Green development of Russian coal-intensive regions: opportunities and innovations

Perspective paper September 2021
Abstract
The authors explore the role of coal mining in the regional economies of Russia and diversification plans of the regions that depend on the coal industry. New development avenues are proposed for coal-dependent regions. This study considers sustainable options only (i.e. fossil free pathways) and provides five major innovative ideas that can be implemented in the regions affected by coal mining. The proposals comprise (1) creating new added value from abandoned coal mines, (2) developing wind and solar PV power generation and production of equipment for these industries, (3) producing and exporting bioenergy (e.g. pellets), (4) establishing sustainable manufacturing through the creation of green special economic zones (GSEZ), and (5) supporting small businesses and entrepreneurship. The key proposal of the paper is the creation of a GSEZ in Kuzbass offering tax incentives and sustainable infrastructure.

Anнотация
Авторы исследуют роль добычи угля в экономиках российских регионов, а также планы диверсификации регионов, зависящих от угольной промышленности, и предлагают новые направления развития для сегодняшних центров угледобычи. В данном исследовании рассмотрены только варианты устойчивого развития (не связанные с ископаемым топливом) и разработаны пять основных инновационных идей, которые могут быть реализованы на территориях, пострадавших от добычи угля. Предложения включают в себя (1) создание новой добавленной стоимости на заброшенных угольных шахтах, (2) развитие производства ветровой и солнечной электроэнергии и производства оборудования для этих отраслей, (3) производство и экспорт биоэнергии (в частности, топливных пеллет), (4) развитие практик устойчивого производства путем создания для этой цели зеленых специальных экономических зон (ЗСЭЗ) и (5) поддержка малого бизнеса и предпринимательства. Ключевым предложением авторов является создание ЗСЭЗ в Кузбассе с налоговыми льготами и зеленой инфраструктурой.
# Table of Contents

1. Introduction 4  
2. The role of coal in regional economies 5  
3. Official diversification approaches 7  
4. Low-carbon coal mining alternatives for Russian regional economies 9  
   4.1. New value added from abandoned coal mines 9  
      4.1.1. Heat pumps exploiting water from flooded coal mines 9  
      4.1.2. Greenhouse and underground farming 9  
      4.1.3. Energy storage in abandoned coal mines 10  
      4.1.4. Uses of abandoned open pit mines 10  
   4.2. Wind and solar PV power options 11  
   4.3. Solid biofuels 13  
   4.4. Green special economic zones 13  
   4.5. Small businesses and entrepreneurship 15  
5. Summary and recommendations 16  
Annex 17  
References 18  

## Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHP</td>
<td>Combined Heat and Power</td>
</tr>
<tr>
<td>ES-2035</td>
<td>Energy Strategy until 2035</td>
</tr>
<tr>
<td>GDP</td>
<td>Gross Domestic Product</td>
</tr>
<tr>
<td>GHG</td>
<td>Greenhouse Gas</td>
</tr>
<tr>
<td>(G)SEZ</td>
<td>(Green) Special Economic Zones</td>
</tr>
<tr>
<td>iCAES</td>
<td>Isothermal Compressed Air Energy Storage</td>
</tr>
<tr>
<td>LCOE</td>
<td>Levelized Cost of Energy</td>
</tr>
</tbody>
</table>
Across the globe, many coal mining regions and communities struggle to diversify from coal. Coal mining activities are usually geographically clustered which means there are towns and communities that are heavily economically dependent on coal, though its role in the national economy is often not significant. As such, supported by national authorities, coal reliant communities need clear, transparent planning and innovative low-carbon ideas for growth to ensure sound energy transitions. At present, Russian coal reliant regions and communities invest their revenues from coal in other economic activities, such as non-extractive and low-carbon industries or small and medium enterprises. However, without structural changes these resources will decrease due to the projected decline of the global demand for coal.

This paper proposes potential avenues to decrease regional economic dependence on coal mining. The novelty of this paper is the focus on low-carbon diversification options without fossil fuel-based technologies, which has been absent in the Russian diversification discourse to date. Even though this approach does not necessarily reflect the mainstream approach to coal diversification and narrative of many Russian actors, the paper provides an assessment of the techno-economic feasibility of a more ecological approach to energy transitions in Russia, as well as new sustainable economic activities. However, its limitations lie in the demographic and human capital analysis, as the replacement of coal exports with exports from new sustainable industries requires a sufficient number of young and educated employees that are committed to stay in the region and to study and reskill. Many coal regions are known for constant population outflow, with the youngest and most creative residents being the first to migrate. Further, the products of new sustainable industries are more difficult to export, and it will take time to establish their manufacturing and export supplies.

