BRICS ENERGY TECHNOLOGY REPORT 2021

BRICS
INDIA 2021

BRICS
ENERGY RESEARCH COOPERATION PLATFORM

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Energy Technology Report
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The report has been prepared under the leadership of Amrita Goldar, Senior Fellow (ICRIER). The project activities were carried out by Diya Dasgupta (Research Associate), Tarun (Research Assistant), Kumar Gaurav (Research Assistant) and Sajal Jain (Research Associate).

Bento Albuquerque

Minister of Mines and Energy of the Federative Republic of Brazil

I applaud the Indian presidency of the BRICS for updating and revising the BRICS Energy Technology Report.

This is a timely and useful instrument for fostering cooperation among our countries, bringing wider benefits for our societies and the world as whole.

I am confident this report will contribute to deepening cooperation on all dimensions of the BRICS platform.

N. Shulginov

Minister of Energy of the Russian Federation

The energy security of our states today depends, among other things, on access to advanced energy technologies. The technological reality in the energy sector is undergoing significant changes. The speed and depth of these changes force us to change both at the level of the development of national energy industries and the level of international cooperation in the energy sector. In this regard, a crucial component of the strategic priorities of BRICS countries is the development of technical cooperation.

We are now at the first stage of the implementation of the "Road Map for BRICS Energy Cooperation up to 2025", where we use research to identify the most promising new technologies of the interest of BRICS countries and develop mechanisms for practical cooperation. We attach particular importance to the possibility to produce technologies in the territory of our countries with the participation of our closest economic partners.

We welcome the launch of the "BRICS Energy Technology Report" prepared by the experts of the BRICS Energy Research Cooperation Platform. I am sure that the results of this research will serve as a solid basis for the formation of joint projects to develop energy technologies both in "traditional" energy sectors and in breakthrough areas, taking into account the needs and interests of our countries.

Raj Kumar Singh

Minister of Power, Government of India

India has demonstrated leadership in promoting energy efficiency and addressing the global issue of climate change. Government of India has undertaken a two-pronged approach to cater to the energy demand of its citizens while ensuring minimum rise in CO2 emissions, so that the global emissions do not lead to irreversible damage to the ecosystem. On the generation side, the Government is promoting greater use of renewables in the energy mix mainly through solar and wind and at the same time shifting towards supercritical technologies for coal-based power plants.

Key focus of the Indian government is on implementing the largest Renewable Energy (RE) expansion programme in the world, envisaging a 5-fold increase in the overall RE capacity from 32 GW in 2014 to 175 GW by 2022, and further to 450 GW in the country by 2030.

Owing to various energy efficiency measures undertaken so far, energy intensity of the country has declined from 0.273 mega joule per INR in 2012-13 to 0.223 mega joule per INR in 2019-20 indicating an efficiency increase of 18%. This will have direct impacts on reduction of emissions intensity which is aimed at 33-35% reduction by 2030 under the Paris Agreement . Energy efficiency is expected to contribute to achieve up to 55- 56% of this target.

The BRICS Energy Technology Report 2021, prepared under the Indian Chairship is a result of joint efforts by sector experts from all member countries. The theme this year was energy demand, which was selected in order to maintain continuity of the ongoing efforts to identify key technologies and build a comprehensive overview of technologies that cater to both the energy demand and the supply side. This report would promote latest technologies in the industrial, buildings and transport sectors that will play a pivotal role in ensuring decarbonization of economy. I am sure that this will open more avenues for cooperation among member countries in the short and long term.

ZHANG Jianhua

Administrator of the National Energy Administration of China

This year marks the 15th anniversary of the establishment of BRICS. In the 15 years, we have witnessed the continued improvement of our cooperation mechanism, expansion of collaboration areas, and enhanced global influence, which shows unique charm in maintaining and practicing multilateralism. Facing a pandemic and major changes both unseen in a century, BRICS countries maintained the momentum of cooperation while boosting domestic economic recovery, lending important impetus to the efforts by the five countries and beyond to combat the coronavirus and rebuild the economy.

