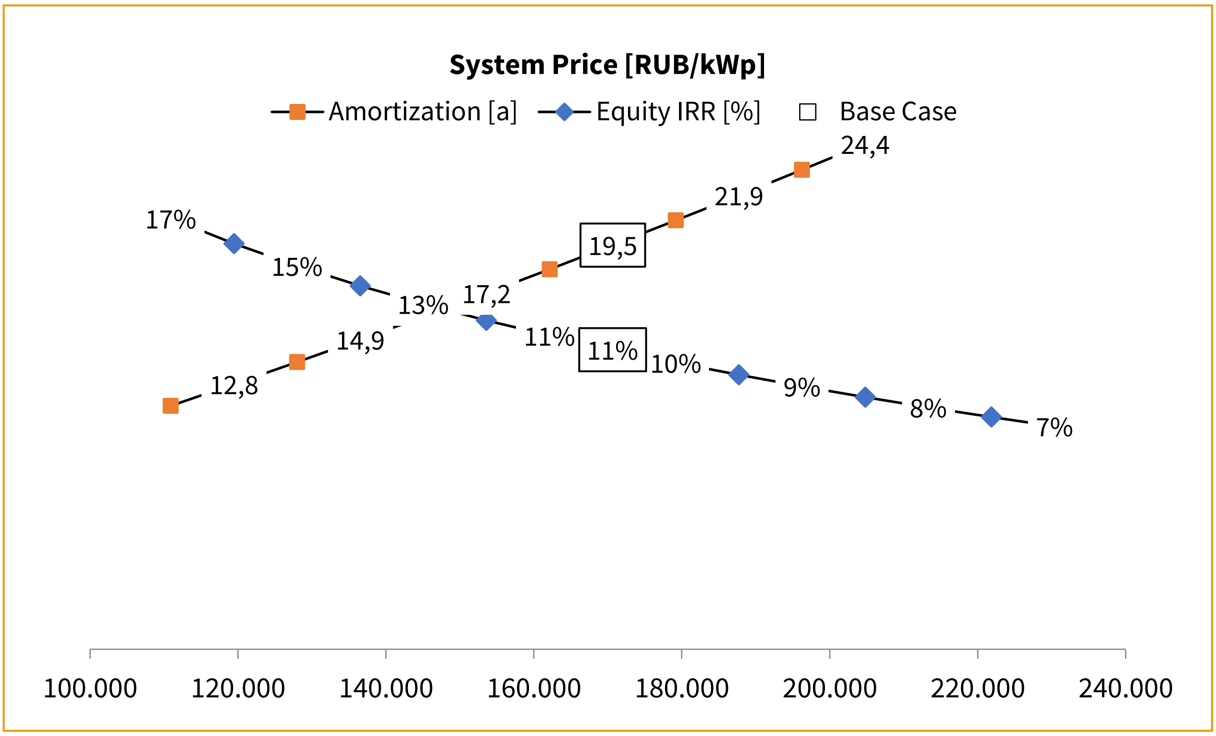

Figure 57 System Price Sensitivity – Severny Diesel-PV-Wind Hybrid; source: eclareon calculations, based on input data researched by EUROSOLAR Russia, 2018

Moreover, the diesel price today and its development over time play an important role for the business case. This is shown in the following two graphs.

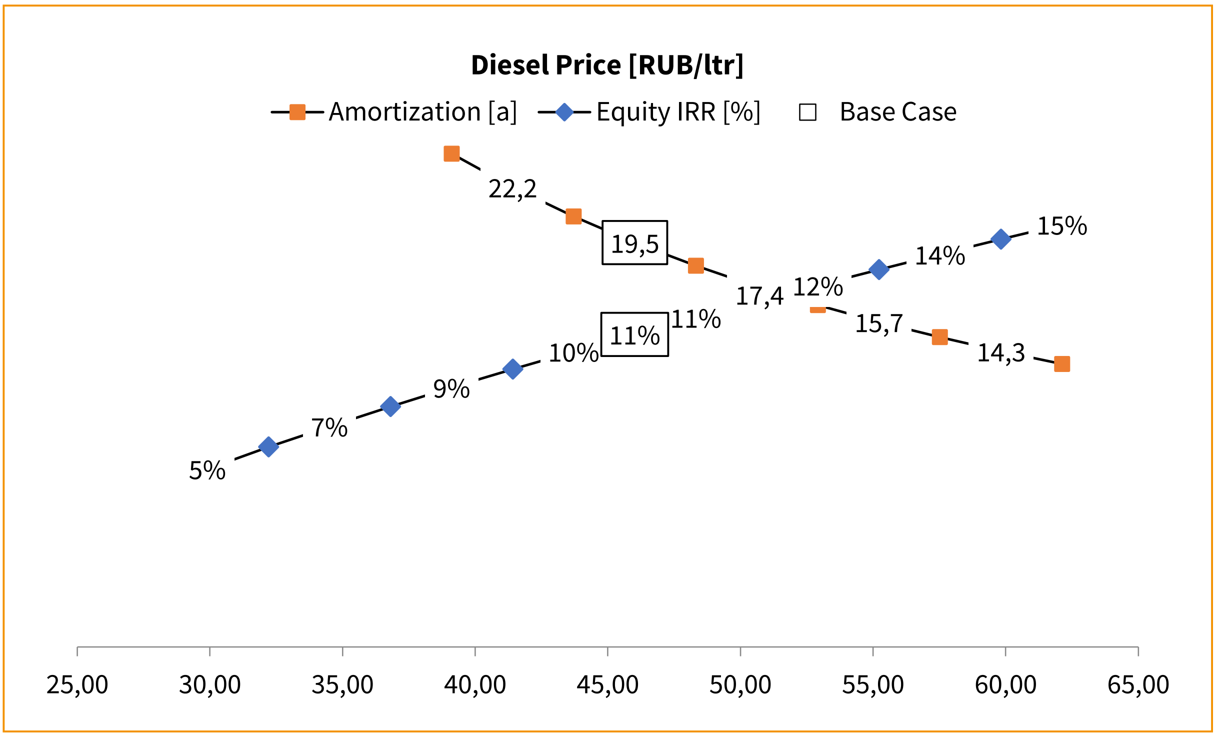

Figure 58 Diesel Price Sensitivity – Severny Diesel-PV-Wind Hybrid; source: eclareon calculations, based on input data researched by EUROSOLAR Russia, 2018

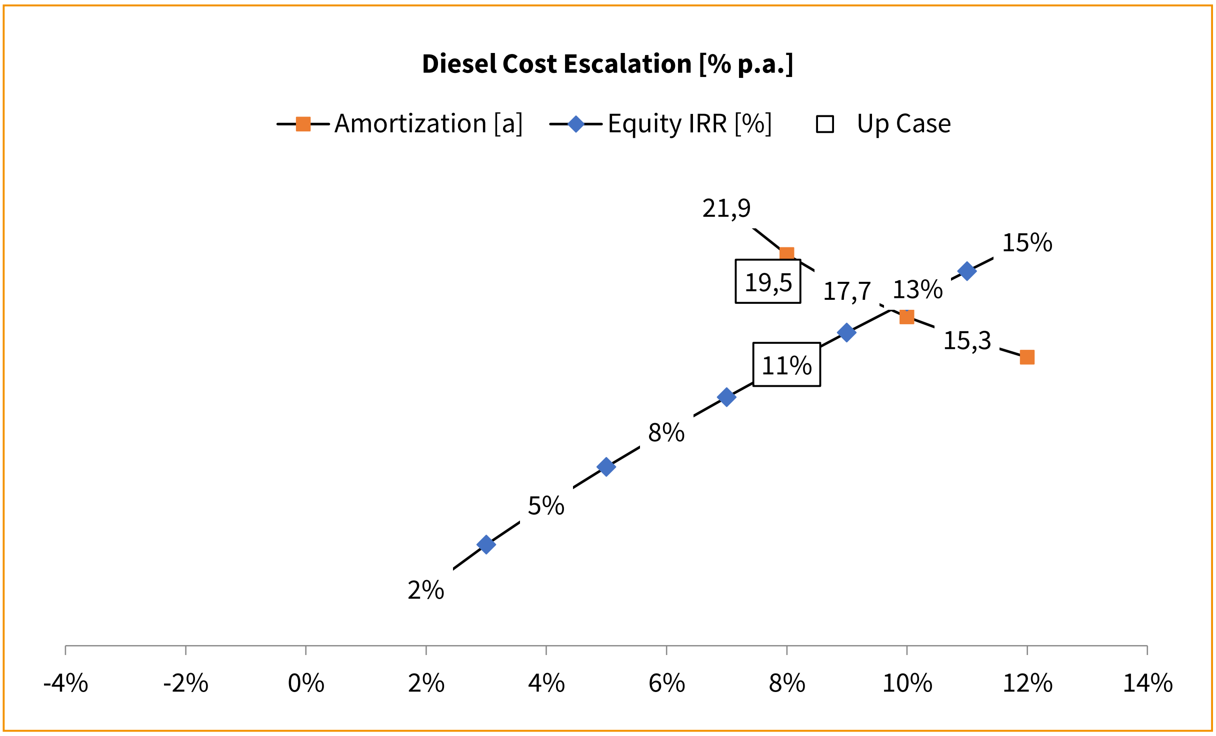

Figure 59 Diesel Cost Escalation Sensitivity – Severny Diesel-PV-Wind Hybrid; source: eclareon calculations, based on input data researched by EUROSOLAR Russia, 2018

The diesel price in the base case was assumed to be at approx. 46 RUB/ liter. These costs are not as high as in isolated territories such as Batagai. This relatively moderate price does not favour the business case: The higher the diesel costs the better the RES business case would be from the perspective of an investor. If the base case assumption were changed, the diesel price sensitivity shows that, with a diesel price higher than 43 RUB/ liter, the payback period would go down while the equity IRR would go up.