This paper predominantly explores new ways of producing energy, specifically addressing the techno-economic potential for green energy transitions in Russia, as well as new sustainable economic activities. However, its limitations lie in the demographic and human capital analysis, as the replacement of coal exports with exports from new sustainable industries requires a sufficient number of young and educated employees that are committed to stay in the region and to study and reskill. Many coal regions are known for constant population outflow, with the youngest and most creative residents being the first to migrate. Further, the products of new sustainable industries are more difficult to export, and it will take time to establish their manufacturing and export supplies.

1. Introduction

This paper predominantly explores new ways of producing energy, specifically addressing the techno-economic potential for green energy transitions in Russia, as well as new sustainable economic activities. However, its limitations lie in the demographic and human capital analysis, as the replacement of coal exports with exports from new sustainable industries requires a sufficient number of young and educated employees that are committed to stay in the region and to study and reskill. Many coal regions are known for constant population outflow, with the youngest and most creative residents being the first to migrate. Further, the products of new sustainable industries are more difficult to export, and it will take time to establish their manufacturing and export supplies.
2. The role of coal in regional economies

Coal plays an insignificant role in the Russian economy. In 2019, the coal rent (revenues above the cost of extracting coal) comprised 0.4% of the Russian gross domestic product (GDP), compared to 9.2% for oil and 2.8% for natural gas rents. In 2020, the share of gross value added of the coal industry in the Russian GDP was estimated at 0.41%, compared to 0.61% in 2019. However, in some regions coal plays a substantial role. Thus, in 2019, the share of coal mining in the gross regional product of Kuzbass comprised of 27.2%. Since Kuzbass produces more than a half of all Russian coal, and other regions normally do not provide estimates for the share of coal mining in their gross regional products, it is assumed that the role of coal is less significant in other regions.

Coal is mined in 18 out of 85 regions of Russia but three quarters of it is produced in three Siberian regions: Kuzbass or Kemerovo oblast (58.2%), Krasnoyarsk krai (9.4%) and the Republic of Khakassia (5.6%). In addition to Siberia, significant volumes of coal are mined in the Far East, primarily in Zabaykalsky Krai (5.3%) and Sakha Republic (4.1%) – these two regions rank respectively fourth and fifth in production (see Annex). In terms of employment, the share of coal mining is negligible in most regions of Russia, as only six of them directly employ over 1% of the working population. The leader by far is Kuzbass with 11.6%, followed by the Republic of Khakassia with 3.7%, Sakha Republic with 2.1% and three regions – Sakhalin Oblast, Komi Republic and Chukotka Autonomous Okrug – each with 1.5% (see Annex). It should also be noted that the overall number of coal sector employees has significantly decreased from 150,000 to 160,000 people at the end of 2017 to about 135,000 people in early 2021 (Figure 1). This data indicates that coal plays a key role only in the Kuzbass economy. In the economies of other mining regions its role, including the social value, is relatively small.
2. The role of coal in regional economies

Despite the small economic contribution of the Russian coal sector in most regions, individual monotowns that arose around shafts and open pits can significantly depend on coal. Coal enterprises are city-forming, i.e. employing more than 50% of the city’s population, for 30 Russian monotowns with a total population of over 1.3 million people. However, among all Russian regions, the highest proportion of the population living in single-industry towns is observed again in Kuzbass at 60.2%. Kuzbass has 24 monotowns, most of which specialise in coal mining. A third of these cities have difficult socio-economic situations, including the coal-mining cities Prokopyevsk and Anzhero-Sudzhensk. Some monotowns in which mines were closed became ghost towns; their population decreased severalfold and many buildings were abandoned. Examples of such cities are Kizel in the Perm Krai, where the population declined after reaching the maximum coal production – it declined from 60,000 people in the late 1950s to 13,000 people at present. Another example is Vorkuta in Komi Republic, the population of which has decreased from 117,000 people in 1991 to 52,000 people at present. However according to some press articles, in reality much fewer people live in the town, and coal is still being mined in Vorkuta.