To accelerate the implementation of the 2030 Agenda, economic recovery through green and low-carbon development represents a compelling consensus shared by the international community. More than 100 countries around the world have pledged to reach carbon neutrality, who are actively promoting energy transition. As Chinese President Xi Jinping pointed out in his remarks at the 12th BRICS Summit, all of us are indeed passengers in the same boat. When the wind is strong and the tides are high, we must be even more focused on our direction. We must keep pace and work as a team to break the waves and navigate steadily toward a brighter future. BRICS countries have respective strengths in energy resource endowments and technical innovation. Facing the common opportunities and challenges of development and transition, BRICS countries hold broad cooperation perspectives in enhancing energy security and low-carbon energy transition. In this context, we BRICS countries should secure new prospects amidst changes. We should work together to enhance all-round cooperation in energy field, explore the future course for green recovery and energy transition, and contribute BRICS' share to tackling common challenges brought by climate change.

This year, at the Indian Presidency's active initiative, BRICS countries overcame difficulties and jointly completed BRICS Energy Report 2021 and BRICS Energy Technology Report 2021 as the ERCP outcomes for this year. The reports update the latest development in energy fields and the progress combating Covid-19, which are of great importance. China is willing to stand with all other countries, actively practice green development philosophy, and contribute to promoting intra-BRICS practical cooperation in energy.

Samson Gwede Mantashe

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

South Africa has one of the most energy-intensive economies globally, and accounts for approximately 40% of all electricity in the African continent. This unsustainable pattern of electricity usage has reduced the country's margin to unsustainably low levels, subjecting the reliability power supply to be under threat. This has undoubtedly have had adverse effects on the country's economy, environment and health.

The South African National Climate Change Response Policy White Paper has already acknowledged that the most promising greenhouse gas mitigation options are primarily energy efficiency and demand side management, coupled with increasing investment in cleaner energy programmes in the electricity sector. It is for these reasons that South Africa adopted the Energy Efficiency Strategy (NEES) in 2005. The NEES was developed with the target of having economic wide energy intensity reduction of 12% by 2015 against the baseline of 2000, and the recently published post-2015 NEES document that will contribute 16% reduction in energy demand by 2030, relative to 2015 energy consumption baseline.

The following are key Energy Efficiency and Demand Side Management projects that are currently being implemented in South Africa to accelerate energy efficiency improvement; namely:

- Energy Efficiency Labelling that prescribes minimum energy performance standards and energy performance rating label of electrical equipment and appliances.
- Industrial Energy Efficiency that is aimed at achieving a wide-scale adoption of energy management systems and methodologies, enhancing institutional frameworks and regulatory environments to accelerate energy efficiency and improve the technical capacity of industry to implement energy savings measures.
- Building Energy Efficiency focusing on the improvement of energy performance of existing and buildings including investment support to implement integrated renewable energy and energy efficient technologies.
- Municipal Energy Efficiency and Demand Side Management Programme with the aim of achieving a net-zero energy of wastewater treatment facilities and improving the energy efficiency of public street lighting.
- Energy Efficiency in Public Buildings and Infrastructure Project aimed at introducing innovative financing mechanism and accelerate the implementation of energy efficiency in the public buildings and infrastructure sector.
- Energy Efficiency Income Tax (12) Allowance, a tax incentive in terms of section 12L of the Income Tax Act, 1962 (Act No. 58 of 1962) that allow for tax deduction of 95c/kWh saved on energy consumption.

South Africa remains committed to continue working with its BRICS member countries on the agreed energy efficiency plan of action, with the view to exchange experiences and good practices.

1. INTRODUCTION

As a part of the BRICS Memorandum of Understanding (MoU) in Energy Saving and Energy Efficiency, energy cooperation among countries has been institutionalised by way of joint research, capacity building and sharing of best practices. Over the course of subsequent Energy Ministers Declarations, several other topics have been included in the fold.

The recently held deliberations of the BRICS Energy Ministers in October 2020 in Russia deepened the scope of work further by focussing on how technology cooperation can be enhanced by way of tangible steps. Two reports namely the BRICS Energy Report and the BRICS Energy Technology Report were presented for consideration. These reports outlined the areas of current deployments and strengths of individual countries. In particular, the reports elaborated on the most essential energy technology requirements in the countries and the common interests and challenges they share. In an attempt to provide a complete picture, it defined the current energy landscape of BRICS nations to identify the potential of each country and the competencies and experience that they can collaborate on. From a future perspective, an attempt was made to tabulate the top 10 BRICS technologies of mutual interests in various sectors/industries. This idea of concretizing areas of mutual technological interest is also contained in the recently circulated 'Roadmap for BRICS Energy Cooperation up to 2025'.

