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RENEWABLE ENERGY PROSPECTS FOR THE RUSSIAN FEDERATION

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About IRENA

The International Renewable Energy Agency (IRENA) is an intergovernmental organisation that supports countries in their transition to a sustainable energy future and serves as the principal platform for international co-operation, a centre of excellence, and a repository of policy, technology, resource and financial knowledge on renewable energy. IRENA promotes the widespread adoption and sustainable use of all forms of renewable energy, including bioenergy, geothermal, hydropower, ocean, solar and wind energy, in the pursuit of sustainable development, energy access, energy security and low-carbon economic growth and prosperity.

This report and other supporting material are available for download through **www.irena.org/remap**

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Abbreviations

°C	degrees Celsius
ATS	Administrator of the Trading System
bcm	billion cubic meters
CCGT	combined cycle gas turbine
CENEF	Center for Energy Efficiency
CHP	combined heat and power
CNG	compressed natural gas
CO_2	carbon dioxide
COP21	21st session of the Conference of the Parties to the UNFCCC
eff.	efficiency
EJ	exajoule
EU	European Union
EUR	euros
excl.	excluding
FAO	Food and Agriculture Organization of the United Nations
FiT	feed-in tariff
FSK	federal grid company
Gcal	gigacalories
GDP	gross domestic product
GFEC	gross final energy consumption
GHG	greenhouse gas
GJ	gigajoule
Gt	gegatonnes
GW	gigawatt
GWh	gigawatt-hour
IEA	International Energy Agency
incl.	including
INDC	Intended Nationally Determined Contribution
IPS	Integrated Power System
IRENA	International Renewable Energy Agency
km^2	square kilometres
kV	kilovolts
kW	kilowatt
kWh	kilowatt-hour
LCOE	levelised cost of energy
m	metres
m^2	square metres
m^3	cubic metres
MMBtu	million British thermal unit
Mt	megatonnes
Mtoe	million tonnes of oil equivalent
MW	megawatt
MWh	megawatt-hour
n.d.	no date
OECD	Organisation for Economic Co-operation and Development
ORC	organic rankine cycle
PJ	petajoule
PV	photovoltaic
R&D	research and development
RE	renewable energy
REmap	Renewable energy roadmap analysis by IRENA
Rosatom	Rosatom State Atomic Energy Corporation
RUB	Rubles
SE4All	Sustainable Energy for All
TFEC	total final energy consumption
TJ	terajoule
toe	tonnes of oil equivalent
TWh	terawatt-hour
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
UPS	Unified Power System
USD	United States dollar
USSR	Union of Soviet Socialist Republics
VRE	variable renewable energy
WWEA	World Wind Energy Association
yr	year

KEY FINDINGS

- In 2010, renewable energy use in the Russian Federation (hereinafter also referred to as "Russia") was dominated by hydropower in the power generation sector, while bioenergy dominated heating in industry and buildings (including district heat generation). In 2010, hydropower accounted for 70% of the total final renewable energy use of 0.6 exajoules (EJ). Bioenergy accounted for most of the remaining 30%. In the same year, renewable energy's share in Russia's total final energy consumption (TFEC) was 3.6%.

- By the end of 2015, total installed renewable power generation capacity reached 53.5 gigawatts (GW), representing about 20% of Russia's total installed power generation capacity (253 GW). Hydropower represents nearly all of this capacity, with 51.5 GW, followed by bioenergy, with 1.35 GW. Installed capacity for solar photovoltaic (PV) and onshore wind amounted to 460 MW and 111 MW, respectively.

- Based on consultation with the Russian government and relevant stakeholders, this report identifies four main drivers which Russia could consider to accelerate the uptake of renewables in its energy mix: economic activity and job creation; science and technology development; energy supply to isolated areas; and improving the quality of the environment.

- In the draft Energy Strategy of Russia for the period up to 2035 ("Energy Strategy to 2035"), Russia has prepared a detailed projection of its energy use by sector and fuel. Based on the calculations which take into account the latest draft of this strategy and other sources, the Reference Case takes Russia's renewable energy share in its TFEC to 4.9% by 2030. This includes Russia's plan to expand its total solar PV, onshore wind and geothermal capacity to 5.9 GW by the end of 2024.

- In the Reference Case, total final renewable energy use nearly doubles from 0.6 EJ in 2010 to 1.1 EJ in 2030. This consumption would be equivalent to 5% of the country's total energy demand in 2030. Total final renewable energy use includes the consumption of power and district heat from renewable energy sources, renewable transport fuels and renewable fuels for cooking as well as water, space and process heating. The Reference Case renewable energy use continues to be dominated by hydropower, which represents more than half of all final renewable energy use. Given the country's large biomass resource availability, biofuels gain a larger market share for heating and transport, accounting for nearly half of all renewable energy use by 2030. Other renewable energy resources (i.e. solar PV, wind, geothermal) contribute 4%.

- Under REmap – the case that considers the accelerated deployment of renewable energy in the Russian energy mix – the share of total renewable energy increases to 11.3% of TFEC by 2030. REmap assumes a mix of renewable energy technologies in both power and end-use sectors. In REmap, the renewable energy share is estimated to be highest in the power generation sector, at about 30% in 2030. This is split into 20% hydropower and 10% wind, solar PV and geothermal renewable power. In the heating sector, the share of renewable energy would be approximately 15%. Transport would see the largest increase with renewable energy's share reaching 8% by 2030, compared to 1% in 2010.

- Under REmap, onshore wind capacity attains 23 GW, solar PV rises to 5 GW and bioenergy reaches 26 GW by 2030. Total installed hydropower capacity reaches 94 GW by 2030. Total renewable power generation grows nearly threefold between 2010 and 2030, from 169 terawatt-hours (TWh) to 487 TWh per year in the same period. This includes about 100 TWh of renewable power available for export to Asian countries from 30 GW of installed hydropower and onshore wind capacity.

- Under REmap, total primary bioenergy demand amounts to 2.4 EJ per year by 2030. This compares with the country's total supply potential, which starts at more than 2 EJ (similar to the level of all demand in 2030) and reaches 14 EJ, according to IRENA. This large range depends on the extent to which forest-based biomass feedstock is available. The large availability of biomass feedstock relative to demand is a favourable outcome, as it indicates the availability of additional resources that can be used for exports. Ensuring the supply of energy crops and biogas feedstocks, however, will be critical, as by 2030, demand for them under REmap reaches the limits of their supply.

- Under Remap, the average annual investment required to fulfil the renewable energy mix is estimated at USD 15 billion per year between 2010 and 2030. Investments for renewable power generation capacity account for nearly all of this, at USD 13 billion per year (excluding transmission and distribution infrastructure). The remaining USD 2 billion per year is for renewable energy capacity in end-use sectors.

- Implementing all REmap Options identified in this working paper would require an average substitution cost by 2030 of USD 8.7/gigajoule (GJ) of final renewable energy. This is the additional cost of all renewables to the Russian energy system that are identified under REmap. This cost is from a business perspective that assumes an 11% discount rate, a crude oil price of USD 80 per barrel and a wholesale natural gas price of USD 3.3 per million British thermal units (MMBtu). Gas is the main fuel assumed to be replaced in the power and heat generation sectors. While solar PV and onshore wind are economically viable in isolated regions, in 2030, they remain more expensive in the wholesale market. This is due to the low natural gas price assumption. Decentralised heating in buildings and for industrial processes is close to cost-competitiveness in 2030, provided that low-cost biomass feedstocks are used for generation.

- When externalities related to human health and climate change are accounted for, renewables identified under REmap can save up to USD 8 billion per year by 2030.

- A number of areas require further attention to realise the potential estimated in this working paper. These include: the continuation of long-term energy planning; the integration of renewable energy into existing energy policies and their implementation; minimising investment and market barriers for solar PV and wind to accelerate uptake at their early stages of deployment; and the creation of a reliable and affordable market for bioenergy.

КЛЮЧЕВЫЕ ВЫВОДЫ

- В России в 2010 году наиболее востребованным видом возобновляемого источника теплоэнергии, используемого в секторах промышленности и жилищно-коммунального хозяйства (включая центральное отопление), была биоэнергия, а в производстве электроэнергии доминировала гидроэнергетика. В 2010 году на гидроэнергетику и биоэнергетику приходилось соответственно 70% и 30% общего конечного энергопотребления (0,6 эксаджоулей, ЭДж) возобновляемой энергии. В том же году доля возобновляемой энергетики в общем объеме конечного энергопотребления России составила 3,6%.

- К концу 2015 года общая установленная электрическая мощность объектов, функционирующих на основе использования возобновляемых источников энергии (ВИЭ), достигла 53,5 Гигаватт (ГВт), что составило порядка 20% от общей установленной электрической мощности в России (253 ГВт). На гидроэнергетику пришлась практически вся установленная мощность – 51.5 ГВт, далее в объеме 1,35 ГВт следовала биоэнергетика. Установленные мощности солнечных и ветряных электростанций составили 460 МВт и 111 МВт соответственно.

- В отчете, основанном на результатах консультации с Правительством России и соответствующими заинтересованными сторонами, выделяются четыре главные движущие силы, которые, по мнению России, ускорят внедрение ВИЭ в структуру российской энергетики: экономическая деятельность и создание новых рабочих мест, развитие науки и технологий, поставка энергии в изолированные энергорайоны, повышение качества окружающей среды.

- В Энергетической стратегии России на период до 2035 был разработан детальный план энергопотребления: как в отраслевом разрезе, так и согласно основным видам топлива. Исходя из расчетов, основанных на проекте Стратегии и данных других источников, при сценарии «обычного хода деятельности» (Reference case) к 2030 году на долю ВИЭ будет приходиться 4.9% конечного энергопотребления (TFEC). Это включает планы России по увеличению солнечных, ветровых и геотермальных генерирующих мощностей до 5,9 ГВт к концу 2024 года.

- При сценарии «обычного хода деятельности» конечное потребление энергии, произведенной объектами ВИЭ, увеличится почти в два раза с 0,6 ЭДж в 2010 году до 1,1 ЭДж в 2030, что в свою очередь составит порядка 5% от спроса на все виды энергии в 2030 году. Конечное потребление возобновляемой энергии включает потребление электрической и тепловой возобновляемой энергии, потребление биотоплива для транспортных средств, приготовления пищи, а также для отопления и технологического нагрева. При сценарии «обычного хода деятельности» гидроэнергетика продолжит оставаться главным ВИЭ, покрывающим больше половины объема конечного потребления возобновляемой энергии. С учетом доступности значительных резервов биомассы в России, рынок биоэнергетики значительно возрастет за счет увеличения использования биотоплива для производства тепловой энергии и использования в транспортном секторе. Таким образом, в 2030 биотопливо придется на половину конечного использования возобновляемой энергии для производства тепловой энергии и в транспортном секторе. Использование остальных видов ВИЭ (солнечных, ветряных и геотермальных) увеличится на 4%.

- Согласно REmap сценарию, в котором рассматривается ускоренное увеличение доли возобновляемой энергетики в энергетическом секторе России, к 2030 году её объем в конечном потреблении достигнет 11.3%. REmap предполагает использование комплекса различных технологий возобновляемой энергетики в секторах производства и конечного потребления энергии. В соответствии с REmap, самая большая доля возобновляемой энергии придется на сектор производства электроэнергии, составив в 2030, около 30%, где 20% – гидроэлектроэнергия, а 10% – такие виды электроэнергии, как ветряная, солнечная и геотермальная. Доля возобновляемой энергии в производстве тепловой энергии составит около 15%. В транспортном секторе будет наблюдаться самый большой темп роста использования возобновляемой энергии: к 2030 году он достигнет отметку 8% по сравнению с 1% в 2010.

- Согласно сценарию REmap, суммарная установленная мощность ветряных электростанций достигнет 23 ГВт, мощность солнечных электростанций возрастет до 5 ГВт, а биоэнергетических установок до 26 ГВт. К 2030 общая установленная мощность гидроэлектростанций возрастет до 94 ГВт. В период между 2010-2030 общее производство электроэнергии увеличится практически в три раза с 169 ТВт·ч до 487 ТВт·ч в период между 2010-2030, что высвободит порядка 100 ТВт·ч электроэнергии, выработанной гидроэлектростанциями и ветроустановками суммарной мощностью 30 ГВт, доступной для экспорта в страны Азии.

- Согласно REmap, в 2030 году спрос на первичные биоэнергетические ресурсы составит 2.4 ЭДж, что, исходя из оценки IRENA, соизмеримо с потенциалом страны 2-14 ЭДж. Это самый благоприятный исход с точки зрения доступности ресурсов, что указывает на возможность осуществления их экспорта. Однако, чрезвычайно важно обеспечить поставки энергетических культур и исходного сырья для производства биогаза, поскольку в 2030 году спрос будет примерно равен предложению.

- Суммарный объем необходимых инвестиций для достижения сценария REmap оценен в 300 миллиардов долларов США за период 2010-2030, что соответствует среднегодовой потребности в инвестициях в размере 15 миллиардов долларов США за тот же период. На ввод новых генерирующих мощностей, функционирующих на основе ВИЭ, потребуется практически весь объем ежегодных инвестиций в размере 13 миллиардов долларов США (за исключением инвестиций на передачу и распределение энергии). Оставшиеся 2 миллиарда долларов США будут направлены на сектора конечного потребления.

- В 2030 году внедрение всех рассмотренных REmap Опций в среднем потребует затрат на замещение в размере 8,7 долл/ГДж возобновляемой энергии. Согласно REmap, данный показатель представляет собой дополнительные расходы на все виды ВИЭ российской энергосистемы. Данная стоимость исходит из условий 11% учетной ставки, цены на нефть на уровне 80 долл/барр и оптовой цены на газ на уровне 3.3 дол за миллион британских термических единиц (BTU). Предполагается, что природный газ будет главным топливом, замещенным в тепло- и электроэнергетике. Хотя солнечные и ветряные электростанции являются экономически жизнеспособными в энергетически изолированных областях, в 2030 цена выработанной этими электростанциями энергии будет оставаться выше оптовой. К 2030 децентрализованное отопление в домах и в промышленности станет более конкурентоспособным, если для выработки тепловой энергии используются недорогостоящие биоэнергоресурсы.

- Если принимать во внимание такие внешние факторы, как здравоохранение и изменение климата, то становится ясно, что благодаря отраженному в REmap потенциалу ВИЭ к 2030 году, можно ежегодно экономить до 8 миллиардов долларов США.
- Необходимо уделять больше внимания целому ряду других сфер в целях реализации всего оцененного в данном документе потенциала ВИЭ, включая продолжение работы над долгосрочным энергетическим планированием, интеграцию возобновляемой энергетики в существующую энергетическую политику и её осуществление, оптимизацию инвестиций и устранение рыночных барьеров для солнечных и ветряных установок для ускорения их адаптации на ранних стадиях развития проектов, и создание надежного и доступного рынка биоэнергоресурсов.

1. INTRODUCTION TO IRENA'S REMAP WORK AND BRIEF METHODOLOGY

1.1 IRENA's REmap programme

REmap aims at paving the way to the promotion of accelerated renewable energy development through a series of activities that include the issue of global, regional and country level studies. REmap analyses and activities also serve to develop other IRENA-related publications that focus on specific renewable technologies, or energy sectors.

The REmap programme is undertaken in close collaboration with governmental bodies and other institutions responsible for energy planning and renewable energy development. The analyses are carried out through broad consultations with energy experts and stakeholders from numerous countries around the world.

At its inception, REmap emerged as IRENA's proposal for a pathway to achieve the United Nations (UN) Sustainable Energy for All (SEforAll) initiative, in its objective to double the global share of renewable energy by 2030, compared to 2010 levels (UN and The World Bank, 2016). Today, attaining widespread development of renewables has also become crucial to meet the objective of the Paris Agreement adopted at the 21st session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (COP21), and the long-term global temperature goal of maintaining the Earth's temperature increase below 2 degrees Celsius (°C) above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C.

In order to achieve the doubling of renewable energy's share at the global level, REmap follows a bottom-up approach. Country-level assessments are carried out to determine the potential contributions that each could make to the overall renewable share. The first global REmap report published in 2014 included a detailed analysis of 26 countries, encompassing the major energy consumers, representing around 75% of global energy demand. The Russian Federation (throughout this text referred to as "Russia") was one of them. The second issue of the report expanded its coverage to 40 countries, accounting for 80% of world energy use.

The REmap analysis of the national plans of these 40 countries suggests that the global share of renewables would only reach 21% under current conditions and policy approaches, unless extra attention is paid to the matter. This indicates a 15 percentage-point gap to a doubling of the global RE share by 2030 (IRENA, 2016a).

The energy sector of Russia has been undergoing several reforms in recent years. This has helped Russia to liberalise its electricity and natural gas markets and adjust prices closer to international levels. The country, however, still lags behind other emerging economies in terms of the efficient uses of its energy, owing to an out-dated transmission and distribution network for heat and electricity, as well as aging industrial and power plant stock. While the focus of the sector is increasingly on improving the energy efficiency of the economy, currently a traditional fossil fuel user, Russia is also now opening its markets to renewables. To raise its renewable energy use, Russia has the potential to employ its vast resources of various types of renewables, including bioenergy, geothermal, hydro, solar and wind for electricity and heat generation, as well as transport.

In 2015, IRENA and the Russian government agreed to prepare this working paper (referred to as the "report" throughout the text) to explore the potential difference renewable energy could make to diversify the country's energy mix. The present report aims at presenting the detailed REmap Russia analysis and elaborates on the renewable technology options that the country could deploy further, in order to achieve a higher renewable share by 2030.

1.2 The REmap approach

This section explains the REmap methodology and summarises details about the background data used for the Russia analysis. The Annexes provide the relevant data and results in greater detail.

REmap is an analytical approach. It assesses the gap between the situation if all countries worldwide would follow their present national plans, the potential additional renewable technology options in 2030 and a doubling of the global renewable energy share by 2030. By March 2016, in IRENA's REmap programme, the renewables potential of 40 countries had been assessed: Argentina, Australia, Belgium, Brazil, Canada, China, Colombia, Cyprus, Denmark, Dominican Republic, Ecuador, Egypt, Ethiopia, France, Germany, India, Indonesia, Iran, Italy, Japan, Kazakhstan, Kenya, Kuwait, Malaysia, Mexico, Morocco, Nigeria, Poland, Republic of Korea, the **Russian Federation**, Saudi Arabia, South Africa, Sweden, Tonga, Turkey, Ukraine, the United Arab Emirates, the United Kingdom, the United States and Uruguay.

The analysis starts with national data covering all energy end-users (buildings, industry, transport and agriculture) and the electricity and district heating sectors. Current national plans using 2010 as the base year of this analysis are the starting point. To the extent data availability allows, information for more recent years (e.g. 2015) was provided where relevant. In each report, a **Reference Case** features policies in place or under consideration, including energy efficiency improvements. The Reference Case includes total final energy consumption (TFEC) for each end-use sector and the total generation of power and district heating sectors, as well as breakdowns by energy carrier for 2010-2030.

Once the Reference Case is prepared, additional renewable technology options are identified and labelled in the report as **REmap Options**. The use of options as opposed to an approach based on scenarios is deliberate. REmap 2030 is an exploratory study and not a target-setting exercise. Each REmap Option substitutes a non-renewable energy technology used to deliver the same amount of energy (e.g. power, cooking heat etc.). The implementation of REmap Options results in a new energy mix with a higher share of renewables, which is called the **REmap** case. Non-renewable technologies include fossil fuels, nuclear and traditional uses of bioenergy. As a supplement to the annexes in this report, a detailed list of these technologies and related background data are provided online.

Throughout this report the renewable energy share is estimated in relation to TFEC.[1] Modern renewable energy excludes traditional uses of bioenergy[2]; the share of modern renewable energy in TFEC is equal to total modern renewable energy consumption in end-use sectors (including consumption of renewable electricity and district heat and direct uses of renewables), divided by the TFEC. The share of renewables in power generation is also calculated. The renewable energy share can also be expressed for the direct uses of renewables only. The renewable energy use by end-use sector comprises the following:

- **Buildings** include the residential, commercial and public sectors. Renewable energy is used in direct applications for heating, cooling or cooking purposes, or as renewable electricity.
- **Industry** includes the manufacturing and mining sectors, where renewable energy is consumed in direct use applications that comprise mainly process heat, and as electricity from renewable sources.
- **Transport** sector, which can make direct use of renewables through the consumption of liquid and gaseous biofuels, or through the use of electricity generated by means of renewable energy technologies.

1.3 Metrics for assessing REmap Options

In order to assess the costs of REmap Options, **substitution costs** are calculated. This report also discusses the costs and savings from renewable

1 Total final energy consumption (TFEC) is the energy delivered to consumers, whether as electricity, heat or fuels that can be used directly as a source of energy. This consumption is usually sub-divided into that used in: transport; industry; residential, commercial and public buildings; and agriculture; it excludes non-energy uses of fuels.

2 The UN Food and Agriculture Organization of the United Nations defines traditional use of biomass as "woodfuels, agricultural by-products, and dung burned for cooking and heating purposes". In developing countries, traditional biomass is still widely harvested and used in an unsustainable, inefficient and unsafe way. It is mostly traded informally and non-commercially. So-called modern biomass, by contrast, is produced in a sustainable manner from solid wastes and residues from agriculture and forestry, and is utilised with more efficient methods (IEA and the World Bank, 2015).

energy deployment and the consideration of related externalities from climate change and air pollution. Four main indicators have been developed, namely **substitution costs, system costs**, **total investment needs** and **needs for renewable energy investment support**.

Substitution cost

Each renewable and non-renewable technology has its own individual cost relative to the non-renewable energy it substitutes. This is explained in detail in the methodology of REmap (IRENA, 2014a) and is represented in the following equation:

Cost of Technology/REmap Options USD/year in 2030 = **Equivalent annual capital expenditure** USD/year in 2030 + **Operating expenditure** USD/year in 2030 + **Fuel cost** USD/year in 2030

For each REmap Option, the analysis considers the costs of substituting a non-renewable energy technology to deliver the same amount of heat, electricity or energy service. The cost of each REmap Option is represented by its **substitution cost**[3]:

Substitution cost USD/GJ in 2030 = (**Cost of REmap Options** USD/year in 2030 − **Cost of substituted conventional technology** USD/year in 2030) / (**Energy substituted by REmap Options** GJ/year in 2030)

This indicator provides a comparable metric for all renewable energy technologies identified in each sector. Substitution costs are the key indicators for assessing the economic viability of REmap Options. They depend on the type of conventional technology substituted, energy prices and the characteristics of the REmap Option. The cost can be positive (additional) or negative (savings) due to the fact that many renewable energy technologies are, or by 2030 could be, cost-effective compared to conventional technologies.

3 Substitution cost is the difference between the annualised cost of the REmap Option and the annualised cost of the substituted non-renewable technology, used to produce the same amount of energy. This is divided by the total renewable energy use substituted by the REmap Option.

System costs

Based on the substitution cost, inference can be made as to the effect on **system costs**. This indicator is the sum of the differences between the total capital and operating expenditures of all energy technologies based on their deployment in REmap and the Reference Case, in 2030.

System costs USD/year in 2030 = **Substitution cost: government perspective** All technologies USD/GJ in 2030 X **REmap Options** All technologies GJ/year in 2030

Investment needs

Investment needs for renewable energy capacity can also be assessed. The total **investment needs** of technologies in REmap are higher than in the Reference Case due to the increased share of renewables which, on average, have higher investment needs than the non-renewable energy technology equivalent. The capital investment cost (in United States dollar (USD) per kilowatt, USD/kW of installed capacity)[4] in each year is multiplied by the deployment in that year to arrive at total annual investment costs. The capital investment costs of each year are then summed over the period 2010-2030. Net incremental investment needs are the sum of the differences between the total investment costs for all technologies, renewable and non-renewable energy, in power generation and stationary applications in REmap and the Reference Case in the period 2010-2030 for each year. This total was then turned into an annual average for the period.

Average investment needs USD/year 2016–2030 = (**Renewable capacity installed** Total GW 2016–2030 X **Average capital expenditure** USD/GW 2016–2030) / (**15** Number of years 2016–2030)

Renewable investment support

Renewable investment support needs can also be approximated based on the REmap tool. Total

4 For the purpose of this analysis, a currency exchange rate of Rubles (RUB) 48 per 1 USD that refers to the year 2014 was assumed.

requirements for renewable investment support in all sectors are estimated as the difference in the delivered energy service cost (e.g. in USD/kWh or USD/GJ, based on a government perspective) for the renewable option against the dominant incumbent in 2030. This difference is multiplied by the deployment for that option in that year to arrive at an investment support total for that technology. The differences for all REmap Options are summed to provide an annual investment support requirement for renewables. Notably, where the renewable option has a lower delivered energy service cost than the incumbent option, which begins to occur increasingly by 2030, it is not subtracted from the total.

Investment support for RE USD/year in 2030 = **Substitution cost: government perspective** Technologies with positive substitution cost USD/GJ in 2030 x **REmap Options** Technologies with positive substitution cost GJ/year in 2030

Government and business perspectives

Based on the substitution cost and the potential of each REmap Option, country cost-supply curves have been developed for the year 2030 from two perspectives: **government** and **business**:

- **Government perspective:** Cost estimates exclude energy taxes and subsidies, and in the latest global REmap report (IRENA, 2016a), a standard discount rate of 10% for non-OECD member countries, or 7.5% for OECD member countries, was used. This approach allows for a comparison across countries and for a country cost-benefit analysis; it shows the cost of the transition as governments would calculate it.

- **Business perspective:** This considers national prices (including, for example, energy taxes, subsidies and the cost of capital) in order to generate a localised cost curve. This approach shows the cost of the transition as businesses or investors would calculate it. In the case of Russia, a discount rate of 11% is assumed.

- By estimating the costs from the two perspectives, the analysis shows the effects of accounting for energy taxes and subsidies, while all other parameters are kept the same. The assessment of all additional costs related to complementary infrastructure is excluded from this report (e.g. grid reinforcements, fuel stations, etc.). IRENA analysis suggests that these costs would be of secondary importance for countries that are just starting with an energy system transformation.

Externality analysis

The externality reductions that would be obtained with the implementation of REmap Options that are considered include: health effects arising from outdoor exposure; health effects arising from indoor exposure in the case of traditional use of bioenergy; and effects on agricultural yields. Additionally, the external costs associated with the social and economic impact of carbon dioxide (CO_2) are estimated (IRENA, 2016b).

Further documentation and a detailed description of the REmap methodology can be found at *www.irena.org/remap* Further details on metrics for assessing Options can be consulted in Appendix of the global report 2016 edition (IRENA, 2016a).

1.4 Main sources of information and assumptions for REmap Russia

In order to introduce the background data and literature that has been used to prepare REmap Russia, the main sources and assumptions are summarised below for each case:

- **Base year 2010:** The energy balances for the analysis base year, 2010, originate from data provided by the International Energy Agency (IEA, 2015a). Where relevant, the data has been updated with the national energy statistics provided by the Russian government. As mentioned earlier, for the REmap analysis, all end-use demand is broken into sectors: industry, transport and buildings.

- **Reference Case:** For Russia, this was based on the Energy Strategy of Russia for the period to 2030 (hereinafter referred to as "Energy Strategy to 2030") and data provided by the Ministry of Energy of the Russian Federation in its latest results of the "Energy Strategy to 2035"

(Minenergo, 2017) (personal communication with the Ministry of Energy of the Russian Federation) accompanied by IRENA's calculations based on the aforementioned data.

- **REmap:** This is based on IRENA's analysis (details of sources and assumptions can be found in Chapter 3 and in Annex 3). The renewable energy technology potential between REmap and the Reference Case is called the "REmap Options".

Finally, energy supply and demand numbers in this report are generally provided in gigajoule (GJ), petajoule (PJ) or exajoule (EJ), the standard for REmap. In Russia, commonly used units are tonnes of oil equivalent (toe) and tonnes of coal equivalent (tce). Below are the relevant conversion factors:

- 1 GJ = 0.0238 tonnes of oil equivalent (toe)
- 1 GJ = 0.0341 tonnes of coal equivalent (tce)
- 1 GJ = 277.78 kilowatt-hour (kWh)
- 1 PJ = 0.0238 million tonnes of oil equivalent (Mtoe)
- 1 PJ = 277.78 gigawatt-hour (GWh)
- 1 EJ = 23.88 million tonnes of oil equivalent (Mtoe)
- 1 EJ = 277.78 terawatt-hour (TWh)

This report is structured as follows: Chapter 2 introduces the current renewable energy situation in Russia. Chapter 3 provides a brief overview of Russia's energy markets; Chapter 4 describes the renewable energy developments according to the Reference Case; Chapter 5 presents the additional potential of renewable energy by 2030 and discusses how this potential could be realised by identifying the possible opportunities and proposing solutions to policy-makers and other relevant stakeholders.

2 CURRENT RENEWABLE ENERGY SITUATION IN RUSSIA

The main purpose of this chapter is to provide an overview of the current state of renewable energy use in Russia. It will look at the drivers for renewable energy deployment and those policies relevant to an acceleration of uptake in the country. The chapter also provides a brief overview of Russia's resource potential.

2.1 Current status of renewables

Power sector

Bioenergy and large hydropower are the main sources of renewables in Russia's energy system. In 2015, total installed renewable power capacity reached 53.5 GW. This represents about 20% of the country's total installed power generation capacity (approximately 253 GW). Small and medium hydropower represents about 280 MW of this total.[5] This total also includes about 1.2 GW of pumped hydro (IRENA, 2016c). There are more than 100 hydropower plants each with a capacity higher than 100 MW. Hydropower is followed by bioenergy, with 1.35 GW of total installed capacity from 39 plants (including 2.9 MW of installed biogas capacity from two plants). The average bioenergy power plant has a total capacity of 35 MW. Most facilities are combined with other fuels (personal communication with the Ministry of Energy of the Russian Federation, 2017).

Excluding hydropower and bioenergy, the remaining renewable power generation capacity is spread among solar PV, wind and geothermal. This amounts to a total of 660 MW. By the end of 2015, total power generation capacity for solar PV and wind amounted to 460 MW and 111 MW, respectively.

Russia has been installing solar PV capacity since 2010, and since 2013, capacity installations have accelerated. For instance, one of the largest solar power plants in the country, in Kaspiysk, Dagestan, came into operation in 2013, with a total capacity of 1 MW (Kavkaz, 2013). In the same year, another five smaller plants, with a total capacity of 166 kW were put in operation. Both solar PV and onshore wind are developing further in Russia.

In 2015, about 57 MW of new renewable energy capacity was introduced (excluding large hydropower and bioenergy). In 2016, new capacity introduced to the system reached about 70 MW. During 2017, the Ministry of Energy of the Russian Federation expects the commissioning of renewable energy capacity of more than 100 MW (Energy-Fresh, 2017).

Installed geothermal capacity, mainly located in the eastern part of Russia, has reached 86 MW end of 2015. One of the most important trends in the development of the country's geothermal energy is the building of binary geothermal power plants. There are three large-scale geothermal power plants in operation in Kamchatka: two of them of 12 MW and one of 50 MW total installed capacity. These are located in the Verkhne Mutnovsky and Mutnovsky fields, respectively, while another plant, with a total installed capacity of 11 MW, is located in the Pauzhetsky field. In addition, on the Kuril Islands (Kunashir and Iturup) two small-scale plants are in operation with capacities of 3.6 MW each (Svalova and Povarov, 2015).

