BRICS

RUSSIA | 2020

Energy Technology Report

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ENERGY RESEARCH COOPERATION PLATFORM

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CONTENT

BRICS ENERGY TECHNOLOGY REPORT 2020

Bento Albuquerque

Minister of Mines and Energy
of the Federative Republic of Brazil

I applaud the Governmet of the Russian Federation for organizing this most timely and useful report on technology cooperation in power and fuel complex.

This report is another example of the various areas of cooperation we can develop among our countries based on our respective research and development efforts with a view to increase energy efficiency and the reduce carbon emissions.

This document showcases the enormous potential for creating new tools to encourage technology partnerships among our countries that will benefit our societies and the world as whole.

Alexander Novak

Minister of Energy of the Russian Federation

International relations are intrinsically linked with the fuel and energy complex and technology development. Exchanging experience and best practices on energy challenges and opportunities may create strong alliances and partnerships between countries and organizations. New technologies enable geographically diversified BRICS countries to create strong energy and economic ties. As never before, international scientific and technological cooperation is relevant nowadays. Global energy transition and the development of Industry 4.0 technologies stimulate countries to achieve national and global goals together.

All the five BRICS countries, being sovereign, self-sufficient and technologically advanced states, are among the ten largest world economies. The partnership of the BRICS countries opens wide opportunities for cooperation in various fields, including the creation of breakthrough technologies and equipment in the fuel and energy complex.

For successful cooperation, it is necessary to understand what technologies are the most required in individual countries and what common interests and challenges they share. In addition, it is essential to determine the resource potential of the countries, as well as competencies and experience they can exchange.

In preparation for the BRICS summit chaired by the Russian Federation in 2020, the “BRICS Energy Technology Report” was prepared by the joint effort of the international experts. More than 60 companies from the five countries assessed around 550 technologies based on various criteria and chose the most relevant and commercially interesting ones for the period of next 15 years. The study can be a guiding document for further cooperation in the development of new technologies in the Union. The main goal of the research was to show that in a rapidly changing world there are numerous areas of technological cooperation in the fuel and energy sector that we should work together on.

Raj Kumar Singh

Minister of Power of the Republic of India

India has been at the forefront of addressing global challenge of climate change and has committed to an ambitious Nationally Determined Contributions (NDCs) of reducing emission intensity by 33-35% in 2030 against the levels of year 2005.

Technological advancements play an important role in mitigating climate change. India has proactively pursued mitigation and adaptation activities and achieved a reduction in emission intensity of GDP by 21% over the period 2005-2014.

The ensuing report provides a peek into the environmental friendly technologies being deployed by the BRICS countries in the energy sector.

Zhang Jianhua

Administrator of National Energy Administration of China

The BRICS has always been an essential platform for major emerging markets and developing countries to strengthen collaboration and safeguard common interests. With joint efforts of the top leaders from the five member states, the BRICS spirit of openness, inclusiveness, and win-win cooperation has been upheld by all members to strengthen unity and address challenges together. Pragmatic cooperation have been achieved in various fields, especially in this year, facing crucial changes in the international landscape, BRICS countries have pulled and supported each other to overcome all the difficulties, made all-out efforts to overcome the impact of the COVID-19 pandemic and thus fully promoted economic recovery and set a model for building a new type of major-power relationship around the world. As President Xi Jinping illustrated at the Plenary Session of the BRICS Brasilia Summit in 2019, "Faced with profound changes rarely seen in a century, major emerging markets and developing countries like us must grasp the trend of the times. We must respond to the call of our people, and shoulder our responsibilities. We must remain true to our unwavering commitment to development and strengthen solidarity and cooperation for the well-being of our people and for the development of our world."

Energy cooperation is an indispensable part of pragmatic cooperation in the economic field of BRICS countries. Among the five countries, there are both energy producers and energy consumers. Each country has its own advantages in resource endowment and technological innovation. Strengthening energy cooperation and seeking ways to energy development and transition will not only help to jointly fight against external risks and climate change, but also have a positive impact on the global energy transition and sustainable development.

According to the consensus reached at the Forth Meeting of BRICS Energy Ministers, with the active initiative by Rotating Presidency of Russia, the BRICS countries have overcome many difficulties and completed the BRICS Energy Report and BRICS Energy Technology Report- the first two cooperative reports under the ERCP framework. I hope that there will be more fruits under the ERCP framework in the future. China is always looking forward to working with all parties to promote energy technology for BRICS and wide around the world with more extensive and mutually beneficial cooperation, so as to lay a solid foundation for the sustainable development of mankind.

Samson Gwede Mantashe

Minister of Mineral Resources and Energy
of the Republic of South Africa

South Africa pragmatically embraces the changing energy landscape and is engaged in a continuous process of identifying how best to transition as a country in a manner that ensures energy security, improves electricity affordability, re-invigorates manufacturing, global value-chain participation and broader industrialisation. Technological advancement and innovation, as well as cooperation is a central feature of our efforts, and we are a firm supporter of intensified BRICS efforts in this regard Our own efforts are aimed at initiatives and policies that enables widespread employment and does not come at the expense of broader society, so that no one is left behind as the country continues to shift to a more environmentally sustainable energy system, ecological landscape and socio-economic development.

Initiatives such as the BRICS Energy Technology Report assist to enhance data sharing and collaboration on information and knowledge management. Importantly, it provides a platform for ongoing and sustained engagement between national experts to drive dialogue that will benefit all BRICS countries collectively. Moreover, it strengthens our joints actions, as it outlines a clear and concise roadmap towards technology cooperation in a practical and measurable manner.

South Africa wish to acknowledges the effort of the BRICS 2020 Chairmanship under the Russian Federation for its efforts in forging all BRICS countries into a common programme, drawing on the strengths of the collective, but also allowing for space that will further nurture national actions towards a shared goal. We hope that this tool will be used by experts to further strengthen their joint cooperation, and assist BRICS to navigate the exciting new realities which confronts the globe.

INTRODUCTION

Creating the conditions for the development and exchange of advanced energy technologies is an essential part of BRICS energy cooperation, especially from the energy transition point of view.

The development of technological cooperation between the BRICS countries has long been on the agenda of the leaders of the five countries. For the first time, technological cooperation in the energy sector was singled out in a separate direction in the joint declaration of the leaders of the BRICS countries in 2010. It emphasized the possibility of cooperation between the union countries in technology transfer in the energy sector.

Subsequently, the leaders of the five countries have repeatedly called for the exchange of knowledge in environmentally friendly technologies, the promotion of the use of energy-efficient technologies, taking into account national policies, priorities and resources, and the expansion of access to technology. In 2017, following the results of the BRICS Summit in China, countries agreed to promote the development of open, flexible, and transparent technologies in the energy field.

Issues of joint development of energy technologies are traditionally part of the ministerial dialogue. Technological cooperation in energy-efficient and clean technologies has become one of the key topics of the Memorandum of Understanding in energy conservation and improving energy efficiency between the BRICS ministries and departments responsible for energy, which was signed in 2015 in Moscow following the first meeting of the BRICS Energy Ministers.