Another sensitivity that has an impact on the key results of a business case is the future development of diesel prices. An investment is paid back over time which means that it is necessary to estimate how certain critical parameters will change over time. Future diesel prices are not assumed to stay as they are today. The annual diesel price escalation in the model was assumed to be at +8% for Severny. If diesel costs were escalated with more than 8% p.a. the payback period and the IRR for the equity would change accordingly: an annual diesel costs escalation of 10% would decrease the payback period to approx. 16 years and increase the equity IRR to 13%. However, it can of course also be assumed that the diesel price escalation is lower than in the base case. If that were the case, the payback would increase and the IRR decrease.

2.4.7 Potential for cooperation/business opportunities

The RES market of Bashkortostan is small, nevertheless, there are some niches and prospective branches which may be of interest for foreign investors and project developers:

- Although the territory of the region is covered by the power grid, there are about 15 settlements which suffer from bad power quality and outages and need alternative power generation, which is complimentary to the existing grid. Replacing outdated cables is often more expensive than installing a hybrid RES power plant. At the same time, energy companies and grid operators are obliged to supply the citizens with energy, thus for them investing into RES would be a suitable solution.

- The region is planning to develop a net of medical aid stations in remote corners of the region, as well as mobile first aid stations. They need energy supply and currently the government is getting ready to invest in modern mobile diesel and petrol gensets to fulfil this aim.
- Small RES projects may be suitable for regional national parks and reserved areas where the grid cannot be built, diesel generation is unperformable and pure usage of energy accumulators is costly.

2.4.8 Risks and barriers

Similar to the situation in other Russian regions, there are a number of barriers which must be climbed on the way to RES project implementation in Bashkortostan:

- There is lack of financial sources in the region which can be used for RES or hybrid projects. Even the case of the hybrid power plant in Severny faced financial problems and cannot launch due to the broken inverter which cannot be replaced by the owner.
- There is a lack of legal framework which defines steps of organization of metering for electricity generated by RES. Simultaneously, there is no legal framework which creates a mechanism of how should consumers of the retail market pay for such RES based energy. Currently, local grid operators have no official rights to build RES based power plants to supply consumers. Exceptions would be the construction of a backup energy facility.
- “Hevel” is already active in the region and local authorities and companies are familiar with its projects and operations. There is a risk, that local companies/consumers/investors would contact a known PV company rather than trust a new player in the market.
- The region is connected to the UPS and a market for autonomous generation is small and not comparable to the one existing in Yakutia or Kamchatka. Although some settlements have bad electricity quality, they are at least connected to the grid, even if it is an old one.

2.5 Krasnodar Krai

The Krasnodar Krai region is located in the southwest of Russia and is part of the Southern Federal District, with a territory spanning 75,500 km^2 [101], the capital city is Krasnodar. The mountain system of the Caucasus stretches roughly one third of the territory, and there are several off-grid settlements and natural reserves in the mountainous area. The regional climate is mostly temperate continental, with average temperatures between -8 and +5 °C in January, and fluctuating between + 22 and + 35^0C in the summer - temperatures at the Black Sea only dip below zero for a few days a year. In 2018, population of the region was 5.5 million people, of which 55% lived in urban areas [102], and the population density was 74 people/km^2.

Figure 60 Map of Russia, Krasnodar Krai region is highlighted; source: eclareon 2019, generated with amCharts Pixel Map

The Krasnodar Krai economy subsists of: food production, fuel industry (annual extraction: 2 million tons of oil and 3 billion m^3 of natural gas), engineering and metalworking, construction materials industry (e.g. cement production), chemical industry, forestry and woodworking.

Krasnodar Krai is one of the fastest growing and simultaneously most energy deficient regions of Russia. Unlike most other Russian regions, the peak electricity consumption in Krasnodar Krai occurs in summer due to its warm climate conditions. The high use of air-conditioning in industrial buildings, offices and private households puts pressure on the electricity grid and power generating facilities, the result being that blackouts occur regularly. On August 8th 2018, the regional electricity consumption reached new levels with a consumption of 5.03 GW, 433 MW higher than the previous peak load in July 2016.

Another pressure on the regional power system is Crimea: after the Ukrainian power system stopped supplying the peninsula with electricity, Crimea became fully dependent on the UPS. The Krasnodar Krai power system has become a bridge between Crimea and the Russian mainland and occasionally has to share its energy with Crimea.

2.5.1 Current energy supply situation and renewable energy potential

The region is part of the UPS and currently produces only roughly 45% of the electricity it consumes annually. In 2017, its electricity generation was 11,489 million kWh and electricity consumption was 25,495 million kWh. Experts and analysts expect further growth in power consumption due to expanding industries, development of seaports and intensive housing construction. The annual growth of electricity consumption is expected to reach 1.7%, which may result in an overall increase of 12.4% for the period 2016-2023. The region has a developed but outdated grid. Therefore, there are no large autonomously working diesel power plants in the region and only several off-grid settlements.

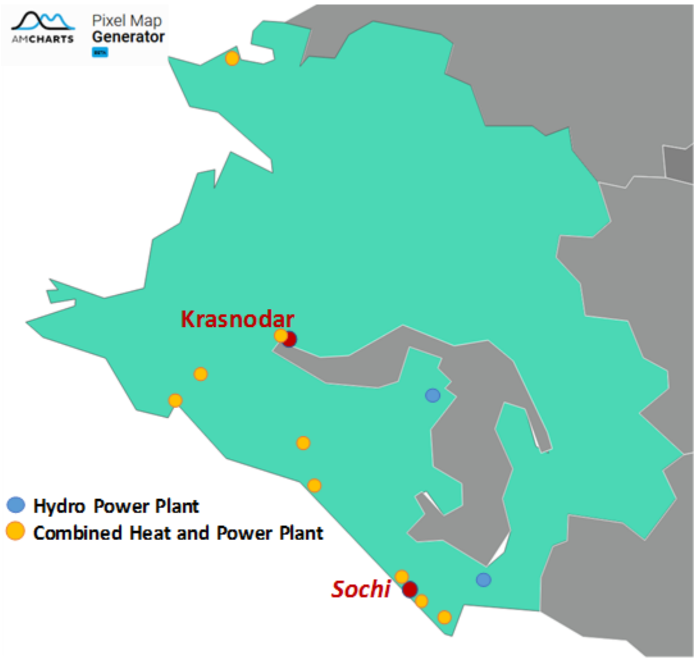

Figure 61 Largest power plants of Krasnodar Krai; source: eclareon, 2019, generated with amCharts Pixel Map, based on "Scheme and Program of development of energy sector of Krasnodar Krai in 2019-2023" [105]

The electricity market in the region has several stakeholders:

- Electricity retail companies (suppliers): "TNS energo Kuban", which covers about 55% of the territory, and "NESK" JSC, which covers about 30% of the territory and was founded in 2003 with the aim to compete with "TNS Kubanenergo" to avoid a monopoly in the market. Both companies purchase electricity wholesale from retail markets and sell it to consumers in the retail market (private households and industry). "TNS energo Kuban" and "NESK" are guaranteeing suppliers of the region. Other small energy retailers cover the remaining 16% of the territory.
- Major electricity transmission (grid) companies: "Kubanenergo" (ROSSETI group) (responsible for the grid 0.4-110 kV and having 11 branches in the region), and "NESK-electroseti" with 26 branches. "Kubaenergo" serves urban areas and NESK is responsible for electricity transmission in rural areas.
- Dozens of small grid operators, active for: Russian Railways PJSC, Kuban Enterprise MES branch of FGC UES JSC, Sochi Enterprise MES PJSC FGC UES.
- Energy-generating companies: the largest are "Lukoil-Kubanenergo", OGK-2 (basically Gazprom)", "Inter RAO"

- Some energy blocks of industries with own generation facilities (entities and private) (e.g. “MagnitEnergo” has their own gas turbines serving greenhouses, etc.)