All the plants in operation today employ single flash technology (Bertani, 2015). The construction of a new plant on the Kamchatka Peninsula with an organic rankine cycle (ORC) is being completed by RusHydro. ORC technology allows an increase in the total installed capacity of the existing plant without drilling new wells, since the geothermal fluid is used more efficiently (Nikolskiy *et al.*, 2015).

Total installed large tidal power plant capacity in Russia is around 400 kW. The country's single plant was built in 1967 and is located at Kislaya Guba. This has a mean tide range of 2.3 meters (Gorlov, 2009).

5 If small hydropower were to be defined according to the IRENA convention of capacity less than 10 MW, total installed capacity would amount to 175 MW.

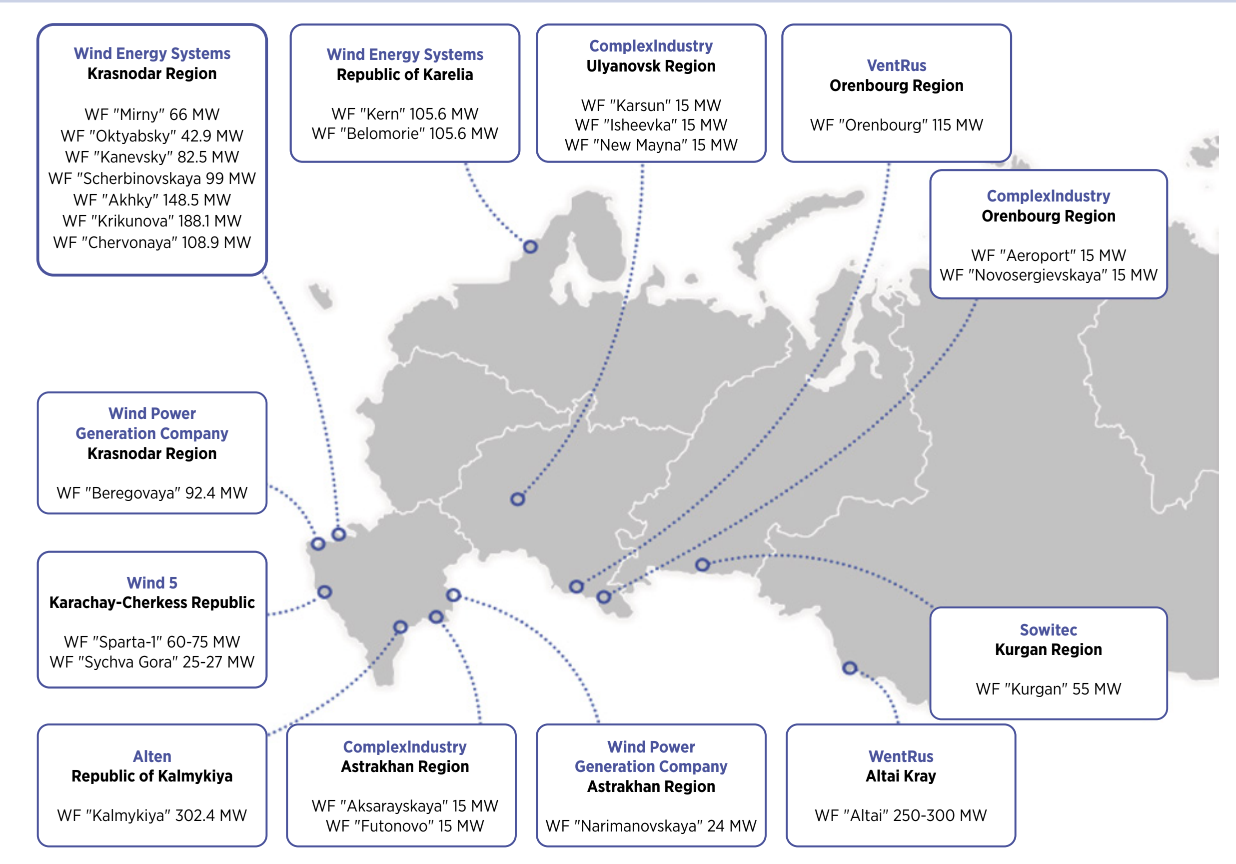
Most renewable energy capacity is built next to demand centres, which are largely in the European part of Russia. Although these are not necessarily the regions with the best resource availability, plants built there benefit from the availability of the existing grid. Meanwhile, off-grid systems are increasingly being built in Siberia and the Far East, where population density is very low.

A significant share of the total bioenergy based generation capacity is located in the northwestern part of the country. Existing solar PV, wind and small hydropower are mainly in the renewable energy resource-rich southern parts of Russia. For instance, the majority of solar PV and onshore wind capacity is located in the southwest of the country.

In autumn 2014, a 5 MW PV station was launched in Kosh-Agach (Greenevolution, 2015) in the Altai Region, with this capacity then doubled in 2015. At the end of that year, two further solar PV stations were put into operation: one in Orenburg and the other in the Republic of Khakasia. At launch, these had installed capacities of 25 MW and 5.2 MW, respectively (Romanova, 2015). The former is one of the largest solar power stations in the country, and is projected to grow in capacity by as much as 15 MW by 2017. In addition, Hevel Solar is planning to invest about USD 450 million for solar PV projects in 2018 (Ayre, 2015).

A considerable impetus to today's development of domestic wind energy was given by legislative and subordinate acts related to wind energy development. These opened opportunities for developers and have resulted in the launching of wind energy projects in different parts of the country. Figure 1 provides an overview of the wind power projects in Russia that are in progress. A large number of these are being developed in southwestern Russia, despite the fact that the wind resources there are somewhat less favourable than in other parts. This is because much of the population lives in these areas of Russia and stronger transmission grids are available.

Figure 1: Wind energy projects in Russia



Source: Ermolenko, 2015

Russia's Energy Strategy to 2030 estimates a total capital investment need for all types of generation capacity (including non-renewable energy) of USD 355-544 billion up to 2030 (at 2007 prices), or on average USD 17-26 billion per year (for all types of power generation capacity). This excludes any investment in network infrastructure, which is estimated at USD 217-344 billion, or on average USD 10-16 billion per year. For renewable energy capacity (including large hydro), the required annual investment in generation capacity up to 2020 is USD 11 billion per year (IEEFA, 2016).

In terms of generation, total electricity production from renewables reached 184 TWh per year in 2015. Hydropower and bioenergy accounted for nearly all of this generation (182.8 TWh/yr). Wind had the lowest share of all (55 GWh/yr). This is explained by the fact that very few wind power plants are in operation today, and these plants have low capacity factors. This is due to the fact that domestic production capacity for wind power is not sufficiently developed. As a result, many wind power components have to be purchased abroad. Nevertheless, the government is taking measures to stimulate the development of wind power generation. As a result of these efforts, in June 2016, the last call for project proposals considered only wind power projects.

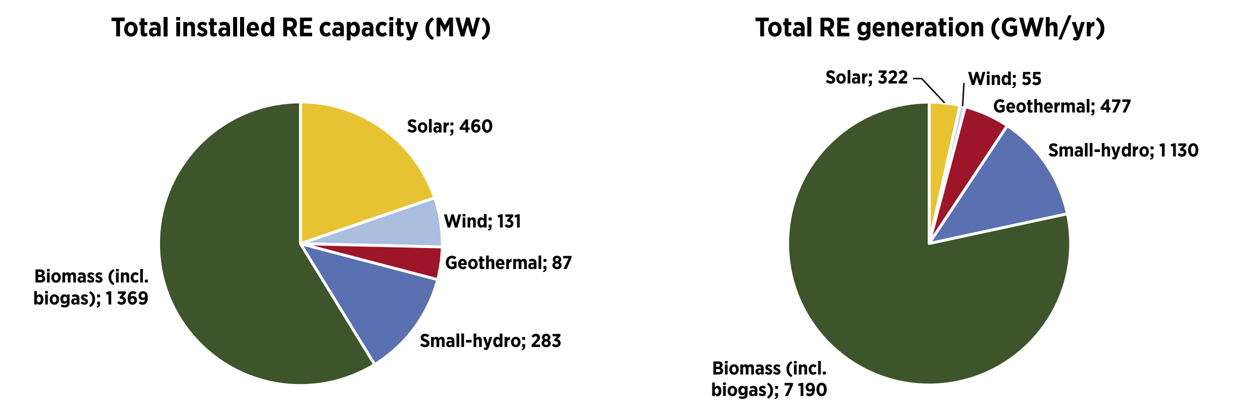
In 2015, generation from small hydropower plants reached 1.1 TWh/yr. The average capacity factor of small hydropower plants is around 46% (approximately 4000 hours per year), which is slightly higher than the 42% achieved by large hydropower plants. Total electricity generation from solar PV plants reached 322 GWh/yr in 2015, and from geothermal 477 GWh/yr (Figure 2).

Hydropower installed capacity grew from 43.7 GW in 2000 to 51.5 GW in 2015 (IRENA, 2016c). This represents an average annual growth of approximately 500 MW. Large hydropower accounted for the majority of the capacity additions. In particular, the last few years of the period saw capacity additions of about 1 GW or more. With these additions, hydropower generation reached around 175 TWh per year in 2015, but still represented a low share, at around 22%, of Russia's economically feasible hydropower potential (Hydropower & Dams, 2014).

The era of a large hydropower generation began in the former Union of Soviet Socialist Republics (USSR) in the 1930s and continued until the beginning of the 1990s. The Russian state-owned company RusHydro is the biggest hydropower producer in the country. This operates more than 70 renewable energy facilities, including:

- Russia's largest, the Sayano-Shushenskaya hydropower plant in Khakassia

Figure 2: Total installed renewable power capacity and generation by technology, 2015



Source: Minenergo, 2017

- the nine stations of the Volga-Kama cascade, with a total installed capacity of over 10 GW
- the high-performance Bureya hydropower station in the Far East (2 010 MW) and the Zeya hydroelectric station (1330 MW) in the Amur region
- the Kolyma hydropower plant (900 MW) in the Magadan region
- the Novosibirsk hydropower plant (455 MW)
- dozens of hydropower plants in the North Caucasus, including the Chirkeyskaya hydropower plant (1 000 MW).

RusHydro is also building a series of hydropower stations in various regions of Russia. The largest of these is the Boguchanskaya hydropower plant (3 GW) on the Angara River in the Krasnoyarsky Kray. The construction of this is being managed in cooperation with RUSAL. In the Moscow region, RusHydro is building the Zagorsk pumped-hydro storage plant, which has an operating installed capacity of 1 200 MW. The second phase of this project is now under construction, with an 840 MW design capacity. Other RusHydro projects in operation include the Zaramagskaya hydropower plant (352 MW) in North Ossetia; the Zelenchukskaya pumped-hydro storage project (140 MW) in Karachay-Cherkessia; and the Gotsatlinskaya hydropower plant (100 MW) in Dagestan, In addition, there are several small hydropower plants under construction. In the Far East, ongoing projects include the Ust-Srednekanskaya hydropower plant (570 MW) in the Magadan Region and the Lower Bureya hydropower plant (320 MW) in the Amur river region (RusHydro, 2016).

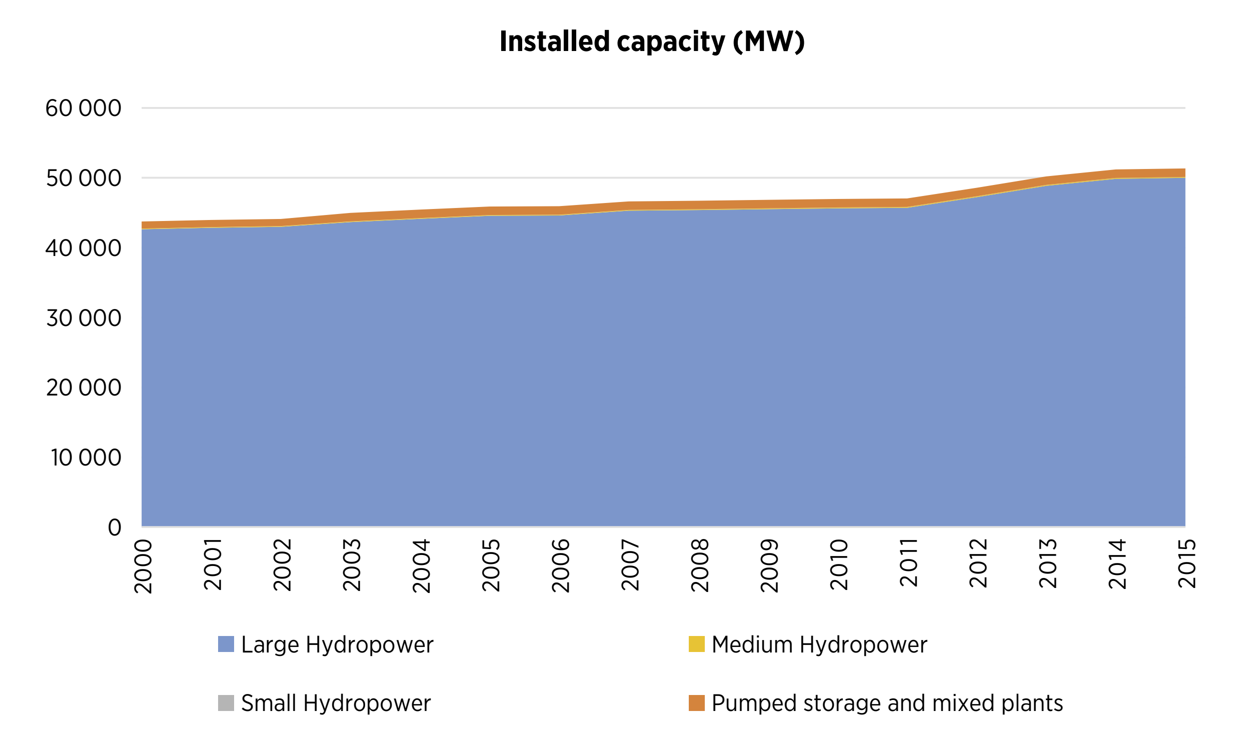
In recent times, Russia's power system has taken important steps towards modernisation, although there is still room for further improvement, with hydropower no exception. Some efforts are already underway to improve the current situation. Russia's EuroSibEnergo has announced a programme for modernization, with a total budget of USD 200 million. Through this programme, three plants – with a total installed power generation capacity of more than 14 GW – will be upgraded. These are the 6 000 MW Krasnoyarsk plant, the 4 500 MW Bratsk plant and the 3 840 MW Ust-Ilimsk plant. The work includes the replacement of a number of power plant components with domestically produced alternatives, such as the hydraulics, turbine runners, generator transformers and switchgears (Michael Harris, 2016).

Meanwhile, some 78% of hydropower's economic potential remains unutilised. This capacity is mainly located in remote areas of Russia, such as in Siberia or the Far East. Utilising this potential may not necessarily be economically feasible, as electricity demand is low in these areas and transmitting this power to the west may be costly. Nevertheless, the government is considering ways to create economic activity based on these resources. One way could be to use this unexploited capacity to supply electricity to data centres. Construction and operation of data storage can be cost-effective in these regions because of the large availability of land and the cold temperatures. As an example, the first data centre in Russia started operation in 2015 in Irkutsk. This centre is located close to three hydropower plants (Bierman and Fedorinova, 2015).

Another strategy that is being discussed for the use of Russia's best wind resources, which are located on the Pacific Coast, is electricity export to China. These resources are close to the northeastern Chinese provinces of Heilongjiang and Jilin – which are heavily polluted. Since 2015, Russia and China have been exploring the possibility of investing in 50 GW of onshore wind power capacity in the Far East (Shumkov, 2015). This can cover about 2% of China's current total final demand for electricity. For the purpose of realising this strategy, 27 resource areas for research have been identified in the northern and eastern parts of Russia, taking into account the economic feasibility of constructing high-voltage transmission lines (Nikolaev, 2016). The best regions determined for this project are located in Taimyr, Sakhalin and southern Siberia. Some private sector stakeholders, however, see the size of this project as too ambitious. Likewise, there are ongoing discussions over the export of hydropower to Pakistan and geothermal power from the Kamchatka peninsula to Japan (Sputnik, 2016).

In addition to China, there are opportunities for the export of electricity produced from wind, biomass and hydropower to Europe. This could create synergies between the two regions, with the European Union (EU) being able to realise its renewable power targets faster and Russia benefiting from the creation of a

Figure 3: Development of hydropower capacity in Russia, 2000-2015



Note: Large hydropower: >10 MW; medium hydropower: 1-10 MW; small hydropower: <1 MW

Source: IRENA, 2016c

local industry (Boute and Willems, 2012; European Commission, 2013).

End-use sectors

In end-use sectors, namely buildings, industry and transport, the main source of renewable energy is bioenergy.

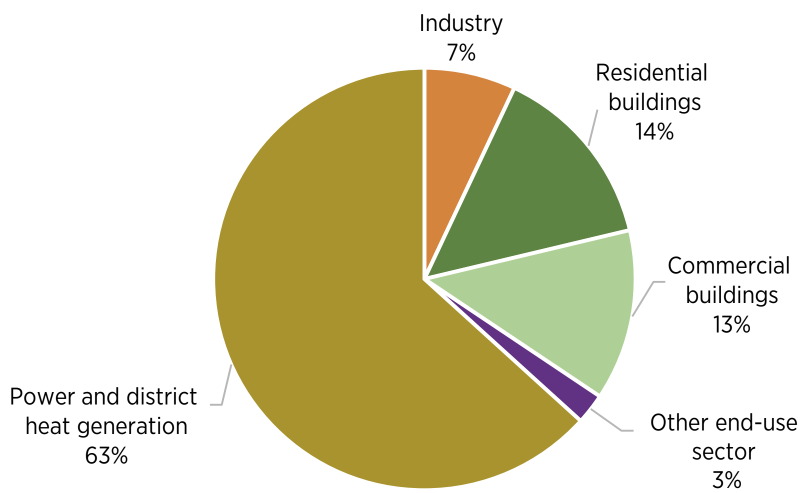
In 2014, total primary bioenergy and waste use reached 290 PJ/yr (see Figure 4). This can be split into 60% waste (i.e. renewable and non-renewable industrial and municipal waste) and 40% solid and gaseous biofuels. About 63% of this total is used for power and district heat generation. The other 37% is used for heating, mainly in buildings, but also to some extent in the agriculture and industry sectors. In power and district heat generation, the main resource is industrial waste. In buildings, solid biofuels are more typically used.

The transport sector has seen limited growth in liquid biofuel use. Current fuel ethanol production is about 150 000 litres per year (3 TJ/yr), representing a negligible share of the country's total transport sector energy demand (3 916 PJ/yr). There is no biodiesel production so far. A joint programme between the private sector's "Corporation of Biotechnology" and the public sector's RosTechnology, however, aims to construct ethanol production facilities using cellulosic feedstocks. One facility, with a total investment cost of USD 20 million, is under construction in Irkutsk and the plan is to produce 30 000 tonnes of butanol and 100 000 tonnes of wood pellets (USDA, 2015). There are also plans to expand production of liquid biofuels in several regions, including Tatarstan, Omsk, Tomsk, Volgograd, Lipetsk, Penza and Rostov (Vasilov, 2013).

The total area of solar thermal collectors in Russia is still small, not exceeding 30 000 m^2 (around 0.03 GW). This is equivalent to 0.2 m^2/1000 people, which is significantly lower than the level achieved in central European countries such as Austria or Germany.

Most Russian solar thermal collectors are installed in the southern regions of the country, including Krasnodar, Stavropol Krai and the Astrakhan region, which have

Figure 4: Breakdown of bioenergy and waste use in the heating and power generation sectors, 2014



Source: IEA, 2015a

the highest levels of solar irradiation. The Republic of Buryatia, situated in the south of Eastern Siberia, also has a high level of solar irradiation and a significant number of operating solar collectors.

NPO Machinostroyniy, which is based in Reutovo (Moscow region) is one of Russia's leading machine-building companies and currently Russia's largest manufacturer of solar collectors. Another large-scale production facility for solar collectors is located in Ulan-Ude (Buryatia), where Chinese parts are mostly used (BVA Media Group, 2013).

Bioenergy

Due to its significant forest area, Russia has a clear advantage in terms of bioenergy resources. Today, Russia has become the fifth largest pellet producer in the world, and the third largest exporter of pellets to the EU (roughly 0.9 megatonnes, Mt) , after Canada (1.6 Mt) and the United States (1.9 Mt) (Ekman & Co., 2013). In 2013, Russian pellet production reached nearly 900 000 tonnes per year, a doubling in output compared to the year before. Actual production could be higher, since not all production is captured in the Russian statistics – the output of smaller plants, for example, is often not reported.

The largest installed pellet production capacity in the country belongs to the Vyborgskaya Forest Corporation. Their plant, which has an annual production capacity of 1 Mt, is located in the Leningrad region (near the Finnish border). Its annual roundwood requirement is 2.2 million m^3 (Ekman & Co., 2013). The company's output determines Russia's overall production and export volume, as 95% of the company's output is exported (representing about half of Russia's pellet exports). In 2015, the company was operating with a 50% capacity utilization rate (similar to the level in the rest of the world).

This is not the only plant in Russia, though. In the past 10 years, more than 200 production plants have been built, with capacities ranging from 1000 to 100 000 tonnes per year (Vasilov, 2013).

Export is typically carried out by trucks or ships from the ports located in the northwest. Railways are used for export to the Baltic states (Rakitova, 2012).

Meanwhile, pellet prices in Europe have come down significantly over the past few years, meaning that transport costs now have a greater significance for the cost, insurance and freight (CIF) price to Europe. This creates a window of opportunity for Russian producers, as they are in closer proximity to the European market than Canada or the United States. The potential volume of export is large, though, and depends on cost competitiveness, amongst other criteria (Sikkema *et al.*, 2014).

The Russian export market is, however, currently facing several economic challenges in its wood pellet trade with Europe. An analysis looking into the logistics of wood pellets in northwestern Russia (St. Petersburg, Vyborg and Ust-Luga) shows that there is a need to optimise the logistics chain, in particular (Proskurina *et al.*, 2016).

According to the Russian forestry sector outlook, the use of wood biomass for energy could double between 2010 and 2030, from 32 million m^3 to 75 million m^3 (equivalent to about 850 PJ/yr in 2030). Consumption, however, is expected to be mainly by domestic users. Export is projected for pellets from regions that have suitable transportation and economic conditions, only (FAO, 2012). Domestic consumption of fuelwood and industrial wood residue will be in regions of Russia with the highest forest cover and where the supply of fossil fuels is difficult, or those regions that require seasonal supplies.

There are different types of forestry products that can be used as fuel. According to a study by the United Nations Food and Agriculture Organisation (FAO), charcoal production is expected to reach 120 000 tonnes by 2030, while briquette and pellet production should grow by nearly 10 times over the period, to 8.5 million tonnes. Wood can also be used to produce liquid biofuels. Today there is no production, but by 2030, liquid biofuel production from wood could reach 405 000 tonnes (equivalent to 0.5 billion litres per year) (FAO, 2012).

Farming in Russia is also an important economic activity. Farms have great potential for producing biogas for power and heat generation, although information about existing biogas plants is limited. Today, there are approximately 10 biogas plants operating in Russia, with the first built in Luchki, Belgorod region, on March 2012, with a total installed capacity of 2.4 MW. Since 2015, the installed capacity has grown to 3.6 MW, with this power produced for own consumption, rather than for sale to the grid.

Meanwhile, interest in biogas plants has been growing in recent years (Kopysova, 2013). A new biogas plant is under construction in the Republic of Mordovia (southwestern Russia), with a total capacity of 4.4 MW and feedstock from cattle and beet pulp. The capital cost of this plant is EUR 5 000-7 000 per kW. The plant is designed as a cogeneration unit, producing 9.6 million kWh of electricity and 18 200 gigacalories (Gcal) of heat per year. This would be sufficient to meet about 13% of the total electricity and heat demand of 1 million inhabitants in the region (Gerden, n.d.).

Costs of renewables in Russia

The levelised cost of electricity (LCOE) generation from solar PV declined worldwide by nearly 60% between 2009 and 2015. In many parts of the world, onshore wind is one of the lowest-cost sources of electricity generation technology. Yet while the improvement in the economic viability of electricity generation from renewable energy holds across all counties, its magnitude differs depending on resource availability and other factors (IRENA, 2016d, 2015). Table 1 shows the LCOE generation in Russia for the year 2014 (excluding large hydro). The costs of renewable and non-renewable energy technologies are shown separately.

Based on the maximum approved capital cost and operation and maintenance (O&M) cost levels for the wholesale market in 2014, the estimated costs of electricity generation (i.e. the LCOE) are the lowest for onshore wind and small hydropower. These levels range between USD 0.09-0.15 and USD 0.11-0.14 per kWh, depending on the capacity factors and the discount rate (assuming a currency exchange rate of RUB 48 per 1 USD in 2014). By comparison, the LCOE generation from solar PV is estimated much higher, at USD 0.25-0.40 per kWh. This is comparable to the level of generation costs seen in countries that are just at the start of utilising their solar PV potential. This analysis assumes, the 2014 exchange rate, however. If the volatility in the RUB/USD exchange rate that was observed between 2014 and 2016 were taken into account (e.g. in 2015, the rate was close to RUB 67/USD), the cost-competitiveness of the technologies would be very different.

By comparison, the generation costs of non-renewable energy technologies from new plants are today lower than the costs of renewables. Based on wholesale gas prices in Russia in 2014 (about USD 105 per 1000 m^3, or about USD 2.3/MMBtu), at a discount rate of 10%, natural gas has the least cost of generation, with this estimated at USD 0.04 per kWh. This compares with industry and residential electricity prices of USD 0.065 per kWh in the same year. Coal-based generation costs are estimated to be slightly higher. This is explained by the slightly higher capital costs and lower efficiency compared to gas, although the price of coal is much lower (in energy terms) and the capacity factor of coal plants is much higher. This comparison also excludes the economic valuation of any human health or climate change externality associated with the use of fossil fuels. If these were accounted for, the difference would be reduced and renewable energy technologies might also be less costly.

Discount rates have a large impact on the LCOEs of renewable energy technologies. A slightly higher discount rate of 12% results in costs increasing by USD 0.02-0.04 per kWh, depending on the technology. The effect is less pronounced for non-renewable technologies. For renewable energy technologies (with the exception of bioenergy), fuel costs do not play a role in the total cost of generation and costs are driven by capital costs and the respective discount rates.

For both the wholesale and retail market, the government offers the development of the maximum capital cost levels, *i.e.* the maximum capital costs allowed by the Russian government for tenders (see Figure 5). For wind, capital cost is estimated to fall by 0.1% per year for both the retail and wholesale markets in the 2014-2024 period. Solar PV falls by 2% per year for both markets, whereas hydropower (both small and large) remains at the same level throughout the entire period. By comparison, the capital costs of bioenergy technologies fall by 0.7% per year.

In reality, the capital costs of technologies can be expected to decrease much faster. For example, the latest IRENA estimates (IRENA, 2016d) show that there is a potential for the global weighted average capital costs of solar PV to decrease by 57% between now and 2025. This is an annual decrease of roughly 5.7% over a 10-year period. This is much higher than the decreases foreseen in Russia, indicating there is a larger potential for the costs to go down.

The expected capital costs considered by individual project applicants for the wholesale market up until 2020 are close to the allowed maximum level for capital

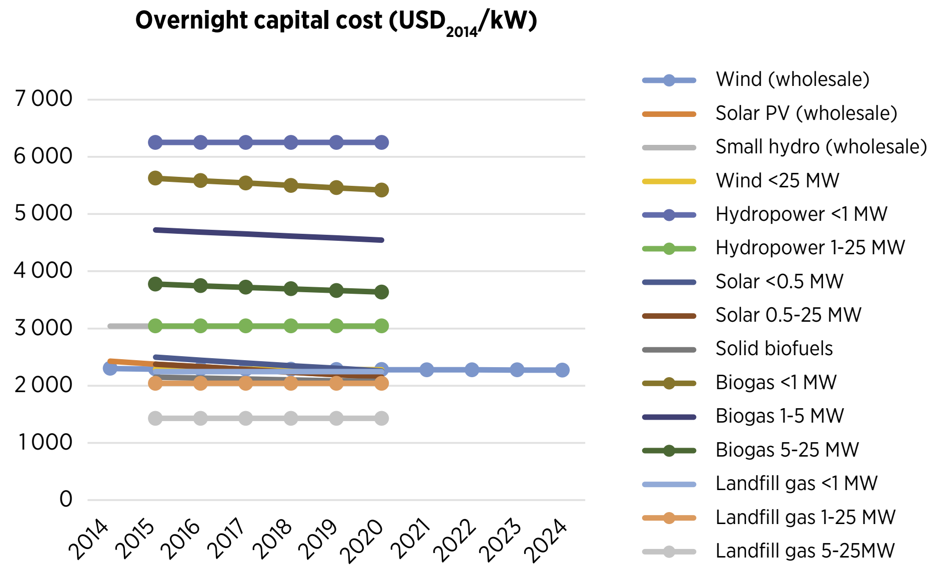
Table 1: Comparison of the estimated LCOE generation in Russia for renewable and non-renewable technologies, based on data from Russia, 2014

	Fuel cost	Capacity factor	Lifetime	Net capacity	Over-night capital cost	Operation & mainte-nance cost	Eff. of gene-ration	LCOE Discount rate=10%	LCOE Discount rate=12%
	(USD /GJ)	(%)	(years)	(MW)	(USD / kW)	(USD/ kW/ yr)	(%)	(USD / kWh)	(USD / kWh)
Coal	1.30	80	60	650	1 800	73	39	0.05	0.05
Natural gas plants	2.77	60	30	650	800	43	55	0.04	0.05
Solar PV utility scale	-	10-14	30	1	2 425	51	-	0.25-0.35	0.29-0.40
Onshore wind utility scale	-	25-35	30	10	2 300	35	-	0.09-0.13	0.10-0.15
Small hydro	-	35-40	40	50	3 040	61	-	0.11-0.12	0.13-0.14

Note: original data for the year 2014 was provided in RUB. To convert from RUB to USD, a currency exchange rate of RUB 48/USD was assumed. Overnight capital costs and O&M costs for renewable energy are based on the data provided by the Ministry of Energy of the Russian Federation and refer to the maximum approved overnight capital costs and O&M cost levels for the wholesale market in 2014/15. Fossil fuel prices refer to the wholesale market.

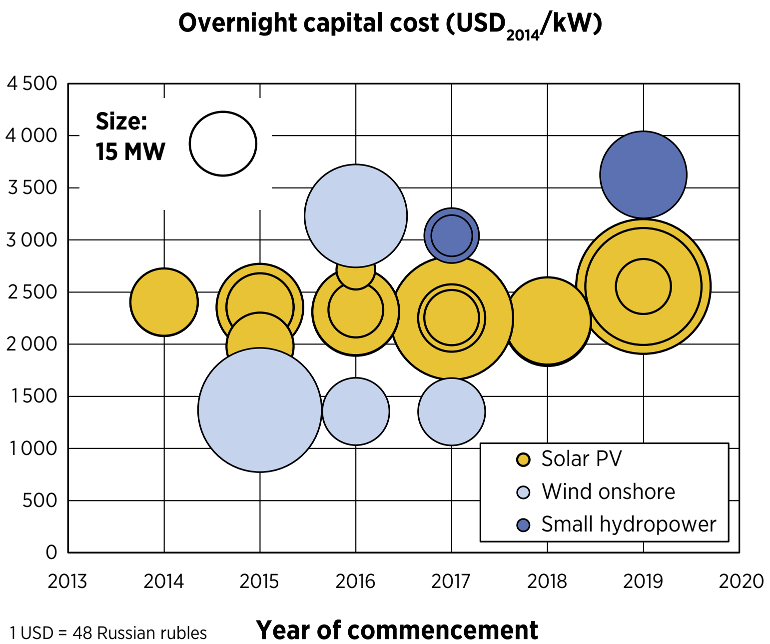
Source: IRENA analysis and Ministry of Energy of the Russian Federation.