Technological cooperation is included in the list of priority areas of work of the BRICS Energy Research Cooperation Platform. In addition, according to the Energy Platform Terms of Reference, the development of joint energy technologies is one of the key tasks of its activities.

According to the BRICS Economic Partnership Strategy 2020 the BRICS countries support the creation of conditions for the development and transfer of energy-efficient and environmentally friendly technologies and equipment and the promotion of such development and transfer, enhancing public-private partnerships to stimulate investment in energy-efficient technologies, conducting research and development (R&D) in advanced technologies that contribute to energy efficiency in areas of mutual interest, and the study of such technologies.

The publication of the BRICS Energy Research Cooperation Platform on technological cooperation of the unification countries is the first joint attempt to determine the mutual interests of the BRICS countries in energy technologies.

Such a study will provide a solid basis for identifying workable ways of practical cooperation between the five countries.

CHAPTER 1

COUNTRY PRIORITIES FOR ENERGY TECHNOLOGY DEVELOPMENT

There are two important processes of transformation in the global fuel and energy complex today. The first is the transition to Industry 4.0 and, in general, the development of engineering and technology, and the second is the energy transition and lean manufacturing which complement each other perfectly. Also, one can observe a global change in corporate culture in the fuel and energy complex when operators think not only about shareholders profit or even operational efficiency but also pay attention to social and environmental obligations. Today sustainable performance is the key priority for many countries and regions and can be achieved by smart combination of all tools and tracking all trends we have today.

One of the most important tools for achieving companies and global goals is international scientific and technical cooperation. Development of new technologies generally takes from 5 to 10 years, and if it is developed by one company in a narrow market, most likely the project will never pay off. In this regard, the question arises of international scientific and technical cooperation, which helps to accelerate the speed of development by transferring technologies and specialists and expand the market by increasing the potential number.

[1.1]

BRAZIL

Brazil is one of the largest developing countries in the world. In 2019, Brazilian GDP, calculated by PPP, amounted to $6828 billion, in terms of per capita - $8.7 thousand. An important role in the country's economy is played by industry, whose share in GDP in 2017 amounted to 20.7%. Brazil has significant reserves of iron, manganese ores, titanium, bauxite, copper, chromite, niobium, etc. In recent years, significant reserves of hydrocarbon resources have been discovered on the Brazilian shelf. The country's electricity industry is characterized by a high share of generation at hydroelectric power stations. The key industries in the manufacturing industry are ferrous metallurgy, aluminum production, mechanical engineering, and the chemical and food industry.

In the past, the Brazilian government stepped up efforts to reduce the country's dependence on foreign energy suppliers and to encourage domestic energy sources to grow. These policies and their outcome benefited the trade balance, national security, and capital goods industry, as well as labor market, of the country. Many innovative energy policies and programs have helped the country grow socially, economically and to achieve renewable energy growth. Technology advancement has been increasing in Brazil's energy sector since the government made efforts to build on the country's energy balance, which relied heavily on hydropower. The government has invested in innovation (R&D, pilot programs, and marketing) to develop the capacity to consume technologies and create important partners for technologies cooperation.

Today manufactures in the country provide up to 90% of domestic demand for industrial goods. Demand for machinery and equipment is satisfied by more than 80%. A positive out-

look on the Brazilian electricity industry is widespread in the expert community: it has great potential for expansion, which means it can interest long-term investors. A suitable legal climate helps to ensure that investment capital attracted from abroad in Brazil enjoys the same jurisdictional regime as national investment.

The strategic vectors of the development of the Brazilian fuel and energy complex suggest a systematic decrease in hydropower dependence by 2035, increase in crude oil exports, strengthening independence from the import of fossil fuels, maintaining leading positions in biofuel production, development of own offshore fields, production of energy equipment, borrowing deep drilling technologies, increased investment in the heat industry.

In the medium term, Brazil's fuel and energy sector will retain competitive advantage in competencies such as biofuels, smart grids, exploration of subsalt deposits of hydrocarbons, hybridization of wind and hydropower systems. The country is a potential partner in the exchange of knowledge, experience and methods for evaluating the effectiveness of smart grid elements, mathematical models and software systems for modeling the operation of energy systems based on IoT, analysis and visualization of large arrays of geological and seismic information.

Moreover, in this new energy paradigm, which relies heavily on renewable energy sources, small nuclear plants can help to give flexibility to electrical systems. The idea is to be able to count on both its base generation quality and the ability to follow the load and complement variations in wind and solar sources.

Accordingly, Small Modular Reactors - SMR would attract a wide range of customers due to its relatively low capital expenditures, small size, modularity, reduced construction terms and compatibility with low voltage networks.

In the field of renewable biofuels, Brazil is committed to RenovaBio, a market-driven carbon reduction regulation. Fully operational this year, the efforts to achieve the goals set by this policy should lead to increased research and development of 2G biofuels, an area in which Brazil could gladly cooperate with interested BRICS partners. The country aims, specifically, to make full use of the sugarcane biomass, including agro-industrial wastes (e.g. bagasse and straw), to produce ethanol and co-generate bioelectricity, besides biodiesel.

Brazil is also a potential recipient of proposals for the joint development of composite towers of overhead power transmission lines of increased reliability, creating software for testing electrical equipment, approbation of computer models of high-tech parts and components for thermal power plants, digitalization of electric networks, cryogenic air separation equipment.

Country is interested in heavy oil refining technologies, in-situ conversion, designing equipment for deep sea drilling, production of electrical cardboard, energy storage and storage, processing, transportation and storage of associated gas from the shelf, construction and utilization of platforms, FPSO, LNG transportation and storage equipment, automated dispatch control systems, systems for collecting synchronized vector measurements.

Brazil has plans to create the first gas underground reservoir, increase gas and oil recovery, develop carbon capture and storage (CCS) technology, start production of small-capacity LNG at the junction of gas pipelines with different pressure ratios.

As the country with the 3rd highest rate of insolation in the world, Brazil plans to intensify its solar energy program by 2035. The country is interested in heat-resistant products based on thin-film technologies using amorphous silicon, silicon with a floating zone, copper and gallium selenide, cadmium telluride, innovative developments in the field of silicon purification for the needs of electronics, vertically integrated solar panels, the production of thin films or crystalline cells for solar cells with high temperature operating conditions.

Country as a coal producer is interested in such technologies as structural and exploratory mining and geological mapping, technologies for producing rare earth metals from coal, coal gasification technologies.

Brazilian activities in R&D related to hydrogen are focused on green hydrogen production i. e. from renewable sources of energy, integrating a national regulation aimed at increasing energy storage capacity in the national electricity sector, as well as creating a diverse green-hydrogen internal and external market.

[1.2]

RUSSIA

Russia is one of the key players at the world's energy markets. Russia is one of the top oil producers in the world, alongside Saudi Arabia and the US. It has the world's largest commercial gas reserves and is the second largest gas producer globally.