In early 2018 the region had a total installed capacity of 2.3 GW (including 23 power plants with a cumulative installed capacity 422.8 MW; 2 HPPs and 5 independent supplier stations with 42.9 MW). Figure 62 shows the structure of installed power capacity in the region at the end of 2017. The largest CHPPs are: Krasnodar CHPP with an installed capacity of over 1 GW (owned and operated by Lukoil-Kubanenergo); CHPP in Adler (364 MW) owned and operated by “OGK-2”, Dzubginsk CHPP (198 MW) and CHPP in Sochi (160.5 MW), both owned by Inter RAO; CHPP in Tuapse (141 MW). All CHPPs are fueled by natural gas.

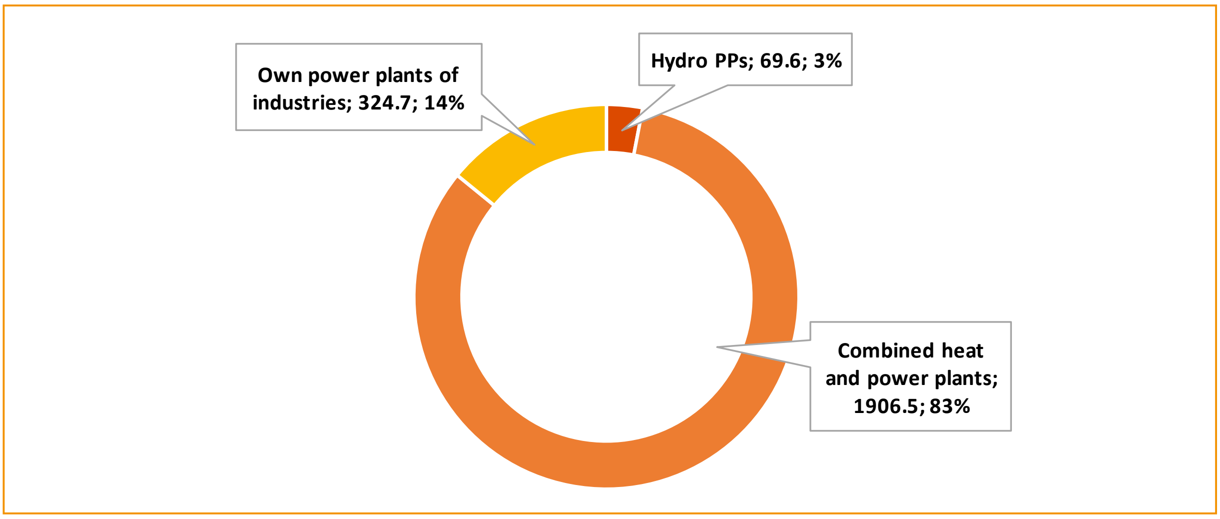

Figure 62 Structure of the installed capacity by type of power plant in Krasnodar Krai in 2017; source: Ministry of fuel and energy of Krasnodar Krai, 2018

In 2017, according to Federal State Statistics Service of Russia, 23,233 million kWh of electricity was consumed in the region[16]. Numbers from this statistical database usually differ slightly from internal databases because different calculation methodologies and sources are used. Electricity consumption by type of consumer is presented on Figure 63. The major energy consumers in the region are the mining industry and residential consumers. A large share of electricity (17% or 3,900 million kWh) is lost in grids while transmitting, mainly due to a high deterioration of electrical equipment, including grids and transformer stations. Nearly 100% of regional substations have exhausted their amortization period and need to be replaced or majorly overhauled [104].

[16] According to Federal State Statistics Service of Russia, information differs from the “Scheme and Program of development of energy sector of Krasnodar Krai in 2019-2023” differs, structure of electricity consumption for 2017 is not available in the document.

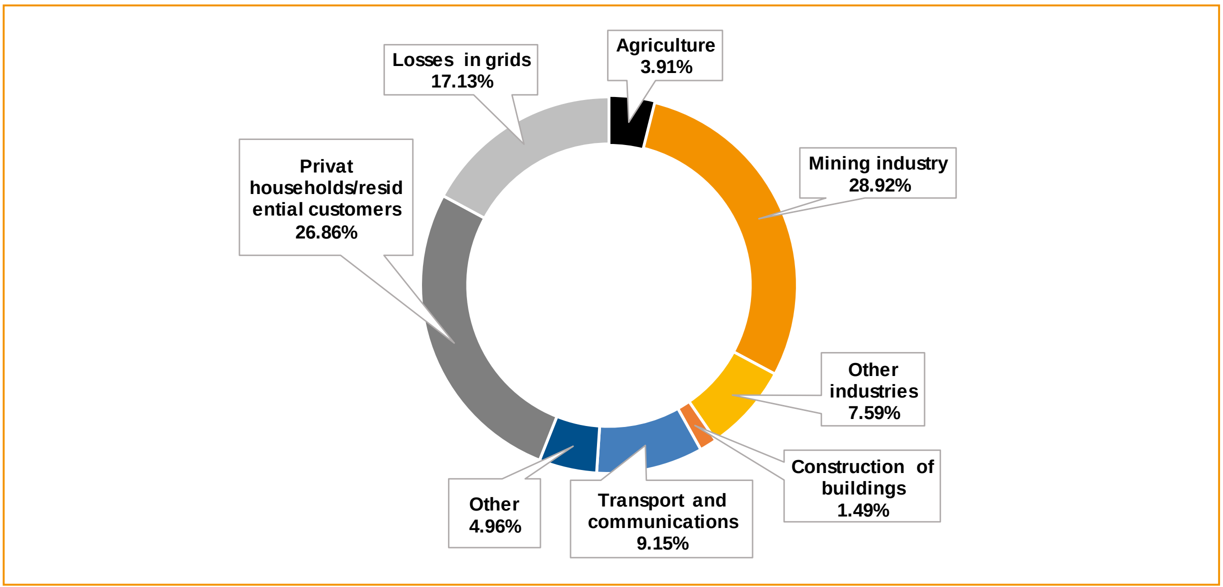

Figure 63 Electricity consumption in Krasnodar Krai by type of consumer, %, 2017; source: Federal State Statistics Service of Russia, 2018 [54]

In Krasnodar Krai, uninterrupted power supply of some districts remains problematic. Due to the lack of installed power capacity and low quality of grid connection, power outages occur frequently in the following regions: Timashevsky, Ust-Labinsky, Krasnoarmeysky, Seversky, Tikhoretsky, Anapa and Armavir.

Aging grid and lack or generating facilities in the region are the major reasons of the low electricity quality and regular outages in the region. Such problems are particularly frequent in rural and coastal areas. which are popular among tourists. Small diesel and petrol generators become an alternative solution and are often used by hotels and private households, despite being connected to the grid. According to estimations of some local experts, there are about 1,000 diesel gensets of different sizes, varying from 3 to 500 kW installed capacity each, in hotels across the region. Official statistics on that does not exist due to the fact, that there are no requirements to register such gensets.

Krasnodar Krai is known as a sunny region: around 280 days a year are sunny [164]. The average yield reaches 1,400 kWh/m^2/year or 109, 669.2 billion kWh [89] [164]. Currently, there are no large solar power plants in the region, solar energy only used locally in some small projects. However, there are proposals for the construction of SPPs with a total installed capacity of 90 MW by 2023 in Krasnodar Krai. These projects are to be divided into smaller PV systems with an installed capacity of 4-5 MW each [104]. Although the RES are not that widespread in Russia yet, there are already many private and pilot installations in the region. They are not included in the official regional energy balance and omit registration; thus, it is tough to estimate their real installed capacity. Examples of such small projects are: a PV system in Sochi, Olympic Park with 127.5 kW in installed capacity; 70 kW of rooftop PV at the railway station in Anapa; and a 31 kW PV system in Apart-Hotel, Sochi, among others [103]. In 2014, there were about 70 solar installations (both PV and solar thermal) in use by social facilities (e.g. sanatoriums, hospitals) as well as industrial entities. The overall installed PV capacity in the region is estimated to be about 4-5 MW: all are small private installations of different capacities varying between 5 and 300 kW (based on a research done by eclareon and IP Kekelidze).

Krasnodar Krai has also very good wind power potential, the technical potential of wind energy (for the altitude of 30 meters) is about 322 MWh/year reaching 455 MWh/year on the coats of the Azov sea (especially Taman peninsula) and 500 MWh/year on the coastal areas of the Black sea.