Figure 5: Development of approved maximum overnight capital cost levels for the wholesale and retail markets, 2014-2024



Note: original data for the year 2014 was provided in RUB. To convert from RUB to USD, a currency exchange rate of RUB 48/USD was assumed. Overnight capital costs for renewable energy are based on the data provided by the Ministry of Energy of the Russian Federation and refer to the maximum approved overnight capital cost levels for the wholesale market in 2014.

Figure 6: Expected capital expenditure of approved renewable energy projects in the Russian wholesale electricity market based on data collected from project applicants, 2014-2019



Note: original data for the year 2014 was provided in RUB. To convert from RUB to USD, a currency exchange rate of RUB 48/USD was assumed. Overnight capital costs for renewable energy are based on the data provided by the Ministry of Energy of the Russian Federation and refer to the maximum approved overnight capital cost levels for the wholesale market in 2014.

costs. The capital costs of the project applicants also assume a safety margin to allow room for uncertainty. Hence in reality, the actual project costs can be 5-10% lower than that indicated, depending on the level of uncertainty assumed by each project participant, and the technology.

2.2 Drivers

Russia has vast resources of both fossil fuels and renewables, with large hydropower and bioenergy an important part of Russia's energy mix. Further development of these resources and other types of renewable energy technologies can contribute to economic growth, diversifying the country's energy mix, improving energy security and reducing energy supply costs in remote regions. They can also help Russia meet its international commitments, such as the objectives of the Paris Agreement. The reduction in domestic consumption of oil and gas that results from the deployment of more renewables can also create the potential for increasing oil and gas exports. An indication of this potential is provided in Chapter 5 of this report. These drivers have been identified through consultation with the Ministry of Energy of the Russian Federation and other stakeholders in the renewable energy industry.

Economic activity and job creation

Russian Government Decree No. 449, of 28 May 2013, on the Mechanism for the Promotion of Renewable Energy on the Wholesale Electricity and Capacity Market obliged renewable energy project investors to use equipment in each installation which is at least partly produced or assembled in Russia (so-called "local content requirements"). The purpose of these measures is to stimulate economic activity in the field of renewable energy and to create jobs in this developing sector.

There are important benefits to scaling up renewable energy in addition to improving its cost-competitiveness. Renewable energy can help economic growth and job creation. Today, for example, there are already more than 65 000 people employed in the Russian hydropower sector, ranking the country fifth in the world in terms of jobs in this industry (IRENA, 2016e). Employment can grow and expand to other technologies, too, with increasing and diversifying renewable energy capacity. With higher shares of renewable energy, total renewable energy related employment in Russia could reach 0.7-1.1 million by 2030 (IRENA, 2016f).

Around each renewable energy technology, there is a large supply chain that creates many business opportunities. Russia has the potential to increase the use of all types of renewable energy technology. Hydropower is already well established and a strong workforce has been built around it, but there is more room for growth in capacity, meaning more employment. Bioenergy potential is also significant, involving economic activity in the agriculture, forestry, infrastructure and trade sectors. Bioenergy entails multiple stages of processing until the end-product arrives at the consumer. These range from cultivation and collection of feedstocks to their processing, transport and combustion. Equipment manufacturers may also develop technologies to aid the use of biofuels.

Today, Russian renewable energy policy is focusing on accelerating the deployment of wind and solar PV. Production of solar modules or wind turbines involves many components, with each being produced in different branches of the industrial sector before they are assembled. Moreover, the design, planning, construction and operation of renewable energy plants require various types of labour, including advanced engineering and technology development skills. Hence, the creation of a larger renewable energy sector in Russia would offer benefits for multiple sectors of the Russian economy, creating activity and jobs for the country.

Science and technology development

Russia is known for its well-developed science, technology, and engineering education system. In 2016, it spent 1.1% of its GDP on research and development (R&D). This is higher than several other G20 and OECD countries (OECD, 2016). This strong institutional basis offers a good opportunity for the country to create markets for R&D firms in the technology sector, which can in the medium-term turn Russia into an exporter of knowledge in the field of technology and engineering (Gupta *et al.*, 2013). Such developments can take place across different areas of the economy, too.

Renewable energy is a viable area in particular, because the country also has vast resources for renewables.

These are spread across the country, while Russia already has a long and successful history in the energy sector, also providing a basis for such development.

The country has indeed, already started working on improving its scientific research capabilities on renewables. In February 2012, a solar technology centre focusing on thin film technologies was founded by Hevel, Russia's single solar module company, and the Skolkovo Innovation Centre at the Ioffe Physical Technical Institute located in St Petersburg. The centre has an experimental process line of 500 kW, which aims to refine the technical characteristics of thin film modules. The government aims to develop new types of solar PV modules and modernise the type of module production process through this centre.

With the deployment of more renewables for power generation and business development across the supply chain, Russia has a great potential to grow its scientific capacity and create similar knowledge centres.

A first step in creating such capacity is the production of renewable energy equipment domestically. Local content contributes to increasing economic activity, thereby creating local employment. With more production capacity, Russia can become a competitive exporter of renewable energy equipment (IRENA, 2014b).

Developing national equipment production and technology capacity brings several advantages. These include advancing technology development and creating the potential for technology and equipment export. These developments require time, however, and, depending on the technology and availability of sectors that can enable synergies, they may come at a high cost. Technology deployment is also subject to R&D risks. Russia could therefore also choose to import more equipment and technology. Yet despite the advantages of imports, such as reducing costs and technology risks, imports also create technological dependence and increase the cost of services.

Over the past few years, Russia has taken a big step forward in developing its technological base for renewable energy development:

- Solar energy: In 2015, Russian scientists from Hevel and the Research and Technology Centre on Thin-Film Technologies in the Energy Sector (the Ioffe Institute) finalised heterostructure technology, manufacturing solar modules of the cascade type with an efficiency of over 40%. This combines the advantages of classic silicon and thin-film technologies, and enables solar modules with an efficiency of over 20%, while also providing attractive pricing. In 2017, Hevel's plant in Chuvashia (LLC Hevel Novocheboksarsk) will fully switch to the production of solar modules using the new technology, increasing its capacity from MW 97 to MW 160 MW/year. The plant's products will have significant export potential (STRF, 2015).

- Wind energy: The state corporation Rosatom has designated the production of equipment for wind power generation as one of its priorities in the development of its machine-building. Its subsidiary filed an application for the construction of wind generation totalling MW 610, with commissioning in 2018-2020. In the future, Rosatom, in cooperation with a technology partner, plans to organise the production of key components for wind turbines, providing not only the construction of its own wind farms, but supplying equipment for wind farms to the international market (Dykes, 2016).

  In 2016, private sector companies Rosnano and Fortum also announced plans to participate not only in the construction of wind farms, but also in the production of equipment for them (Fortum Corporation, 2015).

- Small hydro-power: In December 2016, another company from the Rosatom group – GanzEEM (based in Hungary and a part of Rosatom's Engineering Division, AtomEnergoMash) signed the first official international contract for the supply of container type mini-hydro (the customer was Georgia's International Energy Company) (Harris, 2016).

Energy supply to the isolated population

The organisation of power supply in Russia breaks down into three zones:

- **Zone 1,** which includes the more economically developed areas within the purview of the United Energy System.
- **Zone 2,** which covers areas that are at lower stages of centralised power system formation. Here, isolated district energy systems are or should be in operation.
- **Zone 3,** which includes small isolated energy systems, mainly run by rural inhabited locations not covered by the centralised power supply systems, remote from the fuel supply network. Here, fuel delivery is a complex business. Consumers of this type of zone are concentrated in almost all areas of the north, Siberia and the Russian far east.

Decentralised energy therefore plays an important role in the country. A population of about 20 million, spread across an area that covers 70% of Russian territory, is not connected to the main grid. About half of this population is connected to smaller independent power grids. The other half is served by decentralised generation systems. These systems typically use petroleum-derived products. This excludes around 16 million country houses (or *dachas*), which often have limited access to reliable electricity (Katona, 2016).

Such regions, including Magadan, Taimyr (Dolgan-Nenets), and the Evenk and Chukotka autonomous districts, are able to meet their own fuel requirements, to a certain extent. The Murmansk and Arkhangelsk regions, the Republic of Karelia, and the Tomsk region, however, depend on external fuel delivery. The power connection in the Kamchatka region and its neighbouring areas is entirely dependent on external fuel supplies. Motor fuel and oil products are almost fully supplied to the north from the central regions of Russia.

Information on the population living in the decentralised energy supply areas in Russia is presented in Table 2. Past trends show that the population living in these areas is decreasing, yet the problem of ensuring energy supply remains challenging.

The main problems of power supply using diesel generators in isolated regions are the following:

- poor technical condition of equipment producing electricity
- long-range transportation of fuel and dependence on fuel supplies, thereby high costs of generation
- limited period of seasonal supplies of fuel
- weak transport infrastructure development
- dependence on state financial support

In summer time, up to 8 million litres of diesel fuel and 20-25 million tonnes of coal are transported to this population via the so-called Northern Delivery (GRA, 2016). The costs of transport of this fuel can be significant. Supply costs (including transport) are two to three times higher than the producer price and represent up to 80% of the total end-user price. Diesel prices in these regions have reached about RUB 50 000-100 000 per tonne (USD 1 000-2 000 per tonne). There

Table 2: Population in zones with decentralised energy supply in Russia

Number of citizens in settlements, people	Number of settlements	Total number of people
Up to 50	13 500	172 600
51-500	11 100	2 400 000
501-3 000	5 700	5 900 000
3 001-10 000	580	2 600 000
Total		11 072 600

Source: Surzhikova, 2012

is also a special requirement to transport double the amount of fuel that would in reality be required, in order to maintain a reserve.

The stock of diesel generators that is currently in operation in Russia is not known, yet statistics show that there are at least 900 such diesel generators across Russia, with these generating about 2.5 TWh of electricity per year in 2015 (see Table 3). Other statistics give numbers as high as 50 000 diesel generators, with this potentially including smaller generators as well. Generation from diesel generators represents less than 1% of Russia's total electricity output. Hence it is of minor importance for the country as a whole, yet for remote areas that rely on such sources for electricity, it is paramount.

Electricity is typically generated by old tanker diesel generators that run inefficiently and at low capacity factors. As a result, the costs can be extremely high – sometimes in the order of RUB 60-80 per kWh (or around USD 1.5 per kWh) and in some specific areas, the cost can even reach RUB 125 per kWh (around USD 2.5 per kWh) or more. Costs also increase because each diesel generator has a technician assigned to it who must be available 24 hours a day for maintenance and repair in case of emergency. These high costs hamper socio-economic development in these regions (Kiseleva *et al.*, 2015). Moreover, these settlements are affected by poor air quality from the use of inefficient and outdated combustion equipment. The State Policy of the Russian Federation in the Arctic for the period to 2020 (which addresses a population of about 2 million people living in these areas) clearly mentions the need to overcome these energy related challenges in the Arctic region. The potential role of renewables in this is increasingly being recognised (Pettersen, 2016).

Diesel systems also have large economic implications for the power utility companies. Those active in these regions sell electricity from the grid at a fixed market price. This is significantly lower than the production cost of electricity from these diesel systems, which results in large financial losses. Given electricity needs to be supplied to the isolated populations and such diesel systems are currently the only choice, this loss is covered by the state budget through higher prices charged to the grid-connected consumers.

To reduce dependency on inefficient diesel systems, investing in transmission and grid capacity to reach disconnected settlements is an option, but this requires

Table 3: Location of diesel generators in Russia by number of plants and generation

	Generation (MWh/yr)	Units (number)
Kamchatsky Krai	151 308	181
Sakha Republic	325 215	166
Krasnoyarcky Krai	98 606	70
Khabarovsk Krai	19 297	64
Arkhangelsk Oblast	56 467	58
Irkutsk Oblast	68 312	57
Chukotka Autonomous Okrug	97 352	46
Yamalo-Nenets Autonomous Okrug	1 524 335	42
Khanty-Mansi Autonomous Okrug	34 900	42
Nenets Autonomous Okrug	25 000	36
Primorsky Krai	28 790	28
Komi Republic	14 564	27
Sakhalinsky Krai	50 500	24
Tomsk Oblast	14 689	22
Zabaykalsky Krai	7 103	20
Tyva Republic	9 970	12
Total	**2 526 408**	**895**

Source: Velikovo, 2016

significant investments and time for construction. Replacement of these diesel systems with more efficient ones is challenging because of financing issues. Interest rates could be as high as 18% and more, if the equipment needs to be imported. Various stakeholders also continue to benefit from diesel generation, which slows down diesel equipment decommissioning.

To overcome the related challenges in the off-grid systems, renewables and peat have been included in the Russian government's plans as prospective energy sources that may be widely used.

In isolated regions in particular, renewable energy is economically viable. Currently, there are business models being developed by construction and development banks active in the region to provide loans in addition to the equipment. The types of equipment that can be used in remote areas include more efficient generators, using both off-grid and mini-grid systems that can offer a significantly cost-effective alternative (Boute, 2016). Wind and solar are also both potential substitutes for diesel power generation. While solar can provide electricity for about 4-5 months a year (from May until September) and is subject to both construction (e.g. mounting on frozen ground) and operation challenges, wind plants can operate throughout the entire year. Such systems have started to be built in the Arctic Circle, such as the 1 MW plant in the village of Batagai in Siberia.

Under the state support mechanism for renewable energy, wind power is projected to be cost-competitive by 2024 at the latest in Russia, within the wholesale market. In the medium term, considering the domestic availability of low cost fossil fuels and the steadily decreasing cost of renewable power generation, mixed wind and diesel power generation is also worth considering as a practical solution for local power demand, while further promoting renewable energy. Moreover, the Nenets Autonomous District in northern Russia has recently approved a regional programme promoting hybrid power plants, which primarily run on wind and are backed up by diesel.

Currently, wind farms at the local level in Russia operate with low-capacity turbines, and they are therefore associated with higher costs per unit of output, have been used. Their impact may be improved by means of raising the awareness of the population in the target areas, leading to greater interest in having a more sustainable and environmentally friendly power supply and leading to the use of high-capacity turbines, associated with lower costs per unit of power output.

The Russian energy company RAO Energy Systems of the East, serving energy consumers in the Russian Far East, has also installed 178 solar and wind power plants in this region. These plants, which were mainly installed around Yakutsk, have a total installed capacity of 146 MW. The introduction of these installations allowed the replacement of 40% of the energy that was previously provided by diesel power plants.

New projects are also underway in other remote areas of the country. In Olekminsk, three new plants, with capacities of 80 kW, 36 kW and 20 kW respectively, are being built in three villages. The angle of the solar panels used is changed to maximise solar irradiation in summer and winter times. While they are nearly vertical in the winter season, with an angle of 70^{o}, in summer the angle is set at 40^{o}. These solar systems are equipped with battery storage and are also synchronised with diesel power plants that are set to cold reserve over the summer periods.

In the same region, 13 other solar PV systems are in operation, with a total combined capacity of 1 325 kW. This has resulted in annual savings of 71 tonnes of diesel. This is part of RAO Energy Systems of the East's programme, which involves the construction of 178 solar PV systems, with a total combined capacity of 146 MW (RAO, 2016).

In the region, there are also a number of wind/diesel hybrid plants as well as stand-alone wind plants (RAO, 2015). Implementation of this programme is expected to cost about USD 350 million. Five plants are already installed or under construction or at the planning stage. The total capacity of these wind-diesel hybrid plants amounts to 2.355 MW.

Investment in these plants is expected to be paid back within a short amount of time, as annually these plants are expected to save USD 30 million per year fuel supplies to remote areas (Vorotnikov, 2015). Yet, while these investment are important, in terms of capacity, they are smaller than the potential that can be achieved in grid-connected systems. Hence, policy priorities need to be balanced across the various systems where renewable energy technologies can be integrated.

Off-grid systems also reduce the need for additional transmission and grid costs while reducing losses in the distribution network, as there is no need to convert electricity to high voltage. Development of decentralised generation also avoids high transmission fees. Costs related to the grid account for 41% of the final price of electricity paid by large enterprises. In some regions, this share could be even higher, such as in the Tyumen region, where more than half the price is due to the cost of the grid component. These shares are much higher than in the United States or EU (where they are less than 30%) (Gusev, 2013a).

In addition to the crucial role of renewable energy in improving energy security in remote areas, renewables are also relevant for regions of Russia that are less endowed with a favourable resource base. These heavily import energy from other regions of the country. Taking into account congestion and limits to the interconnector capacity between the different parts of the national transmission network, some grid-connected regions have also started to consider renewables as an option.

Improving the quality of the environment

While not always considered as a main driver, renewable energy may also offer important environmental benefits. In particular, in Russia, transport related emissions from motor vehicles have increased. In around 150 cities, including the largest cities, such as Moscow or Yekaterinburg, vehicle emissions now exceed those from industry and are 10-20 times higher than the maximum allowable concentrations.

Emissions related to coal mining have also seen an increase in recent years. In particular, coal mining cities, as well as cities that predominantly rely on coal for electricity and heat production, are being impacted by high concentrations of particular matter emissions (Slivyak and Podosenova, 2013). Increased use of renewables can help to reduce fossil fuel usage and its related air pollution in both urban and rural areas (IRENA, 2016g).

As part of its contribution to the mitigation of climate change, Russia aims to reduce its total greenhouse gas (GHG) emissions by 70-75% by 2030, compared to 1990 levels (UNFCCC, 2015). Given the country's significant resource potential, renewable energy sources are likely to play an important role in Russia realising the objectives of its Intended Nationally Determined Contribution (INDC). The INDC will be developed in mid-2018, according to Government Resolution No. 2344-r of 3 November 2016.

2.3 Brief overview of the current energy policy framework

Renewable energy

Russia's Energy Strategy to 2030, approved by Government Decree No. 1715-r of 13 November 2009, set a renewables-based power generation target of 4.5% by 2020, excluding large hydropower. The target rose to 20% when large hydropower was included. These levels also had to be sustained until at least 2030 (between 2008 and 2030 domestic consumption of electricity was projected to nearly double, to 1740-2164 TWh/year). Realising this target would require a total development of renewable based power generation capacity of 15-25 GW by 2020 (depending on the mix), and total generation of about 80-100 TWh per year by 2030 (IFC, 2011).

Governmental resolution No. 512-r of 3 April 2013, Approving the State Programme for Energy Efficiency and the Development of the Energy Sector, introduced a lower target for renewables, of at least 2.5% by 2020. The earlier goal of 4.5% was based on a first attempt at making a real assessment of a feasible target. It also referred to a best-case scenario, which considered the socio-economic situation as it was before the global financial crisis. Many further assessments then failed to prove the feasibility of this target under the policy framework of the post-financial crisis period. For these reasons, the Russian government decided to keep the impetus for renewable energy technology development by means of amending the target year in the official decree to 2024 (four years later) and left the target share as it was – 4.5%. The draft Energy Strategy to 2035 provides for a share of at least 2.5%.

Since 2014, there is government support for renewable energy (excluding large hydropower) to achieve a total installed capacity of 5.9 GW by 2024. The earlier target was to increase renewable energy capacity for all technologies by 2020. This target now includes 1.5 GW of solar PV and 0.9 GW of hydro by 2020, and 3.5 GW of wind by 2024. A total renewable energy capacity of between 9 GW and 11 GW is under discussion for 2030.

New legislation has been prepared by the government in view of its support for renewable energy resources. These laws target in particular the development of renewables in the local context, especially wind.

Government resolution No. 1634-r, approved on 1 August 2016, sets out Russia's territorial planning scheme in the field of energy. Annex No. 2 of the resolution has a list of hydroelectric power plants that have a capacity of 100 MW and above and which are planned to be build during the period up to 2030, while Annex No. 3 contains a list of wind power projects of 100 MW and above, also planned to be build during the same period.

According to this governmental decree, Russia has approved plans to build 15 new wind power plants, with unit installed capacities of 100 MW and above, in the period up to 2030. Total new wind power installed capacity is estimated at 4 851 MW. Over the same period, 13 new, large hydropower plants will be built and 14 existing plants, with capacities of 100 MW and above, will be redeveloped. Total new hydroelectric power capacity is estimated at 64 GW.

Renewable energy market development (solar, wind and small hydropower of up to 25 MW installed capacity) was laid down by Federal Law No. 35-FZ of 26 March 2003, entitled "On Electricity", as amended. This law provides support measures for stimulating the production of electricity through the use of renewable energy in both the wholesale and retail markets.

Since 2009, when the government made a decision to accelerate the development of renewable energy, a number of related measures have been designed. In particular, a package of normative legal acts has been drawn up to support the development of renewable energy in the wholesale market, which consists of the following:

- an obligation for grid companies to buy energy generated by qualified renewable energy facilities at regulated tariffs for power loss compensation
- compensation for qualified renewable energy generation facilities, with capacities of up to 25 MW, for the cost of their connection to the power grid
- award of power capacity under agreement with qualified renewable energy facilities generating power using renewable energy.

On the retail market for electric power and capacity, in accordance with Federal Law No. 35-FZ, a mechanism to support renewable energy was established, which guaranteed an obligation for network companies to buy electricity from qualified generating renewable energy facilities at regulated tariffs, set by the regional executive authorities of the Russian Federation.

Following the Presidential decree of the Russian Federation of July 21, 2015 "About some questions of public administration and control in the field of anti-monopoly and tariff regulation" and according to the the decree of the Russian Government of September 4, 2015 No. 941, the Federal Antimonopoly Service approved by its order of September 30, 2015 No. 900/15 the methodological guidelines for price (tariff) determination for electricity generated by qualified renewable energy facilities. These guidelines have been in force since their registration by the Ministry of Justice of the Russian Federation on 28 January 2016. Nevertheless, these guidelines might be subject to revision and do not provide any guarantee of long-term and definitive tariff commitments, a step necessary in creating a framework for energy companies with a long perspective.

Thus, the general legislative and regulatory frameworks for renewable energy development in Russia are in place, including the setting of:

- targets for renewable energy development up to 2024
- rules for trading in the wholesale and retail markets
- consideration of investment capital return, as a part of marginal capital cost, and consideration of changes in exchange rates in Russia in order to reduce the risks associated with fluctuations in the RUB exchange rate against the USD

- mandatory qualification of renewable energy generation facilities participating in the electricity market

- obligation for grid companies to purchase 5% of grid power losses from renewable energy facilities

- compensation for renewable energy facilities of 50% of technical connection costs to the power grid.

As already mentioned in section 2.2, renewable energy sources in Russia can bring a number of benefits, such as increasing economic activity and improving energy security. An overview of the laws and regulations related to renewable energy in Russia can be found in Table 4. A number of regional initiatives have also already been proposed which aim to stimulate the development, production and use of renewable energy sources. Examples include:

- in the Krasnodar Territory, Law No. 723-KZ, of 7 June 2004. "On the use of renewable energy sources in the Krasnodar Territory," where renewable energy refers to the energy of the sun, wind, geothermal sources, natural temperature gradient, natural water flows, and bioenergy (FPA, 2009).

- in the Rostov Region, Regional Law No. 62-ZS, of 12 August 2008, "On the regional target programme on production and use of biofuel by the agricultural sector of the Rostov Region," which approved a targeted programme aimed at ensuring efficient production and use of biofuels in the Rostov region (Rostov, 2008).

- in the Republic of Tatarstan, Law No. 7-ZRT, of 13 January 2007, "On approval of the Development Programme of the Republic of Tatarstan fuel and energy complex for 2006-2020," that, in particular, provides for the creation of facilities for the production of biogas at large poultry farms in the republic (Tatarstan, 2007).

- in the Sakha Republic (Yakutia) , the regional Law No. 313-V, of 27 November 2014, "On renewable energy sources of Sakha Republic (Yakutia)" was approved to create favorable conditions for priority use of renewable energy sources in the territory of the republic with the purpose of improving the social and environmental conditions as well as energy resources (Yakutia, 2014).

The main support mechanism for renewable energy is the auction system. Recent analysis has shown that this mechanism reduces investment risk, as it can reduce sensitivity to external market factors (Kozlova and Collan, 2016). Russia was one of the first countries in the world to introduce a competitive market for capacity, ahead of Europe, and nowadays, many countries auction capacity.

The Russian capacity-based approach to renewable electricity support is somewhat different from the schemes established for the promotion of renewable energy in most other countries, however. Support for renewable electricity (e.g. through feed-in tariff [FiT], premium, green certificate or tendering schemes) is usually linked to the electricity output (production) of renewable energy generating facilities (expressed in MWh). In contrast, the Russian capacity scheme is linked to a capacity supply agreement (i.e. the availability of power plants to produce electricity), expressed in MW or MW per month (Boute, 2012). These agreements allow investors to secure a return on their investment in renewable energy projects through guaranteed capacity payments payable over a term of 15 years. In order to be eligible for these agreements, generators go through an auction process.

In Russia, key contractual conditions are regulated by the government. These include two separate parameters – one is the price of renewable energy source capacity and the second is the duration of capacity supply. Agreements are thus long-term contracts that establish the right for renewable energy investors to benefit from regulated prices determined by reference to the installed capacity of their installations. Anchored in the Russian capacity market, these agreements oblige renewable energy projects, including wind power, to comply with the regulation of capacity supply (e.g. assessment of availability to produce electricity) under the wholesale market rules (the regulatory architecture governing the Russian wholesale market).

Upon winning a capacity auction, the generator that entered into a capacity supply agreement is required

Table 4: Overview of laws and other regulations related to renewables in Russia, in chronological order

	Content
Federal Law No. 35-FZ of 26 March 2003 "On electricity" (as amended)	Classification of renewable energy resources Outlines the main measures to accelerate development of renewable power Defines the role of authorities in implementing government support for renewable energy
Presidential Decree No. 889 of 4 June 2008 "On some measures to improve the energy and environmental efficient of the Russian economy"	Goal of increasing efficiency across main sectors Strengthens the responsibility of failure to comply with standards of impact on environment Application of budget support of renewable energy and clean technology use
Resolution of the Government No. 1-r of 8 January 2009	20% renewable energy share in power generation by 2024 (up to 4.5% of renewable energy production in total power, excluding large hydropower generation)
Resolution of the Government No. 1839-r of 4 October 2012	Legal basis for the large scale development of renewables by 2020, 3.6 GW of wind by 2020 Local content requirements
Resolution of the Government No. 861-r of 28 May 2013 Decree of the Government No. 449 of 28 May 2013	Power supply contract as a mechanism of pay back for wholesale market operating power plants based on renewable energy Target capacity indicators for the renewable energy power plants commissioned from 2014-2020 Limiting values of capital expenditures for construction of 1 kW installed capacity of renewable energy
Resolution of the Government No. 1247-p of 18 July 2013	Targets to 2018: Heat generation with the use of biofuel (including peat and timber waste) – approximately USD 2.45 billion; Production of solid biofuel (including peat and timber waste) – 16 million tonnes Legislation improvements for bioethanol production Start of bioethanol industrial production Analysis of renewable energy application practice for the heating at the local level.
Decree of the Government No. 47 of 23 January 2015	Support mechanism on the retail electricity markets for the "green" energy generating facilities using biogas, biomass, landfill gas and other renewables Procedure for long-term tariff regulation parameters for generation facilities Capital and maintenance costs for qualified facilities are set as not to exceed the maximum levels fixed by the government
Decree of the Government No. 1472-r of 28 July 2015	Legal basis for the prolongation of the Resolution of the Government No 1839-r, 4 October 2012 for the renewable energy targets through 2024
Resolution of the Government No. 1210 of 10 November 2015	amendments to certain acts of the Russian Federation on the use of renewable energy sources in the wholesale power (capacity) market
Resolution of the Government No. 850-r of 5 May 2016	New indicators (targets) on commissioning of new capacities for different types of RES (wind, solar, small hydro) for the period up to 2024
Resolution of the Government No. 1634-r of 1 August 2016	Timeline of the renewable energy generation capacity installation across the country through 2030

Source: IRENA analysis and based on Fortov and Popel, 2014; Kiseleva et al., 2015 to undergo a procedure for qualification. In order to enable state support and adequate regulation, as well as to ensure the sustainability of renewable energy production, the government approved the following qualification criteria for renewable energy generating facilities eligible for the power market:

- The generating object should operate renewable energy sources alone or combined with other energy sources.
- The generating object is supposed to be fully operational (not subject to maintenance, repair or decommissioning).
- The generating object is supposed to be formally connected to the power grids meeting the requirements of the grid operators, as well as be equipped with power metering approved by the national legislation on electricity.
- The generating object is supposed to be on the list of allocation of power generating objects based on renewable energy on the territory of the Russian Federation approved by the Ministry of Energy.

The Administrator of the Trading System (ATS) organises the annual tender and is responsible for the selection of renewable energy investment projects. The selection process is spread over two rounds. In the first round, ATS selects projects that meet the requirements for participation in the scheme. The selected projects proceed to the second round, where the ATS determines which will be invited to sign agreements. In addition, to be eligible for support, any renewable energy generating project needs to provide the use of process equipment components with a certain local production content.

According to Government Decree No. 1472-R, of 28 July 2015, local content requirements apply to all wind, solar PV and small hydropower. By 2024, requirements will reach 70% of all equipment used for solar PV and 65% for small hydropower and wind, starting at 70% in 2017 for solar PV, 45% for small hydropower and 25% for wind. Given the long history of hydropower in the country, local content requirements do not present a significant barrier for such technologies. Solar PV and wind, however, are not yet mature technologies in Russia. The situation for solar PV is relatively better, though, because recent investment has resulted in the foundation of equipment manufacture companies like Hevel Solar, Solar Systems and Schneider Electric. For wind, there is interest from global players such as Siemens. To date, there are no local manufacturers that can deliver equipment at MW-scale.

In the auction system, solar PV, wind and small hydro projects with a total installed capacity greater than 5 MW can compete in yearly federal auctions through a system of capacity-based payment on top of the wholesale energy prices.

So far, four rounds of auctions have been held (in 2013, 2014, 2015 and 2016) and these have awarded a total of 2.06 GW of capacity. Yet, only a few applicants have met the eligibility requirements and the rounds have had limited application. The first auction that took place in September 2013 was more a trial to test the effectiveness of the scheme, and it provided some important lessons. While applications for wind power represented only about 10% of the total offered capacity (110 MW out of 1110 MW), solar PV applications reached 1000 MW, exceeded their offer of 710 MW by 290 MW. Awarded capacities were, however, much lower because of the high local content requirements.

In summer 2016, new auctions were held in the wholesale market. Rosatom State Atomic Energy Corporation (Rosatom) won 610 MW, with an installation plan of 150 MW in 2018, 200 MW in 2019, and 360 MW in 2020. Another 51 MW of auctions were won by ALTEN Ltd (Falcon Capital a.s. and The Republic of Kalmykia) and 35 MW by the private company, Fortum (Ulyanovskaya region). This represents approximately 700 MW of the 3600 MW announced as being targeted for installation by 2024. Since the tender is held for five years ahead, more than 2 GW are still to be auctioned, by 2019. Thus, the remaining eight years should see about 300 MW-350 MW of new capacity per year. Such industry growth is much lower than in countries with a more developed wind power market.