Coal mining produces income and jobs in Russian regions, however it is also a root cause of pollution and increased morbidity and mortality. Local populations have realised the negative impact of mining which has led to protests against new coal mining and transportation activities. While public protests against coal mining hardly took place before 2015, this is now a widespread practice in Kuzbass, the heart of the Russian coal industry. Over 50 protests, mostly by local villagers living next to coal mines, of whom many of their family and friends worked in the coal sector, occurred in Kuzbass since 2015. It is not uncommon for environmental activists to raise their voices against the opening of new coal mines in Russia. Although the local government often responds to protests with administrative and criminal charges against organisers, activists against coal have achieved significant successes. In 2019, for the first time in the history of Kuzbass, a local court case resulted in the recall of the license for the construction of a new coal mine. The court case was started by Ecodefense environmental group, the association of lawyers and journalists Team-29 and a group of residents. This success demonstrated the possibility of establishing effective anti-coal alliances between activists working at local and national levels. In the summer of 2020, a group of local activists set up a protest camp near Cheremza village in Kuzbass. After the two months of protest, the construction of coal mining infrastructure was halted. Protests against the expansion of coal production and the construction of new open-pit mines are also taking place in some other regions of Russia, for example, in the Republic of Khakassia. In the regions of coal transhipment, for example, in Primorsky Krai and Khabarovsk Krai, there are protests against the open-air coal transhipment that causes coal dust air pollution.
3. Official diversification approaches

In 2020, Russia produced 402.1 million metric tons of coal\(^1\). Russian energy strategies have traditionally anticipated for coal mining to grow, including the most recent mines. Thus, the Energy Strategy until 2035 (ES-2035)\(^2\) adopted in 2020 sets the target to increase the volumes of coal mining to 485-668 million metric tons by 2035, i.e. by 21%-66%. At the same time, the ES-2035 demonstrates significant uncertainty regarding Russia’s share in the global coal market: it is expected to either decrease from 14% in 2018 to 12% by 2035 or to increase to 25% by 2035. In the activities section (section IV), the programme of the coal industry development in Russia for the period up to 2035\(^3\), adopted in 2020, assumes an increase in the volumes of coal supplies of up to 429-588 million metric tons by 2035, i.e. a 7%-46% increase. However in annex VI it provides the same figures as ES-2035 (485-668 million metric tons by 2035). These high estimates significantly contradict with the plans of the largest economies, such as the EU, the U.S., China, the UK, Japan and the Republic of Korea, to become carbon neutral by the mid of the century.

Coal regions and monovilles of Russia are not subject to discussions around diversifying local economies in the context of a coal phase-out. For example, the Strategy of socio-economic development of Kuzbass\(^4\), considers minerals, including identification and mining of deposits, as the basis for the development of priority industries in the region.

In some coal mining regions, official ‘clean’ and ‘green’ rhetoric is emerging, however any legitimate or real action behind these words is yet to be seen. For example, in 2020, the Government of the Russian Federation approved the programme ‘Clean Coal – Green Kuzbass’ with 3.5 billion roubles funding from the federal budget for the period until the end of 2024\(^5\). The goal of this initiative is to improve the efficiency of coal mining and processing, as well as reducing the regional environmental damage from the coal industry. In addition, the programme anticipates an increase in coal production\(^6\), which seems to contradict with the nature of mining and associated environmental impacts.

Expansion of coal production is planned in many coal regions. For example, in Khakassia mining is anticipated to accelerate the development of coal mining capacities. In particular, the commissioning of two new coal mines will result in an increase in the volume of coal production from 19.5 million metric tons in 2016 to 46 million metric tons in 2030\(^7\). In the Republic of Khakassia, a project was planned to create and develop the Beysky coal cluster until 2030, with state co-financing for the construction of infrastructure facilities\(^8\). In 2021, the construction of a coal cluster in the north of the Krasnoyarsk Territory commenced, which will produce coal concentrates from coking coal. The project includes the creation of a coal mine in Taimyr and will be carried out with state support\(^9\). In 2010-2020, the volume of coal production in Yakutia has doubled up to 20 million metric tons, and by 2024, the region plans to produce 80 million metric tons\(^10\), although these plans may be thwarted by the lack of rail capacity\(^11\).

In July 2021, the Ministry of economic development of the Russian Federation published plans for economic diversification for Kuzbass and Komi Republic\(^12\). As part of the new plan, Kuzbass is expected to develop the mining of metal ores and other minerals as well as metallurgical production, agriculture, construction, tourism (including the Sheregesh ski resort and other ski complexes), food production, wood processing and production of wood products, production of paper and paper products, coke and petroleum products, chemicals and chemical products, rubber and plastic products, finished metal products, machinery and equipment, and electrical equipment. In the Komi Republic it is planned to extract metal ores and other minerals, to develop wood processing and production of other wood products, to develop production of paper and paper products, finished metal products, except for machinery and equipment, and to develop agriculture and construction. As coal mining in the region has affected the environment and public health, diversifying by mining for different minerals such as metal ores, may still not be the most sustainable or suitable diversification options for the region. Instead, to diversify the region could expand its sectors in tourism, agriculture, food production, and equipment manufacturing. Similarly, the development of...
wood and paper industries should consider sustainability principles, such as responsible sourcing of wood from managed forest. Asides from this, Kuzbass and Komi Republic's economic diversification plans do not affect the coal targets of the Energy Strategy until 2035 and the Program of the coal industry development in Russia for the period up to 2035.