In recent years, radical transformations have taken place in the Russian electricity industry: the system of state regulation of the industry has changed, a competitive electricity market has emerged, and new companies have been created. The structure of the industry has also changed: the separation of naturally monopoly (electricity transmission, operational dispatch control) and potentially competitive (production and sale of electricity, repair and service) functions was carried out, instead of the former vertically integrated companies that performed all these functions, structures have been created that specialize in certain types of activities.

Coal industry in Russia is today one of the backbone industries. Coal is the fifth basic export product of the Russian Federation. In terms of coal exports, Russia ranks third in the world after Indonesia and Australia. The coal industry employs 148 thousand people plus 500 thousand jobs in related industries. Coal enterprises are city-forming for 31 monotowns with a total population of 1.5 million people. 50% of electricity in Siberia and the Far East is produced by coal generation. Coal is the number one cargo for railway workers, it provides 39% of the country's cargo turnover.

There are several groups of technologies that are most relevant for Russian oil and gas sector:

- Digital modeling technologies
- Technologies to enhance or maintain recovery
- Technologies that reduce transaction costs
- Industrial safety technologies
- Technologies for operation in arctic conditions

Russia needs access to oil production technologies at fields of hard-to-recover reserves, offshore drilling and oil production, restoration of production at traditional deposits, horizontal well drilling technologies, development of deposits of high viscosity oil and oil sands, conservation of the ecosystem in oil production basins.

In power sector country is mainly focused on the digitalization of the industry, which is seen as a source of commercial profit in the medium term. The intention to develop new equipment is mainly associated with those technologies which require improvement of operating characteristics.

The country's fuel and energy complex needs components for wind power plants (gearboxes, blades, tubular towers, nacelles, frequency converters, control systems, double feed induction generators), photovoltaic installations (photovoltaic modules, inverters, converters, distribution cabinets for low and medium voltage), hydropower installations (generators, control systems for hydraulic units, power converters, hydromechanical equipment, power plant equipment systems), gas turbine power plants with a capacity of more than 60 MW (burners, heat shields, flame tubes, cooled power and working blades, additive systems and 3D printers for printing with powders of nickel alloys and austenitic steels), micro-gas turbine plants with a capacity of more than 200 kW (combustion chambers, radial-axis turbines, axial-radial compressors, compact ring heat exchangers for recovering the heat of flue gases, high-speed bearings for a speed of 60 thousand revolutions per minute and above), reciprocating volumetric pumps for pumping liquids (bearings, electric motors of increased degree of protection IP and explosion protection, CNC machines), telemetry systems with a hydraulic communication channel (microcontrollers, analog-to-digital converters, non-volatile memory chips, analog signal transmission multiplexers, non-magnetic austenitic chromium-manganese steels, wear-resistant coating surfacing machines), drilling hydraulic wrenches (hydraulic motors, hydraulic pumps, slewing rings), hydraulic fracturing fleets (high-power automatic hydraulic transmissions, high-pressure plunger pumps, internal combustion engines, control systems, component base), electric top drives (hydraulic components, umbilicals, electrics, software), multifunctional inclined drilling rigs (power top drives, hydraulic components).

Russia is interested in implementing projects in the areas of construction, reconstruction and modernization of thermal, hydraulic energy facilities, supplies of oil and petroleum products, oil exploration and production, the construction of coal power plants, construction of distributed energy facilities, reconstruction of obsolete power equipment with replacement for a new one based on gas turbine drives, supplies of equipment for thermal and hydraulic power plants, development and export of main and auxiliary equipment for hydroelectric power stations (turbines with self-propelled guns, generators with excitation systems, turbine shutters, a set of electromechanical and hydromechanical equipment) and thermal power plants (steam and gas turbines, turbogenerators, boiler island equipment, including heaters, steam boilers and boilers -utilizers), development, production and export of electric motors and turbogenerators of medium voltage with a capacity of up to 120 MW, export of gas turbine power plants with a unit capacity of up to 25 MW, combined-cycle plants with a total capacity of up to 30 MW and gas pumping units with a unit capacity of up to 25 MW based on gas turbine engines.

[1.3]

INDIA

India's economy is one of the fastest growing in the world. In terms of GDP (PPP), the country ranks third in the world, behind only China and the United States. India is among the top ten countries in the world in terms of industrial production.

In India, a powerful industrial base has been created and considerable scientific and technical potential has been accumulated. The main industries of the country: automotive, chemical, pharmaceutical, cement, electronics and electrical, light and food, mining (including oil), oil refining, ferrous and non-ferrous metallurgy. India is one of the largest software manufacturers, the financial and technological services sector is actively developing.

India's fuel and energy sector is increasingly profiling on bioenergy and needs technologies for the raw materials by the use of straw and lignocellulosic biomass, fuel and raw materials by the use of cassava and non-grain biomass, highly effective hydrothermal depolymerization of biomass and water-phase chemistry, catalytic synthesis of biological aviation fuel (allows producing from 10 tons of raw materials for 1 ton of biological aviation fuel), creation of boiler houses and steam power plants on biofuels. A promising BRICS international scientific and technical cooperation for the extraction of biodiesel raw materials from breeding varieties of rapeseed, pistachios, jatropha, cottonseed cake and stalks, rice husks, coconut shells, soy husks, coffee waste, jute waste, peanut shells, wood sawdust, yellow fat equal to the production of ethanol from sweet potato and the co-generation of bagasse.

In the field of biofuels, India's fuel and energy complex needs joint research with BRICS partners on promising biomass torrefaction technologies, bacterial cultivation of methylococcus capsulatus, spirulina fuel production, bio-propane production from waste vegetable oils and animal fats, obtaining wood gas or synthesis gas by gasification of biomass, followed by conversion of the

resulting gas to substitute natural gas through methanation, development of hydrogen engines for vehicles, launch of hydrogen power plants with a total capacity of 1000 MW, 2G ethanol production, the introduction of hybrid vehicles running both on diesel and ethanol.

In the oil and gas sector, the country need investments in refineries for heavy and extra-heavy grades of oil, construction of polypropylene production plants, expanding the gas station network for LNG freight vehicles, modernization of existing refineries, laying new gas pipelines, conducting marine seismic exploration on the western shelf, the study of gas hydrates in the Bay of Bengal, the Andaman Islands and the Krishna-Godavari oil and gas basin, conducting geological engineering with deep drilling, expansion of imports of LNG as a gas engine fuel, joint investments in the construction of LNG terminals, the creation of new LNG regasification facilities in India (including the construction of an LNG reception terminal in Dahej).

In the power sector, India is interested in the modernization of power generation facilities, ultra super critical thermal power stations, renovation and modernization services of existing stations, engineering services, modernization and uprating of 200 MW power units, designing new power plants, industrial production of high voltage bushings, implementation and replication of the predictive analytics and remote monitoring system.