One of the conditions for applicants at the auctions is to prove an availability of funds equivalent to 5% of the capital costs. In 2013, a guarantee from a power company with over 2.5 GW of assets was necessary, but this turned out to be a barrier and therefore an alternative of a letter of credit from a certified bank was provided. Other conditions for applicants include:

registration on the wholesale power market; showing connection points in the grid; and following the local content requirements. Projects should also be located in those areas where free market prices apply; hence, isolated regions where renewable energy can easily make economic sense are excluded, as well as the retail market.

In retail markets, another system of auctions is present. For regional governments, projects up to 25 MW can compete where the winner can sell electricity at a specific tariff.

Besides auctions, there have been some amendments to the electricity law to accelerate renewable power uptake. One of these concerns the mandatory purchase of renewable power by grid companies to compensate for losses. Purchases are limited to a maximum of 5% of the forecasted volume of electricity that would be lost (where technical losses amount to 5 TWh per year in local transmission grids). Auction rules are determined by each regional government, which then awards a green tariff for projects. One important difference between the retail market and wholesale market auctions is that up to 2017, there have been no local content requirements in the retail market. After 2017, the local content requirement is 70%. If these content requirements are not met, the tariff may be cut by over 50%.

To date, only 25 installations have qualified for green tariffs, with these representing about 150 MW of total installed renewable power generation capacity. Half of this total was related to geothermal, one-third to solar and the remainder to wind, biogas and combined heat and power (CHP).

The major challenge in the retail market is the tariff decision process. Tariffs are only determined when the project is qualified, hence the business plan has no guarantee of the project revenue. Moreover, delays in the qualification process imply a delay in the adoption of tariffs.

One other challenge is the 5% limit, since a single project can exceed this limit, which will result in limited purchase of generation by the transmission system operator.

Energy efficiency

Improving efficiency is central to Russia's energy sector modernisation strategy, which ranks fifth globally fifth in terms of size. There remains a large potential to improve its energy efficiency.

In 2008, former Russian President Medvedev launched various policies to promote improving energy efficiency. In accordance to the "Energy Strategy to 2030", the other strategic energy goal lies in reducing Russia's energy intensity by 40%, between 2007 and 2020. This reflects the fact that despite Russia's remarkable progress in reducing the energy intensity of its economy – during the period before the economic crisis of 2008-2009 in particular – the economy is still more energy intensive than many other large emerging economies. Russia's energy intensity level stands at USD 9.50 per megajoule (MJ), at purchasing power parity (PPP) and

Table 5: Results of renewable energy auctions in 2013-2016

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	Total
Power capacities to be provided by the projects approved (MW)												
Wind	0	66	50	90	150	200	360	-	-	-	-	406
Solar PV	35	140	199	255	285	270	-	-	-	-	-	1184
Small hydro	0	0	0	21	0	50	-	-	-	-	-	70
Total	0	51	50	90	0	0	-	-	-	-	-	191
National target values (MW)												
Wind	-	51	50	200	400	500	500	500	500	500	399	3 600
Solar PV	35.2	140	199	150	270	270	270	21.45	21.45	21.45	21.45	1 520
Small hydro	-	-	-	124	141	159	159	42	42	42	42	751
Total	35.2	191	249	574	811	929	929	563.45	563.45	563.45	462.45	5 871

Source: ATS Energo, 2016

real, 2011 prices, while Brazil has achieved USD 4.10/MJ, India USD 5.30/MJ, China USD 8.30/MJ, and Indonesia USD 4.10/MJ (IEA and The World Bank, 2015).

The main instruments in realising this potential include: creating awareness, installation of metering, labelling and standardisation. Furthermore, recent years have seen growing electricity and natural prices which came as a result of the liberalisation process. These highlight the importance of improving energy efficiency. Some specific initiatives, such as that initiated by the Ministry of Regional Development as a pilot in seven Russian regions in September 2013, follow this energy pricing rule. The main principle is that households agree to a certain price ceiling for a certain amount of electricity consumption, and when that consumption volume is exceeded, the price increases considerably. The project's aim was to raise household electricity prices to the level of those in industry.

Presidential Decree No. 889 of 4 June 2008 included the area of energy saving and energy efficiency improvements. The 2008 decree was followed by Federal Law No. 261-FZ of 23 November 2009, "On Energy Conservation and Increasing Energy Efficiency". Tis is the legal basis about how these targets can be achieved. In 2010, the Russian Duma also adopted the government programme "Energy Savings and Energy Efficiency up to 2020". Finally, in 2012, 38 additional regulatory acts were introduced to support energy efficiency.

Russia has also gradually developed a comprehensive framework for district heating sector modernisation. District heating plays a key role in the energy system of the Russia. In accordance to the "Energy Strategy to 2030", the potential to improve energy efficiency in the district heating system is estimated to be on average 40%. This potential can be realised by introducing more energy efficient equipment into the system and by modernising the existing capacity via retrofits, as well as by reducing losses in the distribution network. Federal Law No. 190-FZ, of 27 July 2010, on heat supply addresses these efforts. Its aims are to modernise and improve the efficiency of the district heating system, ensure a reliable, environmentally safe and quality supply of heat to consumers, and prioritise the use of co-generation plants. One major improvement this law has achieved was to combine past legislative acts into a single document (IEA, 2014).

The above-mentioned law, as amended, is one of the three key pillars of this process. In addition to introducing progressive mandatory heat metering, the law also requires energy audits to be undertaken, including those of heat generating assets. The law also mandated the government and the regional governments to establish energy efficiency programmes, including the heating sector, considering the energy efficiency requirements for regulated companies (IEA, 2014).

Russia's energy efficiency strategy remains at a similar level of ambition in the draft of the new Energy Strategy for the period up to 2035. This sets a target of reducing energy intensity by 40% between 2010 and 2020. Some research, however, shows that a significant increase in energy efficiency by the economy will not only happen due to these energy intensity reduction goals, which would in any case take place without the introduction of this strategy (Bashmakov, 2015).

Environment and climate change

Both renewable energy and energy efficiency are key components of Russia's climate policy as well. In the past four decades, the country has seen an increase in its average year-round temperature of 0.04°C per year (equivalent to a total 1.6°C), which is higher than the global average (MNR, 2015). According to its INDC, Russia aims to reduce its total GHG emissions by 70-75% by 2030, compared to its 1990 levels (UNFCCC, 2015).

Currently, among the policy-makers, the discussion is also about whether to develop an emissions trading system. There are indeed examples available from other regions (e.g. the EU) and from other countries (e.g. China, Kazakhstan) that can be a starting point. Russia is considering the options over how to develop the best model to suit its domestic energy system and national objectives. For example, the private sector sees carbon pricing as a major risk to their operations, at this time in particular, when the country's current economic situation is considered.

President Putin has also resolved to make 2017 the "Year of the Environment in the Russian Federation". The main focus is to attract public attention to Russia's environmental issues, biodiversity preservation and ensuring environmental security (Kremlin, 2016).

Environmental policy has a long history in Russia. Pollution (water, air and soil) remains a major issue in certain parts of Russia, although this is mainly a result of industrial activity. Earlier environmental standards set a high threshold and therefore meeting these standards was not easy, as they were costly.

The new draft law on pollution aims to categorise plants into four categories, depending on their impact, by focusing on plants that account for 60% of the total pollution in the country. In this context, the Ministry of Natural Resources and Environment of the Russian Federation is preparing about 50 reference books for sectors, technologies and pollutants (10 of them have already been prepared). These reference books will set the standards for industries to control their emissions and will be revised and updated at least once every 10 years.

In realising the implementation of best available technologies, the country's main challenge is financing. The cost of finance is at an interest rate of about 20-24% per annum. For larger companies, this rate can be lower, at around 16%, but with such rates, the cost of production can easily become very high. This has an impact on the cost-competitiveness of Russian industry. Hence, there is an important role for the government in solving the problem of availability of financing, and new resources should be created, since what the banking and private sectors can offer may not be sufficient.

2.4 Renewables potential by resource and by region

Russia has abundant resources for all types of renewable energy types. A recent renewable energy atlas for Russia (Kiseleva *et al.*, 2015) outlines the natural resource potential for solar, wind, small water flows, peat, biomass, waste and wood residues across the country.

The development of renewable energy sources other than hydropower and bioenergy has been progressing slowly in Russia, however. The national energy balance is dominated by the traditional sources of coal, oil and natural gas. Nonetheless, more and more projections show a steady decrease in the fuel share of hydrocarbons, with these set to be eventually overtaken by other sources of renewable energy. The two main challenges in utilising this potential are: how to connect them to the population centres, which are concentrated in certain parts of the country's large territory – mainly across the western, southwest and southern parts of Russia – and how to transition to a more renewables-based energy system from Russia's long history of fossil fuel use. This section provides an overview of the potential, by type of resource.

Solar

Russia has great solar energy potential and vast territories favourable for the building of solar PV stations. Throughout the year, total solar radiation (horizontal surface) can reach 3.5-4.5 kWh/m^2 per day in some parts of the country, in particular in the southwest and southern regions. On average, this is equal to 1200-1500 kWh per year, which is 50% higher than the resource potential in Germany, for example. In these regions, during the summer months, solar radiation can reach up to 6 kWh/m^2 per day.

Wind

According to present estimates, Russia has the largest wind potential in the world. The maximum level of Russia's wind energy resources, measured in terms of gross potential, is part of the average long-term total wind energy available for use in the Russian territory during a year. This figure is 2571843 TWh per year (APREN, 2016).

In contrast to solar, wind is more evenly distributed across the country. Northern parts of Russia (including both the western and eastern regions) as well as the southwest have rich resources for wind, with speeds easily exceeding 8 m/s at 100 metre heights. These can technically generate around 12 GWh per year of electricity.

Favourable areas for wind energy development include the northwestern parts of the country (Murmansk and Leningrad Oblasts), the northern territories of the Urals, Kurgan Oblast, Kalmykia, Krasnodar Krai and the Far East. Seacoasts (with high differences in temperature) have the highest potential for wind, as well as the steppes and some of the mountainous areas. The Russian Far East has around 30% of the country's total potential. Another 16% is located in western and eastern Siberia. Northern Siberia and the Far North have an additional 14% potential. Unfortunately, most of these places are not close to regions with a large population (WWEA, 2012).

The technical potential of wind energy in a region is that part of the gross potential that can be used by up-to-date wind energy equipment, in compliance with the applicable environmental standards. In total, the technical potential of Russia's wind energy is estimated at more than 50 000 TWh per year (APREN, 2016).

The economically viable annual wind energy potential of a region is measured by the amount of electricity which can be supplied to consumers from wind power plants, whose construction is economically sound at the existing cost levels for generation, transportation and consumption of energy and fuel in that region, and with standard environmental quality being ensured. The economic potential of Russia's wind energy is 260 TWh per year – i.e. about 30% of the electricity generation by all the electric power stations in the country, while the share of wind farms currently existing in Russia is less than 0.1% of total electricity generation (APREN, 2016).

There are varying levels for potential estimates for wind power in Russia, particularly in terms of expressing these in GW. The currently available estimates indicate a total of 90 GW, but given the size of the country (and thus not considering grid access), the potential can run from thousands to 20 000 GW.

Geothermal

Following wind, Russia has a significant potential for geothermal. Numerous regions in the country contain reserves of hot geothermal fluid. These reserves have temperatures ranging between 50 °C and 200 °C. Depths range between 200 m and 3 km. The main areas in the country with good potential include the European part of Russia (central Russia, northern Caucasus, and Dagestan), Siberia (Baikal rift area), the Krasnoyarsk region, Chukotka, Sakhalin, the Kamchatka Peninsula and the Kuril Islands. In total, there is a potential of some 2 GW of electricity and more than 3 GW of heating capacity (Svalova and Povarov, 2015).

Hydropower

Russia has the greatest water resources in the world. The combined length of the country's rivers is more than 8 million km, with most of these 100 km or less in length (FAVR, 2016). Hydro's economically feasible potential is nearly five times the current capacity in operation, in particular in the eastern part of Siberia. For small hydropower, the largest potential is in the central and eastern parts of the country.

Ocean and tidal power

The north of Russia has significant tidal resources. The White Sea and the Sea of Okhotsk see some of the highest tidal ranges in the world, with these reaching more than 10 metres. Some potential sites for tidal power installations include Mezen and Tugur, which have mean tidal ranges averaging 5.5 m and offer a combined potential of around 22 GW, covering a basin area of more than 3 500 km^2 (Gorlov, 2009). The total tidal generation potential is estimated to be in the order of 90 GW (Helston, 2012).

Bioenergy

Finally, Russia has abundant resources for bioenergy, in all its forms – from forestry products and peat to agricultural residues and various forms of organic waste.

Russia owns more than one-fifth of the global forested area, with some 1 180 million hectares within its territory. A significant share of this total forested area is in Siberia. The potential of wood from forestry residues and net regrowth of forests amounts to 200 million m^3 per year and the potential cutting area is about 600 million m^3 per year. This is roughly equivalent to 190 Mtoe per year (or about 8 EJ per year).

The total annual quantity of agricultural organic waste amounts to 625 million tonnes, equivalent to an energy content of 80 Mtoe per year (3.3 EJ per year). Organic waste offers a great potential for biogas production, with Russia's current potential for biogas production at 73.7 billion m^3 (2 EJ), with half of that being in the South federal and Volga federal districts. Other districts with large potential are the Siberian and Central districts (Karasevich *et al.*, 2014; Vasilov, 2013). Production of biogas from wastewater sludge is today around 15 PJ, which would be mainly sufficient to meet the heating demand of wastewater treatment plants. Total potential for landfill gas is 20 PJ (Tveritinova, 2008). Agricultural residues are mainly located in the central and southern parts of Russia. Similarly, animal waste is located in these same regions, but also partly in the eastern areas of the country.

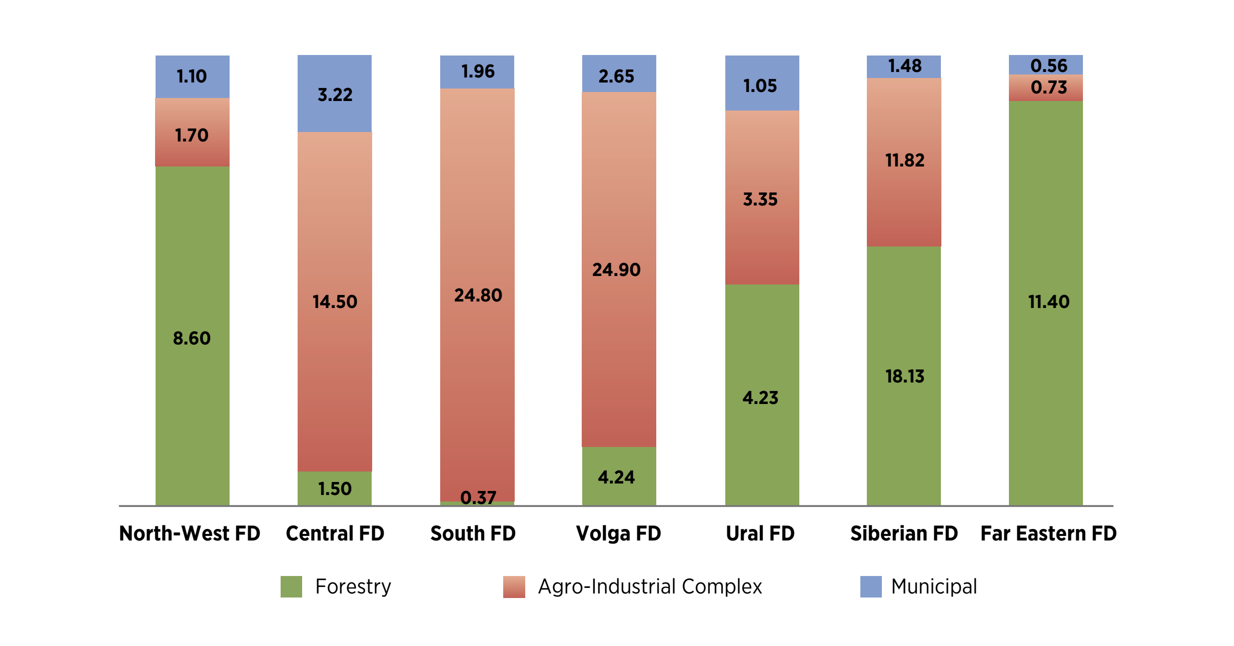
The volume of industrial and municipal waste is around 165 million tonnes per year. Municipal solid waste and sewage sludge are largely in parts of the country where population density is high, such as the central, southern and southwestern regions.

The composition of the potential waste differs based on the federal district. In the Southern Federal District, agro industrial bioenergy dominates, as opposed to the far eastern federal districts, where forestry dominates (see Figure 7).

When all this potential is combined, Russia's bioenergy has an economic potential of at least 69 Mtoe per year (3 EJ per year), with this reaching 129 Mtoe per year (6 EJ per year) when the technical potential is considered (Kiseleva *et al.*, 2015; Vasilov, 2013). Excluded from this total, the total stock for peat has a great potential as well, amounting to 60 000 Mtoe per year (2 500 EJ per year).

IRENA has also carried out its own assessment of the biomass supply potential in Russia (IRENA, 2014c). According to this assessment, the potential for biomass supply in Russia can range from 44 Mtoe per year (1.8 EJ per year) to 335 Mtoe per year (14.1 EJ per year). The greatest potential in the high end of the range comes from fuel wood (or energy crops from forest land), at around three-quarters. There is, however, great uncertainty about whether this potential can actually be utilised, because of barriers concerning the collection of feedstocks, such as a lack of infrastructure.

Figure 7: Structure of waste as a biomass source for bioenergy for federal districts of Russia, 2012



Unit: million tonnes of conventional fuel

Source: Vasilov, 2013

Table 6: Biomass feedstock supply potential in Russia in 2030

	Low (PJ/year)	High (PJ/year)	Supply cost (USD/GJ)
Energy crops from non-forest land	-	-	-
Harvesting residue	239	493	4.5
Agro-processing residue	218	461	1.2
Animal manure & post-consumer household waste	18	498	3.5
Energy crop from forest land	0	10 386	6.5
Wood logging and processing residue	801	1 728	8.8
Wood construction, demolition and furniture waste	572	518	8.8
Total	**1 848**	**14 084**	**4.6–7.3**

Source: IRENA analysis

3 BRIEF OVERVIEW OF ENERGY SECTORS AND ENERGY MARKETS

This section presents an overview of Russia's energy markets and its current energy system. The section starts by explaining the structure of Russia's power sector (Section 3.1). In Section 3.2, the current consumption of energy by sector and by technology is outlined. Section 3.3 provides a brief overview of conventional energy sources in Russia. This section ends with Section 3.4, which describes the recent status of energy prices and subsidies.

3.1 Power sector structure

In the early 1990s, the Russian electricity system was replaced by a vertically integrated monopoly. This was the basis of the first power sector reform. This structure, however, resulted in a market design that operated inefficiently in terms of production schedules and dispatching. Moreover, the financial performance of the power system was negatively impacted by developments in country's economy. These outcomes set the scene for a second power reform, which took place during the last decade. The main objective of this reform was to increase the efficiency of the electricity industry. The transition period ended in 2011.

This reform had important consequences for the power sector's structure and operation and had several components. The existing monopoly was dismantled, and fossil fuel-based power generation power plants were privatised, resulting in the creation of several companies, although nuclear and hydropower capacity still remains state-owned.

The sector has also been unbundled. There are now two separate companies, one for dispatch (the market operator) and another for grid operation. The transmission networks remain owned and regulated by the state. Capacity markets have also stayed regulated. In terms of the power markets, there are now separate wholesale and retail markets.

In the wholesale electricity market, electricity can be traded according to four different mechanisms: (i) regulated bilateral agreements; (ii) unregulated bilateral agreements (free pricing); (iii) day-ahead market (free pricing); and (iv) the balancing market. Wholesale market participants are also obliged to sell power on the retail market for a defined volume of electricity. In the retail market, generators that cannot participate at the wholesale market generate power. In addition, consumers, suppliers and distributors participate in the retail market. There is also the wholesale market for capacity, where the capacity that each generator must maintain is traded. The purpose of this market is to provide long-term adequacy and prevent generation supply shortage. This capacity is traded for the long-term (up to 10 years), resulting in capacity supply contracts determined by competitive prices. There is also a balancing market, which is operated by the system operator. This market reacts to any potential change at each of the 8 400 nodes in Russia's power system (IEA, 2014; King & Spalding, 2013).

In 2014, the wholesale electricity market had the largest value in Russia's power industry, with an estimated total of EUR 12.5 billion per year. Its value is followed by the wholesale capacity market, which totalled EUR 4.2 billion per year in 2014. Finally, ancillary services had a total value of EUR 19.6 million per year in 2014. This market has an important role in ensuring system reliability, providing proper maintenance of equipment and complementary characteristics and components (FGC UES, 2015).

Before the second power sector reform, the Russian power system had seven dispatch zones: North West, Centre, South, Volga, Ural, Siberia and Far East. The links between individual zones were weak, which impacted system stability and market operations. As a result of interconnection constraints, the potential for trade between remote locations and price levelling across regions was limited.

After the reform, two main price zones were formed, namely the European Russia & Urals (North-West, Centre, South, Volga, and Urals) price zone – which accounts for 78% of wholesale market volume – and the Siberia price zone, which accounts for the remaining 22% (in energy terms).

In the European Russia & Urals zone, fossil fuel-based and nuclear plants dominate the system, while typically, old inefficient gas units normally set the price. In Siberia, half of the plants are run-of-river plants, and the other half are coal and lignite-based generation facilities.

In addition to these two pricing zones, there are two non-pricing zones. The first non-pricing zone contains the two administrative regions in the northwest dispatch area that are excluded because of their weak transmission links. This zone is regulated by the government. The second non-price zone is the Far East dispatch zone, which also remains under regulation.

In the second half of 2013, the price of electricity in the non-regulated wholesale market reached around EUR 0.027/kWh. This is mainly linked to the changes in the price of gas. Depending on the grid voltage, the grid tariff ranges from EUR 0.019/MWh (>110 kV) to EUR 0.045/MWh (<0.4 kV). A sales mark-up (EUR 0.003/MWh) and other expenses (<EUR 0.001/MWh) determine the rest of the electricity end-price structure. Hence, grid tariffs can represent 38%-60% of the total end-price, depending on the voltage level (Bystrov, 2014).

The Russian power market has seen large investments in recent years, from both domestic and international independent electricity generation companies. Yet, while liberalisation has created opportunities, the main driver behind investments has been long-term regulated capacity agreements (with regulated returns), rather than free market prices. This has created an important opportunity for the modernization of the country's power system. In addition to these wholesale power generation companies, a territorial generation company, a state-owned hydro and a state-owned nuclear company, and finally one power export/import company, which also owns plants along the Russian borders, were formed.

Based on data from 2014, the total length of the transmission lines in Russia was 139 586 km. Of the total high-voltage lines (220-750 kV), two-thirds are 220 kV and a quarter 500 kV. The total length of distribution lines was 2.2 million km, with 10 kV and 110-150 kV accounting for more than half of the total. The country has 480 000 distribution and 947 transmission substations. All power systems are connected by high-voltage lines and they operate in synchronous mode, except in the eastern part of Russia (FGC UES, 2015). The country is part of the Integrated Power System/Unified Power System (IPS/UPS) energy system. This is a large-scale synchronous transmission grid covering 15 countries, including ten countries of the former USSR, Mongolia, and the Baltic countries. Parts of Finland and some regions of China are also supplied by the IPS.

The transmission company, the Federal Grid Company of the Unified Systems (FSK), serves 95% of the country's total area and accounts for nearly all transmission. Four distribution system operators also have high-voltage lines that serve the Bashkirian, Tatarstan, Irkutsk and Moscow regions. These systems have a total share of only about 2% of the total high-voltage transmission of the entire country (FGC UES, 2015).

As part of the reform process, the transmission network has been restructured. Two companies were selected from the RAO EES monopoly, namely the Federal Grid Company which became responsible for the >330 kV and the 220 kV grid lines and the Holding MRSK which became responsible for the distribution networks (<150 kV). Both of these companies belong to the federal government (Chernenko, 2013).

3.2 Energy consumption by sector and technology

In 2014, Russia's total energy consumption reached 16.4 EJ per year (391 Mtoe per year). The industrial sector accounted for the largest share of this total (38%), followed by buildings (35%) and transport (24%). Other sectors (e.g. agriculture, fisheries etc.) account for the remainder (3%) (Figure 8).

Natural gas (mainly in buildings) and oil and its products (mainly in transport) account for the largest share of the country's total final energy consumption, with shares of 24% and 22%, respectively. Coal, which is exclusively consumed by the industrial sector, accounts for only 10%. The direct use of renewables is minor, representing less than 1% of the total. Bioenergy and waste are the main resources.

District heating plays a particularly important role. In buildings, it represents nearly half of the sector's total energy demand. Likewise, in the industrial sector, it represents a quarter of the sector's total final energy demand. Of the entire Russian energy system, district heating consumption represents 28% of total demand. Finally, electricity accounts for 16% of the country's total final energy demand. In buildings and industry, its share is as high as 20% of the sector's total final energy demand.

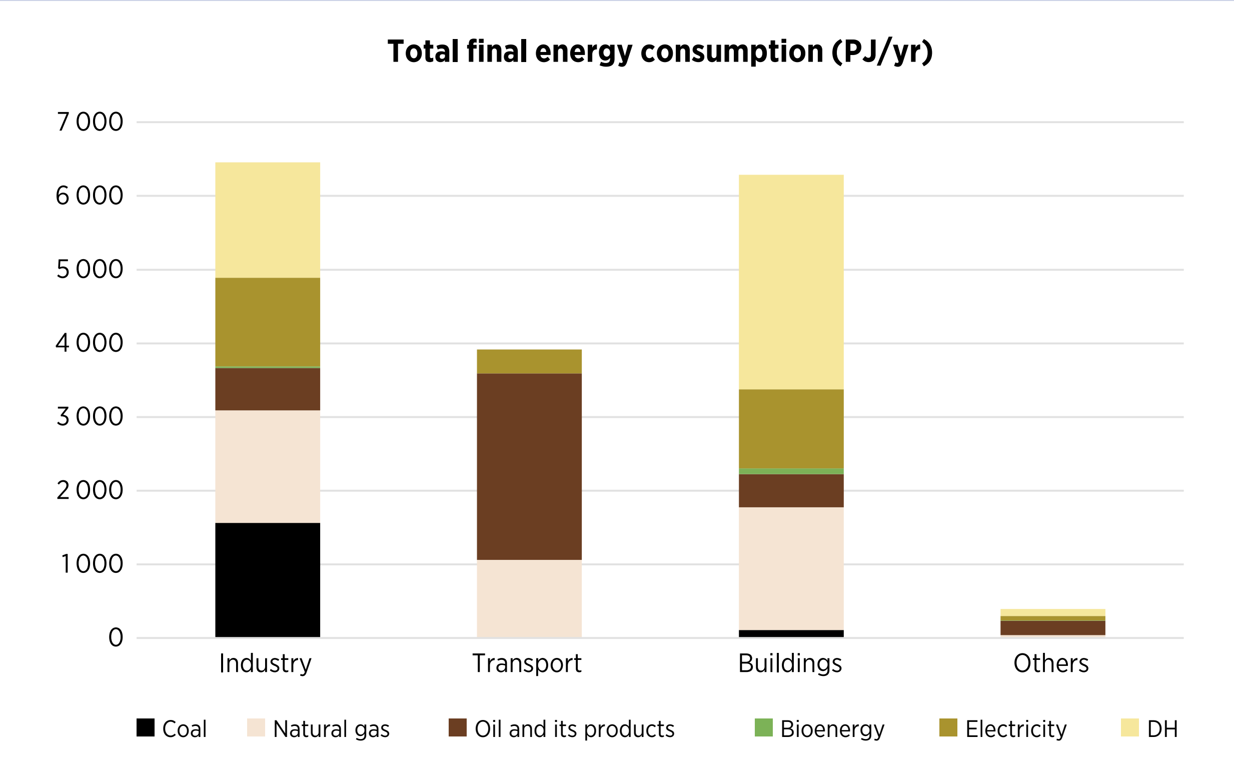
Russia's demand for energy has seen only minor changes in the past decade and has remained in the 16-17 EJ range since 1995 (see Figure 9). In terms of sectoral breakdown, changes have been minor.

Power sector

As opposed to total energy demand, which has remained constant over the past decade, total demand for electricity has increased. Electricity generation went up 1.2% annually between 1995-2014, reaching a total of 1058 TWh. Today, gas accounts about half of total generation, followed by hydro, nuclear and coal, which have similar, 15%-17% shares in total generation. Oil and peat both have the smallest shares in total production, at 0.8% and 0.1%, respectively. Renewables (excluding large hydropower) are dominated by the use of bioenergy and waste (0.3%), followed by geothermal (0.04%). Shares of solar PV and wind are relatively small (IEA, 2015a). At the regional level, the Ural region accounted for the largest share of consumption in 2015, at 25.6%, followed by the central region, with 23% (Minenergo, 2016).

There are about 700 grid-connected power plants in operation, countrywide. In 2015, total installed capacity was around 253 GW, up from 248 GW in 2014. In 2014, 51.7 GW of this total was renewable power generation capacity and 26 GW nuclear. The remaining 170.3 GW, representing approximately two-thirds of this total, were thermal plants (oil, gas and coal). Peak load in 2014 was 135 GW (Bystrov, 2014).

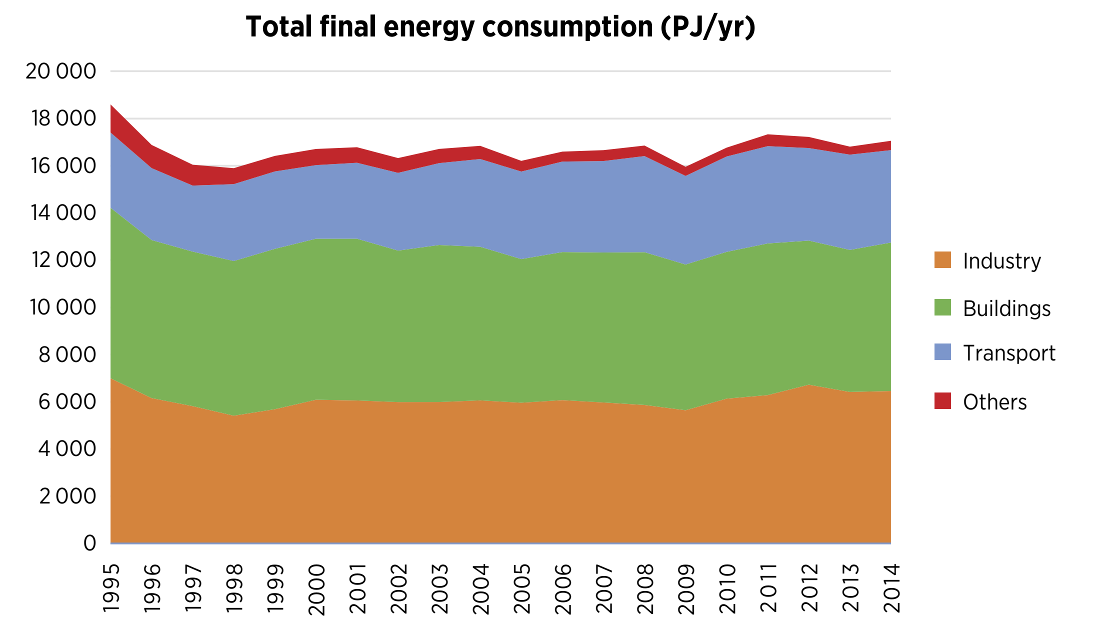
Figure 8: Breakdown of Russia's total final energy consumption by sector and technology, 2014



Note: Transport includes natural gas pipelines.