Lessons from Energy Technology Report (2020)

The report emphasised on comprehensive measures that are needed to promote foreign direct investment in the fuel and energy complex in BRICS nations, to create a transparent system for partners' access to licenses for exploration and development of oil and gas fields, to liberalize technological transfer, and customs and tax and tariff incentives for partner countries. It stresses that the development of mutually favourable strategies in the oil and gas sector will be instrumental for BRICS countries for facilitation of trade in energy machines, materials, equipment, and components.

Keeping in mind the dependence of national fuel and energy complex on traditional types of energy, it is essential to account for and include general projects on oil production and oil 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. At the same time, it is also vital to encourage cooperation of scientific, research organizations, technology centres and institutions of the participating countries. Further, the report discussed the challenges that energy cooperation between BRICS countries faces.

With the pandemic having modified energy transformation plans for the near future, the report exerted that BRICS nations will need to strengthen the circulation of information on energy policy, rules and standards. The reports identified the creation of an integrated technological operator on the basis of BRICS as a vital need of the hour, that will keep a unified accounting of technologies, and develop a balanced approach to the development and implementation of new standards.

Overview of Energy Technology Report (2021)

Carrying the previous exercise forward, the India Presidency has prepared a questionnaire on similar lines focussing on the demand side and proposes that a study on energy demand be undertaken with the theme of what technologies will be critical for achieving deep decarbonization of energy demand. The motivation for the same stems from the desire to maintain continuity of the ongoing research exercise and build a comprehensive overview of technologies that cater to both the demand and the supply side. Such an exercise also draws importance from the fact that the focus now has to be on the hard to abate sectors and ways to decarbonize the same. Similar to the way in which the previous Energy Technology Report provided clear and succinct guidance with respect to sectoral cooperation; the proposed study aims to build on it further and explore the demand side aspect in order to paint a complete picture of prevailing and anticipated future energy systems.

The structure of the report is as follows. Chapter I provides the introduction while Chapter II depicts the energy profiles for BRICS member countries. The methodology adopted has been showcased in Chapter III followed by the analysis of results in Chapter IV. Finally, Chapter V chalks out the way forward. Outcomes of this year's presidency have been presented in Annexure I.

2. OVERVIEW OF ENERGY DEMAND TECHNOLOGIES IN BRICS COUNTRIES

Country Profiles

Brazil

Brazil is one of the largest emerging economies, with a GDP in 2020 estimated at 2.99 trillion dollars (GDP, PPP – constant 2017 international $, World Bank). The indicator decreased by 4.1% over 2019 due to the effects of the COVID-19 pandemic. With a population of nearly 213 million, per capita income stood at $14,000.

The country is largely a commodity-based economy, with its main export components being soybeans, crude oil and iron ore. It has substantial reserves of iron, manganese, titanium, bauxite, copper, chromite, niobium, among others. In recent years, reserves of hydrocarbon resources have also been discovered.

In 2020, in terms of **energy**, the Brazilian economy shows significant dependence on oil derivatives and biofuels, with shares of 33.1% and 33.7% in the Total Energy Supply (TES[25]), respectively. The other sources have the following participation: coal (4.9%), natural gas (11.8%), hydropower (12.5%) and wind and solar (2.0%).

Since the oil crisis in the 1970s, the Brazilian government has made efforts to increase the share of biofuels in its energy matrix. Through some programs, such as the National Ethanol Program in 1975, and the National Program for the Production and Use of Biodiesel in the early 2000s, the country has achieved unprecedented results in terms of the use of bioenergy in the transport sector. In 2020, for example, bioenergy reached 24.5% of the energy consumption matrix in the sector, an indicator 8 times the global figure. More recently, with the National Biofuels Policy (RenovaBio), Brazil continues its objective of promoting expansion of ethanol and biodiesel.

The contributions of wind and solar energy to the **total energy supply** started in this century, and are still at low levels. Together, they contributed to 2.0% of the TES as of 2020. Although modest, this figure is higher than the world average of 1.8%. Brazil has abundant natural resources of solar radiation, bauxite, silicon and strong and constant winds, which favour the strong expansion trend of these energy sources in its energy matrix.

Figure 1 shows the 2020 TES matrix, which amounted to 287.6 million toe, 2.2% lower than in 2019, due to the effects of COVID-19. In 2020, while the share of non-renewable energy fell by 6.2%, with a strong reduction in air and road transport, share of renewable energy increased by 2.5%.