This state of affairs indicates the need for further options to diversify the economies of Russian coal mining regions. In light of global trends, these options would benefit from being low-carbon.
4. Low-carbon coal mining alternatives for Russian regional economies

Asides from the industries that are desirable to develop and that are already mentioned in the new diversification plans of Kuzbass and the Komi Republic, such as tourism, agriculture, food production and equipment manufacturing, there are other industries that can substitute lost regional incomes from coal mining without severe damage to environment and public health, create new jobs and spur regional economic development. One option is to create new added value using both abandoned underground coal mines and abandoned coal open pits. Recent years have seen an increased interest towards the utilisation of abandoned mined underground spaces. Some of these spaces have already been converted into science laboratories, underground farms, storage facilities, industrial museums and even hotels and restaurants. In fact, development of mined underground space becomes a growing industry globally that is crucial for decarbonisation, circular economy and sustainable economic growth. It should be noted that in this paper we do not consider usage of underground space for fossil fuels, such as natural gas, oil storage and carbon capture and storage, nor waste disposal, including radioactive waste, though some of them are being actively developed in the world.

4.1. New value added from abandoned coal mines

4.1.1. Heat pumps exploiting water from flooded coal mines

The stable temperature of mine water in abandoned and flooded coal mines provides a valuable low temperature geothermal resource that can be used for district heating with zero greenhouse gas (GHG) emissions. Using heat pumps that raise mine water temperature to suitable levels, heat pumps operate on electricity that can be produced from renewable energy sources to avoid GHG emissions.

There are many similarities between the coal mining and the geothermal energy industry, such as the required skills (drill cutting, flow extraction, expertise in geological formations, etc.) and equipment used. By developing the geothermal energy sector in coal mining regions, laid-off coal workers have an opportunity to easily transition to a new career. Importantly, geothermal heating technologies are economically viable. In Europe, producing energy with heat pumps that use mine water brings economic savings of over 70% compared to heating with natural gas. In Russia, due to the abundance of cheap natural gas and coal, this economic benefit might be lower but is still significant.

4.1.2. Greenhouse and underground farming

The abundance of cheap geothermal heating can instead give an impetus to mine owners to consider greenhouse farming. Underground farming is also an option for abandoned coal mines. The USSR had some experience in this sphere; in 1990, cucumbers and tomatoes were planted in abandoned iron mines at the depth of 370 m in the Krivarog mining bureau. Underground farming has numerous benefits compared to conventional farming, such as independence of seasonality, weather and environmental conditions.

Box 1. International experience: Heat pumps

Examples of heat pumps exploiting mine waters include Markham Colliery in the United Kingdom, Springhill in Canada, Park Hills in the USA, several examples in Saxony, Germany, Minewater in Netherlands, and many others. Such examples are also found in Russia, e.g. Novoshakhtinsk colliery. In Novoshakhtinsk, a city in Rostov Oblast with population of 110,000 people, the volume of mine water exceeds 11 million m³, and has a temperature of 18 - 23 °C. Using mine water, the pilot heat pump station of the city supplies thermal energy to the central district of the city (8% of the city’s total heat consumption), including five critical infrastructures and facilities: central city hospital No. 1 (ten buildings), children’s city hospital (four buildings), school No. 27, vocational school No. 58 (five buildings), and nursery No. 34 ‘Mishutka’. The construction of the heat pump station allowed the closure of seven old ineffective coal-fired boiler houses. Geothermal heating can be a way of diversification for coal mining companies. There are examples of coal mining companies that consider geothermal heating, e.g. Grupe Hunosa in Spain.
4. Low-carbon coal mining alternatives for Russian regional economies

Underground farming, including farming in former mines, is a prospective research topic with a small number of research and pilot projects to date. Underground data processing is another potential avenue for the usage of abandoned coal mines. Russian coal mining regions have an opportunity to become pioneers in these spheres.