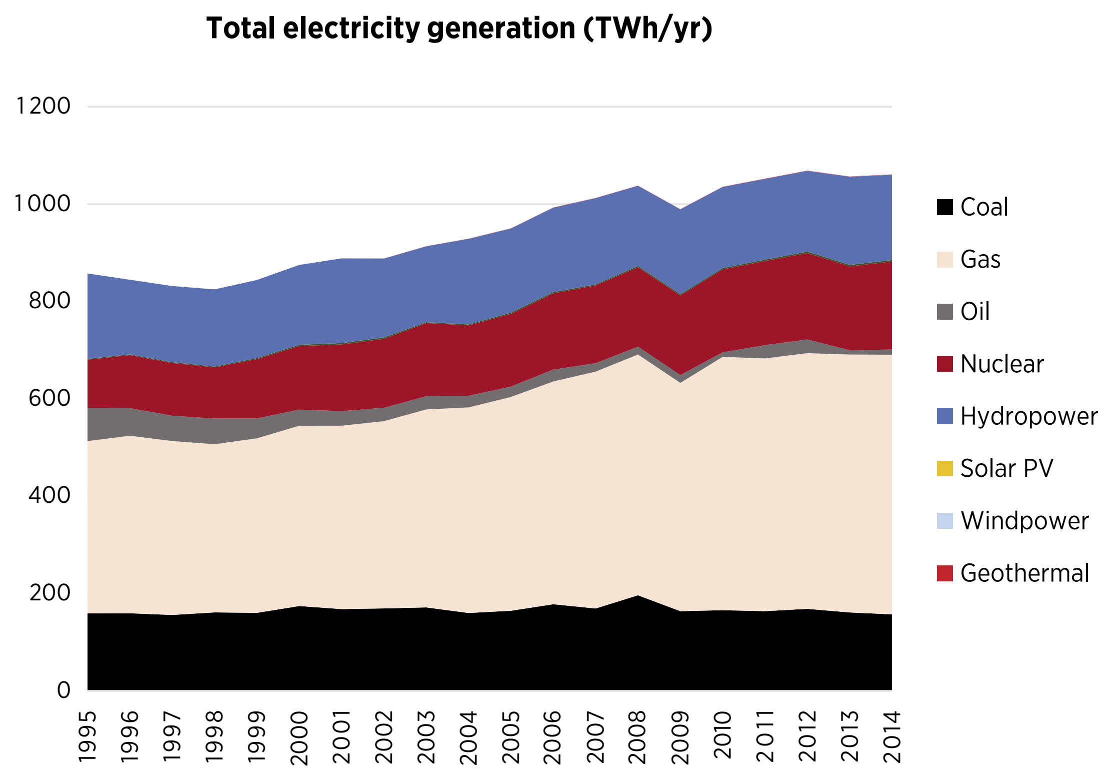
Source: IEA, 2015a

Figure 9: Breakdown of Russia's total final energy consumption by sector, 1995-2014



Source: IEA, 2015a

Figure 10: Breakdown of electricity generation by resource, 1995-2014



Source: IEA, 2015a

In 2014, 6 GW of new grid-connected power plant generation capacity was added to the system (Finpro, 2014). The year 2015 saw total additions of 4.7 GW (the majority in the Ural region) (Minenergo, 2016).

Overall, capacity additions have been rather slow since 1990. In recent years, additions have been mainly of natural gas-based capacity, with this rapidly growing. In 2014 and 2015, in addition to natural gas, hydropower was also extensively favoured, indicating that the current mix of power generation is likely to continue in the following years as well. The technology mix, however, is changing, with more capacity for (combined cycle) gas turbines being added, as opposed to steam turbines.

Current reserve margins in Russia are quite high, ranging from 20% to 30% (and the range is higher when individual regions are compared). These margins are more than the sector actually requires, which is on the order of 16%. This has meant that on one hand there has been less need for investment, given the availability of unused capacity, and, on the other, there have been unclear reserve margins as a result of aging and inefficient plants – meaning significant investment will be required for the construction of new capacity and the retrofitting of existing plants (Chernenko, 2013; E.ON, 2012).

The average age of the current stock is around 30 years old, with a significant share of the capacity being more than 20 years old. About half of all capacity operates by exceeding its lifespan. As for the power plant capacity, current grid infrastructure is old, leading to a number of operational problems. Such a grid infrastructure leads to bottlenecks in cross-regional power flows, for example, and limits interregional market coupling. The energy sector, including oil and gas production sites, needs about USD 100 billion in investments per year until 2030 to modernise its ageing system. This will not be possible without a massive rise in investment, including foreign direct investment.

CHP generation plants remain the key technology, although not all the technologies employed are necessarily classified as CHP. They do, however, all generate heat as a by-product, with this used as a source for heating in buildings or industry. As a result, one can consider all power generation from fossil fuel-based plants as CHP, with this representing today around two-thirds of total generation (IEA, 2015a).

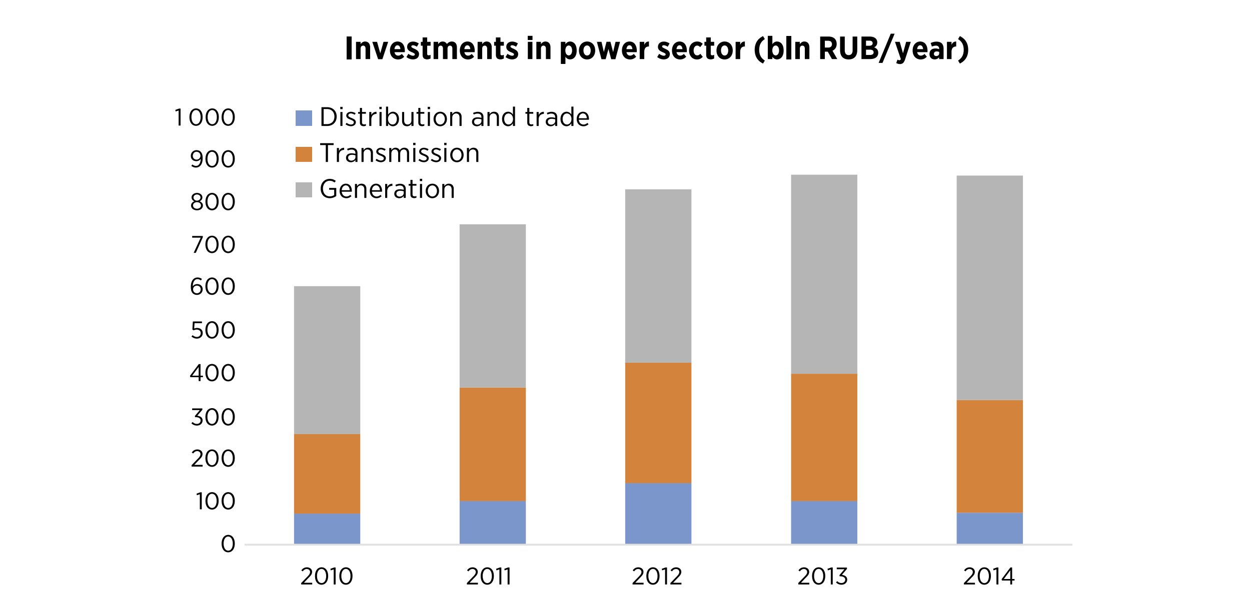
These 'CHP' plants also generate an equally high amount of heat and electricity. The power-to-heat ratios of these plants are around 0.7, or even higher. The fuel utilisation efficiency of these CHP plants in generating both heat and power ranges up to 60%. These values are lower than those achieved in European countries and countries with similar climatic conditions, where plants operate at around 75%-85% efficiency.

When the heating component is excluded from the equation, the efficiency of power generation still remains among the lowest in the world. In 2012, the average efficiency of power generation from fossil fuels averaged around 32%, lower than in Indonesia, which achieved 33%, but higher than in India, with 28% (Hagemann *et al.*, 2015). Old, coal-fired CHP plants have efficiencies as low as 23%, whereas the newly built combined cycle gas turbines (CCGT) plants have much higher rates.

Indeed the higher penetration of CCGT plants is a promising development because of the better performance they offer. Typically, "E" and "F" class turbines are being installed in Russia. These classes have relatively good efficiency (58%-60%), but are still slightly lower than the efficiencies of advanced "G" and "H" classes (60%-62%). While the efficiency difference is marginal, too, the impact of this on the profitability of plants is large. Overall, net profit margins from the wholesale market increase with higher shares of CCGT equipment in total capacity (Strategy& and PwC, 2015).

Total investments in the Russian power system (both generation and infrastructure) recently reached RUB 864 billion per year (approximately USD 13 billion per year, according to the exchange rate in November 2016) (see Figure 11). Generation capacity investments represented approximately 60% of the total, with 30% being represented by transmission investments. Distribution and trade infrastructure investments accounted for the remaining 10%.

Figure 11: Breakdown of investments in Russia's power system, 2010-2014



Source: AC, 2015

End-use sectors

Materials production and other manufacturing industry sub-sectors have a long history in Russia. The country is a large producer of all types of bulk materials, including iron, steel, chemicals, fertilisers, cement, aluminium, pulp and paper, as well as food, wood and other products.

The iron and steel sector is by far the largest energy consumer in the country, accounting for more than a quarter of the sector's total final energy demand. The chemical, petrochemical and non-metallic minerals (e.g. cement) sectors account for 20% and 12% of the total, respectively. The industry sector's remaining demand for energy is split across food, paper, wood products, machinery and other smaller sectors.

Industry is the single largest user of electricity in Russia. It accounts for two-thirds of the country's total electricity demand (FGC UES, 2015).

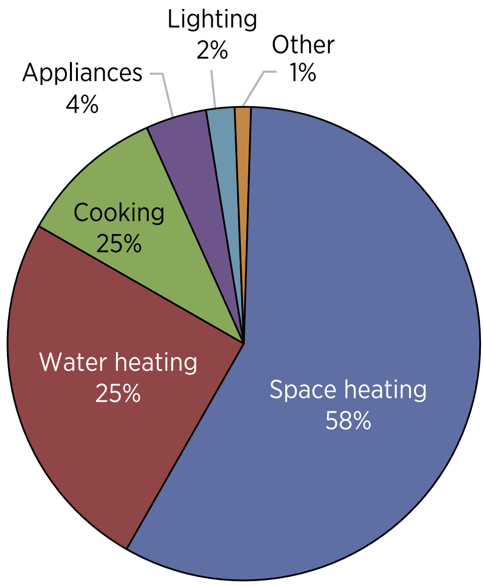
The equipment and facilities employed by the industrial sector today are aging, however, and therefore have low levels of efficiency. About half of the sector's equipment was installed before 1985 (Finpro, 2014). As a result, the energy efficiency of the sector ranks among the least, worldwide.

Depending on the sector, there is the potential to achieve energy savings of between 10% and 40%, compared to the level achieved by the best available technologies employed today.

Russia's energy saving potential is about 470-481 Mtoe, spanning across all sectors of its economy. The savings potential in the industrial and residential sectors is equally highest, with these two together representing a third of the country's total saving potential (Bashmakov, 2015).

The building sector (three-quarters of which is residential) is the second largest energy consumer in the country. The sector is characterised by its large demand for heating, which is to large extent met by district heating. Buildings account for 60% of total district heating and about 20% of the total electricity generated in the country.

Figure 12: Breakdown of energy use in the residential sector, 2008



Source: Lychuk et al., 2012

More than 80% of all energy used in the residential sector is related to heating. This can be split into space heating (58%) and water heating (25%). Cooking accounts for about 10% of the total. The share of electricity demand related to appliances and lighting is slightly over 5% of the total (see Figure 12).

Demand for cooling is negligible today, but recent trends show some increase in air conditioner purchases, since the average temperature in the country has been rising and average income has been growing. In particular, in large cities, the population is demanding more air conditioning and ventilation. In the mid-2000s, air conditioner ownership in Russia was about six per 100 households, with Moscow accounting for half of the total quantity and St. Petersburg second, with around 20% of the total. Given the cool summers in the country, ownership will be lower than in most other parts of the world, but market trends still show a rapidly growing rate of purchase (Lychuk *et al.*, 2012).

Households account for 18% of the total electricity demand in the country. Other buildings account for 2% (FGC UES, 2015).

In the former USSR, most buildings were constructed between 1960 and 1985. The building stock in urban areas follows a few standard types of buildings, and they are typically characterised by low levels of energy efficiency. In 2012, the total floor area of buildings in Russia was around 5.44 billion m^2, equivalent to 38 m^2 per person (Hagemann *et al.*, 2015). According to the Federal State Statistics Service of the Russian Federation, in 2013, almost 200 million m^2 of new residential floor area had been added into the market, or less than 4% of the current level (IEA, 2015b).

Since 2003, Russian buildings have witnessed some growth in the number of new and renovated constructions. These new buildings have generally better efficiency than the older stock. Thus, the average energy use of the residential sector was halved between 2003 and 2013, from 670 kWh to 380 kWh per m^2.

According to a 2008 study (Sargsyan and Gorbatenko, 2008), the average heating intensity of multi-family houses in high-rise buildings was around 229 kWh/m^2 per year in the mid-2000s. For new high-rise buildings, the efficiency was significantly better, at about 77 kWh/m^2 per year. Retrofitted buildings have also significantly better efficiency, at around 151 kWh/m^2 per year.

There is a similar relationship in the energy efficiency of hot water production among new, retrofitted and existing buildings. The hot water energy intensity of buildings with access to district heating that were built before 1990 ranges from 0.09 Gcal-0.18 Gcal per m^2 per year. Renovated buildings of this age have an energy intensity close to the low end of this range, or even less, at 0.06-0.09 Gcal/m^2 per year. Buildings that were built between 1990 and 2000 have lower hot water energy intensity, at 0.04-0.06 Gcal/m^2 per year, and finally, buildings that were built after 2000 have the lowest intensity, at 0.04 Gcal/m^2 per year, on average (Sargsyan and Gorbatenko, 2008).

A comparison of energy use in existing buildings with new and renovated ones shows a significant potential for energy savings in both hot water and space heating applications. According to the same study, the economically feasible potential is around 35%. The technical potential is much higher, reaching about 50%.

Despite a significant gain in recent years in improving the sector's energy efficiency, however, the gap with countries (or regions in countries) with similar climatic conditions, such as Canada, China, Finland or the United States, shows a further improvement potential of up to 80%. The majority of this savings potential can come from measures addressing external walls, windows and doors (Paiho, 2014).

The potential for energy efficiency improvement is, however, only being realised slowly, given the policy environment and the investment and time required for change. Analysis has shown, though, that in sectors where energy efficiency policies and the measures state programmes have been implemented more actively (e.g. by municipal institutions), there have been remarkable energy savings.

Overall, the investment needed to improve the efficiency of the building stock is significant, though. Russia's building stock requires renovation. This amounts to approximately 40% of all buildings which would require a total investment of USD 75 billion (IEA, 2015b).

Since 2009, significant amounts of federal subsidies have also been allocated to regional programmes for improving energy efficiency, given high interest rates and the high upfront costs of energy efficiency measures – particularly when compared to the low energy tariffs (Paiho *et al.*, 2013). Federal funding alone, however, is not sufficient for this purpose. Beyond funding, there are several other fundamental challenges to improving the energy efficiency of Russia's building sector. These include the following (Finpro, 2014; Paiho *et al.*, 2013):

- outdated norms and long permission processes, which act against building renovation
- a lack of sub-metering for electricity, hot and cold water as well as heating
- regulatory issues around mechanical ventilation system design, installation and maintenance
- a lack of clarity about the liability of the state in renovating buildings and the undeveloped status of homeowner associations
- a lack of information about the actual technical condition of buildings
- a general lack of information/awareness on energy efficiency.

Improving the energy efficiency of Russia's residential sector would create a number of benefits, such as increase purchasing power, make mor enatural gas resources available for exports and domestic consumption (e.g. chemical industry), and create regional development (OECD, 2013). Less demand for energy in the building sector would also allow utilisation of the large potential of renewables in the sector, and their easier integration into the system. With less demand for total energy, it is easier and cheaper to transport biofuels, or connect buildings to district heating systems, while less roof area is required for solar water heaters on buildings that are located in regions where potential exists.

About a quarter of the total energy demand in Russia is related to transport sector activities. Together with communications, the transport sector recently accounted for 12% of the country's total electricity demand (FGC UES, 2015). During the last decade, Russia's road transport has experienced a continous growth. The vehicle stock has grown by 50% from 31 million in 2005 to 47.9 million in 2013. Light vehicles dominate the stock with a share of more than 80%, which is equivalent to 38.8 million cars. The use of more cars has increased the demand for fuels which is now the major contributor to transport's growing energy demand. Nearly two-thirds of all demand comes from the European part of Russia (Gusev, 2013b). The number of vehicles running on liquefied petroleum gas (LPG) is increasing. In 2011, there were 1.4 million such vehicles. In 2012, a government decree was issued to shift half of all public transport from gasoline and diesel to LPG (Gusev, 2013b). Furthermore, there is growing use of compressed natural gas (CNG) vehicles in the country. In 2013, consumption of this reached 400 million m^3, which represented 1% of total global consumption (AC, 2015).

District heating sector

Today Russia operates the largest district heating system in the world. Installed thermal capacity for this in 2007 was 541 GW, from around 50 000 systems. In total, there were more than 17 000 district heating utilities. The municipal centralised heating network alone stretches for a total 170 000 km, and three out of four citizens are supplied with district heating (Euroheat & Power, 2013; IEA, 2015b; Lychuk *et al.*, 2012).

Climate conditions in Russia have a major impact on the parameters of the heating sector. Low outside temperatures create the need to run large heating capacities. Along with this, the heat generation sector is tightly linked to power generation, which is why any failures of the heating sector will result in extra electricity consumption. As a result, peak power consumption is determined by weather conditions. For example, a one-degree temperature drop in the European part of Russia will result in a 0.6% increase in power consumption (which is a 6%-7% difference in heating). About half of the power and heating market is dominated by low-cost natural gas.

Traditionally there was no metering and no individual controls on heating, so losses were high. Recently, there has been a shift from district heating to individual boilers, but policy is aimed at preserving the centralised district heating systems. Gas dominates as fuel in the European part of Russia, while coal dominates in Siberia. In Arkhangelsk, biomass residues from forestry are used, while in Belgorod, manure from pig farms is used. Out of 33 400 boilers, 1600 were fired by biomass in 2007 (IFC, 2011).

About 70% of all heat production is through central systems and is delivered to end-users via district heating networks (Boute, 2012). Around 35%-45% of all district heating is consumed by the industrial sector and 55%-65% is consumed by buildings. Of the total consumption in buildings, about two-thirds is in the residential sector.

A wide range of technologies is used for centralised heat production, with total capacity split equally between CHP and heat-alone systems. Industrial surplus heat (roughly 5% of all generation) and heat from nuclear power plants (0.2% of all generation) are also sources of production (Euroheat & Power, 2013; IEA, 2015a).

Most CHP installations are under the control of regional electricity production companies. These companies also control the district heating networks. Other suppliers of heat are the regional generation companies, which are independent from the RAO UES. Smaller boilers for district heat generation are owned by either private companies or municipalities (Boute, 2012).

The average district heat boiler efficiency is about 75%, which is about 10-15 percentage points lower than the levels in Europe or the United States. The majority of the district heating network's capacity was built before 1990, and thus has a great potential for improving its energy efficiency. According to the Russian Government, 70% of the infrastructure needs to be replaced in the near future, and 30% of is in need of urgent replacement (Euroheat & Power, 2013; IEA, 2015b; Lychuk *et al.*, 2012).

This aging network also causes distribution losses. These amount to 20-25% of the total heat generated, a factor 2-10 times higher than that seen in countries that also operate district heating systems in similar climatic conditions (Sargsyan and Gorbatenko, 2008). Moreover, in the case of buildings where there is no demand in the summer, CHP plants operate in condensing mode part of the year, which results in low efficiencies. In fact, even in winter, when heat demand is high, some plants must operate in heat-only mode, as electricity supply exceeds demand (IFC, 2011).

Modernising the district heating sector is essential. The government is aware of this challenge. The purpose of the Federal Law No. 190-FZ of 27 July 2010 (the Federal Heat Law) is to regulate heat production, distribution and supply to end-users. At the same time, it is an integrated approach to improve the sector's energy efficiency (including the deployment of renewable energy) (Boute, 2012).

One main challenge is lack of metering. Metering is considered either too expensive or technically too difficult to install. Despite a number of obligations to increase numbering since the mid-2000s progress was limited. The Federal Law No. 261-FZ of 23 November 2009, On Energy Conservation and Increasing Energy Efficiency, aims to meter for about three-quarters of all district heat supply to be metered. The remainder 25% is exempt as demand is too low (<0.2 Gcal per year) (IEA, 2014).

In addition, in 2014, a market reform was approved by the government and a roadmap was developed that describes the sector's strategy from 2015 onwards. This reform aims to be completed by 2020 in major industrial cities with a population of more than 100 000, as well as in cities that have a CHP plant in operation, and by 2023 in smaller cities.

Realising modernisation investments also requires improvement in the existing heat tariff structure to ensure energy savings are stimulated, rather than de-incentivised. The previous, cost-plus approach of tariff setting did not ensure financial viability for investments. Indeed, it has resulted in the opposite, encouraging companies to consume more energy. In principle, tariffs should allow the recovery of investments. In the particular case of biofuels, there is a need to also recover fuel costs, since logistics can increase biofuel costs. With the reform of the Russian heating sector, long-term tariff methodologies will be used to improve efficiency and accelerate renewable energy uptake.

It is also possible to apply these tariff changes at the region level, since one of the main tasks of the regional tariff authorities is to increase energy efficiency of the sector through financial incentives (FTSRF, 2015).

3.3 Conventional energy reserves, production and trade

A significant share of the Russian government's income is from the oil and gas business. In absolute terms, Russia's income from the oil and gas sector is the second highest in the world, after Saudi Arabia. In terms of oil and gas' share of total income, Russia is the fourth highest in the world, after Saudi Arabia, Indonesia, and the United States (Whitley and van der Burg, 2015).

The energy sector is an essential part of the Russian economy. This includes revenues created by exports and supply of affordable energy commodities. Approximately half of Russia's budgetary income is oil and gas related (around RUB 7 trillion). In 2014, oil and gas income was RUB 0.9 trillion higher than in 2013 (approximately USD 20 billion). The energy sector provides more than a quarter of Russia's total GDP (Galkina *et al.*, 2014).

Russia has significant reserves of all types of fossil fuels. Around 5.5% of the world's crude oil, 18% of its coal and 17% of its natural gas reserves are located in Russia (AC, 2015). In 2015, Russia continued to be the third largest oil producer and second largest gas producer worldwide (BP, 2015). Both private and state-owned companies operate in the oil and gas sector, which accounted for 10% of the country's GDP back then (Nesterlenko *et al.*, 2015).

Crude oil

Crude oil and natural gas liquid production reached around 520 Mt per year in 2014, and the country has experienced around 1.2% annual growth in production over the past six years. Rosneft accounts for more than a third of Russia's total production, at 190.9 Mt per year.

After the United States and Saudi Arabia (which exceeded Russia's production capacity in 2011), Russia is the world's third largest crude oil producer. Production in the Ural Federal District continues to account for by far the largest share (nearly 60%), however, this region's share in total production has been decreasing since 2006. Instead, production in the greenfield sites of Siberia, the Far East and Volga regions is increasing.

Changes in the breakdown of regional production have resulted in Siberia becoming the largest region for the flaring of associated gas. This is due to the lack of infrastructure for gas utilisation, which means Siberia now accounts for nearly half of the total associated gas flaring in the country. In 2008, its share was less than 5%. Gas flaring is an inefficient practice. The limited availability of technology and an insufficient gas processing and transport infrastructure result in oil companies having to flare gas instead of using it as a raw material. The mandatory share of gas utilisation is 90%-95% of the total, but 25%-30% of the total gas is being flared. This amounts to 12-16 billion m^3 (bcm) per year. In 2015, gas flurry in Russia has increased to 21 bcm/yr (Snow, 2016), this represents two thirds of Moscow's annual gas requirement of 30 bcm.

Investments in the oil sector have shown an increasing trend over the past five years, with annual investment in crude oil production reaching around RUB 1200 billion in 2014. Annual investments in the refining sector reached about RUB 500 billion the same year. Pipeline investments, which had been flat for the previous five years, increased in 2014 to reach around RUB 400 billion.

Meanwhile, production of oil from conventional fields is stagnating and Russia will have difficulty maintaining current production levels. Giant fields are becoming mature and have to be replaced, but new fields, which are more capital intensive, are not being opened.

Throughout 2015, production grew because of an increase in exports (Gusev, 2013a). Yet, given new economic conditions post-2015, there are major uncertainties around the energy sector caused by the oil price drop and sanctions on technology and finance. As a result, companies are making more cautious investment projections and cutting back on exploration and new projects. This is not only the case in oil, but also in gas.

About 60% of all crude oil production in the country is refined (approximately 294 Mt per year) and since 2010, refining has been growing at about 3% per year. The Volga region is by far the largest refining region in the country, representing about one-third of the total.

A range of products is produced in Russia's petroleum refineries. In 2014, heating oil production reached 78 Mt per year, diesel 77 Mt per year and gasoline 38 Mt per year. More than half of the total production of gasoline and diesel is in line with Euro 5 standards.

A large share of crude oil and petroleum product production is also exported, yet the absolute volume of crude oil exports has been slowly declining since 2006, and in 2014 this reached around 225 Mt per year. On the other hand, exports of petroleum products have been increasing fast. Standing at around 100 Mt per year in 2005, these reached around 160 Mt per year in 2014. About half of all exports are to Organisation of Economic Cooperation and Development (OECD) countries, with fuel oil and diesel fuel accounting for half of all OECD exports.

Natural gas

The Russian natural gas sector is also an important contributor to federal and regional budgets, albeit to a considerably lesser extent than the oil sector.

Russia remains the second largest producer of natural gas worldwide, after the United States. In 2014, production reached around 640 bcm. This represents 1.3% of Russia's total natural gas reserves, which were 49.5 trillion m^3 (tcm) in 2014. These fields are in the central northern parts of the country, with the largest reserves at Urengoy, Bovanenkovo, Shtokman, Zapolyarnoye and Yamburg. Production also takes place in the Nadym-Pur-Taz region.

The bulk of production still stems from the western Siberian gas fields owned by Gazprom. This is the largest gas producer in the country, with its production accounting for 70% of Russia's total. The largest producing gas fields are Zapolyarnoye, Urengoy and Yamburg, which account for more than 40% of total output.

Independent gas producers are, however, also gaining market share. In 2007, their share in total production was around 16%, with this rising to 29% by 2014. Novatek is the largest independent gas producer, having delivered 53.5 bcm in 2014 (AC, 2015).

Gazprom sells its gas at a regulated price, which has seen an increase in recent years. Gazprom is not allowed to offer discounts, while independent gas producers can.

In line with government policy to liberalise the internal natural gas market, in 2014, gas trading began on the St. Petersburg International Mercantile Exchange. The volume of natural gas traded on this platform has been constantly increasing. As a result, recent years have seen an increasing market share from such producers – at the expense of Gazprom's decreasing market share.

With the existing large gas fields being exploited, the Russian gas sector is now entering a new stage. In this phase, new gas fields are being explored and developed. Production costs from these fields are higher, however, as some of them are located in the extreme, hyperborean conditions of the Arctic region, implying an increase in future production costs.

Natural gas is used where it is also explored and produced, such as in western Siberia and the Urals. Through the further development of remote gas fields in eastern Siberia (e.g. Kovykta field in Irkutsk) and the Far East (e.g. Sakhalin island) eastern regions will be further gasified (Holz *et al.*, 2014). Russian energy strategy foresees the continued expansion of natural gas, and its significance remaining great in Russia's energy sector over the coming decades.

Approximately 30% of all Russian gas production is exported, with 70% of it consumed domestically (485 bcm). The production of electricity and district heating account for around 52% of the total consumption of natural gas (121 bcm and 114 bcm, respectively in 2013). These figures are followed by the industry and residential sectors, with consumption volumes of 56.9 bcm and 49.5 bcm, respectively. Gas transportation and other uses account for the rest. Some 36% of all exports are to Germany, followed by Turkey, which accounts for 27.3% of all Russia's gas exports.

Recent years have seen the Russian government giving great priority to Liquefied Natural Gas (LNG) exports and the liberalisation of these. A law on this came into legal force on 1 December 2013, which opened up an export opportunity to the Asia-Pacific countries. Earlier, gas export had been under a Gazprom monopoly.

The country's single LNG plant (accounting for 4.4% of the total global LNG market) is based on Sakhalin Island, north of Japan. Production capacity at the plant is 9.6 million tonnes per annum, and it produces about 14.4 bcm per year. Production is exported to Japan by sea.

There are plans to expand LNG production, and Gazprom has two projects for doing this – namely the Vladivostok LNG plant (10 million tonnes) and the Sakhalin-1 plant (5 million tonnes). These are both scheduled to start in 2018. Another Gazprom project, in the Baltic Sea, is planned to commence in 2020 with the export port in Ust'Luga. The plan is to export 10 million tonnes of LNG and 5 million tonnes of compressed natural gas (CNG) each year. Another LNG project (from an independent producer) has a total production capacity of 2.6 million tonnes per year and is located in the Nenets Autonomous District. One other project is the Yamal Liquefied Natural Gas scheme, run by Novatek, which in 2017 planned to become Russia's first Arctic LNG producer.

Coal

Despite holding the second largest proven coal reserves in the world (157 Gt), Russia ranked as the sixth largest coal producer in the world in 2014, after China, the United States, India, Indonesia and Australia. In 2014, coal production reached 358 million tonnes. There are more than 240 coal mines that are being operated in Russia. This can be split into 96 underground mines and around 150 surface mines. The total production capacity of these mines is more than 360 million tonnes per year.

Three-quarters of all coal is mined by open-pit mining (Slivyak and Podosenova, 2013), with coal basins located in the south and eastern parts of the country. Two other large basins are in the north (Pechora basins) and in the southwest (Donets basin). Kuznetsk Basin, in the south of Russia, produced more than 200 million tonnes of coal in 2014 and is the single largest producer of coal in the country. Nearly 85% of all production takes place in the Siberia district.

Different types of coal are produced. Up to 80% of all output is hard coal. Coking coal made up 24% of total production, with a total volume of 86 million tonnes. All coking coal is upgraded. On the other hand, only a quarter of total steam coal production is upgraded.

Production by the private company, SUEK, accounts for 28% of Russia's total coal output. Investment in the coal industry saw a sharp increase between 2010 and 2012. Following the 2012 peak, the trend was reversed and investments declined to RUB 58 billion per year in 2014 (approximately USD 1.2 billion). This is explained by coal companies freezing their projects, given Russia's complicated economic situation.