2.5.2 Electricity tariffs and costs

Krasnodar Krai is a part of the wholesale electricity market's first price zone. In 2018, Krasnodar Krai rated 11th among territories with the highest electricity tariffs for private households [92]. A stable growth of tariffs has been present since 2016. Electricity tariffs in the region are controlled and established by an executive authority, the Regional Energy Commission, which is part of the Department of Prices and Tariffs of the Krasnodar Krai. This authority also falls under the regulation and control of the Krasnodar Krai administration and the Federal Antimonopoly Service of Russia [105].

In 2019, the major tariffs for private households were:

- Rural population, night tariff - 1.97 RUB/kWh (0.03 EUR/kWh) - day tariff - 3.66 RUB/kWh (0.05 EUR/kWh)
- Urban population (households with gas stoves), night tariff - 2.82 RUB/kWh (0.04 EUR/kWh)- day tariff - 5.24 RUB/kWh (0.07 EUR/kWh)
- Single rate tariff (no differentiation by time or voltage) rural population - 3.28 RUB/kWh (0.04 EUR/kWh); urban population (households with gas stoves) - 4.69 RUB/kWh (0.06 EUR/kWh)

For non-residential consumers, including all industries and guaranteeing suppliers, the electricity tariff is set at unregulated prices within the limits (ceiling prices). Table 10 presents marginal levels of unregulated electricity prices for "TNS energo Kuban", prices for "NESK" are kept at nearly the same level.

Type of voltage / type of tariff	High voltage (110 kV and higher)	Middle first voltage (35 kV)	Middle second voltage (20-1 kV)	Low voltage (0,4 kV and less)
Ceiling electricity prices for February 2019, RUB/kWh (EUR/kWh) with VAT, electricity for non-residential consumers with loads under 670 kW, first price category				
Single rate tariff	6.31 (0.08)	6.67 (0.09)	8.10 (0.11)	9.46 (0.13)
Ceiling electricity prices for February 2019, RUB/kWh (EUR/kWh) with VAT, electricity for non-residential consumers with loads under 670 kW, second price category				
Double day time tariffs				
Night tariff	4.09 (0.05)	4.46 (0.06)	5.88 (0.08)	7.24 (0.10)
Day tariff	8.47 (0.11)	8.83 (0.12)	10.26 (0.14)	11.62 (0.16)
Tree day-time tariff				
Night tariff	4.09 (0.05)	4.46 (0.06)	5.88 (0.08)	7.23 (0.10)
Semi-peak zone	6.35 (0.08)	6.72 (0.09)	8.14 (0.11)	9.50 (0.13)
Peak zone	13.01 (0.17)	13.37 (0.18)	14.80 (0.20)	16.16 (0.22)

Table 10 Some ceiling prices for the retail market's consumers (non-residential consumers) of the electricity provided by "TNS Energo Kuban" in 2019; source: "TNS Energo Kuban", 2019[160]

Other non-residential consumers which have energy receivers with the maximum capacity over 670 kW, have different energy prices which are changing every hour and in accordance to the rules of the 3rd-6th price categories (see section 1.3).

Cross-subsidization also occurs in Krasnodar Krai, despite there being many attempts to phase it out. In 2018, the total amount of cross-subsidization was about 8,904.6 million RUB (approx.118.7 million EUR) [107].

2.5.3 Regional business environment & specific legal and regulatory framework for energy supply

Krasnodar Krai is known for being energy deficient and lacking in modern high-quality grids. This causes power outages and energy shortages, forcing consumers to use decentralized power generation (both autonomous and combination with grid supply). Major consumers of off-grid energy generation or combined grid generation are: shops, recreational enterprises, private households and garden houses, catering facilities and infrastructure facilities such as gas pipe stations and mobile communication stations. Although a concrete number of off-grid gensets or installed off-grid capacity is unknown, the issue is important for the region.

Local authorities are interested in RES development and are attracted to the idea of energy independence from other regions. An additional motivation for the administration of the region to develop RES in off-grid areas is reduction of losses in grids and costs of grid construction. In the case of a settlements located in mountainous areas and far from the major grid line, grid construction has to travel several dozen kilometers before reaching consumers.

Regarding the regulatory framework, Krasnodar Krai is subject to the basic laws focused on the renewable energy sources listed in section 1.3 of the report. In addition, there are other legislative acts supporting RES in the region.

In 2004, the Legislative Assembly of Krasnodar Krai enacted law No. 723-KZ "On the Utilization of Renewed Sources of Energy in Red Army Krai"[131], which contained the following directives:

- Local government can assist legal entities and individuals in the production of equipment for the use of renewable energy sources and RES usage.
- Priority places for using renewable energy sources are:
    1. decentralized energy supply zones, with low population density, and where construction of traditional power plants and high-voltage grids is economically unprofitable;
    2. zones which do have power supply but of a low quality and with frequent outages, which leads to a significant economic damage and negative social consequences
    3. settlements and places of mass recreation of the population with a difficult ecological situation
    4. natural protected areas and reserves where grid construction is prohibited but where some demand in energy exists (e.g. recreational zones inside national parks)

In 2013, Decree No. 1183 approved the state program “Development of the fuel and energy complex” [132]. The goal of the program is to reduce energy costs, payments for energy supply services and ensure the improvement of competitiveness and financial stability of the regional economy, also with the help of development and usage of energy-efficient equipment and implementation of renewable energy facilities. The program is coordinated by the Ministry of Industry and Energy of Krasnodar region.

This program also includes a subprogram: “Energy Saving and Increasing the Energy Efficiency of Krasnodar Krai for the Period 2014–2020”, which lists the following activities aimed to develop RES and EE: introduction of solar collectors, PV installations, WPPs, geothermal PPS, use of biogas in agriculture, solid domestic waste recycling, use of heat pumps

Krasnodar Krai has also a regional development strategy, approved by the Law N 3930-KZ "On the Krasnodar Krai's Social and Economic Development Strategy until 2030" [133]. According to the law, the goal of the power industry development of the Krasnodar Krai is to provide population and entities with accessible and affordable energy through a combination of innovative development of conventional energy technologies and the active implementation of RES.

This goal is to be achieved through:

- formation of an effective legislative framework ensuring the development of the fuel and energy complex with the help of a public-private partnership
- active interaction of industry associations, businesses and authorities while solving problems of industrial development
- increasing the availability of financial resources for the fuel and energy industry development
- attraction of relevant investors and applying state support mechanisms (preferential loans for priority projects and areas at the discount rate of the Central Bank)
- establishment of a grace period for the land lease
- active use of renewable energy sources, especially solar thermal systems, PV and wind power plants.

2.5.4 Regional specific business case

In Russia, there are several mobile operators, providing communication and internet services to the population and entities. One of the largest is "Beeline" (owned by PJSC "VimpelKom"), which in 2004 installed the first hybrid PV-wind-diesel power generating facility on one of its mobile phone transfer towers in Moldavanka settlement. In the area, the mobile signal was weak due to mountainous terrain, thus an additional tower was needed [134]. Connecting the tower to the grid was problematic due to estimated high costs and rocky slopes with frequent rockfalls, which made stretching the power grid nearly impossible. In these conditions RES power stations are the ideal solution. The named system contains a combination of wind, PV and diesel genset along with an energy storage system lets the system function during all types of weather conditions. The project is called "Autonomous hybrid power plant in Moldavanka village" and was financed by "Beeline". The company is also an owner and operator of the power facility. Design and construction works were carried out by engineering company "Clever Energy".

The composition of the installation is the following:

- PV system consists of 7 solar modules (Micromorphic, Pramac (Switzerland) 125W x 26pcs) with total installed capacity 3,25 kW;
- wind turbine of 2 kW capacity
- diesel generator with rated capacity of 40 kW;
- energy storage system 420Ah, 20 kWh;
- remote control.

Construction of the station took 7 days. The contractual relationship between key project stakeholders is illustrated by the scheme on the Figure 64.