4.1.3. Energy storage in abandoned coal mines
Abandoned coal mines can be converted into underground energy storage facilities using pumped hydroelectric energy storage technology. The technology itself is mature, commercial and applicable at the utility scale representing 99% of the global electric power storage capacity. The technology has been put into practice on the surface in many locations in the world, however not underground. Underground energy storage can be combined with intermittent renewable electric power generation facilities, such as solar PV and wind power plants. Electricity generated from solar PV and wind power plants when electric power is abundant, pumps mine water from the underground reservoir located in the abandoned shaft to the surface reservoir using excess electric power. When solar PV and wind electric power generation is not sufficient, water from the surface reservoir is released to the underground reservoir through a hydroelectric turbine that generates electric power.

Brownfields left from coal mining could be used for the construction of surface reservoirs. Shafts can be utilised for the construction of underground reservoirs without further damage to the environment and landscape. Another advantage of the underground pumped storage hydropower plant is that its per unit cost is estimated to be lower than for most other energy storage concepts. Replacing expensive fabricated storage vessels with existing abandoned shafts offers large cost benefits. Energy storage in abandoned coal mines is another possible field for further research, innovation and cooperation with foreign partners (e.g. from Ruhr area), as well as for pilot projects. One further potential area to use abandoned coal mines as energy storage is isothermal compressed air energy storage (iCAES). This concept also requires experimental testing through pilot projects.

4.1.4. Uses of abandoned open pit mines
Abandoned open pit mines can also be used for different economic activities. They need restoration that comprises topographic restitution, water drainage construction and soil restoration. There are two types of soil restoration; purely environmental without carrying an economic benefit, and productive, which implies sowing the degraded land with fast-growing energy crops to produce biofuels. Restoration activities themselves are also an important avenue for coal mining regions that need environmental reclamation. This can create new jobs in the restoration sector, improve the investment attractiveness of the regions and boost local eco-tourism, especially in the regions where tourism is already established, such as Sheregesh in Kuzbass. If the degraded lands are sown with energy crops, this can also create a biofuel industry with export potential.

Box 2. International experience: Underground farming in the UK
There are examples of functioning underground farms, such as the Growing Underground project in the UK that uses a former WWII air-raid shelter located at 30.5 m under Clapham Common in London. Crops are grown free of pesticides using hydroponic systems, LED lighting and 100% renewable energy.

Box 3. International experience: Energy storage
Underground pumped hydro storage is not a novel idea and was first documented as early as 1917. Since then, however, it has only been used in technical and economic feasibility studies, for instance a study for the Ruhr area in Germany where hard coal mining was phased out in 2018.
4. Low-carbon coal mining alternatives for Russian regional economies

4.2. Wind and solar PV power options

According to a wide number of studies\(^{36,37,38,39}\), solar PV and onshore wind energy are now the cheapest sources of electric power globally, after tenfold cost reductions for solar PV power generation and threefold reductions for wind power during the last decade. Moreover, competitiveness of utility-scale solar PV and wind power continues to improve, due to falls in solar PV modules and wind turbine prices, declining plant costs, and increasing capacity factors. According to Carbon Tracker, it is now cheaper to build a new renewable energy power plant than to continue operating an existing coal capacity for 39% of the global coal power fleet\(^{40}\).

Russia has abundant renewable energy resources. For instance, to generate all Russian electric power from solar, less than 5% of the land is required\(^{41}\). However, modern utility-scale solar PV and onshore wind energy only started to develop in Russia in 2013. Due to a late start, the small market size (Russian wind market reached 1 GW only in early 2021) and requirements to use a certain percentage of locally manufactured equipment (localisation requirements), costs of wind power generation in Russia in 2020 were about twice as high as global costs. Still, newly commissioned wind power plants in Russia already generate cheaper electric power than new coal power plants\(^{42}\). Costs of solar PV power generation are estimated at 127 $/MWh\(^{46}\), compared to the global average of 37 $/MWh\(^{44}\) (both estimates for 2020). According to Carbon Tracker, by 2030, all existing coal power generation in Russia will cost more than commissioning new renewable power generation plus storage\(^{45}\).

Most coal mining regions in Russia have favourable conditions for wind and solar PV power development. Direct normal irradiation in some areas of Zabaykalsky Krai, Irkutsk Oblast, Primorsky Krai, Amur Oblast, Buryatia Republic, Tuva Republic is significantly higher compared to the maximal irradiation in Germany (Figure 2) where solar PV power plants produced 10.5% of all electric power in 2020\(^{46}\). The costs of generating solar PV electric power (Levelized cost of energy, LCOE) in Kuzbass in 2021 are estimated to start from 5.8 eurocents/kWh, from 5.5 eurocents/kWh in Rostov region, from 4.2 eurocents/kWh in Zabaykalsky krai, which is cheaper than grid electric power for small enterprises and individual entrepreneurs. In seven coal mining regions solar PV energy is economically viable at least in the sector of small businesses (Figure 3).