25 Also called Energy Matrix or Total Energy Demand – includes final sector consumption, own consumption, non-energy uses, transformation and distribution losses and statistical adjustments.

This was primarily influenced by the contribution of wind and solar energy, in addition to increases in production of sugar, cellulose and grains, which use biomass as energy.

In this context, **share of renewable energy** in the TES was 48.4% , a percentage more than three times the global average . Thus, Brazil is one of the countries with the lowest carbon intensity due to energy use. In economic conditions similar to or above Brazil, only 0.4% of the world's GDP is less carbon intensive, and is concentrated in 5 countries with a population of less than 6 million inhabitants each. The indicator rises to 3% of GDP if another 25 countries with primary economies in which biomass in food cooking is the main source of energy are computed.

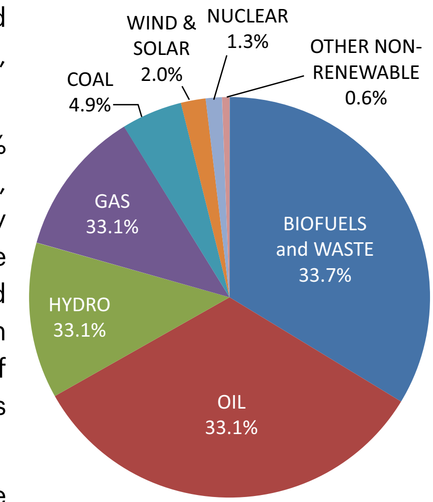

Figure 1: Brazil's Total Energy Supply 2020

Source: SIE Brasil

Electricity access in Brazil has already reached almost the entire population with residential coverage of 99.8%, with 97% of the service being of good quality. At the end of 2020, 86.7 million electricity meters were installed covering 86% of the households .

In 2020, the **installed capacity** for electric power generation reached 179.5 GW, with a predominance of renewable energy (roughly 83.4%, almost three times the global figure). Hydroelectric plants continue to maintain the highest proportion, 60.9%. Wind and solar energy have continued to maintain high growth rates in recent years, and account for 14% of installed capacity as of 2020.

In 2020, **electricity generation** was to the tune of 621.2 TWh, of which 24.7 TWh were net imports while the remaining was generated domestically. In terms of composition of the **Total Electric Energy Supply** - TEES matrix (Figure 2), hydro electric supply (including net imports) stands out with a share of 65.2%, followed by 9.1% for biomass and 10.5% for wind and solar (renewables adding up to 84.8%) .

Although hydro energy has been losing share, Brazil is the second largest generator in the world, after China. The vulnerability of hydro generation in relation to long periods of drought, such as the one that has been occurring since 2011, tends to decrease, as other sources of electricity generation, such as natural gas, bioenergy, wind and solar assume greater participation in studies of expansion of the sector.

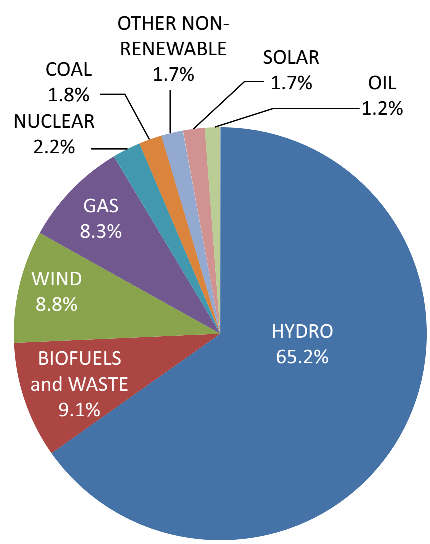

Figure 2: Brazil's Total Electricity Supply 2020

Source: SIE Brasil.

In 2020, **Final Energy Consumption** - FEC[26] was 254.6 mtoe, an amount corresponding to 88.5% of OIE (includes final consumption in economic sectors and losses in transmission and distribution), while losses and

26 FEC – all energy consumed by economic sectors, including for non-energy uses. Includes the energy sector's own consumption.

adjustments accounted for 11.5%. In the world, the losses related to the TES are of the order of 25%, an indicator twice that of Brazil due to greater thermoelectric generation from fossil and nuclear fuels.