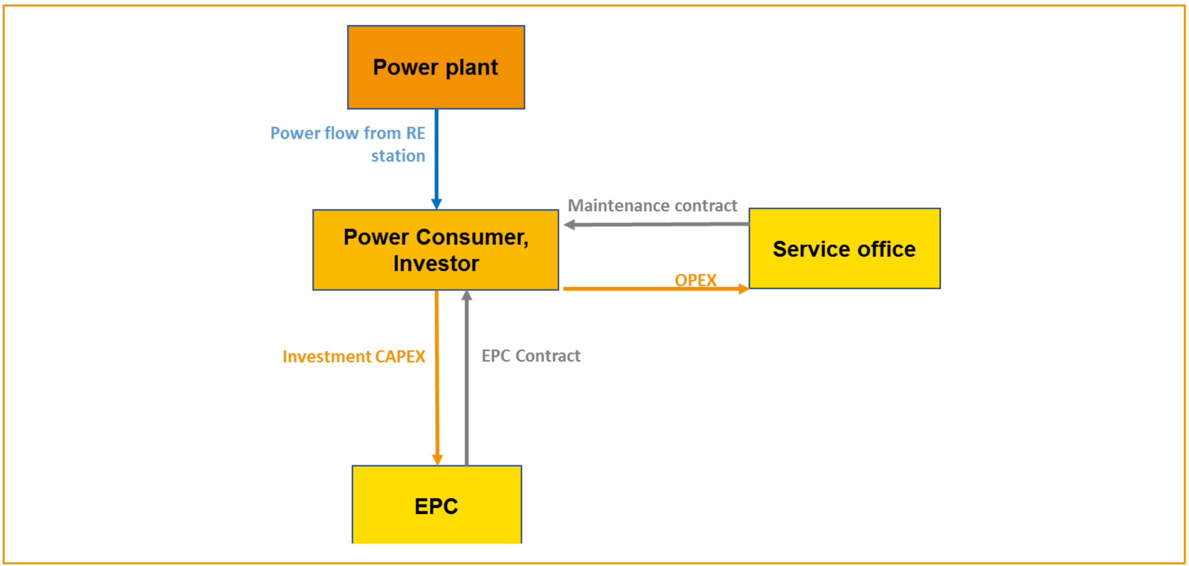

Figure 64 Scheme of relations between different stakeholders while implementing a new project; source: eclareon 2019

2.5.5 Business model description

The hybrid PV-wind-diesel installation with energy storage in Moldavanka settlement which serves base transmitting station of company "Beeline" represents the diesel savings and revenues from the PV installation. "Beeline" is simultaneously the power consumer, investor and the plant operator. The system was built with an aim to cover the energy needs of this investor and to make him fully energy autonomous.

The overall duration of the project's implementation in the region is usually about 3 months. Before starting a project, it is important to negotiation with the local authorities and responsible ministries (e.g. the Ministry of Fuel and Energy Complex, Housing and Communal Services of Krasnodar Krai). This takes on average 2 weeks or longer.

Delays may happen due to the poor communication between different agencies, ministries and administration departments, one needs to address each utility separately and sometimes several approaches are needed before the necessary reply is received. These steps are presented on the scheme (Figure 65):

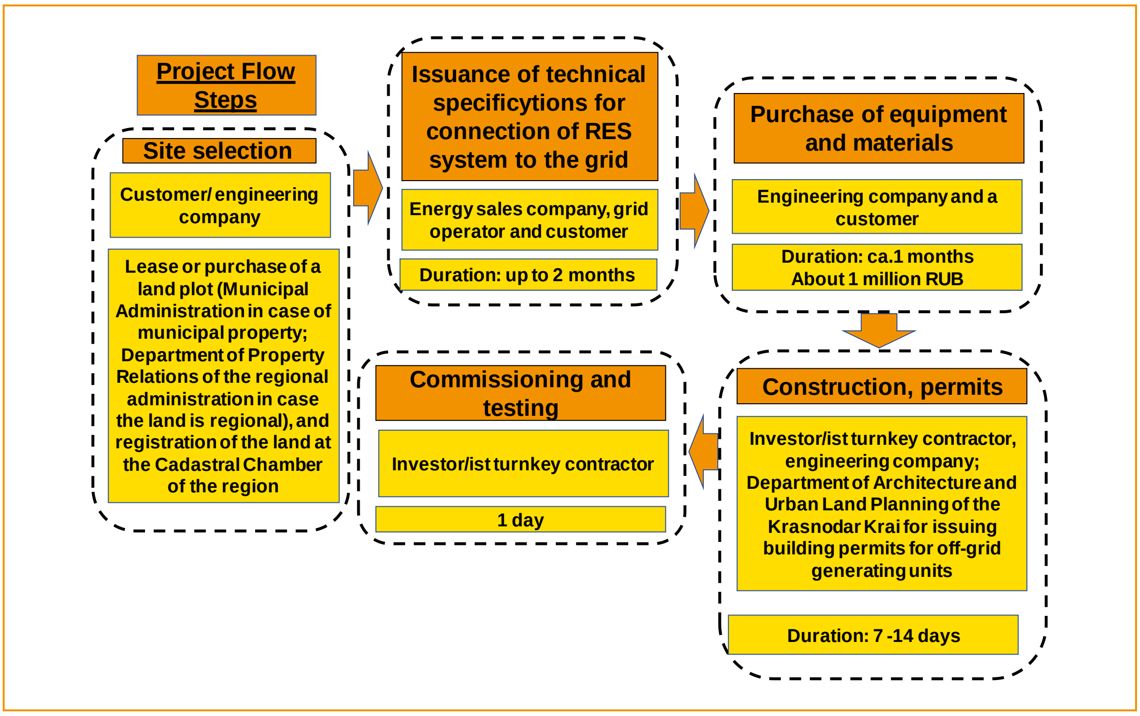

Figure 65 Project steps for Krasnodar Krai RES projects; source: eclareon 2019

Climate conditions permit construction and installation works to be carried out throughout the year. To transport the necessary equipment both roads and marine ways (the Black Sea) are necessary and these are accessible year-round – only the Azov Sea can be covered with ice in winter, so shipping is possible only after the route has been laid by an icebreaker [135].

2.5.6 Profitability analysis (inputs, outputs, scenarios, sensitivities)

In the following, an exemplary profitability analysis for the RES share of a PV-wind diesel hybrid installation with 20kWh battery storage is presented as the regional specific business case. This an example of a project that was already realized in 2004 which limits the comparability to installations that could be built today substantially However, based on further analysis in the region of Krasnodar, the authors of this report believe that especially PV hybrid cases can be economically more attractive than this particular installation combining wind, PV and Li-ion storage on a rather small scale. For PV business cases in the region of Krasnodar please do refer to BSW Solar’s “Enabling PV Russia” report [136].

The base case assumptions and results can be found in the following figure:

RE System		
Project Duration	Years	25
Wind Generator Size	kWp	2,00
Wind Capacity Utilization Factor	%	15%
PV Generator Size	kWp	3,25
Specific PV Generation	KWh/kWp	1.280
Battery Capacity	kWh	20,00
Total System Cost	RUB	978.887
Battery Replacement Interval	Years	8
Total Battery Replacement Costs	RUB	710.170

System Operation		
Average Yearly Generation	kWh/a	6.350
Direct-Consumption Rate	%	90%
Genset efficiency	kWh/ltr	3,00
Average Replaced Diesel Consumption	ltr/year	1.863
Diesel Price (1st Ops Year)	RUB/ltr	44
Diesel Price Escalation	% p.a.	8%
Fixed Operation Costs	RUB p.a.	19.578
Longterm Insurance Costs	% p.a.	-

Financing			
Debt (Gearing)	-	RUB	-
Loan Tenor		Years	-
Grace period		Years	-
Debt Interest Rate		%	12%
Initial Equity		RUB	978.887
Additional Equity		RUB	210.873
Discount Rate		%	10%
Longterm Inflation Rate		%	4%

Results		
Net-Present Value	RUB	65.755
Project IRR	%	12%
Equity IRR	%	11%
Payback Period	Years	23,25
LCOE (no subsidy)	RUB/kWh	24,98
Min DSCR**	x	-
Min LLCR***	x	-

* LCOE: Levelized Cost of Electricity
** DSCR: Debt Service Coverage Ratio
*** LLCR: Loan Life Coverage Ratio

Figure 66 Project Overview – diesel -PV – wind- hybrid Krasnodar; source: eclareon calculations, based on input data researched by EUROSOLAR Russia, 2018

The graph shows that the installation is viable from a financial perspective but that the payback period is very long with > 23 years. No debit finance is assumed given this long payback period. The Li-ion battery and the battery replacements every 8 years are cost drivers as shown in the cash flow for equity graph below. It can also be seen that the cash flow available for equity also increases year by year based on the assumption that the diesel that is replaced by solar power is becoming more expensive every year. The equity is paid back after approx. 23 years. In the graph this is illustrated by the blue line crossing the horizontal x-axis.

The capacity factor of the wind installation was again reported to be rather low which means that there may be potential to improve project attractiveness for future installations in the region: a yearly average efficiency of a standard onshore wind turbines would rather be between 20% and 30%. But as stressed before, the installation Krasnodar is not standard. Longer periods of interrupted operations due to technical problems and/ or missing spare parts could explain this rather low capacity factor. If the experience from this installation were taken into account, we believe that the capacity factor could be higher. The impact of such a higher capacity factor can be seen in the following figure when moving to the right on the horizontal x axis: a capacity factor of 20% could bring the equity payback down to approx. 20 years, everything else left unchanged.