Non-conventional energy sources in India account for about 23.6% of the total installed generation capacity of the country, i.e. 371 GW (as on 30.06.2020). India is fifth in the world in terms of overall installed renewable energy capacity i.e. about 133.36 GW. In the field of wind energy, Indian companies have considerable competencies in the manufacture of gearboxes for wind turbines, the creation of wind parks, including marine, hybrid tower construction technologies for offshore wind energy, production of wind generators, consulting and assessment of wind resources, development of wind energy infrastructure, installation, commissioning and long-term maintenance of wind energy projects, electronic control of wind farms. India produces about 50 models of ergonomic wind turbines, which will continue to be in demand in Brazil and China.

Renewable energy in the country has shown a steady growth during past few years. As of June 2020, India's renewable power installed portfolio stands at 133.36 GW (87.67 GW from solar & wind and 45.69 GW from hydro power), out of the total 371 GW installed capacity in the country and major share is from solar and wind power (87.67 GW, solar- 35.12, wind - 37.82).

The Government of India has set up a target of 175 GW of renewable energy by 2022. These renewable generations are concentrated in few States and the percentage contribution from RE is going to increase substantially during the coming years. With the increasing penetration of renewables, there are certain challenges in the form of seasonal and daily variability and intermittency. These need to be resolved.

Balancing power may be arranged through development of more Pumped storage Projects, making the thermal power stations equipped with proper controls (flexible operation of thermal power Plant) capable of fast ramping. Further, India has achieved milestone in RE sector as in recently conducted auction for an innovative 400 MW Round–the-Clock (RTC) renewable energy supply including energy storage the first year tariff has been obtained Rs.2.90 per kWh.

As India continues to grow rapidly, there are significant opportunities to further increase the ambition of the country's energy efficiency policies and programmes. Energy efficiency can also play a key role not only in fostering economic efficiency and competitiveness, but also in achieving India's objectives to limit greenhouse gas (GHG) emissions growth under the country's Nationally Determined Contribution (NDC).

Research & Development is a priority focus area in the power sector. With the total installed capacity of over 371 GW (as on 30.06.2020) and with a vision for providing affordable quality power to each strata of the society, it is not only necessary to ensure, that state-of-the-art technology is utilized but also that appropriate technology is developed keeping in view the social operating conditions in the country and the need to observe economy in a capital intensive sector.

India has prioritized certain areas of research in the field of energy efficiency and energy conservation which can help in achieving India's objectives to limit greenhouse gas (GHG) emissions growth. Areas identified are as under:

- Exploring possibility and knowledge sharing in carbon capture and utilization techniques.
- Setting up of testing facilities for popular appliances like (AC, Transformers, and LED Lamps) to ensure quality and prevent sale of compromised quality products in the country.
- Improving operational efficiency through new technologies in the areas of refinery; upstream installation (exploration) amongst others
- Enhancing efficiency by minimising distribution losses.

With the push towards the use of EV's in India, upgradation of the grid system, power quality issues, renewable energy based (mainly solar PV) power supply at decentralized areas and battery energy storage systems needs to be developed.

The introduction of energy efficient equipment and technologies, LED lighting projects, compulsory energy audits to reduce energy consumption, smart grid technologies have been implemented in India to a great extent. India would look forward to share these experiences and draw upon the experiences of other BRICS nations.

Further, the following areas/technologies may be considered for energy cooperation among BRICS nations:

- The cooperation with regard to integration of Variable Renewable Energy (VRE) in India. Best practices of other energy technologies and their end use may be shared.
- Electric charging Infrastructure for electric vehicles (e-mobility).
- Fuel cell technology- manufacturing of fuel cell, sourcing raw material for fuel cell and adoption of fuel cell in different applications including the application in transportation and power grid application
- Storage and transportation of hydrogen – technologies and safety aspects. Viability studies and long term application studies of hydrogen economy.
- De-carbonization through initiatives which includes e-mobility, energy storage, flexibilisation of coal based thermal plants, use of gas based plant having high ramping capability, utilization of industrial waste heat, disposal of biomedical wastes and its conversion to energy, waste to energy conversion etc.
- Technologies for smart grid, offshore wind, R&D for clean and innovative technologies like fuel cells, carbon capture, utilization and storage (CCUS) technology.
- Storage batteries - manufacturing, applications, disposable, reuse of disposed material and its recycling.
- Issue of cybersecurity need to be given priority by sharing best practices and cyber incidents and developing institutional mechanism. Further, cooperation is sought in development of an indigenous cyber security test bed.

In addition to the above:

- India may provide cooperation in providing engineering and consulting services to BRICS countries for design and development of thermal and hydro power projects, solar projects, wind projects etc. Further, India's maturity on small hydro technology can be shared with BRICS countries.
- International solar alliance (ISA) is a first treaty-based intergovernmental organization headquartered in India. It will provide a dedicated platform for cooperation among solar resource rich countries and the wider global community. The ISA has set a target of 1000 GW of solar energy by 2030, which would require mobilization of $1000 billion. BRICS countries may join ISA which will in turn strengthen the cooperation in solar energy field.

[1.4]

CHINA

The Chinese economy is showing high growth rates, largely determining the situation in the global economy. At the end of 2019 China's GDP continued to grow at 6.1%.

The leading role in the Chinese economy is played by industry (share in GDP is 39%). The country's specialization in the world system of division of labor is determined by labor-intensive industries due to the comparative cheapness of labor in the domestic market. China is one of the world's largest manufacturers of engineering products, chemical, light and textile industries. The automotive industry is actively developing. The most industrially developed provinces are in the east and southeast of China. World-wide industrial clusters have formed in the agglomerations of Shanghai and Guangzhou.

During the global economic crisis, the role of China as a major banking and financial center increased. The volume of loans provided by state-owned Chinese banks to foreign commercial organizations has increased. There is an increase in the number of initial public offerings on the Hong Kong Stock Exchange, which, together with the Shanghai Stock Exchange, is one of the largest in the world.

The most promising areas for the influence of BRICS companies on the PRC electric power industry remain: the introduction of advanced energy-efficient equipment and technologies, LED lighting projects with increased energy saving, ways to reduce energy consumption, smart grid technologies, utilization and recycling of waste raw materials, power system optimization, increasing electricity supplies to China, gas power generation, supplies of impellers, blades, hydraulic turbine elements, gas turbine engines for hydroelectric power stations.

In the oil and gas sector, the fuel and energy complex of the PRC may need to localize advanced logging technologies during drilling (LWD), processing straight-run gasoline into high-tech poly-

mer and aromatic products, enhanced oil recovery in the fields, engineering in the field of subsea mining complexes, introduction of new equipment for petrochemical enterprises and the creation of oil refineries, joint projects for oil production, refining, storage and transportation of oil. China is open to cooperation on underwater and under-ice exploration of offshore hydrocarbon deposits using underwater autonomous homing devices.

In oil and gas sector country needs key technologies for exploration and development of unconventional and difficult to exploit oil and gas, such as continental tight gas, high rank coalbed methane, marine shale gas, tight oil and shale oil, promote the intelligent development of oil and gas exploitation. Country also needs R&D and application of heavy and poor crude oil processing technology, tackling the problem of clean oil production technology to meet the needs of oil upgrading.