With regard to FEC in Brazil, the industrial sector takes up the lion's share (32.1%), followed by transport (31.2%), energy sector (11.2%), residential (10.8%), agriculture (5.1%), non-energy uses (4.9%) and services (4.7%).

In the transport sector, 94.6% of consumption accrues from road transport, which has a high share of ethanol and biodiesel biofuels. The flex-fuel technology fleet is roughly 85% of the total light vehicle fleet. The industrial sector accounts for 80% of energy consumption resulting from energy intensive sectors such as metallurgy, mining, non-metallic, basic chemicals, cellulose and sugar.

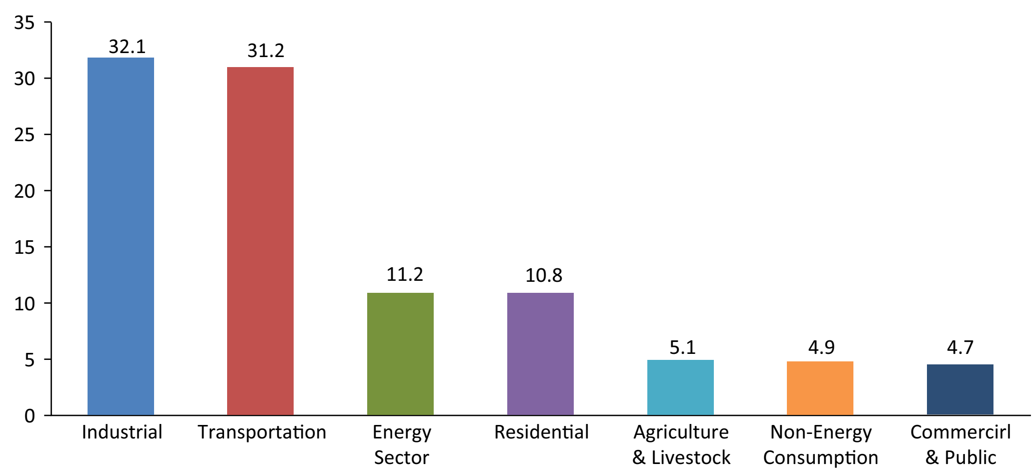

Figure 3: Brazil's Final Energy Consumption by Sector (%)

Source: SIE Brasil.

Although Brazil has an efficient energy matrix, efforts are being made to promote energy efficiency at the level of final energy consumption by sectors. In this regard, the 2011 National Energy Efficiency Plan was prepared and its review is in progress.

Brazil's medium-term energy policy is reflected in the studies of the Decennial Energy Expansion Plan (PDE), which are updated annually, covering the electricity and energy sectors as a whole. The 2050 National Energy Plan (PNE), launched in 2020 and updated every five years, provides a long-term integrated energy strategy.

The results of the expansion studies consider the use of renewable sources as one of the pillars of the Brazilian energy policy, in order to meet the climate goals that are carried out within the scope of the National Policy on Climate Change.

Table 1: List of policies for clean energy transition in Brazil 27

Area	Policy
Universalization	Programme - 'More Light for the Amazon'
Policies to foster renewable energy	Program for the Incentive of Alternative Energy Sources - PROINFA -for the expansion of alternative sources (wind, SHP, solar and biomass) with priority dispatch for wind energy.
	New Energy Auctions and Alternative Energy Auctions PNH2 – National Hydrogen Programme
	Resolution CNPE 2/2021 determined that regulatory agencies should prioritize issues related to energy transition in the allocation of regulated R&D funding
	Platform Inova-e and Energy Big Push
Distributed generation (DG)	The DG can be connected to the distribution network or be in the consumption centre, which reduces the need for power transmission structure and avoid losses
	Program for the Development of Distributed Generation: it aims to expand and deepen the actions to stimulate energy generation by the consumers, from renewable energy sources (in particular solar photovoltaic), such as tax exemption for auto producers and economic incentives for public buildings, hospitals, etc.
Biofuels	National Ethanol Program - PROALCOOL: It aims to intensify the production of ethanol fuel to replace gasoline in Brazil
	National Program for the Production and Use of Biodiesel - PNPB (2004): aims to introduce biodiesel into the Brazilian energy matrix
	Law 11,097 / 2005 - Introduces biodiesel in the Brazilian energy matrix, stipulating the minimum percentage of 5% in the diesel mixture.
	National Biofuels Policy (RenovaBio): it encourages the production of ethanol and biodiesel and establishes annual greenhouse gas reduction targets.
Increase the use of Natural Gas	In 2016, BNDES, the Brazilian Development Bank, announced that it will no longer finance fuel oil and coal thermopower plants, directing investments with the long-term interest rate for projects with high social and environmental returns.
	Law 12.351 / 2010, called the "pre-salt regulatory framework", establishes the end of Petrobras' natural monopoly and allows the participation of private agents in oil and gas exploration in these areas
GHG emissions control of fossil-fuel- red power plants	Normative instruction by IBAMA in 07/2009
Energy efficiency	National Policy on the Conservation and Rational Use of Energy: it establishes maximum levels of energy consumption or of EE for machinery and in the country.
	Procel - National Energy Conservation Program: it works on several fronts: information, education, industries, public buildings, energy efficiency labelling, appliances, banning of incandescent lamps etc.
	Compulsory investments in Research and Development: 1.0% of Net Operating Revenue (ROL) of companies in the electricity sector. As of 2016, the distributors must allocate 0.75% to R&D and 0.25% for energy efficiency.