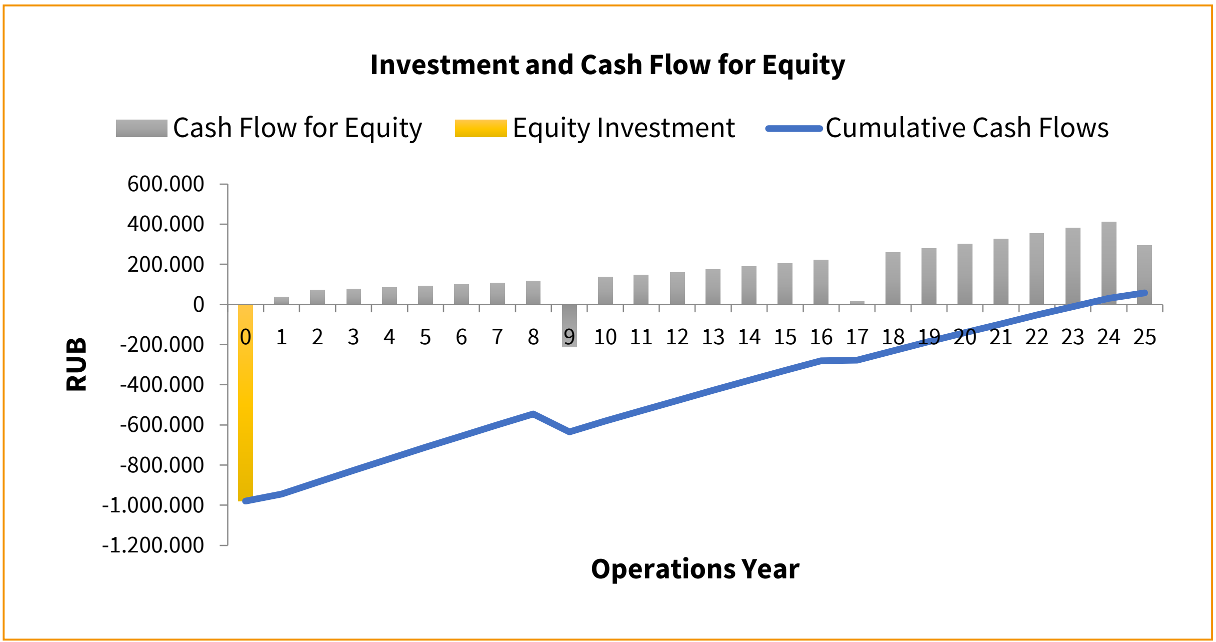

Figure 67 Equity Cash Flow – diesel-PV–wind- hybrid Krasnodar; source eclareon calculations, based on input data researched by EUROSOLAR Russia, 2018

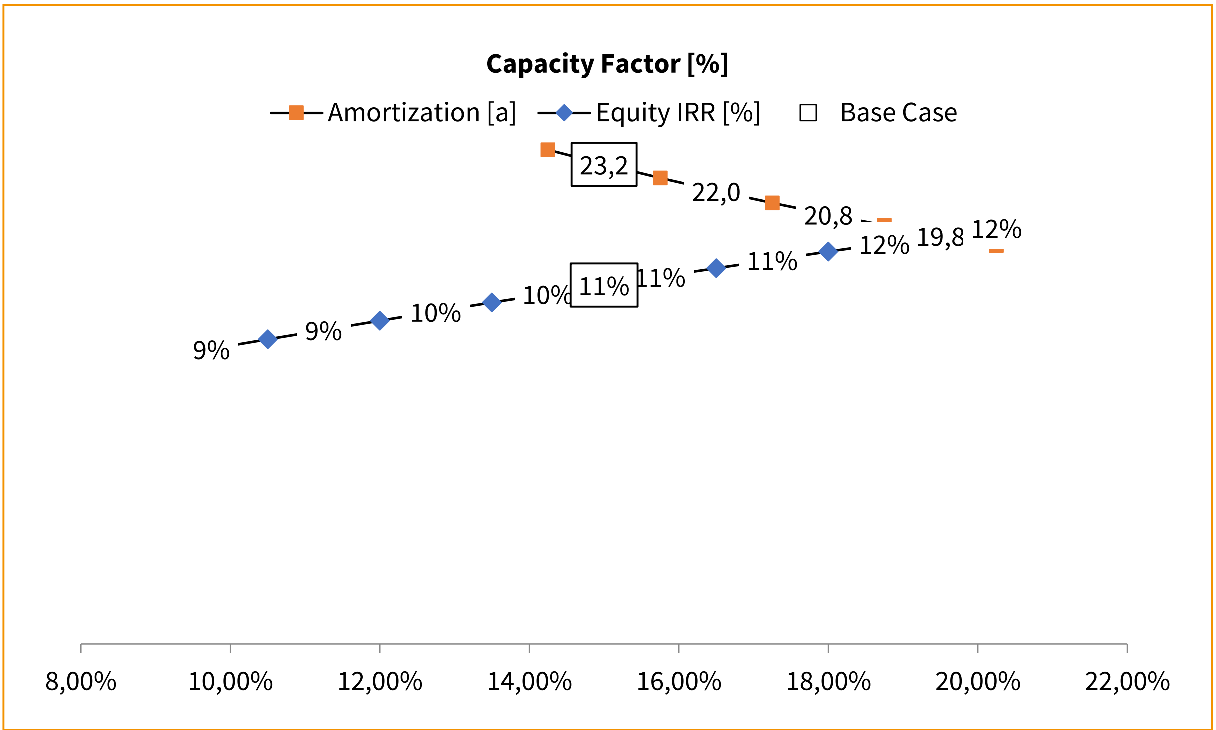

Figure 68 Capacity factor Sensitivity – diesel-PV–wind-hybrid Krasnodar; source: eclareon calculations, based on input data researched by EUROSOLAR Russia, 2018

Another sensitive factor is of course the system price. This is illustrated in the next graph. The base case values are again shown in rectangles. In this case, the payback period increases when the costs are higher than in the base case calculation. The researched system price per kWp for the installation in Krasnodar were very high at approx. 185.000 RUB/kWp. The costs of the 20 kWh battery system assumed to be as high as 25.000 RUB/ kWh contributes substantially to the high system costs. Moreover, the fact that the installation of PV and other RES in Russia were a rather recent phenomenon which means that actors did not yet have the chance to accumulate years of experience. However, once these very specific projects become more standard and more experience is accumulated, costs may go down and, as a consequence, payback time will be shorter and the equity IRR will be higher. This can be seen in the following graph when moving to the left on the horizontal axis where system prices are displayed.

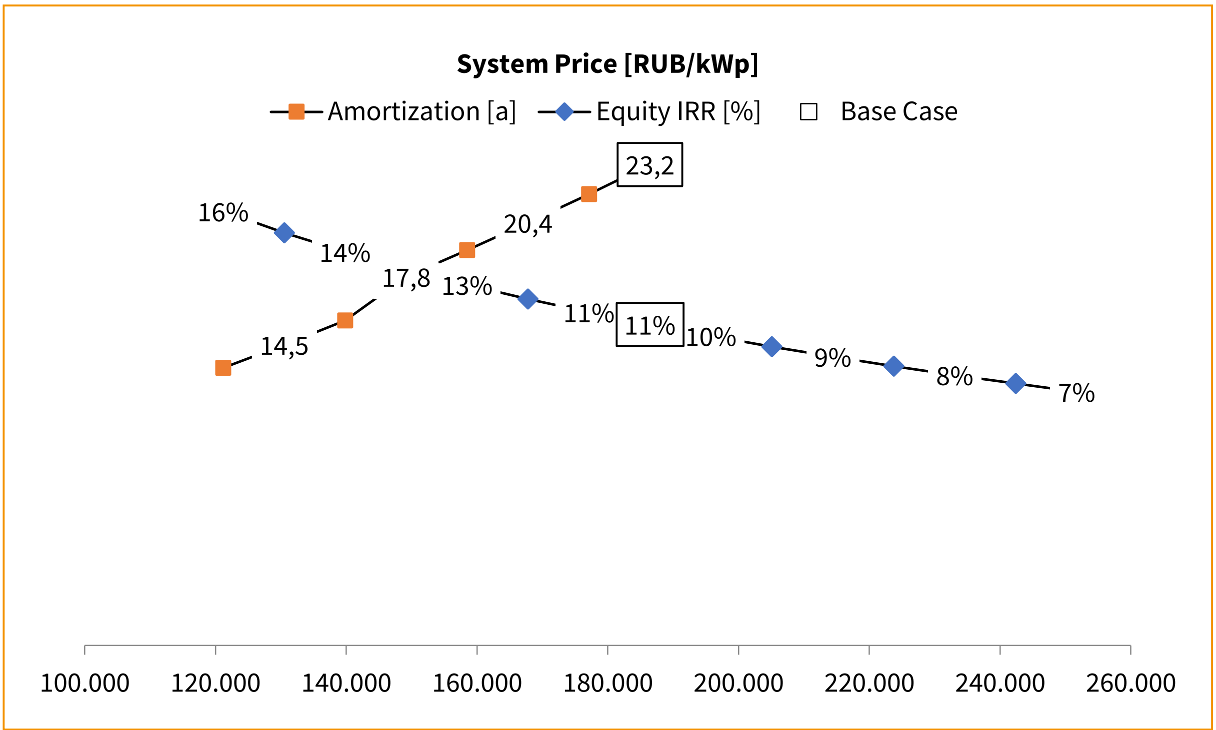

Figure 69 System Price Sensitivity – Project Overview – diesel-PV–wind-hybrid Krasnodar; source: eclareon calculations, based on input data researched by EUROSOLAR Russia, 2018

Moreover, the diesel price today and its development over time play an important role for the business case. This is shown in the following two graphs.