In power complex country needs ultra-supercritical coal fired power generation, integrated coal gasification combined cycle, carbon capture and storage, integrated removal of multi pollutants and other technologies, improve the flexible operation and flexible regulation capacity of coal-fired units, and promote the generation efficiency and overall energy efficiency level of coal-fired plants, key technologies of renewable energy systems, such as solar energy, wind energy and hydropower, as well as the experimental demonstration of the utilization of marine energy and geothermal energy, promote the large-scale, low-cost and efficient development and utilization of renewable energy, technologies on high proportion renewable energy distributed grid-connection, distributed energy supply, intelligent distribution network and micro grid, play a key role of advanced power electronica devices on renewable energy power generation, large capacity flexible DC transmission technology, DC grid technology, large-scale interaction between supply and demand, multi energy complementary comprehensive utilization technology to ensure large-scale renewable energy export, and improve the technical level of key equipment and systems of power grid.

Influenced by the energy resource condition, coal has always played a basic role on China's energy consumption, which is why the country potentially needs to exchange modern technologies to reduce ash content, chemical cleaning of coal, improving the efficiency of coal mining, resource saving and smokeless coal mining, development of an integrated underground communications system, fire safety and mining safety monitoring, pumping water under high pressure, seismic analysis and mine safety. It will be potentially important for the China to achieve by 2035 the creation of a technology for the hydrogenation of coal into diesel and gasoline (achievable in possible cooperation with South Africa). The country is open to proposals for the supply of high-quality coal products: coking coal, anthracite, coal for PCI, steam coal. In coal sector country also needs key technologies on low rank coal transformation and quality improvement, coal based multi generation, coal gasification, coal to clean fuel and chemicals, promote the green and efficient development and utilization of coal.

[1.5]

SOUTH AFRICA

South Africa is a large developing country with the most powerful and diversified economy in Africa. Industry in South Africa forms 29.7% of GDP. The extractive industries are the most developed. South Africa plays an important role in the world in the extraction of platinum group metals, gold, diamonds, manganese, uranium ores and vanadium.

The country is a major coal producer and the undisputed leader in the production of synthetic liquid fuels from coal. Ferrous and non-ferrous metallurgy is well developed. The production of mining equipment, transport and agricultural engineering are of great importance. Locomotive and carriage building provides the railway network of the entire region. The automotive industry is well developed. The South African Republic ranks 6th in the world in coal mining, but among the strategic tasks for the development of the fuel and energy complex until 2035, it determines the attraction of foreign investment in green energy technologies, solar and wind energy.

South Africa continues to pursue a diversified energy mix that reduces reliance on a single or a few primary energy sources. The extent of decommissioning of the existing coal fleet due to end of design life, could provide space for a completely different energy mix relative to the current mix.

The South African power system consists of the generation options, which are 38 GW installed capacity from coal, 1.8 GW from nuclear, 2.7 GW from pumped storage, 1.7 GW from hydro, 3.8 GW from diesel and 3.7 GW from renewable energy. The country also supply a number of international customers, including electricity utilities in the Southern African Development Community (SADC) region.

Coal will continue to play a significant role in electricity generation in South Africa in the foreseeable future as it is the largest base of the installed generation capacity and it makes up the largest share of energy generated. Due to the design life of the existing coal fleet and the abundance of coal resources, new investments will need to be made in more efficient coal technologies to comply with climate and environmental requirements. Given the significant investments required for CCS technology, South Africa could benefit from establishing strategic partnerships with international organisations and countries that have made advancements in the development of CCS, CCUS and other HELE technologies.

Koeberg Power Station reaches end of design life in 2024. In order to avoid the demise of the nuclear power in the energy mix, South Africa has made a decision regarding its design life extension and the expansion of the nuclear power programme into the future.

In line with power system requirements, additional capacity from any technology deployed should be done at a scale and pace that flexibly responds to the economy and associated electricity demand. In this regard small nuclear units will be a much more manageable investment when compared to a fleet approach.

Natural gas: There is inadequate supply of natural gas due to limited importation from the region and limited transportation infrastructure, lack of regasification of imported liquefied natural gas (LNG).

South Africa is exploring investment opportunities to introducing a variety of natural gas sources which could be economically available within a 25-year planning horizon to 2040. Gas to power will form an important anchor for these investment opportunities. Gas to power technologies in the form of combined cycle gas turbine (CCGT) will provide the flexibility required to complement renewable energy. While in the short term the opportunity is to pursue gas import options, local and regional gas resources will allow for scaling up within manageable risk levels. Exploration to assess the magnitude of local recoverable shale and coastal gas are being pursued and must be accelerated.

There is enormous potential and opportunity in this respect and the Total gas resource discovery in the Outeniqua Basin of South Africa, piped natural gas from Mozambique, indigenous gas like coal-bed methane and ultimately shale gas, could form a central part of the country's strategy for regional economic integration within SADC.

Co-operation with neighbouring countries is being pursued and partnerships are being developed for joint exploitation and beneficiation of natural gas within the SADC region.

Renewable Energy: Solar PV, wind and CSP with storage present an opportunity to diversify the electricity mix, to produce distributed generation and to provide off-grid electricity. Renewable technologies also present huge potential for the creation of new industries, job creation and localisation across the value chain.

Distributed generation through biomass, biogas and municipal waste are areas holding great potential for improving municipal revenues. All municipalities have sites for processing waste; they also have sewer outfall sites. Technologies are available for these resources to be added to the generation mix at sub-utility scale. Most small-scale generation technologies have low capacity factors, meaning that typically the power is not generated throughout the day and night. For a balanced and safe interconnected power system to be operated sustainably, the intermittent power generators have to be integrated and controlled through smart technologies.

The biomass and a government-backed biofuels programmes could improve the economics of the initiatives and create job opportunities in rural and urban centres.

Hydro: South Africa's rivers carry potential for run-off river hydro projects. These have been proven feasible with a number of facilities in operation by farming communities. With regard to import hydro, South Africa has entered into a Treaty for the development of the Grand Inga Project in the Democratic Republic of Congo (DRC), with some of the power intended for transmission to South Africa across DRC, Zambia, Zimbabwe and Botswana.

In addition to this generation option providing clean energy, the regional development drivers are compelling, especially given that currently there is very little energy trade between these countries, due to the lack of infrastructure. The potential for intra-SADC trade is huge as it could open up economic trade.

Energy storage: The recent Integrated Resource Plan continues to make provision for significant rollout of renewable energy and storage which requires South Africa's high-grade resources in at least six commodities, vanadium, platinum, nickel, manganese, rare earths, copper and cobalt and these are critical for global energy storage sector

South Africa participates and trades electricity through the Southern African Power Pool (SAPP). Transmission infrastructure is required to further unlock regional energy trading and enable development of generation projects. Increased collaborations and alignment at regional level is key to unlocking already identified generation and transmission infrastructure projects.

South Africa has a high dependence on importation of liquid fuels due to the fact that the current production capacity does not meet national and export demand. The country's refinery infrastructure needs to be upgraded to produce petroleum products that are much cleaner than the current specification.