27 Available at: https://www.climate-transparency.org/wp-content/uploads/2019/04/Brazilian-Policy-Paper-En.pdf

For Brazil, the opportunities to increase energy efficiency lie in transport, industry and building sectors, according to IEA.[28] According to the Nation Energy Plan 2050, the country is interested in exploring following technologies:

Table 2: Technology need requirement as per Brazil PNE 2050

Area	Technologies
Transport	» Flexfuel vehicles: Internal combustion engine operated with gasoline or ethanol. Achieve maximum efficiency via reduction of weight, improvements in the injection system, use of combustion gases (turbo), engine design, electronic components onboard or aerodynamic improvements of the vehicle. » Liquefied Natural Gas (LNG), Natural Vehicle Gas (CNG) and Biomethane: the use of LNG in vehicles, especially for heavy trucks and boats. The expansion of the use of CNG in heavy and light vehicles. » Biodiesel: Biodiesel and Biomethane in vehicles, especially heavy vehicles. » Renewable diesel or green diesel (Green Diesel): Green diesel is a renewable fuel, formed by a mixture of hydrocarbons with composition chemical similar to fossil fuel. » Electric vehicles: batteries technology, availability of raw material for its manufacture, technological aspects in the field of safety, the infrastructure for charging, electrification of hybrid vehicles, technology associated with flexfuel motorization. » Fuel cell for the production of hydrogen from biofuels and gas (natural gas and biomethane) » Transport fuel switching
Industry	» Substitution of sources to the retrofit of existing installations, » Innovations in processes and products with lower energy content » Digitalization of industrial operations. » Self-production of energy and use of renewable energy sources such as distributed mini-generation and thermal solar energy. » Use of charcoal for steel production » Renewable raw materials to replace petrochemical production » Use of densified biomass (briquettes and pellets as an example) in thermal processes » The production of steel from charcoal. » Regulation for electric motors up to 500 hp and distribution transformers. » Brazilian Labelling Program: distribution motors, pumps and transformers » Energy efficiency gains: improvements in production management, as well as replacement of equipment, recycling of materials and residual energy flows from processes. » Leverage the use of energy self-production opportunities (electricity and fuels) originating from the production of sugarcane, cellulose & paper, steel, chemical, among others. » The exploration of potential generation from solar energy and biomass. » hydrogen as a raw material in the synthesis of several products and in industrial processes » End-use fuel efficiency

28 Available at: https://www.iea.org/articles/e4-country-profile-energy-efficiency-in-brazil

Area	Technologies
	» End-use power efficiency » Energy recovery from waste » Liquid biofuels » Solid biomass (iron, steel) » Solar photovoltaics » Concentrated Solar Power
Buildings	» Space cooling technologies » Space cooling efficiency gains » Labelling programs, building codes, benchmarking, operational energy performance assessment, energy diagnostics and retrofit.
Hydrogen	» Carbon capture and use technology (CCUS) for a cleaner hydrogen (blue hydrogen). » Hydrogen from renewable sources (green hydrogen) » Biohydrogen » Storage technologies of hydrogen as compressed gas, liquid hydrogen, ammonia liquid and in hydrides
Storage technologies	» Flywheels » Reversible Hydroelectric Power Plants (UHR) » compressed air storage (Compressed Air Energy Storage Systems – CAES) » Batteries - development of high energy density batteries with high charge rates, fast loading and unloading ability to meet high demand peaks and long service life, and use of inert materials or materials that are environmentally friendly » Air Energy Storage tablet (CAES) » BMS - Battery Management Systems » Reverse Pumping » Supercapacitors » Energy storage in gas form » Flywheel » Thermal storage with and without phase transformation » Thermochemical (reactors) » CAES - compressed air energy storage » LAES - liquefied air energy storage » Super magnet » Smart meters