The diesel price in the base case was assumed to be at approx. 44 RUB/ liter. These costs are not as high as in isolated territories such as Batagai. This relatively moderate price does not favor the business case: The higher the diesel costs the better the RES business case would be from the perspective of an investor. If the base case assumption were changed, the diesel price sensitivity (Figure 70) shows that, with a diesel price higher than 44 RUB/ liter, the payback period would go down while the equity IRR would go up.

Another sensitivity that has an impact on the key results of a business case is the future development of diesel prices. An investment is paid back over time which means that it is necessary to estimate how certain critical parameters will change over time. Future diesel prices are not assumed to stay as they are today. The annual diesel price escalation in the model was assumed to be at +8% in Krasnodar. If diesel costs were escalated with more than 8% p.a. the payback period and the IRR for the equity would change accordingly: an annual diesel costs escalation of 10% would decrease the payback period to approx. 19 years and increase the equity IRR to 13%. However, it can of course also be assumed that the diesel price escalation is lower than in the base case. If that were the case, the payback would increase and the IRR decrease.

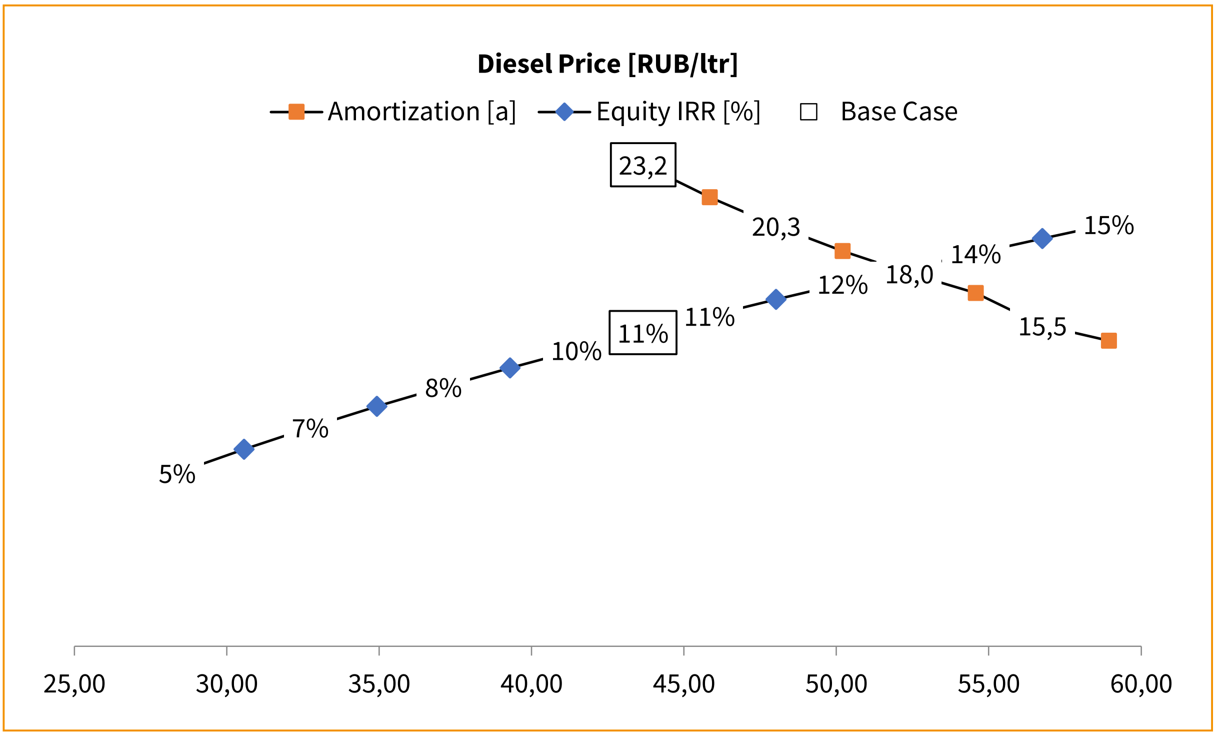

Figure 70 Diesel Price diesel-PV–wind-hybrid Krasnodar; source: eclareon calculations, based on input data researched by EUROSOLAR Russia, 2018

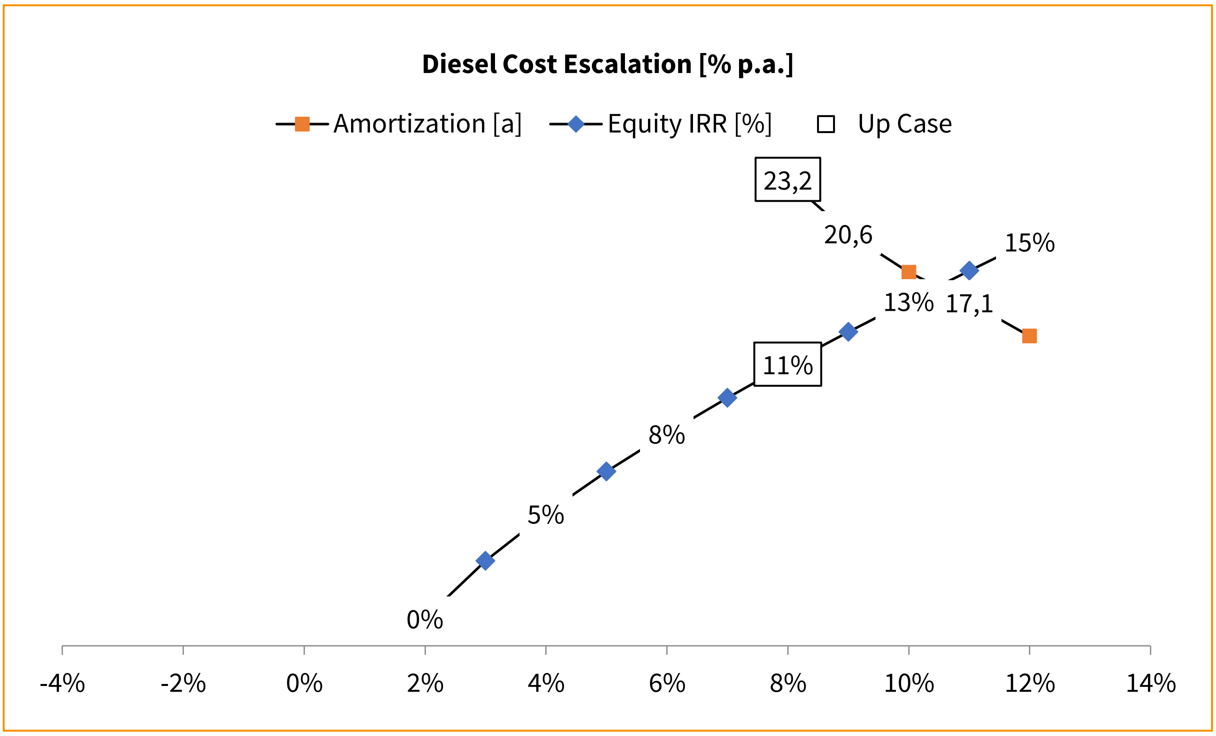

Figure 71 Diesel Cost Escalation diesel-PV–wind-hybrid Krasnodar; source: eclareon calculations, based on input data researched by EUROSOLAR Russia, 2018

2.5.7 Potential for cooperation/business opportunities

Krasnodar Krai is a very promising region for the development of RES, especially solar, but lacks experience in the sector. However, there are a range of potential customers investing in the region, thereby making the region more interesting for foreign investors and PV project developers. The region is covered by the centralized grid, but due to its high level of deterioration, the quality of electricity supply is often low and power outages occur frequently. The region is known for its hot summers, therefore, even short outages of a couple of hours often lead to food spoilage at central warehouses and profit losses for companies.