![Figure 2. Direct normal irradiation in the coal mining regions of Russia compared to Germany and the UK, kWh/m² per day\(^{47}\)](image)
4. Low-carbon coal mining alternatives for Russian regional economies

Figure 3. Russian coal mining regions with competitive solar energy for small enterprises* in the southern part of the region

Some coal mining regions of Russia have attractive wind energy resources. At the height of 150 meters, the mean wind speed for the 10% of windiest areas in Germany is 9.65 m/s, and 11.22 m/s in the UK. In Chukotka Autonomous Okrug, Sakhalin Oblast, Kamchatka Krai and Krasnoyarsk Krai, the mean wind speed for the 10% of windiest areas is higher than in Germany, and wind speed in most other coal mining regions including Kuzbass is also suitable for wind energy (Figure 4). The wind energy industry requires infrastructure suitable for advanced heavy-weight logistics. Many key coal mining regions offer suitable access to such infrastructures due to their location on the Trans-Siberian Railway and Baikal-Amur Mainline, with developed automobile logistics that can also be adapted to wind energy requirements. Some coal mining regions in Russia have already started to build their first wind power plants, e.g. Rostov Oblast.

Figure 4. Mean wind speed for the 10% of windiest areas in the coal mining regions of Russia compared to Germany and the UK at height 150 m, m/s*
4. Low-carbon coal mining alternatives for Russian regional economies

4.3. Solid biofuels
Many Russian coal mining regions have established wood and wood processing industries. For instance, Krasnoyarsk Krai with the second largest share in coal mining takes the third place in the production of rough timber in Russia. Irkutsk Oblast is the seventh largest coal mining region and the biggest timber producing region, and Primorsky Krai the tenth and ninth largest producer respectively. The official economic diversification plans of Kuzbass and Komi Republic comprise the development of wood processing and production of wood products as well as paper and paper products. These industries leave large volumes of wood residue and waste, which is a raw material for pellets that is used to produce heat and power worldwide. Regular white pellets are combusted at biomass-fired combined heat and power (CHP) plants. Steam exploded black pellets can be burned at existing thermal power plants instead of coal with only minor modification of facilities allowing 100% conversion of a plant from coal to solid biofuel.

Asides from bioethanol, wood pellets are one of the most widely traded biofuels. Their global market is well-established with Russia being among its main suppliers. Russian coal mining regions that are rich in timber already produce pellets, mostly for export. Deliveries are carried out even over distances of thousands of kilometres, for example, from Irkutsk to Europe (over 7,000 km). At the same time large volumes of wood residue remain unprocessed (up to 85% in the whole country) representing a huge potential for the development of export-oriented pellet production. It should be noted that sustainability is a very sensitive issue in biofuels production, and the authors would like to emphasise that pellets should be produced only from wood residues or energy crops without affecting land use or biodiversity, and energy crops should not compete for land with food crops and forests.

4.4. Green special economic zones
Special economic zones (SEZ) can be defined as ‘demarcated geographic areas contained within a country’s national boundaries where the rules of business are different from those that prevail in the national territory. These differential rules principally deal with investment conditions, international trade and customs, taxation, and the regulatory environment; whereby the zone is...

Box 4. International experience: Green industrial zones
An example of an eco-industrial park is Denmark’s Kalundborg Symbiosis founded in 1972 and positioned as the world’s first industrial symbiosis with a circular approach to production. The symbiotic collaboration was not originally planned and arose spontaneously. Some of Kalundborg habitants are large enterprises, e.g. Novo Nordisk, Statoil, Ørsted. They exchange water, steam and materials (gypsum, sludge, waste gas, fly ash, etc.). The eco-industrial park cannot necessarily be characterised as environmentally friendly since it contains an oil refinery and has been producing electric power from coal for decades. However, its symbiotic relations have increased both the environmental and economic efficiency, and in 2020, after three years of work, its Asnæs power plant operated by Ørsted was converted from coal to biomass (woodchips).
4. Low-carbon coal mining alternatives for Russian regional economies