CHAPTER 2

MUTUAL INTERESTS

At the earliest stage of the of the BRICS partnership, the goal of increasing energy efficiency by development of new environmentally friendly technologies and renewable energy sources was set. In addition, it was intended to offset the consumption of fossil fuels by increasing international scientific and technical cooperation in the field of energy research and development. The importance of an international cooperation mechanism for analyzing the long-term consequences of biomass energy development, promoting the so-called the “fourth energy transition”, elaboration of relevant directives in national jurisdictions.

Energy interaction issues have invariably been included in the working agenda of each BRICS summit. The emphasis in them was gradually shifted to such areas of international scientific and technical cooperation in the fuel and energy complex as specialized training for power engineers, R&D, consulting services, transfer of advanced energy technologies.

Meeting the growing needs of the national economies of the BRICS countries and approaching environmental and climatic problems was directly dependent on the development and exchange of energy-saving technologies. In the field of international scientific and ttechnological cooperation, the parties agreed to expand the supply of environmentally friendly energy and renewable energy sources, provide access to know-how, pioneering technologies, and key competencies in the fuel and energy complex.

Within the BRICS, the imperative was formulated to continue international scientific and technological cooperation aimed at introducing renewable energy and green energy technologies, without deviating from considerations of national policy, priorities, and the resource base available to each country.

Within the BRICS agreements are emerging on the exchange of experience in terms of planning, generation and consumption of energy, energy cooperation, mutual support for diversifying energy supplies. The international scientific and technical cooperation focuses on the joint creation and exchange of clean technologies and equipment for the generation, storage and consumption of energy, the widespread use of renewable energy sources and the optimization of natural gas consumption. The BRICS countries commit themselves to promoting the efficient and environmentally friendly use of fossil fuels, to carry out joint exploration and development of new technologies for the extraction of hard-to-recover resources, to intensify the international scientific and technological cooperation in the field of clean coal technologies, natural gas, and unconventional gases.

Since 2016, the expansion of the use of low-carbon fuels has become a new vector of the BRICS energy policy, and since 2017, BRICS countries has announced its readiness to work to create open, flexible and transparent markets for energy products and technologies. Joint efforts are aimed at efficient consumption of fossil fuels, widespread use of gas, and hydropower. The BRICS Energy Research Cooperation Platform brings together experts from energy companies and representatives of research institutes, who carry out analytical and research activities pursuing the interest of BRICS on energy development and developing proposals for coordinating energy policy measures. The platform assumes the formation of a consolidated and independent source of references for external institutions (banks, research institutes, international organizations) to enable them to view the key trends and uncertainties in the energy sector, growing markets, new energy technologies, promising R&D areas in accordance with the BRICS priorities.

In 2020 BRICS Energy Research Cooperation Platform launched survey to identify technological needs and mutual interests of five countries.

More than 60 companies from fuel and energy sector of BRICS countries participated in the survey.

The companies were offered to fill in three questionnaires (separately for oil and gas, electric power, and coal industries).

The questionnaire for the oil and gas industry was divided into seven sections:

- Exploration
- Drilling and completion
- Development and production
- Offshore projects
- Preparation, transport and storage
- Oil refining
- Petrochemicals

The questionnaire for the electric power industry was divided into three sections:

- Generation
- Grids
- Consumer

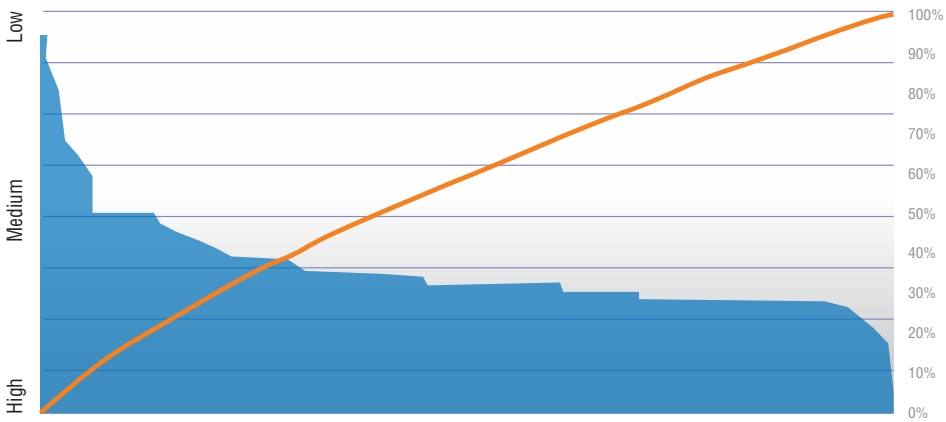
The questionnaire for the coal industry was divided into three sections:

- Exploration
- Facility construction and production
- Processing, refining and transportation

The final list included 547 technologies.

Of the technologies presented in the survey, most were rated as especially important (from commercial point of view in the short and medium term).

Figure 1 Distribution of survey results by importance (pareto chart)



According to the survey results, the most relevant (from the commercial point of view) were technologies related to digitalization (which will be introduced in medium- and long-term but are needed today) and clean energy technologies.

The analysis identified the technologies which according to the respondents are the most promising:

Systems for autonomous processing and interpretation of seismic data in stream mode have been the topic for discussions in the oil and gas industry for a relatively long time until now, when the development of data analysis technologies opened the way for the systems which meet industry requirements. Thanks to stream processing and data interpretation, geologists will be able to identify potential hydrocarbon traps or the location of coal seams in no time. The technology will reduce costs in case of early detection of potential reservoirs and will help mitigate environmental risks, as the length of seismic profiles will be reduced.

Grid monitoring technologies will allow grid operating companies to promptly identify and track affected areas remotely without involving local stuff, and short circuits protection will reduce damage to companies and consumers. The introduction of these technologies will require almost complete digitalization of the grids system.

In-situ conversion is a branch of technologies which allow to convert mineral resources located in the reservoirs into high-margin products (per fractions). Currently, there are

successful experiments on converting coal into gases of various fractions, so that the technology can be adapted to the needs of the oil and gas industry and abandon some of the processes at refineries / gas processing plants.

Geophysical equipment for interwell space monitoring - at the moment, geophysical equipment can determine characteristics of formations only in an immediate vicinity of a wellbore. Correlation of geological sections and development of comprehensive models of the fields is carried out mainly manually, often the interpretation is not reliable. Western companies have already developed technologies to increase the range of geophysical instruments to obtain the sections between adjacent wells. This technology will help better understand the geology of the fields and better predict future production.

Digital twins are applicable in any branch of the fuel and energy sector. These are a digital copy of physical objects which is used for stimulation of certain processes. Now, there is several projects which experts classify as 'Digital Shadows', because they do not take into account all the parameters that describe actual processes. In the future, 'Digital Twins' will help to control the production directly, thereby reducing transaction costs.

Smart Grid is an advanced electricity grid that uses information and communication platforms and technologies to collect data about energy production and energy consumption, which can automatically increase efficiency, reliability, economic benefits, as well as the sustainability of electricity generation and distribution.