- Krasnodar Krai is an energy deficient region which needs additional energy generating capacity. RES could provide the region with energy, especially considering the perceptiveness of PV, wind and other RES in the region (see section 2.5.1).
- Krasnodar Krai is not comparable to Moscow in terms of wealth and business development perspectives. However, the economy of the region is developing quickly, creating new business opportunities. Due to the peculiarities of the Russian, and especially southern Krasnodar Krai mentality, many people are eager to invest in private PV system in private households.
- The region is relatively wealthy, with a significant portion of the population being “snowbirds”. Many of these individuals have private cottages in Krasnodar Krai and have PV modules on their roofs because it is seen as a sign of personal success.
- Krasnodar Krai is called the “breadbasket of Russia” due to its vast wheat fields and highly developed crop, vegetable and fruit production. Numerous manufacturers, canneries, oil and dairy producers have their facilities close to fields and greenhouses. They consume a lot of energy for different purposes, such as cooling in case of goods’ storage and heating for conservation and pasteurization. Additionally, some unprocessed crops such as green beans must be processed and canned in the first couple of days after harvest, which means, that factories sometimes have to work 24 hours to prevent quality losses. Some of these companies are now starting to consider alternative energy solutions. PV is not the only electricity source being considered for electricity generation, with solar thermal technology being considered for steam and hot water production and solar cooling.
- New farms keep developing in the region with some being established in undeveloped areas which often have no grid connection. In this case, it is economical for them to install PV modules instead of stretching a grid to their facilities, as grid connection costs can be very high.
- Krasnodar Krai is famous for its sun, heat, sea and picturesque sceneries and therefore attracts lots of tourists. Most of the tourist areas are at the seashore, where hotels vary in size and quality. After Sochi hosted the Olympic Games in 2014, the region became even more popular. Since then, hotels have had to ensure their power supply during outages with autonomous power supply solutions, which are nearly primarily petrol and diesel gensets.
- Local authorities are open minded and already include RES in official programs and scenarios of the regional energy system development. This process supports RES and gives a reason to be rather optimistic about the development of renewable energy sources in the region.

2.5.8 Risks and barriers

The following risks and barriers exit when developing RE in Krasnodar Krai:

- As is the case in other Russian regions, Krasnodar Krai lacks the financial resources to support the development of RES projects and private investors are often hesitant to invest in new technologies, such as solar PV, in Russia.
- Krasnodar Krai, also known as Kuban, is a specific region with a kind of "southern mentality" that is different to Moscow or Saint-Petersburg, leading to private companies and public authorities not always "walking their talk" in Krasnodar Krai. This could be the cause of a range of difficulties during a project's implementation, as negotiations (the talk) may be deemed successful and promising but with the implementation (the walk) often being more cumbersome. This should be considered during a project's initial negotiations phase with local partners. Personal contacts with local authorities and companies would be of help.
- As in other regions, there is a lack of supporting schemes and suitable legal framework for PV project development.
- There is a lack of information and data on regions with decentralized power supply and/or without the grid connection, slowing down research and efforts to understand the stand of off-grid generation in Krasnodar Krai. The analysis of the current situation and data collection should be undertaken on site before each large RES project.
- There is no mature RES market in the region and the largest CHPPs are gas-fired. The exception is small business companies which offer complex RES solutions for the power supply of private houses. Consequently, foreign organizations need to cooperate with Russian partners in the field of marketing, logistics and search for partners among local players.
- The shores of the Azov Sea are rather unsuitable for RES projects due to a strong humidity in winter and intensive icing of the grids and generating facilities. Another region where one could meet problems is Novorossijsk city, where harsh winds happen on a frequent basis. This makes it complicated to develop wind power projects in this region.

Conclusions and Recommendations

This report has shown that there is significant potential in using RES in remote areas that are not connected to a central or larger local electricity grid, and could provide relief to at least 10 million Russians. RES, such as wind and PV, were introduced to these areas in 2014, so are still very much infants in regard to their market development. Wind and PV installations are used to complement existing fuel-based installations, which are mostly run on diesel. The motivation behind installing RE solutions differs between regions because, while there are regions that are completely isolated with no connection to any type of grid, such as the Far North, Far East and Siberia, there are also regions that are serviced by the central grid but where areas can be found that are only serviced by distributed energy generators, most often gensets running on diesel.

In this report, Sakha Yakutia and Kamchatka were selected to present typical business cases for isolated territories. The situation today is such that installed diesel generators in these territories are frequently old and inefficient and need to be modernized and/or replaced. Traditionally, isolated settlements were only powered by fossil fuel generators but more recently RE technologies have emerged in these regions. The reason for this is mostly economic: project initiators are state-owned regional utilities. They are called “guaranteeing suppliers” who have the legal mandate to assure the energy supply in remote settlements. These utilities often suffer from a lack of investment capital and are therefore interested in installing energy solutions, which are the most economically viable and affordable. As a result, public investors have opted to complement existing diesel installations with RE solutions to reduce the dependence on expensive diesel deliveries to the settlements in remote areas. A potential to decrease the share of the diesel power in the hybrid energy installations further is to increase the share of RE by introducing modern energy management systems and storage solutions. These are however, often not made due to investment capital constraints. The business case calculations in this report have confirmed that high diesel costs make the payback of RE investments possible, but a number of challenges should be taken into consideration, such as, the extreme climate conditions that the equipment needs to be able to withstand and the high demands on logistics. In the past, some technical solutions failed because they did not take into account the challenging environment of these isolated/remote territories to the extent necessary. In remote areas that are not isolated territories the situation is different. This report looked into RE off-grid applications in the regions Bashkortostan, Altai and Krasnodar. Diesel prices in these areas are not as high as in the isolated territories. Here, fossil fuel savings need to be supplemented by low initial capital expenditures and other motivations, such as, high opportunity costs for alternative energy solutions and the costs associated with connecting an off-grid area to the grid.

The use of RES is a young and small phenomenon in Russia’s energy landscape. Following several dormant years, RES have started to appear, even if only as a centralized energy source. The distribution of RES, be it in isolated territories or other off-grid areas, needs to be promoted to deliver success stories. The latter can be realized with pilot projects which have the potential to show that RE can be a reliable and economically viable alternative. The development of new RES markets is not stable in Russia but the potential is most certainly there. To exploit this further and accelerate the momentum of recent developments, capacity-building and stakeholder discussions, as well as a positive pioneering spirit, will be needed by all public and private, Russian and non-Russian stakeholders alike.

Figures

Tables

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Abbreviations

Acronym	Definition
BSW	Bundesverband Solarwirtschaft (German Solar Industry Association)
CAPEX	Capital Expenditures
CHPP	Combined Heat and Power Plant
DC	Direct Current
Dcode	Distribution Code
DENA	(dena)Deutsche Energie Agentur – German Energy Agency
DPP	Diesel Power Plant
DPP	Diesel Power Plant
DSCR	Debt Service Coverage Ratio
DVGK	Far Eastern Generating Company
EEG	Erneuerbare Energien Gesetz (Renewable Energy Source Act, Germany)
EIA	Environmental Impact Assessment
EIRR	Economic Internal Rate of Return
EPC	Engineering, Procurement and Construction
ESIA	Environmental and Social Impact Assessment
EU	European Union
FIT	Feed-in Tariff
FOREX	Foreign Exchange
FSA	Fuel Supply Agreement
FX	Foreign Exchange
GDP	Gross Domestic Product
GHG	Green House Gas
GIZ	Gesellschaft für Internationale Zusammenarbeit
GPP	Geothermal Power Plant
GWp	Giga Watt peak
HPP	Hydro Power Plant
HV	High Voltage
ICT	Information and Communication Technology
IEA	International Energy Agency

IEMS	Intelligent Energy Management System
IFC	International Finance Corporation
IMF	International Monetary Fund
IPP	Independent Power Project
IRR	Internal Rate of Return
I_{SC}	Short Circuit Current
JSC	Joined Stock Company
KPI	Key Performance Indicators
kV	Kilovolt
kW	Kilowatt
kWh	Kilowatt hours
kWp	Kilowatt peak
LCOE	Levelized Cost of Electricity
LLCR	Loan Life Cycle Coverage Ratio
Ltd.	Limited Liability Company
LV	Low Voltage
MDG	Millennium Development Goals
MW	Megawatt
MWh	Megawatt hours
MWp	Megawatt peak
NPP	Nuclear Power Plant
NPV	Net Present Value
OEM	Original Equipment Manufacturer
OPEX	Operational Expenditure
PJS	Public Joint Stock Company
PPA	Power Purchase Agreement
PV	Photovoltaic
PVPS	Photovoltaic Power Systems Program
RE	Renewable Energy
RES	Renewable Energy Source
ROE	Return on Equity
ROI	Return on Investment
RSFSR	Russian Soviet Federative Socialist Republic

RUB	Russian Rubles
SHS	Smart Home Systems
SME	Small and medium-sized enterprises
SO UPS	System Operator of the United Power System
SPP	Solar Power Plant
SPV	Special Purpose Vehicle
SRS	Solar Residential Systems
UN	United Nation
UPS	United Power System of Russia
USD	United States Dollar
VAT	Value Added Tax
WACC	Weighted Average Cost of Capital

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