Compared to gas and oil, trade of coal is limited. Russia remains, however, a large exporter of coal worldwide – third after Indonesia and Australia – with about half of its output sold to other countries. The largest importers of Russian hard coal are China, the United Kingdom and the Republic of Korea. Following its exports, a quarter of total supply is consumed by power plants. Coking plants and consumption by the residential sector then account for 12% and 7% of the total production, respectively in 2014 (AC, 2015).

3.4 Energy prices and subsidies

Today, there are two domestic natural gas markets, with all prices for private households regulated and all industrial consumers having access to the wholesale market (Aune *et al.*, 2015; Holz *et al.*, 2014).

In 1996, the natural gas price was USD 45/1000 m^3, one of the lowest in the world (USD 1.40/MMBtu). Since 2000, however, subsidies for domestic consumers have been slowly reduced, and gas prices have increased slightly to a level of around USD 1.80/MMBtu by 2010. In 2013, the regulated price reached USD 3.50/MMBtu and in 2014, USD 3.10/MMBtu (Aune *et al.*, 2015; Henderson and Mitrova, 2015).

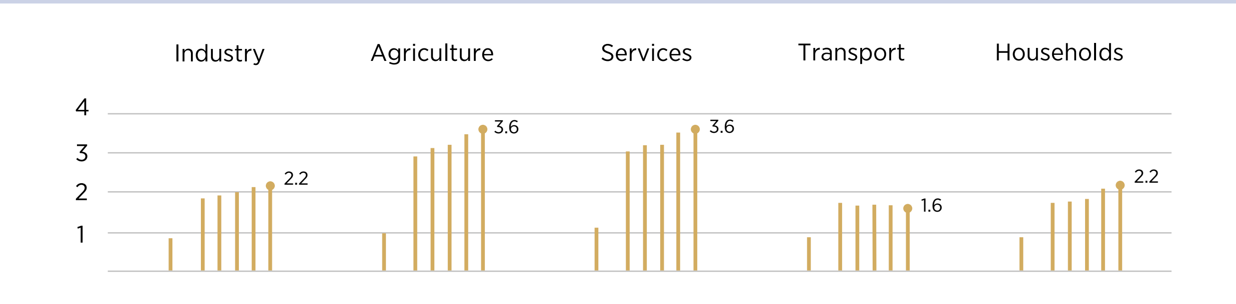
Gas prices differ by zone. In 2013, for example, wholesale gas prices ranged from USD 2.20/MMBtu in the Yamal Nenets Autonomous Okrug to USD 3.10/MMBTU in the north Caucasus. Gas prices also differ by end-user. For industry, the gas price in 2007 was USD 1.4/MMBtu.

In December 2010, the government adopted a directive to maintain the regulation of wholesale gas prices for until 2014. In the period 2011-2014, a special formula was thus used to adjust the price (Aune *et al.*, 2015; Holz *et al.*, 2014). In 2014, wholesale prices then increased to USD 2.30/MMBtu.

The government has also authorised gas price rises to European netback parity (European price minus the extra costs of transportation and export duties). The plan was to gradually increase both domestic gas and electricity tariffs, with industry prices achieving parity in 2011, and households a few years later. With the global recession, however, and decreasing oil prices in recent years (which have also had an impact on gas prices), netback parity would have been too high to be realised. Gazprom's view was that a netback parity that would cover Russia's largest company's investments and sustain natural gas production had to be reached. Given that such an increase might have a negative impact on consumers, though, the government postponed this goal to 2018. The government however, is sticking to its plan to raise natural gas prices. In late 2013, the decision was made to freeze prices until summer 2015 and let them rise gradually to 2030, with industry prices growing annually by 3.2% per year for industry and 3.5% per year for households (Aune *et al.*, 2015).

Recent years also saw an increase in household electricity prices by 50% over a six year period (Lisin *et al.*, 2015). Since 2010, electricity prices for households have exceeded the price for industry by about 10%, though the ratio has come down in recent years (AC, 2015). The agriculture and service sectors pay about 50% more than the industrial and household segments (see Figure 13). In 2013, the average electricity subsidy was around USD 0.021 per kWh (based on USD 22.3 billion per year electricity subsidies against production of around 1 070 TWh per year of electricity). This compares with a household electricity price of USD 0.065/kWh the same year.

Figure 13: Average electricity prices by consumer groups in Russia, 2004 and 2010-2014



Note: in RUB/kWh and nominal.

Source: AC, 2015

Cost and purchase prices of hard coal have increased gradually over the past decade, from below RUB 1000 per tonne in 2004 to around RUB 2500 per tonne in 2014. Coking coal prices have been fluctuating, as in the rest of the world. Purchase prices peaked at RUB 6500 per tonne in 2011, but stayed at RUB 4000 per tonne in 2013/14. The cost price of coking coal is more stable, and follows the level and trend of hard coal prices (AC, 2015).

Today's Russian energy sector remains subsidised, with a major focus on households across the country and an average subsidisation rate of 19.6%. The main motivation for continuous subsidy of fossil fuels in most countries is a social one, as sustainable access to basic energy services raises the living standards of the poor. Affordable modern energy services greatly provide for general economic development. As a result, for a long time, energy prices for domestic users had been kept artificially below the cost of production and transport. In order to prevent any energy market distortions and maintain efficiency on the consumption end, as well as to ensure market openness and competitiveness, in 2014, energy subsidies represented 3.3% of Russia's total GDP, a figure that amounted to USD 62.4 billion. This was split into 2.1% related to interventions that resulted in final prices to end-users (USD 39.6 billion) (IEA, 2016) and 1.2% related to subsidies for fossil fuel production (USD 22.8 billion) (Ogarenko *et al.*, 2015). Total subsidies to end-users were related to electricity and gas and amounted to USD 22.1 billion and USD 17.5 billion per year, respectively.

4. WHERE WOULD THE REFERENCE CASE TAKE RENEWABLES BY 2030?

Russia's Reference Case (business as usual) has been prepared on the basis of the country's draft Energy Strategy to 2035 (Minenergo, 2017) and data provided by the Ministry of Energy of the Russian Federation accompanied by IRENA's calculations based on aforementioned data.

The draft Energy Strategy to 2035 updates a previous version that had a 2030 outlook. The main differences between the two strategies are the energy price assumptions and the growth in total demand for energy. The 2035 outlook assumes a crude oil price of between USD 70 and USD 90 per barrel, by 2030. At approximately 10%, growth in demand for energy (including demand for fuels for power generation and district heating) is also assumed to be much lower between 2010 and 2030.

Data for the base year, 2010, has been taken from the IEA Energy Balances (IEA, 2014a) and data provided by the National Statistics of the Russian Federation. The growth in each energy carrier and sector for 2010-2030 is the basis for the analysis presented in this report and is supplied for Russia's entire energy system in its draft "Energy Strategy to 2035". If necessary, data from the "Energy Strategy to 2030" (2010) has also been used.

Russia's TFEC in 2010 amounted to 17.2 EJ per year. According to Russia's draft Energy Strategy to 2035, by 2030, TFEC will increase by about 28%, to 22.1 EJ per year. This is equivalent to an annual rise in total energy demand of about 1.2% over the 2010-2030 period. In primary energy terms, this is equivalent to a growth of 0.7% per year. By comparison, primary energy demand grows slightly less, at 0.2% per year over the same period, according to the latest Russian energy outlook prepared by the Energy Research Institute of the Russian Academy of Sciences (Makarov *et al.*, 2016).

In the Reference Case, the total demand for fuels for generation of power and district heating stood at 15.3 EJ per year in 2010. In the Reference Case, by 2030, this remains at the same level of 15.2 EJ, in spite of the fact that generation of power increases and demand for district heating remains more or less the same over the entire period. This is explained by improvements in energy efficiency in generation and the avoided losses in distribution of electricity and district heating. Under the Reference Case, efficiency improves by between 10% and 20%, depending on the technologies.

During 2010-2030, total electricity demand increases faster than TFEC, at 1.4% per year. This represents an increase in end-use electricity demand from 725 TWh to 960 TWh per year. By comparison, gross electricity generation rises to 1285 TWh per year. The difference between generation and consumption is explained by the energy industry's own consumption, and transmission and distribution losses. The share of electricity in TFEC climbs slightly, from 15% in 2010 to 17% in 2030. District heating demand remains at the 2010 level, or even declines slightly. This means heat for buildings will be produced more from decentralised systems.

Table 7: Total final energy consumption in Russia according to the Reference Case, 2010-2030

	2010 (PJ/year)	2030 (PJ/year)
Industry	7 394	8 409
Transport	4 040	5 538
Agriculture	375	461
Buildings	6 216	7 313
Total	**17 179**	**22 191**
Fuels & renewable energy	9 773	14 252
Electricity	2 617	3 466
District heating	4 789	4 472

Source: IRENA estimates based on Russia's Energy Strategy to 2030 and 2035

5. POTENTIAL OF RENEWABLE ENERGY TECHNOLOGY OPTIONS BEYOND THE REFERENCE CASE IN 2030

5.1 Selection of REmap Options

REmap Options are the additional renewable energy technologies deployable beyond the Reference Case, in 2030. They have neither a technical nor a cost limit. More renewable energy is possible beyond REmap Options. They are estimates based to a great extent on IRENA's assessment from studies envisaging accelerated renewable energy uptake in Russia to 2030, along with the experiences of other countries and input from renewable energy experts.

The rationale behind individual renewable energy technology is explained below. Table 8 provides a summary of technological development during 2010-2030, according to the Reference Case and REmap.

Wind

Onshore wind potential is in the southwest, northern and far eastern regions of Russia. These are the regions where also most of Russia's wind farms are presently located.

For grid-connected onshore wind capacity used for domestic consumption of power, if the potential estimated according to the REmap case is implemented, an annual installation rate of about 660 MW during 2010-2030 would be required. Grid-connected wind farms are planned to be commissioned in 2018 and after, with unit installed capacity expected to reach 100 MW. Yet, in 2015, approved wind onshore projects were ten times lower than REmap requires.

The first onshore wind farms in Russia, designed for the decentralised energy supply of isolated energy loads, were very small, with an average plant size of 6.5 MW per farm. Up to 2030, new farms will be larger, and even up to 500 MW. An additional 1 GW of remote wind onshore capacity has been estimated, which can substitute for diesel-based generation capacity, to a great extent. This is beyond the wind portion of the total capacity that is planned for the Russian Arctic by 2030 – namely, 1 091 MW hydro, 600 MW nuclear and 400 MW of onshore wind.

The annual capacity factor for onshore wind is assumed at 25% by 2030 (2 200 hours per year). Considering the relatively small projected installed capacity, it should be possible to find locations with higher average yields. In certain parts of Russia (e.g. Kamchatka, Arkhangelsk, Murmansk, Krasnodar, Astrakhan, Rostov, Stavropol, and the North Caucasus regions), wind farm capacity factors can reach 35% (3 000 hours per year).

Finally, a 10 GW potential for wind in Siberia and the Far East is estimated, with the capacity being used mainly for export to China and other countries in Asia. Utilising this potential, however, is subject to much uncertainty, with the most important concern being the lack of grid connections – not only between China and Russia, but primarily within China itself, which is struggling to minimise the curtailing of its current wind power output.

Hydropower

The main challenge for hydropower is the distance between the resource (in Siberia) and the demand (mainly located in western Russia). Under the Reference Case, 54 GW large hydro and 1 GW small hydro are installed. There is great remaining potential for both large and small hydropower in the country, however. This is estimated at 19 GW and by 2030, would take the total installed capacity to 74 GW in REmap (compared to 55 GW in the Reference Case). This compares with the 53.4 GW that was installed in 2015.

Realising the potential estimated in REmap would imply the installation of more than 20 large hydropower plants. Out of the 19 GW additional potential, 10 GW is new plants replacing aging non-renewable power generation capacity. The remaining 9 GW is for aluminium plants, mining and for meeting other additional demand for electricity in industry, as well as growing demand for electricity in transport. Most of this capacity will be installed in the Siberia, Volga and Far East regions of Russia. There is an additional 20 GW of capacity for export to Asian countries (including China), though some of this capacity could be required for balancing Russia's power system.

Solar PV

Total installed solar PV capacity is estimated to reach 2.7 GW by 2030, according to the Reference Case. This implies an annual installation rate of 135 MW per year. Up to 2024, Russia aims to implement a total solar PV installation capacity of 1520 GW in its wholesale market, only. Between 2024 and 2030, another 1180 MW will need to be implemented under the Reference Case. This is somewhat on the low side and may underestimate the potential in retail markets. In REmap, a total of 5 GW of grid-connected capacity for 2030, with an annual installation rate of 250 MW per year, is estimated.

Capacity factors in the wholesale market range from 10%-13%, depending on where this capacity will be implemented (900 and 1140 hours per year). This potential would exist in south and western parts of Russia, and excludes any capacity for the isolated regions. In such areas, solar PV can operate for only 4-5 months a year, and the capacity factor is approximately 10% or lower (<900 hours per year). Hence, substituting all the remaining diesel capacity with solar PV (after accounting for regions where wind is deployed) is not possible. The estimated potential for solar PV in isolated regions of Russia is 80 MW by 2030.

Geothermal

The geothermal potential in Russia is mainly in the eastern parts of Russia (Kamchatka). Demand for electricity in these regions is limited, but small scale geothermal plants can be deployed there to meet some industrial electricity demand (e.g. mining and ship building). This is in addition to meeting the electricity needs of Kamchatka's urban areas, in which three-quarters of the peninsula's population lives. The potential in REmap is estimated at 1 GW by 2030. This is ten times higher than that envisaged under the Reference Case.

Bioenergy

Bioenergy is expected to serve a variety of applications, ranging from the power and district heating sectors to end-use sectors like buildings, manufacturing and transport.

REmap estimates a total potential of 26 GW bioenergy-based power generation capacity by 2030. About 22.3 GW is related to CHP, split between 19 GW for district heating (with about two-thirds of the total additions beyond the Reference Case being biogas) and 3.2 GW for industry. Although Russia's energy strategy states that heating will be through the increased use of more decentralised systems in buildings and industry, CHP use for district heating generation will still play a role. The Russian government's plan is to modernise the existing district heating system with the aim of improving efficiency and overall cost-competitiveness. As part of these modernisation efforts, bioenergy can play an important role.

Finally, an additional potential 1.5 GW from landfill gas also exists (mainly in the central and western parts of Russia).

Bioenergy also has potential in decentralised heating units in buildings and industry, with a total potential of about 600 PJ, split between 300 PJ for buildings and 300 PJ for industry (with a third for industrial CHP). In addition, from the district heating sector, about 500 PJ of heat can be generated.

In transport, a total potential of 15.4 billion litres of liquid biofuel use has been estimated (5.5 billion litres of biodiesel and 10 billion litres of ethanol).

Other technology and strategies to increase renewable energy use

For industry, an additional potential of 30 PJ for geothermal heating (in Kamchatka) and 30 PJ of solar water heating (mainly in the southwest) has been estimated. There is also potential for electrification for data centres (in Siberia) for about 24 TWh per year, and for new aluminium plants of about 10 TWh per year (with an estimated growth in production of aluminium of 20% between 2010-2030). In transport, there is also the possibility that high speed long-distance trains in the more populated areas in the central and western

Table 8: Renewable energy use in the base year, Reference Case and REmap, 2010-2030

		Unit	2010	Reference Case	REmap
1. Electricity generation					
Installed Capacity	**Non-RE**	**GW**	**183**	**203**	**188**
	Renewable energy	**GW**	**47**	**65**	**150**
	Hydropower (incl. large hydro)	GW	47	55	74
	Hydropower (for export)	GW			20
	Wind onshore	GW	0.013	4.7	13.3
	Wind onshore (for export)	GW			10.0
	Wind onshore (remote)	GW			1.0
	Biomass & waste	GW	0.025	2.1	2.1
	Biomass & waste (CHP), DH, solid biomass	GW			6.1
	Biomass & waste (CHP), DH, biogas	GW			13.0
	Biomass & waste (CHP), industry	GW			3.2
	Landfill gas	GW			1.5
	Solar PV (utility-scale)	GW	0.003	2.70	5.0
	Solar PV (remote)	GW			0.08
	Geothermal	GW	0.082	0.100	1.0
Electricity Generation	**Non-RE**	**TWh**	**867**	**1057**	**933**
	Renewable power generation	**TWh**	**169**	**227**	**487**
	Hydropower (incl. large hydro)	TWh	166.1	206.0	286
	Hydropower (for export)	TWh			76
	Wind onshore	TWh	0.004	6.0	18.6
	Wind onshore (for export)	TWh			21.3
	Wind onshore (remote)	TWh			2.3
	Biomass & waste	TWh	2.8	6.0	6.0
	Biomass & waste (CHP), DH, solid biomass	TWh			17.4
	Biomass & waste (CHP), DH, biogas	TWh			37.1
	Biomass & waste (CHP), industry	TWh			9.2
	Landfill gas	TWh			4.4
	Solar PV (utility-scale)	TWh		3.5	6.5
	Solar PV (remote)	TWh			0.1
	Geothermal	TWh	0.5	1.0	10.0
2. Heat Supply					
Biomass DH (generation), solid biomass		EJ	0.1	0.155	0.3
Biomass DH (generation), biogas		EJ			0.2
Biomass heating (buildings)		EJ	0.08	0.12	0.33
Solar water heating (buildings)		EJ			0.03
Biomass heating (industry), CHP		EJ			0.13
Biomass heating (industry), boilers		EJ	0.015	0.015	0.26
Geothermal heating (industry)		EJ			0.03
Total heat supply		EJ	**0.2**	**0.3**	**1.2**
3. Liquid biofuels					
Conventional ethanol		EJ		0.100	0.2
Advanced ethanol		EJ			0.01
Biodiesel		EJ		0.100	0.2
Total		EJ		**0.2**	**0.4**
4. Ratio of electricity generation					
Total installed capacity		GW	231	268	308
Gross power generation		TWh	1036	1284	1420
Capacity ratio of renewables (incl. large hydro)		%	20.4	24.1	43.2
Renewable energy share in power generation (incl. large hydro) (excl. export)		%	16.3	17.6	29.4
Variable renewable energy share in power generation (excl. export)		%	0.0	1.1	2.1
5. Ratio of total final energy consumption					
Total final energy consumption (TFEC)		EJ	17.2	22.2	23.4
All renewable energy		EJ	0.6	1.1	2.6
Renewable heating		EJ	0.2	0.3	1.2
Renewable transport fuels		EJ	0.0	0.2	0.4
Renewable electricity		EJ	0.4	0.6	1.1
Renewable energy share in TFEC		%	**3.6**	**4.9**	**11.3**

Source: IRENA analysis

regions (similar to the Moscow-St Petersburg high-speed train) may reduce demand for aviation.

5.2 Renewable energy use: prospects to 2030

Reference Case

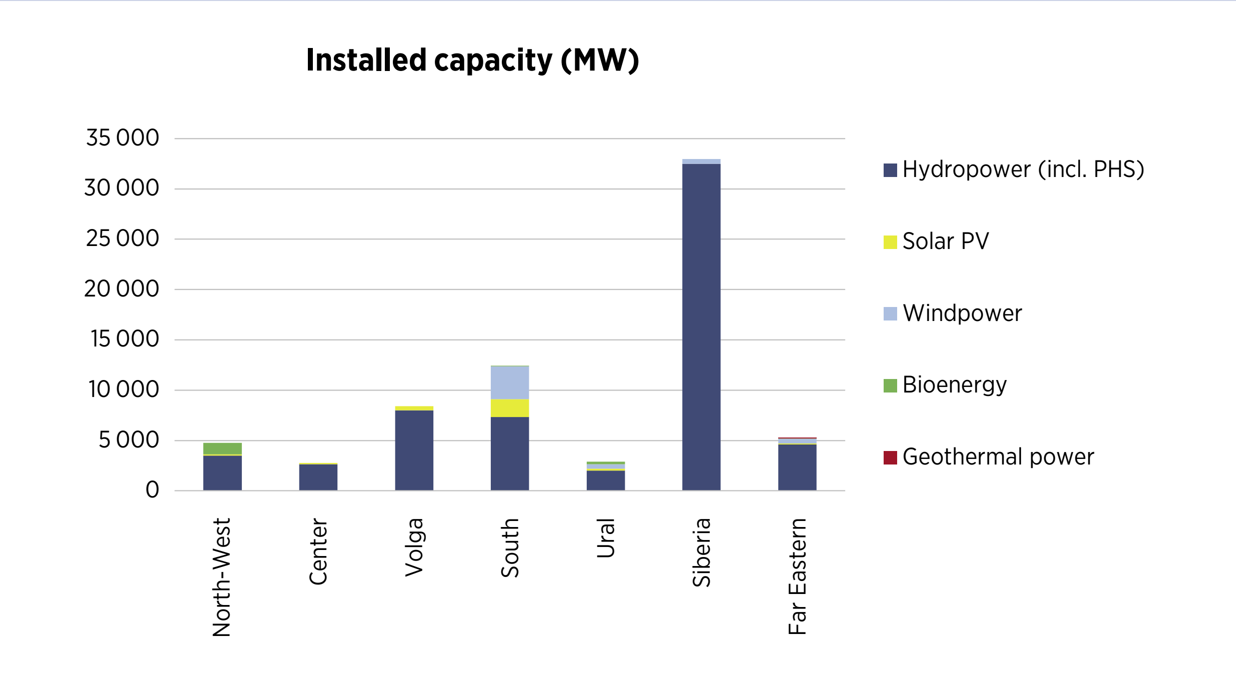
According to the Reference Case, renewable energy's share in Russia's TFEC grows from 3.6% in 2010 to 4.9% in 2030. This is equivalent to a total of 1.1 EJ in final renewable energy use by 2030, including direct uses of renewable energy for industry, buildings and transport, as well as its supply for electricity and district heating consumption in these sectors.

Renewable energy's share in the power sector is projected to increase from 16.3%-17.6%, with an increase across all renewable power generation technologies. Total installed power generation capacity increases from 231 GW in 2010 to 268 GW in 2030, according to the Reference Case, representing a continuation of recent annual capacity addition trends. The largest growth in power generation capacity takes place in the South and Far East regions. The Far East currently has the smallest installed capacity among the seven federal districts of Russia. Total installed capacity in the region grows from 9.3 GW to 13.6 GW as a result of the increase in thermal and hydropower capacities. In the South, the increase is explained by the additions of wind, solar and hydropower. In addition, wind capacity grows in the Siberia, Ural and Far East regions, whereas solar PV is added in the Volga, Ural, Centre and Northwest regions. Total installed power generation capacity in Siberia and the Volga grows only slightly.

For the heating sector, renewable energy's share climbs from 3.3%-4.1% in industry, and decreases from 10.9%-6.3% in buildings. The equivalent transport figure would increase from 1.2%-4.2%. These shares include the quantities of electricity and district heating consumed from renewable energy sources.

Final renewable energy use is projected to increase from 0.6 EJ in 2010 to 1.1 EJ in 2030. In 2010, hydropower accounted for 71% of total final renewable energy use in Russia. The remaining 29% was related to bioenergy. Hydropower continues to dominate the mix, although its share is expected to decrease to 52% in 2030 at the expense of an increase in bioenergy's share, to 45%. Other renewables account for the remaining 3%.

Figure 14: Installed renewable energy capacity in Russia according to the Reference Case, 2030



Source: IRENA analysis

REmap

With all the REmap Options implemented, total renewable energy use in Russia's total final energy consumption would reach 2.6 EJ by 2030 (excluding exported renewable power from hydropower and wind, which would add another 0.25 EJ, if they were domestically consumed). Of this, 42% would be for renewable power consumption (1.1 PJ) and 60% for renewable gas, heat and fuels (1.5 EJ). Total renewable energy use in Russia's TFEC would reach 11.3% in REmap, compared to 3.6% in 2010 and 4.9% in 2030 in the Reference Case.

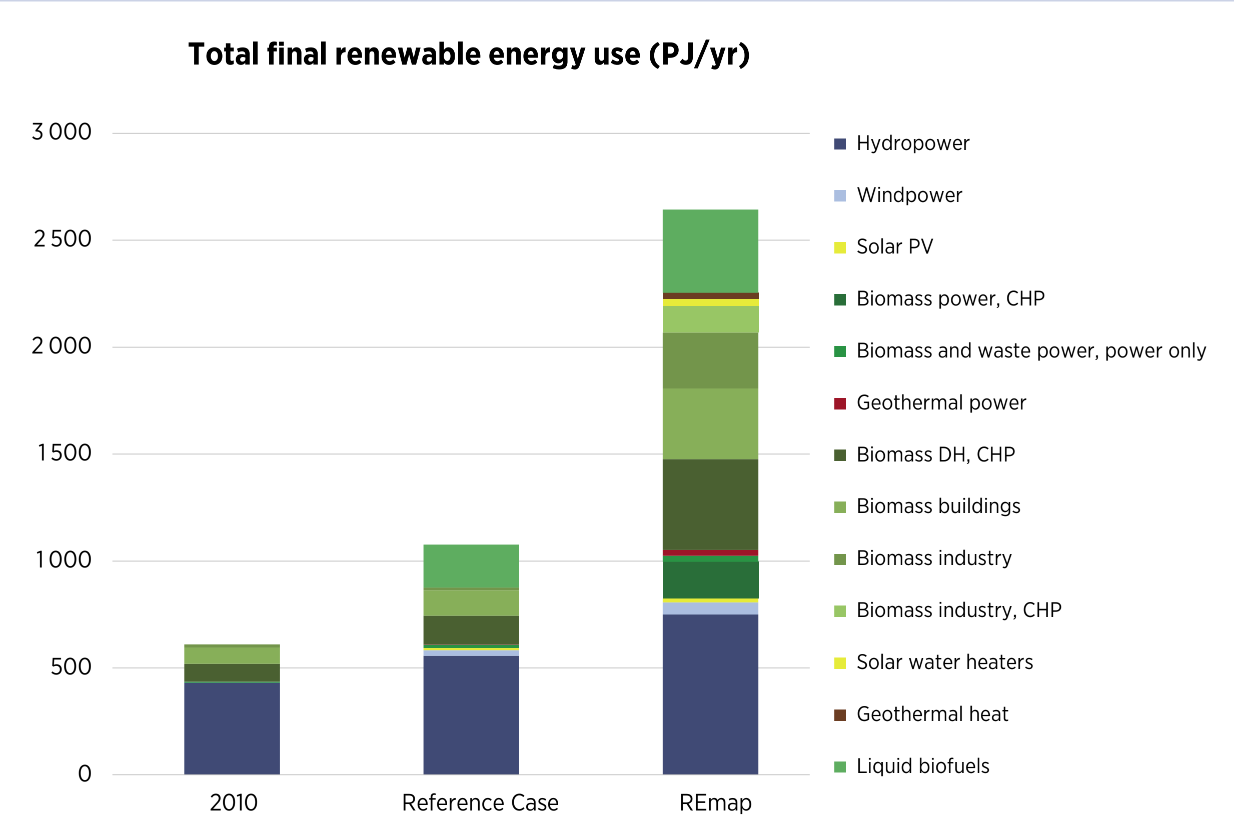
Installed renewable power capacity would rise from 65 GW in the Reference Case to 150 GW in REmap, a difference of 85 GW (including the 30 GW capacity of hydro and onshore wind installed for exports to Asia). One third of the increase comes from hydropower (an additional 39 GW). Another quarter comes from onshore wind (20 GW). The remainder is largely bioenergy for power, followed by solar PV and geothermal.

As a result of these additions, total annual renewable energy power generation would be more than double that of the 227 TWh provided in the Reference Case, reaching 390 TWh (excluding 97 TWh for exports to Asia. This is equivalent to a 29.4% share of renewable energy in Russia's power generation sector.

Solar PV and wind capacity will also be further deployed in Russia. Their output is correlated to the intensity of the resource at any given time, as opposed to demand for power, and therefore cannot be controlled. Therefore, they are known as variable renewable power. Consequently, wind and solar generators cannot follow power demand in the same way as thermal or hydropower generation, with their share in total generation expected to reach 2.1% by 2030.

While this share is too low to result in any demand for these resources' integration into the grid, in certain parts of the Russian power system, additional measures may be required. For instance, in this study, isolated regions of Russia could meet a large share of their demand

Figure 15: Renewable energy use in TFEC, 2010-2030



Source: IRENA analysis

from wind instead of diesel. This will require these wind systems to be either hybrid with existing diesel systems, or supported by battery storage capacity. Most of the grid-connected wind and solar PV capacity will be in the western parts of Russia. In these regions, their share in total generation can be as high as 5%, thus requiring measures to maintain flexibility in the system.

Significant new capacity will also be added to the heating and transport sectors. The greatest increase would likely originate from bioenergy. Under REmap, total annual final bioenergy demand for transport fuels and heating, including district heating, would triple to 1.6 EJ, compared to approximately 0.5 EJ in the Reference Case.

Table 9 shows renewable energy developments by sector over 2010-2030, as well as total renewable energy use by sector when REmap Options are implemented. The power sector would have the highest share of renewables by far, at 30%. This can be split into 20% hydropower and 10% other renewables (wind, solar PV and geothermal). In sectors where heating plays the main role (industry, buildings and district heating), renewable energy's share would be around 15%. Under REmap, the transport sector's renewable energy share would reach around 8% by 2030, compared to 4% in the Reference Case.

Given bioenergy's potential in heating, power generation and as transport fuel, under REmap, it becomes the most important source of renewable energy in Russia's total energy mix, by 2030. Biofuels would account for two-thirds of the total final renewable energy use in REmap (see Figure 15), while hydropower would account for 28%. The remaining 6% would be split between 3% onshore wind, 2% solar (power and heat) and 1% geothermal.

Total annual primary biomass demand would be 2.4 EJ under REmap (Figure 16). About half of the total demand would be for wood pellets and residues to generate power, district heating, and other heating for buildings (1 EJ, 60 Mt/yr). The other half would be split between energy crops (0.65 EJ) for transport fuels and residues and biogas for industrial heating and district heat generation (0.75 EJ). End-use sectors would account for half of the total primary bioenergy demand, with the other half for electricity and district heat generation.

This total demand compares with a total supply potential of 1.9-14.1 EJ (IRENA, 2014c). There is a risk, however, that demand could be higher than the low-end of this potential supply. The bottleneck depends on whether the supply potential of biogas and energy crops can be realised. For other feedstocks, there is sufficient potential of supply, even when the significant resource potential of fuel wood is excluded.

IRENA's assessment excludes any energy crop supply potential. The country still has unutilised arable land that can be used for this purpose, without competing for food production (e.g. Schierhorn et al., 2014).