Ice-resistant SSDR: it is not possible to recover oil on the Arctic shelf without a modern 11th (ice) class Semi-Submersible Drilling Rig (SSDR). Among the main differences between an ice resistant SSDR and a conventional one, the following can be outlined:

- use of the SSDR supporting braces which cross the waterline and increase the ice impact on the platform;
- an ice (reinforced) belt and conical ice-breaking elements on the parts which are ice affected;
- protection for a riser or a special central column inside which the riser is located.

Geodata systems – systems designed to collect, store, analyse and graphically visualise spatial data and related information. They have been used for a relatively long time, but both methods of spatial analysis and the approach to collecting and processing data for them are constantly developing. In general, they help enterprises make better decisions in a limited availability of time.

Telemetry technology (remote transmission of large amounts of data) is the other technology that requires significant improvements. Taken the length of wells increasing, the rapid transfer of a large amount of data becomes an urgent need for companies. On average, an increase from 20 to 30,000 bits per second is required.

Intrawell multiphase flow pumps – the use of multiphase flow pumps eliminates the separation of multiphase systems and helps to transport the multiphase mixture to central processing facility. These technologies are widely used and most promising in the development of offshore oil fields.

Ship evacuation systems – in arctic conditions.

Virtual reality technologies for personnel training have already been used by several companies across BRIKS of the fuel and energy sector but since it takes a long time to develop training programs for each facility item, technologies are not yet commercially profitable.

The technologies for enhanced oil recovery (EOR) are usually tertiary methods to increase oil recovery, the effectiveness of which should increase in the future.

Analysis of equipment malfunctions – in streaming mode it can increase the interrepair period and, accordingly, the operational and capital investments of enterprises.

Coal chemistry technologies – methods have not found their application in the past but are now relevant for the industry due to low prices for raw materials. Production of high-margin products can improve the country's coal industry.

Catalysts, additives – new petrochemical products are a driver for the development of new catalyst production, the octane number also increases every year, that requires the new types of additives.

Smart electricity meters are the basis of digitalization of power grids, accurate accounting of data from them will maximize generation of electricity in the country.

Integrated data analysis system is a relatively new but already proven field of science. Full automation of the analysis and exclusion of a human from it will significantly reduce the costs of companies.

[2.1]

OIL AND GAS SECTOR TECHNOLOGICAL MUTUAL INTERESTS

BRICS states partners today need advanced technologies to maximize oil flows through high-yield wells and optimize the layout of the subsea production network, tertiary oil production methods.

In the oil and gas sector Russia can provide technologies of construction of multilateral wells at development sites with a complex geological structure, drilling multilateral wells of large lengths of total penetration of trunks in the reservoir, optimization of the waterflooding system, the creation of equipment for geophysical research of wells and MLWD systems.

India can act for BRICS as a supplier of schemes and technologies for super-megapower solar parks of the Kunta type with a generation of 100 MW, large-scale facilities using solar roofs network connection, solar energy projects for several power supplies, combining solar photovoltaic energy with a storage battery and solar thermal energy with thermal energy storage (including biomass burning as additional fuel) and coal-based power for round-the-clock electricity supply, the construction of photovoltaic solar power plants with a capacity of up to 11.5 MW. Russia may be offered a scheme for developing technologies for using the water surface on canals, lakes, reservoirs, agricultural ponds, and the open sea for large solar power plants.

China and Russia have achieved major results in oil and gas cooperation. The China-Russia crude oil pipeline is China's first mainland crude oil import channel, and the eastern natural gas pipeline is under operation from December 2019. The Yamal LNG project has been implemented, and the natural gas produced has been sold to China. China is willing to strengthen cooperation with Russia in the integration of upstream, midstream and downstream oil and gas fields.

[2.2]

ELECTRIC POWER SECTOR TECHNOLOGICAL MUTUAL INTERESTS

Table 1. **Top10 BRICS mutual technology interests in electric power industry** (by value chain)

	Generation	Grids	Customer
1	Cyber Physical Personnel Tracking Systems	Technology to produce electrical cardboard for transformers	Ability to set custom operation algorithms - turn on the light at full brightness when waking up, set soft light while reading, etc.
2	Flywheel-based storage systems	Gas-filled lines. In a gas-filled cable between the conductor and the insulation there are cavities filled with nitrogen under a pressure of up to 3 MPa.	Dimming the room when you turn on the TV or projector.
3	The provision of the most important system services for ensuring the reliability of renewable energy power plants: voltage regulation with reactive power, frequency regulation, frequency restoration at different stages of a system failure, maintaining a hot reserve, etc.	High Voltage Switchgear Motor Drive	Simulate the presence of the owners in the house with the help of light to ensure safety.

4	The use of biomass in order to generate on its basis electric and thermal energy at TPPs and TPPs of various capacities in the steam-power cycle: preliminary gasification of biomass with its subsequent combustion in the furnace the device of the boiler unit with obtaining a pair of relevant parameters.	Controlled AC electric networks based on FACTS devices (flexible (controlled) AC power lines): creation of STK (static thyristor compensator)	Light notification of various events.
5	Storage systems based on lithium-ion batteries	High voltage outdoor switchgear (switchgear) with optical current sensors	Furniture and interior items management: cornices, curtains, automatic doors, cabinets, lampshades, armchairs, sleeping beds, etc.
6	Improving the efficiency of solar panels by creating multi-layer panels	Mobile Team and Resource Management Systems - Digital Operations Team Management (WFM)	“Light scenarios” - design possibilities of light accentuation and shading of interior items.
7	Storage Battery Based Storage Systems	Digital current transformers (on Rogowski coil) 110 kV	Automation of water supply systems - for example, closing the water supply valves when there is no person in the house.
8	Integration of Solar Power Stations with Energy Storage	Cobots to perform work on the maintenance of electrical networks in extreme conditions for humans, to enhance	Automatic adjustment of the brightness of the light depending on the illumination, time of day and the number of people in the room.
9	Increasing the efficiency of solar panels due to the application of nano-sized aluminum spikes on flexible surfaces of flexible panels	Integrated Volt VAR Control	Automatic regulation of the operation of humidifiers, dehumidifiers and air ionizers depending on the humidity indicator.

10	Increasing the efficiency of steam turbines by raising the parameters of sharp steam	Integration and integration of various IT systems at various hierarchical levels (SCADA, GIS, OJUR, OMS, DMS, AMI, etc.)	Furniture and interior items management: cornices, curtains, automatic doors, cabinets, lampshades, armchairs, sleeping beds, etc.

In the field of bioenergy, Brazil can supply other countries with bioethanol energy technologies, creation of hybrid cars such as FFV, combining gasoline with ethanol, production of engines that optionally operate on ethanol, cogeneration of wind and biomass, replacing biomass fuel. In Brazil, industrial designs for hydrogen-powered hybrid trucks with a lifting capacity of up to 2 tons are in demand. Besides, Brazil has already started studies for a roadmap envisaging a green-hydrogen internal and external market. Chinese technologies for commissioning hydrogen power plants, the construction of third-generation hydrogen gas stations, the production of PEMFC-class hydrogen fuel cells for automotive applications, and hydrogen injection methods using an electric drive. Obtaining industrial images and their implementation will increase the maneuverability of hydrogen transport, the development of which is Brazil's strategic objective, and increase the rate of gas extraction from hydrogen gas in fuel cells.