given a business environment that is intended to be more liberal from a policy perspective and more effective from an administrative perspective than that of the national territory\(^54\). SEZ have a long history dating back to the late 1950s and appear in a large variety of names and forms\(^55\). The concept of green SEZ or GSEZ has been developing and evolving for more than a decade, as SEZ are major GHG emitters. Vivid Economics identifies three types of special economic zones (GSEZ) that can contribute to green growth and are not mutually exclusive: (1) eco-industrial parks that offer shared infrastructure and elements of circular economy, (2) low carbon zones that have set their own emissions targets and can serve as pilot regions for new green policies, and (3) green industrial clusters focused on green technologies and products\(^56\). According to Vivid Economics, GSEZ are most effective when aligned to the national objectives and sectoral specifics of an economy.

Examples of low carbon zones exist even among the Russian coal mining regions. Sakhalin Oblast has been selected as a pilot region to create a carbon trading system which can be applied in other Russian regions afterwards, and it has set a goal to become carbon neutral by 2025. However, Sakhalin Oblast has a developed fossil fuels sector with no phase-out plans; the carbon neutrality goal is not supported by a strategy, renewable energy is barely considered within the carbon neutrality discourse, and forest accounting and gasification are planned as the key measures to achieve carbon neutrality. Thus, the Russian ‘first low-carbon zone’ is so far merely a formality rather than a real change that depicts more ambitious, greener goals and a low-carbon strategy for its achievement.

Based on the diversification options discussed in this paper, the authors recommend to create a strong GSEZ in Kuzbass, since it is the most affected coal mining region in Russia and requires new low-carbon sources of income. Such a zone could encompass the whole territory of the region and could combine functions of an eco-industrial park; offering shared green infrastructure, elements of a circular economy and functions of a green industrial cluster focused on green technologies and products. Such a GSEZ has the potential to attract foreign investment and develop international economic cooperation. Residents of Kuzbass GSEZ could comprise agricultural enterprises, food producers and equipment manufacturers mentioned in the new diversification plan of Kuzbass, as well as new manufacturers of equipment for renewable energy industries and progressive foreign industrial companies that might be attracted by new opportunities of sustainable manufacturing.

4.5. Small businesses and entrepreneurship

Box 5. International experience: China’s Solar Valley

An example of a green industrial cluster is China’s Solar Valley focused on applying solar-based technologies in buildings, transportation and entertainment. The valley is in Dezhou, about 200 km from Beijing, covers an area of 3,000,000 m\(^2\) and is the largest solar industrial area in the world. The project was launched in 2004 by Himin Solar Energy Group in partnership with the Dezhou local government. The valley offers support for solar manufacturing, R&D and testing, personnel training, it has a conference centre, an exhibition centre and the world’s first all-solar hotel.
4. Low-carbon coal mining alternatives for Russian regional economies

As small enterprises are underrepresented in many of these regions, another possible avenue for coal mining regions is entrepreneurship. In 13 out of 18 coal mining regions, the number of small enterprises’ employees per 1,000 of population is below the average national value (Figure 5), including all top-5 mining regions: Kemerovo Oblast (Kuzbass), Krasnoyarsk Krai, Republic of Khakassia, Zabaykalsky Krai, Sakha Republic. Only Khabarovsk Krai, Novosibirsk Oblast, Primorsky Krai, Magadan Oblast and Kamchatka Krai have a level of entrepreneurial activity that is higher than the average national level. Many Russian coal mining regions lack cafes and restaurants, tourist services (e.g. Sheregesh in Kuzbass) and other simple services. Favourable entrepreneurial environments and available state support can help retaining young and creative residents and thus strengthen local communities and economies.

Figure 5. Employees working for small enterprises* in coal mining regions of Russia, employees per 1,000 population, 2019

* Small enterprises in Russia are enterprises with up to 100 employees and yearly income up to 800 million roubles (9.4 million euro).
5. Summary and recommendations

This study explores international experience of diversifying coal mining regions, exploring both commercial and emerging (theoretical) avenues. Even though the official Russian discourse does not take into consideration many of the diversification opportunities presented in this paper, it is demonstrated that an ecological approach to coal and energy transitions are feasible from a techno-economic perspective.

Established and commercial options include commercial development of underground coal mine space, such as science laboratories, entertainment facilities (industrial museums, hotels and restaurants), district heating with heat pumps using renewable electric power and water from abandoned mines, restoration of open pit mines, growing energy crops at the restored lands, renewable (solar PV and wind) electric power generation, fuel pellets manufacturing, manufacturing equipment for renewable energy, promoting entrepreneurship.