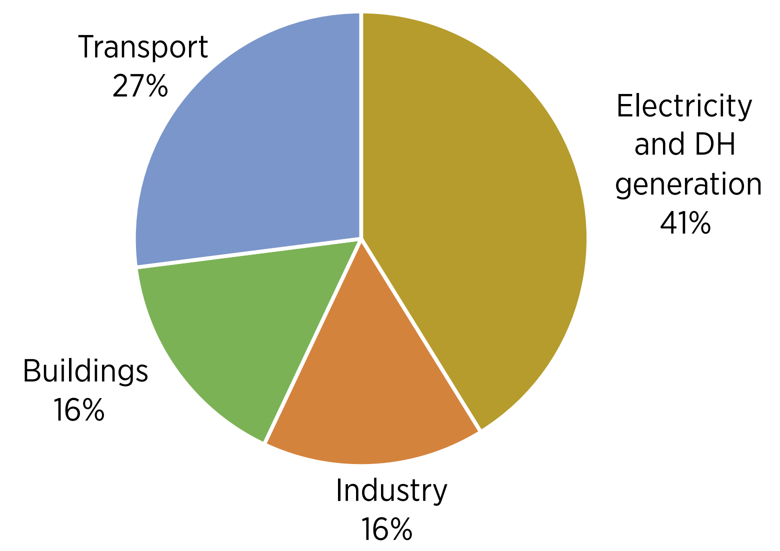
Table 9: Renewable energy share and total renewable energy use by sector, 2010-2030

		Renewable energy share (%)		
		2010	Reference Case 2030	REmap 2030
Industry	Excl. electricity & district heating	0.3	0.3	8.5
	Incl. electricity & district heating	3.3	4.1	13.9
Buildings	Excl. electricity & district heating	3.3	4.0	11.9
	Incl. electricity and district heating	10.9	6.4	16.2
Transport	Excl. electricity	0	3.3	6.6
	Incl. electricity	1.2	4.2	8.2
Power generation		**16.3**	**17.6**	**29.4**
District heat generation		**2.1**	**3.0**	**13.5**
TFEC	Incl. electricity and district heating	3.6	4.9	11.3

Note: Renewable energy share includes renewable and non-renewable industrial and municipal waste.

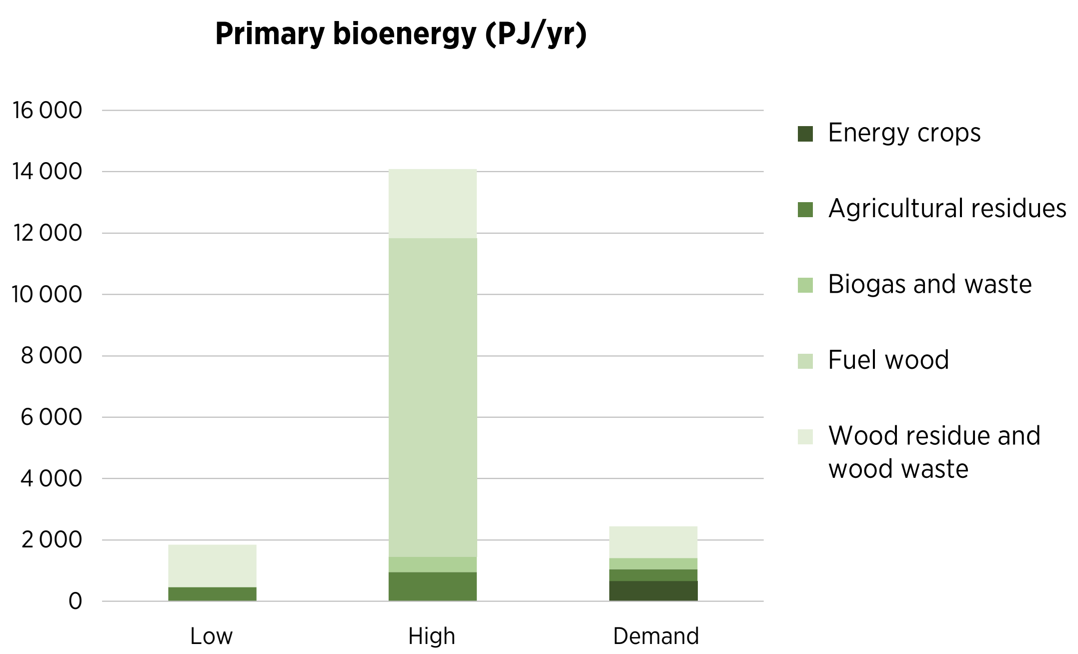
Source: IRENA analysis

Figure 16: Breakdown of primary bioenergy demand in Russia, 2030



Source: IRENA analysis

Figure 17: Comparison of bioenergy demand and supply, 2030



Source: IRENA analysis

5.3 Renewable energy cost and benefits

Costs of renewables in Russia

Table 10 provides an overview of the substitution costs by sector for 2030, based on the perspectives of business and government. In the business perspective, energy prices are based on a discount rate of 11% and take into account the current Russian energy tax and subsidies in energy prices. In the government perspective, prices are based on a discount rate of 10% and exclude tax and subsidies in energy prices.

In the business perspective, the most cost-effective options are in the industrial sector, from bioenergy-based CHP, and the buildings sector, from bioenergy-based decentralised heating systems. The options for district heating are more expensive, compared to low-cost natural gas. In the power sector, most renewable energy technologies are also mainly compared with low-cost natural gas for power generation, resulting in relatively higher costs of substitution (the fuel that was chosen for substitution with renewables). On average, the government perspective results in lower costs of substitution, as the prices of fossil fuels that are substituted exclude any subsidies. The energy prices in the business perspective are lower than in the government perspective in 2030, as they include subsidies. As a result, the renewable energy mix assumed under REmap is more expensive to implement.

Figure 18 and Figure 19 rank the costs of REmap Option substitutions and show their contributions to the potentially increased share of renewable energy. Table 11 shows the substitution costs of REmap Options in 2030 for Russia (the same information plotted in Figure 18 and Figure 19). The cost of most options ranges from -USD 25 to as high +USD 30 per GJ, from both perspectives. There are some outliers. Remote applications of solar and wind to replace expensive diesel offer significant savings.

From the business perspective, solid biomass CHP offers the lowest substitution cost for district heating, compared to the uses of expensive diesel fuel in Siberia. Likewise, space heating in Siberia in buildings through decentralised systems offers a cost-effective potential. Transport biofuels can also be equally cost-competitive. The substitution costs of most biomass-based power generation technologies range between USD 1 and USD 5 per GJ of final renewable energy.

Grid-connected utility scale solar PV and wind onshore are more expensive than their natural gas counterpart, with substitution costs estimated at between USD 20 and USD 35 per GJ, these costs have been based, however, on the approved maximum overnight capital costs for the wholesale market, according to the information provided by the Ministry of Energy of the Russian Federation for the period 2014-2024 and a continuation of the trend in this period until 2030. In reality, overnight capital costs in 2030 could be much lower than these levels, improving the cost-effectiveness of renewable power. Moreover, wind and solar PV costs are compared with the generation of electricity from low-cost natural gas (USD 3-4/MMBtu). Finally, assumed capacity factors (15%) for solar PV are rather on the low-side, since these utility-scale plants are assumed to be deployed in areas close to demand, where resource availability is relatively low.

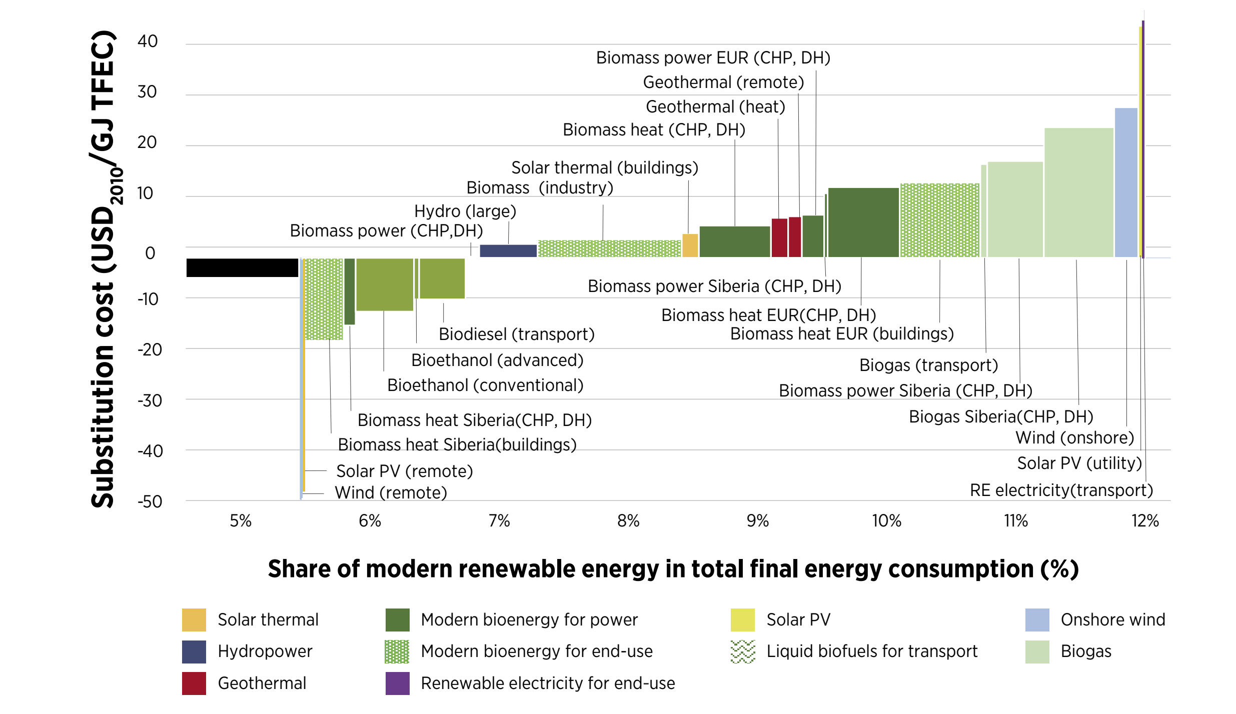
With a capacity factor of 20% and a solar PV overnight capital cost of USD 1200/kW in 2030, the substitution

Table 10: Average substitution costs of REmap Options by sector, 2030

	Business perspective (national prices)	Government perspective (international prices)
	(USD/GJ)	(USD/GJ)
Industry	4.7	2.2
Buildings	4.6	0.4
Transport	4.9	-2.9
Power	10.6	6.3
District heating	18.9	13.9
Average of all sectors	8.7	4.4

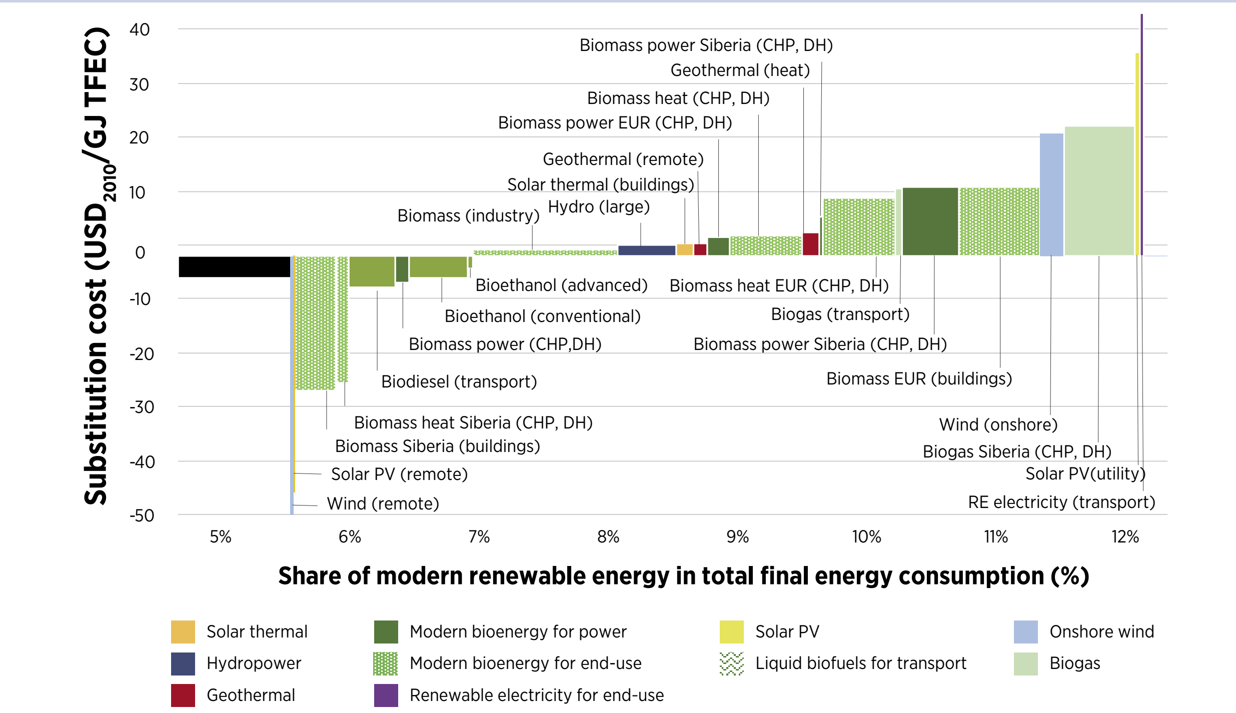
Source: IRENA analysis

Figure 18: Renewable energy cost-supply curve by renewable energy resource in 2030 from the business perspective



Source: IRENA analysis

Figure 19: Renewable energy cost-supply curve by renewable energy resource in 2030 from the government perspective



Source: IRENA analysis

Table 11: Substitution cost of REmap Options by technology in 2030 based on the perspectives of government and business and potential by technology

REmap Option by sector	Business perspective (USD/GJ)	Government perspective (USD/GJ)	REmap Options potential (PJ/year)
Power consumption (energy transformation)			
Wind Remote (average)	-110.4	-91.5	6.2
Solar PV remote (average)	-62.3	-41.3	0.2
Autoproducers, CHP electricity part (solid biomass) (average)	-4.9	0.2	24.5
Hydro (Large) (average)	1.9	2.7	101.9
Geothermal remote (average)	2.5	8.2	24.0
Public CHP electricity part EUR (solid primary biomass) (average)	3.4	8.5	39.5
Public CHP electricity part Siberia (solid primary biomass) (average)	7.3	12.7	7.0
Landfill gas ICE (average)	12.5	18.5	11.8
Public CHP electricity part Siberia (biogas) (average)	12.8	18.9	99.0
Wind onshore EUR (average)	22.8	25.6	41.4
Solar PV (Utility) (average)	37.9	45.7	8.0
District heating consumption (energy transformation)			
Public CHP heat part Siberia (solid primary biomass) (average)	-23.4	-13.3	22.1
Public CHP heat part EUR (solid primary biomass) (average)	10.7	14.0	125.5
Public CHP heat part Siberia (biogas) (average)	24.1	29.8	120.7
Industry and agriculture			
Biomass boilers (average)	1.2	3.8	248.7
Autoproducers, CHP heat part (solid biomass) (average)	3.8	6.5	125.6
Geothermal (heat) (average)	4.3	4.7	30.0
Buildings (residential and commercial) sector (energy end-use)			
Space heating: Pellet burners Siberia (average)	-25.1	-16.3	70.0
Space heating: Solar (thermosiphon) (average)	2.4	4.7	30.0
Space heating: Pellet burners EUR (average)	12.8	15.0	140.0
Transport sector (energy end-use)			
Biodiesel (passenger road vehicles) (average)	-5.9	-8.2	80.0
First generation bioethanol (passenger road vehicles) (average)	-4.0	-10.7	100.0
Second generation bioethanol (passenger road vehicles) (average)	-2.3	-8.3	10.0
Others	110.0	110.0	3.0

Source: IRENA analysis

cost is re-estimated at USD 11/GJ when compared with natural gas based generation that assumes the same gas price. This is 60% lower than the initial cost of substitution. At a wholesale natural gas price of USD 12/MBtu, solar PV becomes cost-competitive with gas-based electricity generation in Russia.

Benefits of REmap Options and export potential in Russia from renewables

Implementing REmap Options would cut fossil fuel demand by 8% by 2030, compared to the Reference Case. Total gas and oil demand in REmap would be 9% lower than in the Reference Case. Nuclear demand would be 11% less and coal demand 4% less. The liberated fossil fuel resources can also contribute to increasing the country's exports of these to other countries.

Lower fossil fuel use cuts CO_2 emissions. In 2030, Russian CO_2 emissions are estimated at 1573 Mt in the Reference Case. If all REmap Options identified in this report are put in place, total emissions reduce to 125 Mt under REmap. This is equivalent to a reduction of 8% compared to the Reference Case (or an annual absolute volume of 125 Mt CO_2). Compared to the level of energy-related CO_2 emissions in 1990, which was 2178 Mt CO_2, this is equivalent to a decline of 15.8% by 2030. Russia's INDC aims to reduce all GHG emissions by 25-30% compared to the 1990 level. Assuming the same level of ambition for energy-related CO_2 emissions, renewable energy technologies identified in this report would account for half of the total reduction needed to realise Russia's INDC.

Table 12 shows a number of financial indicators for Russian REmap Options. These require an additional USD 6.5 billion per year by 2030. Externalities related to human health can reduce these costs by USD 0.4-4.0 billion per year. With a range of USD 17-80 per tonne of CO_2, related externalities can save another USD 2.6-14.2 billion each year. Thus, REmap Options can result in total savings of up to USD 7.8 billion per year by 2030, once externalities are accounted for.

There is a significant capacity of hydropower and onshore wind being built under REmap that is intended for exports of electricity to China. In addition, a large volume of bioenergy (mainly fuel wood) remains unused in the country, which can be exported to Europe in the form of wood pellets.

Electricity's export potential from a total of 30 GW of power generation capacity (10 GW of onshore wind and 20 GW of hydropower) translates to USD 10 billion of export benefit annually, in 2030 for the country (based on the LCOE of wind onshore and hydropower). The ability to utilise this potential, however, is subject to great uncertainty, since this electricity may not be sold at all times to neighbouring countries. In addition, realising the potential of power exports to China and other Asian countries requires investments in new transmission grid capacity. These are not accounted for, and when these costs are included, they would reduce the total volume of benefits. One other export option for utilising this renewable power potential is the electricity-based production of hydrogen and methane, with this subsequently fed into the existing gas pipelines.

After accounting for domestic uses of wood products, the remaining solid biofuel potential (mainly fuel wood) is approximately 70-170 Mtoe per year (or 3-7 EJ per year). Assuming a price for solid biofuels of USD 110 per tonne, the export benefit is estimated at between USD 20-USD 45 billion per year. Hence, by 2030, renewables create an additional export market of USD 30-56 billion per year.

Implementing the renewable energy mix identified under REmap requires cumulative investment of USD 300 billion between 2010-2030. By comparison, the Reference Case requires USD 46 billion over the same period.

To 2030, total average annual investment needs in renewables will amount to USD 15.2 billion (see Table 13). USD 2.3 billion is required each year to realise the Reference Case, and an annual extra USD 12.9 billion per year would be needed to satisfy REmap Options. The majority of additional investment needs are in the power sector (USD 13 billion per year), in particular for hydro (USD 5.9 billion per year) and wind (USD 2.2 billion per year). Biomass technologies (including the capacity to produce liquid biofuels for the transport sector) also require an annual addition of USD 6.3 billion. Biomass CHP technologies alone will require total investments of USD 4.2 billion per year on

Table 12: Financial indicators for renewable energy use in Russia from the government perspective

Annual energy system costs and benefits in 2030 (USD billion)	
Incremental system cost in 2030	6.4
reduced human health externalities	from 0.4 to 4.0
reduced CO_2 externalities	from 2.2 to 10.2
System costs with externalities in 2030	from -7.8 to 3.9
Incremental subsidy needs in 2030	11.2

Table 13: Annual average investments needs in 2010-2030

Sector	Reference Case (USD bn/yr)	REmap (USD bn/yr)
Power generation and district heating (including CHP)	1.9	13.3
Industry	0.0	0.6
Buildings	0.1	0.5
Transport	0.3	0.7
Total	**2.3**	**15.2**

Resource	Reference Case (USD bn/yr)	REmap (USD bn/yr)
Hydropower	1.0	5.9
Wind	0.4	2.2
Solar PV	0.2	0.4
Solar water heating	0.0	0.1
Geothermal	0.0	0.4
Biomass	0.7	6.3
CHP	0.0	4.2
Power-only systems	0.3	0.4
Heat-only systems	0.1	1.0
Liquid biofuels production	0.3	0.7
Total	**2.5**	**13.9**

Source: IRENA analysis

average. Investment in geothermal (power and heat) solar water heaters would require USD 0.4 billion and USD 0.1 billion per year on average, respectively.

5.4 Barriers to renewable energy uptake and suggested solutions

There are several main barriers that are currently holding back growth for renewable energy-based electricity and heat generation in Russia, while other challenges are anticipated in implementing the REmap Options. These have been discussed and suggestions for mitigation are grouped into:

- general issues for renewables in the Russian energy sector
- long-term planning and policy implementation
- general power market issues
- barriers to wind power
- barriers to solar PV
- barriers to bioenergy.

General issues for renewables

Various barriers to renewable energy uptake in Russia have been discussed. One challenge that remains is the cost of renewable energy projects. While both solar PV and wind have seen significant cost decreases in recent years, in Russia, costs remain above the global average. This is partly explained by the only recent introduction of these technologies into the country, while higher costs are also partly driven by the country's characteristics (e.g. large territory that requires long-distance transport of equipment, which in turn, increases costs).

Renewable energy technologies also have to compete with long-term energy business practices based on a conventional approach, under which the supply of heat and power is secured by a large hydrocarbon resource base. As for all other production countries, Russia has been impacted by the recent dramatic drop in crude oil prices. This has resulted in a high availability of energy and low availability on the fuel production end. As a result, end-user energy prices have increased. Other main impacts have been on currency exchange rates and interest rates, with the latter currently as high as 18% for any given investment in renewable energy technologies. For companies operating in the industrial sector, depending on their size, interest rates can range between 16% and 24%.

Although energy price growth improves the cost-competitiveness of renewable energy technologies, the current surplus in generation capacity in the country, high cost of capital and the unstable capital costs of imported components of equipment limit medium- and long-term investment in renewables.

During the international Renewable Energy Congress held in Moscow on 27-28 October 2015, a number of these barriers were highlighted in the conference report to the Government of the Russian Federation (Reencon, 2015). Based on speeches and statements at the Congress, the following barriers for renewable energy development in Russia were identified:

- The country has an excess of installed capacity (load in relation to the installed capacity is 0.69). More renewable energy capacity will increase this disproportion.
- Due to the variability of wind and solar power, renewable energy capacity reduces the dispatchable characteristics of the power system and also, crucially, increases the flexibility of traditional energy generation (nuclear power, existing heat-and-power plants using gas, coal or biofuels).
- Given the difficulties stemming from the variability of wind and solar power, there is a need to provide a large reserve capacity from traditional electricity generation sources – although, as examples from IRENA analysis show, there are many countries with higher shares of variable renewable energy resources that do not require such high back-up capacity to maintain system flexibility, whilst reaching even higher shares of variable renewables.
- Insufficient density of electricity transmission grids limits the possibilities of free electricity flows.

Opportunities and proposed solutions

There is a need to develop the grid to better integrate renewable energy, enhance trade and deal with variability. Given the urgent need to modernise the grid, it becomes important to link grid modernisation plans with plans for utilising renewable energy's potential, as suggested by REmap. In this context, this report has also highlighted the potential of renewable electricity export to Asian countries generated from hydropower and wind, and to Europe from northwestern Russia, generated from wind and other renewable energy resources. This will require expansion of interconnector capacity, which also creates flexibility in the system, allowing higher shares of variable renewable energy in the power sector.

Modernisation is not limited to the transmission grids, either, but is also required across all of the power system, including generation capacity. New coal, gas and nuclear capacity should be equipped with better flexibility by accounting for the higher shares of renewable electricity in the system under REmap.

Grid integration of renewable energy should also be complemented by federal regulations that should consider decentralised power supply options as a most promising way of providing electricity to isolated regions. This would require approving the necessary regional and local legal framework for allocating state financial resources in expanding the use of renewable energy.

The Federal Government of Russia has long been focusing on ensuring the economic feasibility of renewable energy projects, as well as securing the capital investment approved in 2013-2014. For instance, currency risks were addressed in Government Resolution No. 1210 of 10 November 2015, which introduced a correction factor for the currency component of the planned renewable energy capital expenditure. In addition, the Decree considered the growth of the cost of capital and provided the investor with the right to delay power delivery by up to 12 months. Similar measures may need to be continued in the coming years to create a stable investment environment and reduce risks, thereby increasing investor confidence.

Long-term planning and policy implementation

Russia has made significant progress in developing its energy policy across all types of technology and sectors. A recent example of this is the country's Energy Strategy to 2030. This document is now is outdated, however, and requires revision. Despite the country's assessment of the prospects for renewable energy development in Russia up to 2030, the next version of the country's Energy Strategy to 2035 is constrained by the fact that the government has not yet approved it.

The Conference of the Parties to the UN Framework Convention on Climate Change (UNFCCC) in its twenty-first session by its decision invited Parties to communicate, by 2020 their long-term low greenhouse gas emission development strategies. Following this UNFCCC request, the Government of the Russian Federation by its resolution No. 2344-r of 3 November 2016, among others, instructed responsible ministries and agencies to develop and to submit in December 2019 to the Government a draft of the strategy of long-term development with low level of greenhouse gas emissions to 2050. This would set out the actions required to ensure low levels of GHG emissions. Renewable energy could play a key role in Russia's long-term strategy of climate change mitigation, yet to date, the extent of this remains unclear, even in the recently released INDC (UNFCCC, 2015).

The monitoring of renewable energy's progress in achieving the targets established by the Russian government constitutes another major barrier. Most recently, the Russian government approved a list of Best Available Technology Reference Books to be developed, including six books on the country's fuel and energy sector. These included volumes relating to crude oil, natural gas production, oil refining, processing of natural and associated gas, coal mining and refining, and, finally, fuel combustion in large installations for energy production. The technologies provided by the reference books are likely to become the most obvious templates for the industry to follow in current and future modernisation projects. Yet none of the reference book developers have reported the practices available for implementing renewable energy technologies in improving production and energy efficiency in environmental and economic performance, leaving these outside the focus of the Russian government's current plans on this issue (Russian Energy Agency, 2015).

Opportunities and proposed solutions

Russia is in the midst of reshaping its energy policy. In order to create a stable and predictable policy environment, long-term energy and climate strategies need to be completed. The government could consider renewable energy in these strategies, as well as under its short-term policy efforts, in view of the country's large potential for all such sources, and the multiple benefits they offer to the Russian economy.

At the early stages of the sector's deployment, the existing policy frameworks should also follow a practical approach to accelerate deployment while ensuring that the projects are profitable and deliver the agreed results.

General power market issues

Today, the level of competition in the Russian power market is low, with the market model containing a natural monopoly of infrastructure, primarily in the electricity transmission grids. Similar international market models charge the government with ensuring an efficient sector by using stimulus regulations and ensuring a steady reduction in the power grid components of power tariffs for end-users, as well as ensuring non-discriminatory access to the grid. As a result of these factors, there are negative signals for the consumers and the existing market efficiency decreases, thereby increasing the generation costs.

There remain a number of organisational and legal challenges faced by the power market. For renewable energy, the main issue is related to the certification of installations, which can be obtained only after building the plant. This rule leaves investors with uncertainty and additional risk. Regarding the specific case of renewable energy technologies, there is no real, regulated mechanism for grid access, a situation that contradicts the existing legal requirement to accelerate renewables-based electricity generation. Recent trends show that the situation has recently improved, however, thanks to the approval of a decree allowing further stimulus measures and improvement of generation's support for renewable energy, but more attention is needed.

Opportunities and proposed solutions

Creating a more competitive power market can help to incentivise flexible operation and efficiency, while bringing in new investors – particularly those operating in renewable energy technologies. This could help realise and go beyond the goals set by the government. The absence of any intensive competition in the Russian power markets presents a good opportunity for the authorities to tackle the relevant issues with new regulations at the federal, regional and local levels.

Wind power

Capacity supply agreements

Given the challenges in guaranteeing the hourly availability for generation of variable wind power facilities, Decree No. 449 of 28 May 2013 establishes specific capacity rules, and includes regulations for other types of renewable energy.

Using the mechanism, the Decree amended the wholesale market rules in order to integrate capacity supply agreements into the wholesale market architecture. The Decree establishes rules for the selection of renewable energy projects, capacity supply by variable renewable energy installations and capacity pricing.

Such an approach could limit support for renewable energy, including wind power. Moreover, the capacity scheme covers facilities with a capacity at least equal to 5 MW. This is also the minimum limit for participating in the wholesale market (IEA, 2014).

Competitive capacity selection

Decree No. 449 of 28 May 2013 provides a mechanism for the promotion of renewable energy in the wholesale electricity and capacity markets. It aims to facilitate greater investment flow in the development of the Russian energy market, based on the principles of energy sustainability and energy security. The mechanism does not, however, stand for a clear rule in competitive capacity selection for generating capacities based on renewable energy, including wind energy. The mechanism places projects selected in the preliminary round that do not exceed the maximum amount of installed capacity set by the government for each type of renewable energy technology on a more preferable ground. ATS includes all these projects in the register of selected renewable energy technology projects. If all those selected exceed the capacity limit set by the government, ATS selects the projects with the lowest capital cost. Importantly, the capital cost of renewable energy investment projects – as submitted in bids – is the only selection criteria taken into account in the second selection round. ATS does not take into account other potentially relevant criteria, such as the development capacity of the project (e.g. wind monitoring, feasibility study, planning stage and permissions), the capacity factor of the investment project, a project's ability to contribute towards ensuring supply-demand adequacy in energy deficit regions, or its ability to integrate into the network.

Renewable energy investment projects, including wind power generation, are expected to remain below the limit for yearly overnight capitals set by the government up to 2024 (including both equipment and grid connection costs). Because the average capital costs of renewable energy investments varies, the government will be challenged with a regulatory intervention to reduce capital cost limits to handle this variability.

The bidding mechanism seems to have become an incentive, whilst discouraging some of the investments. On the one hand, it paves the way for the wind generation that would be developed as a result of the cooperation of investors and operators. On the other hand, the mechanism imposes a high eligibility restriction. The 5 MW threshold, combined with fixed operation costs, stands for a financial risk that cannot be managed in advance. Wind farm generation is variable, and it can be higher than is stated in the application – or lower. That is why it is important to support projects that stand for a power output within a certain range. There are many cases where farms with reported low capacity factors have outperformed farms with relatively high factors. It appears that in a certain way and considering the early stage of the market, the Russian wind power market is overregulated and hence not attractive to investors, who, in addition, have to struggle with many logistical barriers and others when entering a new market.

Other issues

The current policy pays particular attention to the qualification process in support of renewable energy technologies. Gaining qualification, however, can be challenging. So far, only a very limited number of renewable energy installations have successfully passed the qualification procedure. There is a risk that the duration of this procedure (and possible delays in this process) could prevent renewable energy investors from achieving the deadline for which they committed.

Large-scale wind power plants require a large amount of land. Even in a country like Russia, with abundant land resources, investors face challenges in some regions because of high land prices. As a result of administrative barriers, it is also not easy to convert agricultural land into industrial land (though a combination of both wind and agricultural land has been shown possible). This is particularly so in the European part of Russia.

In this analysis, a large potential for electricity generated from exports is estimated. Yet, no structure exists to transmit this to potential countries. This may eventually be costly when the investments in infrastructure are accounted for. Therefore, there are many uncertainties regarding the utilisation of this potential.

Opportunities and proposed solutions

Being a relatively new technology in the Russian energy market, wind power can have short-term opportunities in the local supply system, provided that off-grid power receives an adequate legal framework.

The current renewable energy support mechanism was originally initiated to provide support for the expansion of capacity up to the mid-2020s (the new target limit for wind energy is set through 2024). The mechanism was also launched as a rather top-down action. This results in possible challenges for the evolution of the wind energy business. A broader understanding of the goal may create an opportunity to consider bottom-up action as a means of increasing the share of wind energy generation in meeting national total power demand.