China can supply energy storage systems at electric power facilities, innovative technological models in MSW management systems (sorting and processing "waste into energy"), ultra-high voltage transmission technologies, transmission of ultra-high voltage power lines of wind farms with a capacity of up to 50 GW, digitalization of electric power facilities and the creation of digital power grids. The Chinese CCE program involves the introduction of new technological solutions potentially demanded by the BRICS countries to optimize the oil and gas production system, thermal regeneration of heavy oil, ergonomic water injection system, re-injection of carbon dioxide, tight collection and transportation of oil and gas, supporting integrated technology for energy conservation and ventilation of natural gas, conversion of ethylene cracking furnaces, heat recovery in plants using natural gas as raw materials, restoration of adsorption at a differential pressure, replacing traditional coal technologies using water-coal slurry or advanced pulverized coal gasification technology.

South Africa can supply (or partner in joint development and project management in the field) solar energy technologies. With the involvement of the competencies of specialists from South Africa in the BRICS countries, projects can be implemented to introduce high-tech heterostructure photovoltaic cells, the integration of photovoltaic elements in architectural solutions and transport, construction of solar power stations of increased power was carried out.

The development of wind energy in a well-ventilated oceanic zone of South Africa is possible with the use of Chinese industrial designs of two-bladed turbines, innovative developments in the field of storage of batteries, PEMFC class proton exchange membrane fuel cells and SOFC solid oxide fuel cells up to 10 kW. India may become a supplier of modern gearboxes for wind turbines, technologies for creating industrial marine wind parks, hybrid towers for offshore wind energy.

[2.3]

COAL SECTOR TECHNOLOGICAL MUTUAL INTERESTS

Table 2. **Top10 BRICS countries mutual technology interests in coal sector** (by value chain)

	Exploration	Facility construction and production	Processing and Transportation
1	Structural and exploratory mining and geological mapping	High-tech solutions in the field of reinforcing and pipe elements	The use of waste fuel and energy complex in the production of porous aggregate based on liquid glass composition
2	Geochemical research methods	Gamification Technologies	Automated Vehicle Applications
3	New methods for real-time rock analysis in borehole conditions	Technologies allowing to make a remediation project even before the development / development stage	Technologies for producing rare earth metals from coal
4	Development of geophysical methods for researching wells with a sounding depth of several meters	Designs of mobile roof holders for mining pillars of coal with a chamber-pillar system for the development of seams	“Internet of things”, forming the complexes “Intelligent transport and control centers”
5	Development of geophysical equipment for interwell space exploration	Residential Protection Technologies	Ash and Slag Recycling

6	Development of new principles of telemetry for the transfer of large amounts of data in real time from downhole equipment	Adhesion-chemical agglomeration technology for coal sludges and pits	Ash utilization technologies to increase the complexity of the use of solid fuels
7	Unmanned sampling devices for geological exploration stage	Underwater coal mining method	Coal sand production technology
8	Augmented reality systems for drilling control and formation monitoring	Technologies for the development of coal seams	Fire retardants to prevent spontaneous combustion of coal depots
9	Rock Properties Modeling Technologies - Digital Core	“Internet of things”, covering coal mining and forming complexes “Digital mine / quarry”, “Intellectual section”	Technologies for processing spent coal lining of aluminum electrolysis cells
10	Basin modeling based on big data analyses and machine learning: accurate identification of facies zones, identification of the main stages of geotectonic development; tectonic zoning;	Technologies of kinetic formation of internal dumps (explosion delivery)	Protection against corrosion and contamination of the heating surfaces of the waste heat boiler included in the low-power energy complex based on the binary ORC cycle

CONCLUSION

BRICS countries need comprehensive measures to promote foreign direct investment in the fuel and energy complex, create a transparent system for partners' access to licenses for exploration and development of oil and gas fields, liberalize technological transfer to the fuel and energy complex, and customs and tax and tariff incentives for partner countries. The model of payments for the supply of gas and petrochemical equipment, reagents, and chemicals to the BRICS countries because of the fulfillment of long-term agreements for the export of crude oil and received oil products requires legal elaboration. The BRICS countries will potentially benefit from developing mutually beneficial strategies in the oil and gas sector that facilitate trade in energy machines, materials, equipment, and components.

Taking into account the dependence of the national fuel and energy complex on traditional types of energy, it is appropriate to include: general projects on oil production and oil refining, refining, storage and transportation of oil, organizing trading in oil, natural gas, hydrogenated coal and other clean energy resources, general commercially viable projects for the establishment, financing and equipping of international power generation enterprises using materials, equipment and technology created in the BRICS member countries, general projects for electricity generation, import and export of electrical energy, encouraging cooperation of scientific, research organizations, technology centers and institutions of the participating countries, encouraging free circulation within the BRICS between educational, scientific and technological centers, industrial enterprises and design bureaus of information related to environmentally friendly technologies, "green energy", efficient use of energy resources, renewable energy sources.

In the sectoral respect, the vectors of BRICS energy cooperation will have to meet the challenge of solving the problems dictated by the needs of clean coal energy generation technologies, hydrogen energy, competition of motor fuels, electric transport infrastructure, cybersecurity of the fuel and energy complex, digitalization of energy and smart grids, energy internet, continued gasification, operability of electric power systems, integrated energy systems, energy storage systems, forecasting energy balances and big data in the energy sector, oil exploration and production, competition of traditional types of energy with renewable energy sources, wind energy, solar energy and biomass energy, distributed power systems.

The COVID-19 pandemic has adjusted energy transformation plans for the near future. Increasing attention will be drawn to the protection of power engineers and energy complexes from the impact of extreme factors of epidemiological origin, increasing the sustainability of energy supply to medical institutions, the stability of power systems to jumps in the incidence of maintenance personnel, preventing power outages. In a number of cases, the crisis caused by the coronavirus will predictably have a stimulating effect on the plans of the BRICS countries for digitalization, the emphasis on the energy transition as a macroeconomic tool for the early withdrawal of national economies from the crisis.

In the post-crisis period, the BRICS countries need to strengthen the circulation of information on energy policy, rules and standards that consider the interests of all participants in the energy market. The demand for physical security of the energy infrastructure, multilateral coordination of efforts in the fight against accidents and system failures will increase. It is highly desirable to create an integrated technological operator on the basis of BRICS, which would keep a unified accounting of technologies, develop a balanced approach to the development and implementation of new standards, licensed management decisions, form a base of patterns and licenses for the fuel and energy complex of the BRICS countries, taking into account the principles of the global division of labor, national energy priorities, donor capacity and compensatory needs of each participating country.

All above is adequate measures to maintain the energy development of the BRICS by 2035 – an expanding global and transcontinental actor of the multipolar world system.

NOTE

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