Any other sustainable options could also suit diversification purposes, such as sustainable farming, tourism, processing industries (food and consumer goods manufacturing). Emerging and theoretical options comprise underground farms, underground data processing, underground energy storage facilities using pumped hydroelectric energy storage or isothermal compressed air energy storage (iCAES) technologies. These options are suitable for R&D, demonstration and pilot projects.

Box 6. Establishing a Kuzbass GSEZ

A GSEZ could comprise the following:

1. renewable power and heating generation available for its residents and local population, mainly solar, wind, geothermal and biomass solutions with storage;

2. equipment manufacturing for renewable energy industries to supply both the regional market and the neighbour regions – Kuzbass should become a Siberian renewable energy equipment manufacturing hub with ambitions to supply its products for export markets;

3. a hub for creating value from abandoned underground coal mines and abandoned coal open pits, including geothermal heating, underground farming, energy crop farming, renewable energy storage, science laboratories, entertainment facilities, such as underground industrial museums, hotels and restaurants;

4. symbiotic relations and exchange of water, steam and materials (including waste materials) between the residents of the GSEZ;

5. modern services for sustainable tourism, especially at the Sheregesh ski resort (hotels, restaurants, rental services, infrastructure);

6. tax incentives and other benefits for the residents of the GSEZ that meet the requirements of GSEZ, i.e. manufacturing products for green industries, reducing GHG emissions, participating in symbiotic relations, etc.
<table>
<thead>
<tr>
<th>Region</th>
<th>Share of the region in the total coal production in Russia, 2018, %</th>
<th>Coal mining employment*, employees, 2020</th>
<th>Share of coal mining employment in the total employment*, 2020, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kemerovo Oblast (Kuzbass)</td>
<td>58.2%</td>
<td>88 085</td>
<td>11.6%</td>
</tr>
<tr>
<td>Krasnoyarsk Krai</td>
<td>9.4%</td>
<td>4 949</td>
<td>0.5%</td>
</tr>
<tr>
<td>Republic of Khakassia</td>
<td>5.6%</td>
<td>4 661</td>
<td>3.7%</td>
</tr>
<tr>
<td>Zabaykalsky Krai</td>
<td>5.3%</td>
<td>2 420</td>
<td>0.9%</td>
</tr>
<tr>
<td>Sakha Republic</td>
<td>4.1%</td>
<td>7 524</td>
<td>2.1%</td>
</tr>
<tr>
<td>Novosibirsk Oblast</td>
<td>3.3%</td>
<td>2 769</td>
<td>0.3%</td>
</tr>
<tr>
<td>Irkutsk Oblast</td>
<td>3.0%</td>
<td>4 232</td>
<td>0.6%</td>
</tr>
<tr>
<td>Sakhalin Oblast</td>
<td>2.5%</td>
<td>2 632</td>
<td>1.5%</td>
</tr>
<tr>
<td>Komi Republic</td>
<td>2.3%</td>
<td>4 691</td>
<td>1.5%</td>
</tr>
<tr>
<td>Primorsky Krai</td>
<td>2.0%</td>
<td>3 312</td>
<td>0.6%</td>
</tr>
<tr>
<td>Khabarovsk Krai</td>
<td>1.4%</td>
<td>2 560</td>
<td>0.5%</td>
</tr>
<tr>
<td>Rostov Oblast</td>
<td>1.2%</td>
<td>6 515</td>
<td>0.6%</td>
</tr>
<tr>
<td>Amur Oblast</td>
<td>0.8%</td>
<td>1 715</td>
<td>0.6%</td>
</tr>
<tr>
<td>Buryatia Republic</td>
<td>0.6%</td>
<td>1 351</td>
<td>0.6%</td>
</tr>
<tr>
<td>Tuva Republic</td>
<td>0.2%</td>
<td>632</td>
<td>0.9%</td>
</tr>
<tr>
<td>Chukotka Autonomous Okrug</td>
<td>0.2%</td>
<td>420</td>
<td>1.5%</td>
</tr>
<tr>
<td>Magadan Oblast</td>
<td>0.1%</td>
<td>127</td>
<td>0.2%</td>
</tr>
<tr>
<td>Kamchatka Krai</td>
<td>0.005%</td>
<td>33</td>
<td>0.0%</td>
</tr>
</tbody>
</table>

Table A1. Major coal mining regions in Russia\(^{28}\)

* Average number of employees (excluding external part-time workers) for the full range of organisations for the reporting period
Find out more about Climate Strategies and our work at:
climatestrategies.org