After numerous revisions, the qualification procedure and local content confirmation content procedure still need improvements and clarification. This is especially so, since it is necessary to bring these into line with regulatory interventions aimed at reducing capital cost limits in order to handle wind energy variability. Given the presence of regional programmes for promoting wind energy, the status of hybrid generation systems remains unclear under both the national support mechanism eligibility and the qualification criterion, and therefore requires further attention.

Other alternatives about how to utilise renewable power can be sought, such as hydrogen/methane production and injecting this into the existing Russian gas grid.

Solar PV

Solar PV based generation costs are relatively high, in particular when compared with the low-cost generation of electricity from fossil fuels, which is the main barrier to accelerated uptake.

One of the other major obstacles to the development of solar PV has been the lack of a federal law and clear state policy in this area. Under the current circumstances, solar PV development in Russia is limited to public sector initiatives and gives minimal signs of investment by the private sector. The industry is also still suffering from a shortage of affordable equipment. There are localisation requirements for this, but at the moment, the localisation rate is low. Few local producers and their prices are close to foreign equivalents. In terms of logistics, customs clearance and installation cost may vary significantly (especially for distant and isolated regions).

Experience has also shown that transport of solar panels to remote regions is also difficult and expensive. Panels were sometimes broken during transportation, with the project developer having to reorder them, leading to additional costs. Such issues could also apply to various wind power components, such as the blades, if, for instance they had to be transported to the more remote parts of the country's vast territory.

In the context of Russia, too, one disadvantage of solar PV is its dependence on weather conditions and amount of daylight. The richer regions, such as Moscow and Saint Petersburg, are characterised by a low insolation rate; hence, less power is generated. In contrast, in regions such as Dagestan and Altai in the south, solar PV plants are likely to perform as efficiently as in southern Italy.

Opportunities and proposed solutions

There are already a number of Russian energy companies reporting initiatives aimed at ensuring the energy security of their operations by means of PV stations in remote areas, including the Arctic. These initiatives are efficient enough to enable the remote control of process equipment in severe weather conditions in the absence of any cable-supplied power. This creates new opportunities for public and private sector cooperation in expanding off-grid mechanisms in supplying power to remote areas and ensuring general national energy security.

As mentioned above, under a more flexible federal regulation, solar PV is likely to become a more feasible solution for Russia's power sector.

As for wind power, the Russian power market's capacity based regulation has resulted in low competition and a rather centralised energy supply system. The suggested renewable energy support mechanism is rather expected to regulate top-down actions, but not limit the evolution of bottom-up projects in solar power generation.

The recent bidding for renewable energy projects in June 2016 showed a surplus in the applied solar power generation limit, which will prevent investors from further expanding the share of PV generation. The national support mechanism could be revised to increase the limits for renewable energy projects, including solar PV.

Bioenergy

If Russia were able to implement all the renewable energy potential identified under REmap, biofuels alone would represent two-thirds of the total final renewable energy mix by 2030. Currently, biofuels are considered traditional sources of energy, and few specific government policies support their deployment, as opposed to the growing focus on wind and solar from both industry and policy-makers.

In the absence of a comprehensive approach to the development of bioenergy, there are thus no specific mechanisms for state support and use of biofuels. The National Standard of the Russian Federation 52808-2007, entitled, "Unconventional technologies. Biowaste Energy. Terms and Definitions," was adopted in 2007. It is not currently clear, however, how to comply with this standard, as the consumer market in Russia is not ready for the emergence of new fuels on the one hand, and on the other, today's vehicle fleet is not designed to actually run on them.

An improvement in this situation is expected after the approval of special state regulations. In recent years, a draft of a federal law entitled, "On the development of biofuels production and consumption," has been developed (Russian Biofuels Association, 2016). Approval of this state law should be a decisive step forward in improving the current situation.

The explanatory note to the draft federal law says that, potentially, it is possible to produce:

- up to 5.5 million tonnes of rapeseed oil in Russia per annum (0.5 million tonnes can be used to supply food demand, about 2.0 million tonnes for export in the form of dimethyl, and the rest may be used domestically for liquid biofuel production)
- about 3.0 million tonnes of bioethanol from biomass
- 730 million m^3 of biogas from manure
- more than 1.0 billion m^3 of waste from bioethanol production
- 300 000 tonnes of biofuels produced from sawdust
- 800 000 tonnes of pellets from timber industry waste.

Running against the REmap estimate of great potential in the use of biofuels across all energy applications is the fact that currently, there is also no established market. Biomass power is growing only slowly, while its current and planned uses for heating and transport are negligible. For instance, in Russia as a whole, in the absence of a state regulation on liquid biofuel production and use, the main factors hindering its development include the high cost of biofuel production and therefore the low return on investment, as well as the absence of a regulatory framework to create a market.

When the estimated demand for biomass is compared to its total potential of supply, there remains a large surplus. This indicates that Russia's domestic resources can easily meet its demand potential. While this is true at the level of the entire country, in practice, however, it will require the mobilisation of significant volumes of resources, nationwide. This is in particular an issue because most demand for energy is in the European part of Russia, whereas biomass feedstock resources are generally in Siberia and other remote areas, where few people live.

As mentioned in this report, biofuels can create a major opportunity for the Russian economy, as they can be exported to neighbouring European countries, where they are in great demand. This market is not yet utilised to its full potential, though – partly because of a lack of logistical capability in collecting and moving biomass across borders, and partly because energy and trade policies do not consider this as a priority, compared to exports of oil, gas or coal.

Currently, the infrastructure for such resource mobilisation does not exist. Infrastructure includes both road and rail for transport, but also mechanisms to collect wood waste and residues from dense forests, as well as from agricultural areas. Existing forest and land management frameworks will also need to be improved to adapt to growing resource needs for energy production.

Utilising the potential estimated in REmap requires efforts in all stages of the biomass chain, namely supply, internal logistics and demand. Currently, none of these stages is the focus of energy policies, which creates a large barrier.

Opportunities and proposed solutions

Using the country's biomass potential may require a significant change in the domestic fuel market. Indeed, to utilise this potential, a market needs to be created, with biomass, to date, having lagged behind other renewable energy technologies, in particular the use of biofuels in heating and transport. For example, early opportunities for biomass feedstock use from the forestry and agriculture sectors exists, in particular in the form of waste and biogas, which are left unused and within close proximity of the population. Incentives for accelerating the collection and creating supply markets on one hand, and setting targets and developing incentives for consumers on the other, would contribute to the creation of such markets.

In addition to tackling the challenges within the country, biofuels also offer a prospective source of additional income from exports to Europe. This requires raising awareness across the various sectors of the economy about the potential of this opportunity. There is a necessity for a solid legal framework, ensuring the advantage of international trade cooperation for Russian producers of biogas, bioethanol and wood pellets.

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ANNEX A:

Energy price assumptions

	Units	Government perspective	Business perspective
Crude oil[1]	(USD/bbl)	107	81
Coal	(USD/tonne)	68	68
Electricity household	(USD/kWh)	0.12	0.09
Electricity industry	(USD/kWh)	0.06	0.05
Natural gas household	(USD/MMBtu)	4.1	2.3
Natural gas industry	(USD/MMBtu)	5.9	3.3
Petroleum products	(USD/litre)	1.58	1.26
Diesel	(USD/litre)	1.02	1.29
Gasoline	(USD/litre)	0.79	1.28
Biodiesel	(USD/litre)	0.75	0.92
Conventional ethanol	(USD/litre)	0.43	0.60
Advanced ethanol	(USD/litre)	0.46	0.65
Harvesting residue	(USD/GJ)	4.5	4.5
Process residue	(USD/GJ)	1.2	1.2
Biogas and waste	(USD/GJ)	3.5	3.5
Fuel wood	(USD/GJ)	6.5	6.5
Wood residues and waste	(USD/GJ)	8.8	8.8
Municipal waste	(USD/GJ)	1.2	1.2

[1] Crude oil price is the average of the optimistic and conservative scenarios (USD 70-90/bbl) (Minenergo, 2017).

ANNEX B:

Technology cost and performance of analysed technologies

	Main fuel type	Capacity factor	Lifetime	Capacity	Over-night cap. cost	O&M costs	Fuel demand	Con-version effi-ciency
	(-)	(%, cap)	(years)	(kW)	(USD/kW)	(USD/kW/yr)	(GJ/kW/yr)	(%, eff)
Industry								
Autoproducers, CHP electricity part (solid biomass)	Processing residue	42	25	10 000	757	19	17	80
Geothermal		55	42	100	1500	38		100
Biomass boilers	Harvesting residue	85	25	500	580	15	30	88
Autoproducers, CHP heat part (solid biomass)	Processing residue	42	25	32 000	757	19	17	80
Natural gas (steam boiler)	Natural gas, industry	85	25	2 000	100	3	28	95
Buildings								
Space heating: Solar		12	20	5	200	5		100
Space heating: Pellet burners EUR	Fuel wood	30	15	20	774	19	11	85
Space heating: Pellet burners Siberia	Fuel wood	30	15	20	774	19	11	85
Space heating: Natural gas (boiler)	Natural gas, household	85	15	20	162	6	30	90
Space heating: Petroleum products (boiler)	Petroleum products	50	15	20	175	6	19	85

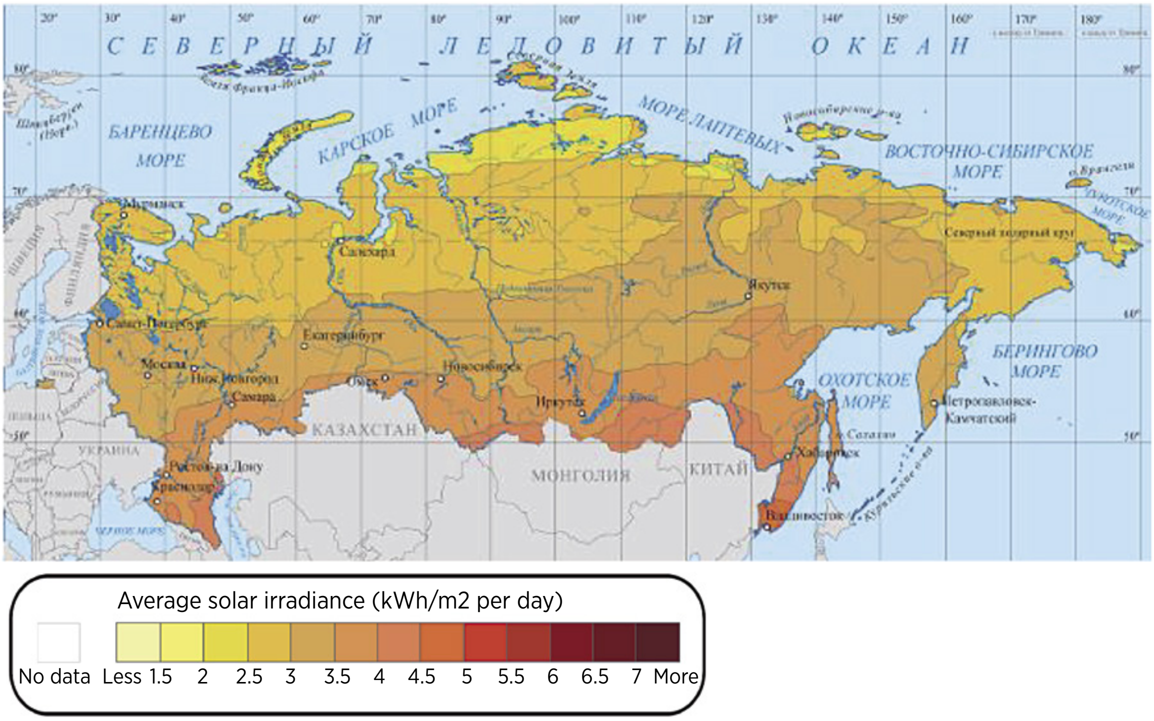
	Main fuel type	Capacity factor	Lifetime	Capacity	Over-night cap. cost	O&M costs	Fuel demand	Con-version effi-ciency
	(-)	(%, cap)	(years)	(kW)	(USD/kW)	(USD/kW/yr)	(GJ/kW/yr)	(%, eff)
Power								
Hydro (large)		44	60	100	3 040	60		100
Wind onshore EUR		25	30	100	2 258	60		100
Wind remote		25	60	100	3 000	80		100
Solar PV remote		10	30	0.1	2 000	75		100
Solar PV (utility)		14	30	1	1 750	65		100
Landfill gas ICE	Municipal waste	42	25	1	1 905	48	41	32
Geothermal remote		58	50	25	4 800	192		10
Public CHP electricity part EUR (solid primary biomass)	Wood residue and wood waste	42	25	10 000	755	6	17	80
Public CHP electricity part Siberia (solid primary biomass)	Wood residue and wood waste	42	25	10 000	1 125	6	17	80
Public CHP electricity part Siberia (biogas)	Biogas	42	25	10 000	2 100	23	17	80
Nuclear	Nuclear fuel	84	60	1 200	3 580	125	80	33
Natural gas (non-OECD)	Natural gas, industry	60	30	650	755	26	34	55
Diesel (Gen-set)	Diesel	40	20	0.1	1 700	43	50	25
District heat								
Public CHP heat part EUR (solid primary biomass)	Wood residue and wood waste	42	25	32 000	755	6	17	80
Public CHP heat part Siberia (solid primary biomass)	Wood residue and wood waste	42	25	32 000	1 125	6	17	80
Public CHP heat part Siberia (biogas)	Biogas	42	25	32 000	2 100	23	17	80
Natural gas EUR	Natural gas, industry	85	25	2.0	550	8	30	90
Petroleum products	Diesel	50	25	2.0	200	3	18	90
Coal Siberia	Coal	85	25	2.0	450	7	30	90

	Main fuel type	Capacity factor	Lifetime	Capacity	Over-night cap. cost	O&M costs	Fuel demand	Con-version effi-ciency
	(-)	(%, cap)	(years)	(kW)	(USD/kW)	(USD/kW/yr)	(GJ/kW/yr)	(%, eff)
Transport								
First generation bioethanol (passenger road vehicles)	Conven-tional ethanol	12	15 000	28 000	2 800	1.64		
Second generation bioethanol (passenger road vehicles)	Advanced ethanol	12	15 000	28 000	2 800	1.64		
Petroleum products (passenger road vehicles)	Gasoline	12	15 000	28 000	2 800	1.6		
Petroleum products (passenger road vehicles – diesel)	Diesel	12	15 000	30 000	3 000	1.54		
High speed train for passenger aviation	Electricity	35	6 900 000	18 000 000	1 800 000		0.37	
Petroleum products (passenger aviation)	Kerosene	30	200 000 000	50 000 000	5 000 000	5.52		

ANNEX C:

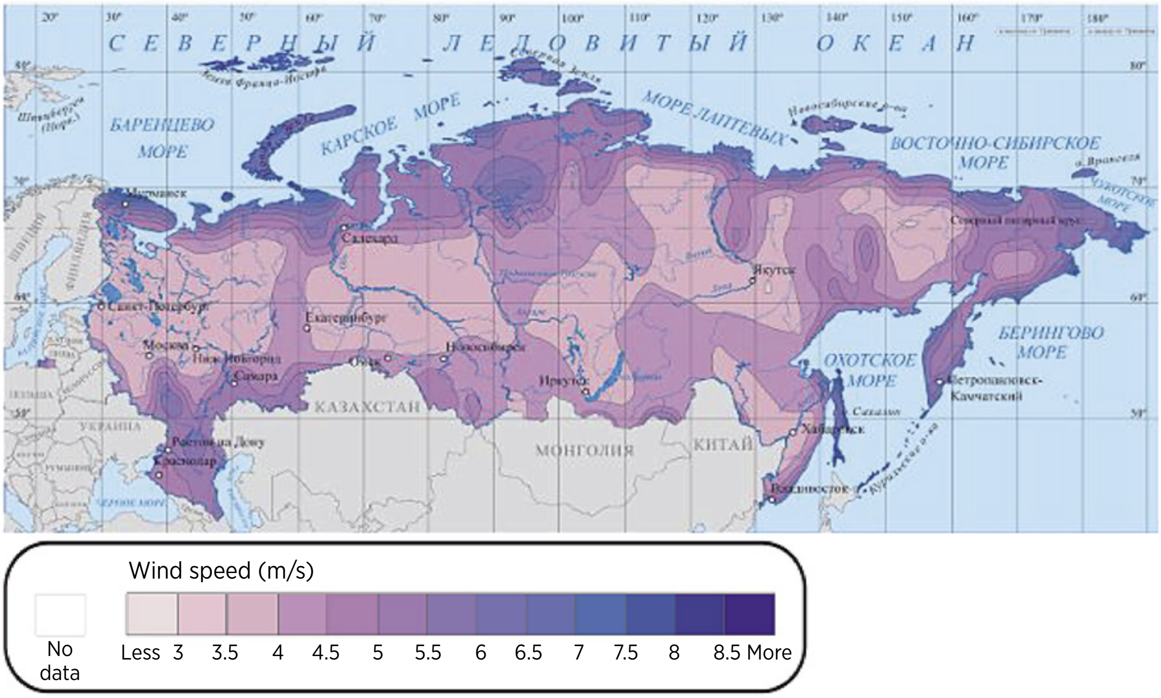
Resource potential

Figure 20: Total average daily solar radiation on the inclined surface of the southern orientation with an inclination angle equal to the latitude of the area (year)



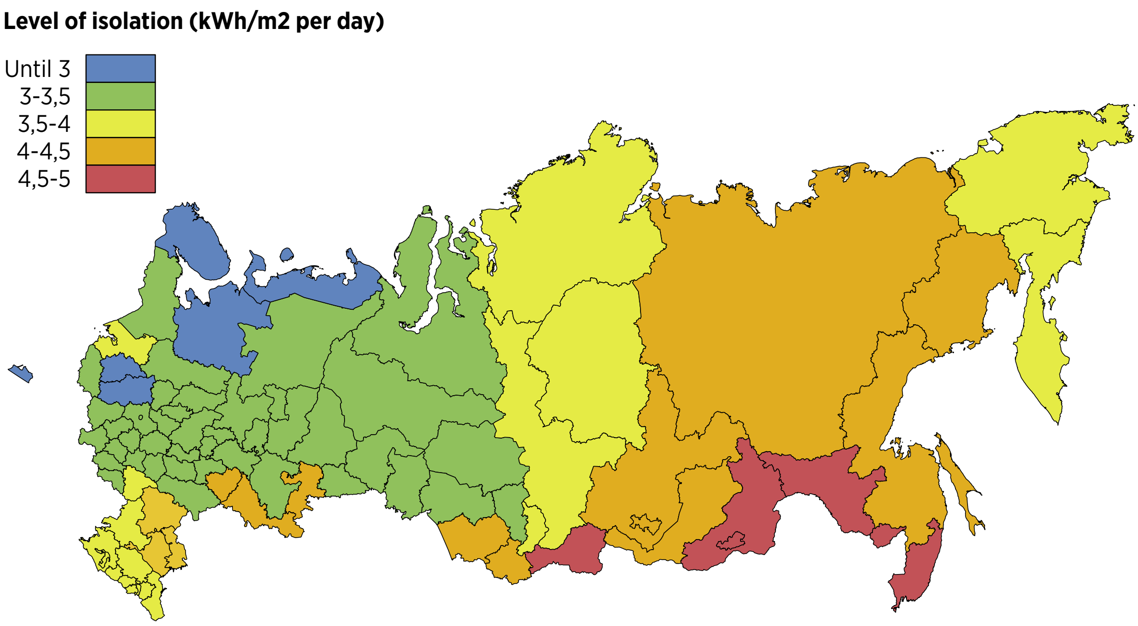
Source: Popel and Fortov, 2015

Figure 21: The average wind speed at a height of 50 m



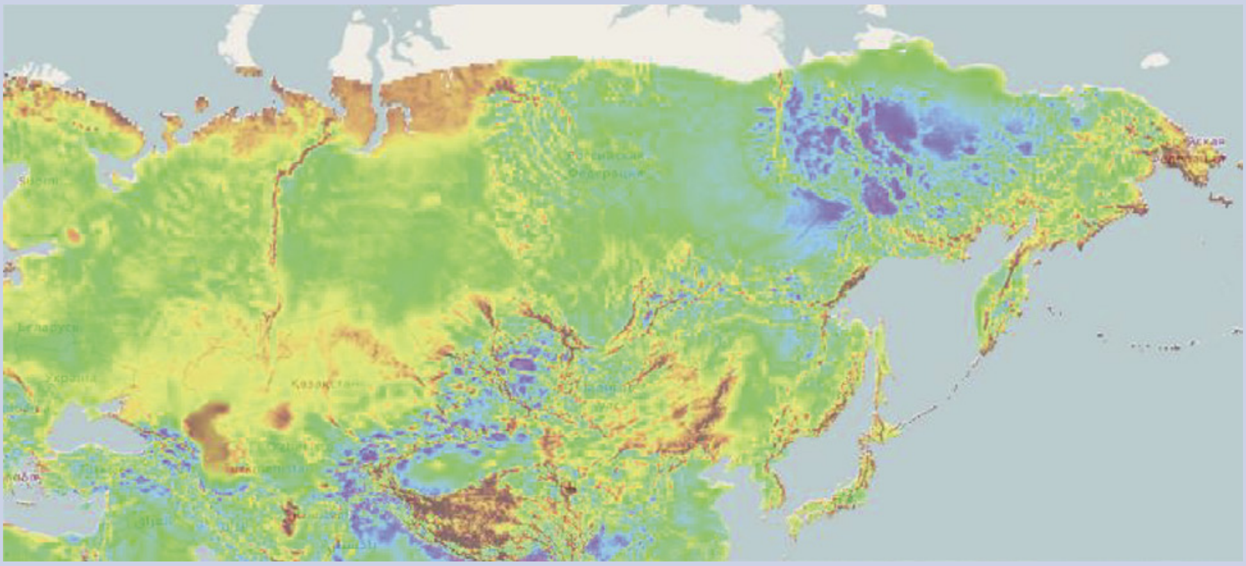
Source: Popel and Fortov, 2015

Figure 22: Daily solar insolates rates in Russia



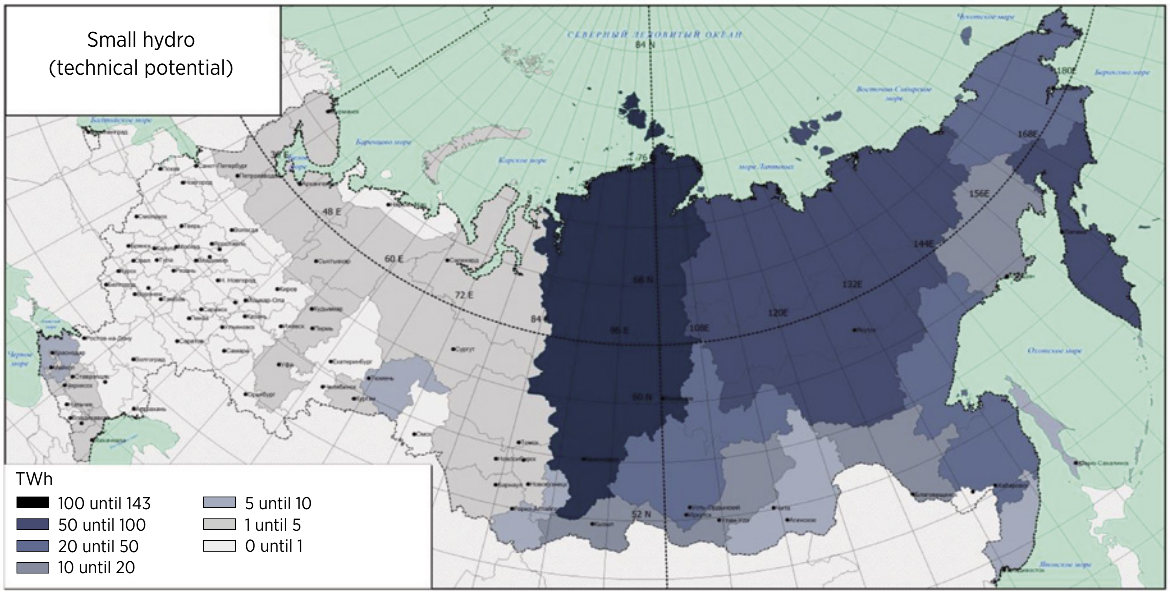
Source: GISEE, 2016

Figure 23: Global wind dataset 5km onshore wind at 80 m height



Source: IRENA Global Atlas, 2016

Figure 24: Regional technical potential of hydropower in small rivers



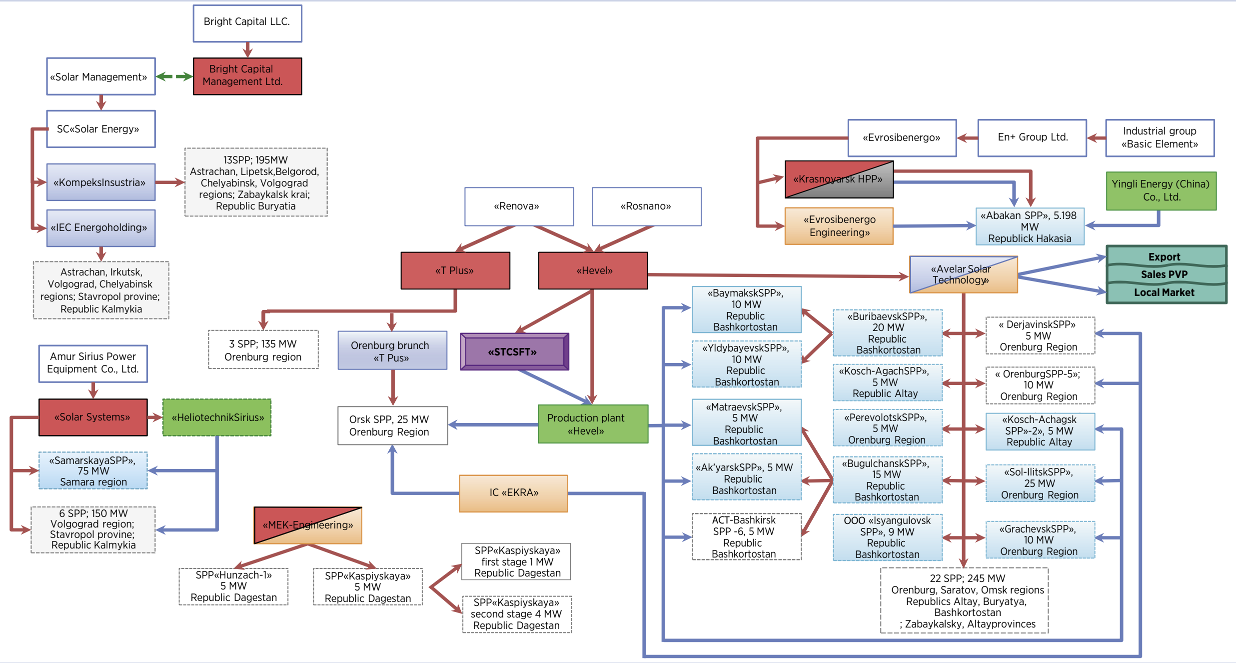
Note: in TWh per year

Source: Kiseleva et al., 2015

ANNEX D:

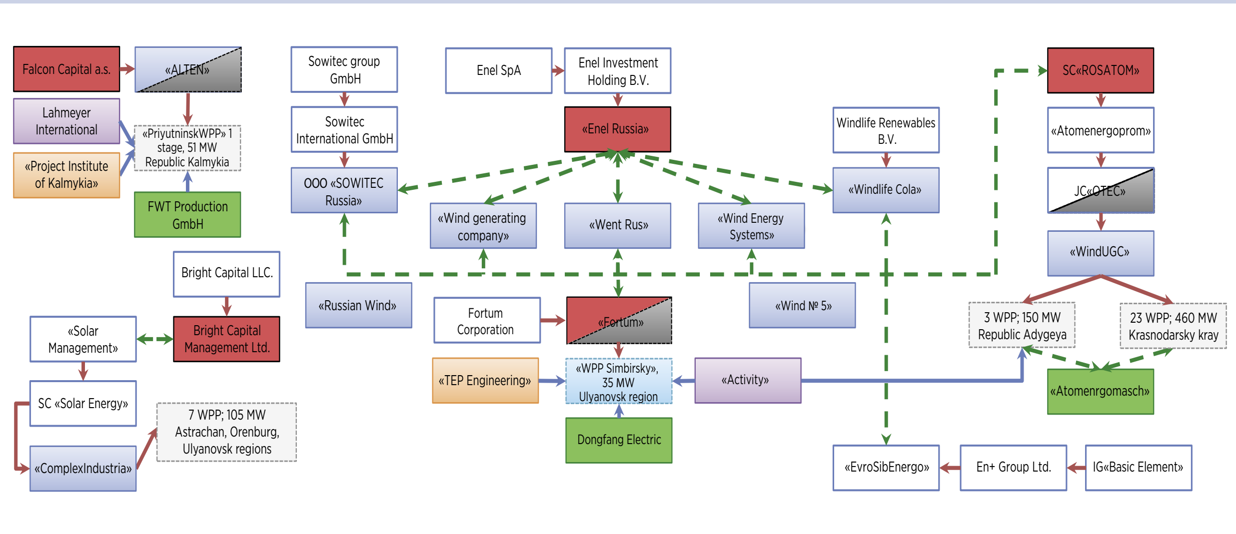
Key players in the Russian wind and solar PV power sectors

Figure 25: Solar power sector players of Russia (as of October 2016)



Source: Ermolenko, 2016

Figure 26: Wind power sector players of Russia (as of October 2016)



Source: Ermolenko, 2016

ANNEX E:

REmap Summary Table

	2010	Reference case 2030	REmap 2030
Total primary energy supply (PJ/year)			
Coal	4 810	5 006	4 829
Oil	3 714	6 186	5 465
Gas	13 836	14 532	13 166
Nuclear	1 874	2 288	1 823
Hydropower	599	742	1 000
Modern bioenergy	285	577	2 022
Solar thermal	0	0	0
Solar PV	0	0	11
Wind	0	36	110
Geothermal	18	36	360
Total	**25 136**	**29 404**	**28 786**
Total final energy consumption (PJ/year)			
Coal	1 844	2 678	2 674
Oil	3 249	5 781	5 091
Gas	4 572	5 451	4 890
Modern biofuels (solid)	98	143	717
Modern biofuels (liquid and gaseous)	0	200	390
Solar thermal	0	0	30
Geothermal	0	0	30
Electricity	2 617	3 466	3 400
District heat	4 799	4 472	4 356
Total	**17 179**	**22 191**	**21 577**
Gross electricity generation (TWh/year)			
Coal	166	161	161
Natural gas	521	663	568
Oil	9	12	12
Nuclear	170	224	186
Hydropower	166	206	278
Bioenergy	3	6	74
Solar PV	0	0	3
Onshore wind	0	10	31
Geothermal	1	1	10
Total	**1 036**	**1 284**	**1 322**

	2010	Reference case 2030	REmap 2030
Electricity capacity (GW)			
Coal	49	36	36
Natural gas	105	138	120
Oil	6	5	5
Nuclear	24	32	27
Hydropower	47	55	74
Bioenergy	0	2	26
Solar PV	0	3	5
Onshore wind	0	5	14
Geothermal	0	0	1
Total	**231**	**276**	**308**
District heat generation (PJ/year)			
Coal	1232	1045	889
Natural gas	4010	3778	3617
Oil	312	235	206
Nuclear	15	48	48
Bioenergy	120	155	501
Total	**5688**	**5261**	**5261**

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