Russia

To ensure sustainable socio-economic development of the Russian Federation, it is necessary to gradually change the structure of the economy by diversifying it in proportion to growing climate challenges, which will also contribute to the achievement of global goals enshrined in international agreements on climate. The adaptation of the Russian Federation to climate change is associated not only with the need to minimize the emerging complex risks, but also with the creation of conditions for the implementation of emerging favorable opportunities (an increase in the productivity of agriculture and forestry, an increase in the availability of sea routes in the Arctic Ocean, a reduction in the heating season).

Changing the trajectory of the energy market development in the coming decades creates new opportunities for Russian innovative companies (hydrogen and nuclear energy, technologies and components for renewable energy and micro-energy, energy storage technologies for capturing, storing and processing carbon dioxide, export of "green" energy).

Technological development is a critical element in the transformation of the power system and identifying the key technologies to achieve the goals is the first step in this process. For innovative development in Russia, it is of high importance to synchronize actions for the development, validation, formation of an educational and scientific base for perspective technologies and the industrial production and application of innovative technologies and materials in the energy industry.

Based on the goals and objectives presented in Russian S&T Foresight 2035 (aimed at identifying the most promising areas of science and technology development in Russia to ensure the realization of the nation's competitive advantages), Russia's Energy Strategy 2035, Law "On Strategic Planning in the Russian Federation ", 2014, Innovative technology development programs for domestic energy companies, as well as orders of the Ministry of Industry and Trade of the Russian Federation and other regulatory legal documents adopted recently, a list of some critical technologies for industries, housing and communal services, energy and other industries is presented in Table 3.

Table 3: Technology Needs/Prioritized technologies for Russia[29]

Area	Technology
Industry – Iron and steel	» Top gas recycling blast furnace » Blast furnace: hydrogen enrichment and/or CO2 removal using of work arising gas » Blast Furnace: converting works arising gases to fuels and chemicals » Smelting reduction with Carbon Capture Utilization and Storage » Direct electrolysis of iron ore » Carbon capture and storage and carbon capture and utilisation
Industry - Cement	» Chemical absorption, partial capture rates (less than 20%) » Chemical absorption (full capture rates) » Calcium looping » Oxy- fuelling » Novel physical absorption (silica or organic based) » Direct Separation » Membrane separation » Calcined clay » Carbonation of calcium silicate » Magnesium oxides derived from magnesium silicate

29 Based on Submission by Russia

Area	Technology
Transportation	» Traction Motor and Controller manufacturing » Traction modular lithium-ion batteries for electric buses with dynamic charging (IMC) manufacturing » Advanced Chemistry Cell Manufacturing » Mega chargers/HPCCV: Electrification » Proton-exchange membrane fuel cells » Fuel Cell Electric Vehicles » Integrated ticketing, pedestrian and bicycle facilities

India

India's **total energy supply** is dominated by coal, with a share of approximately 45 per cent. As of 2018, the corresponding shares for crude oil, natural gas, nuclear energy, hydro, wind & solar energy, biofuels & waste are 29.48%, 5.7%, 1.07%, 1.41%, 1.08% and 20.13% respectively.

India stands 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. As per the Third Biennial Update Report (BUR 3) submitted to United Nations Framework Convention on Climate Change (UNFCCC) in 2018, it has been highlighted that India has proactively pursued mitigation and adaptation activities and achieved a reduction in emission intensity of GDP by 24% in the period 2005-2016.

The country has done a commendable job with regard to **renewable energy** deployment and accounts for one-fifth of the global renewable energy deployment targets for 2030. India aims to reach 175 GW of renewable energy capacity by 2022 and 450 GW by 2030. Additionally, as per the NDCs, India is committed to achieve about 40 percent cumulative electric power installed capacity from non-fossil-fuel energy resources by 2030. As of November 2020, against this target, the country has already achieved 38.18" % generation capacity from non-fossil fuel sources (MOEF&CC, 2021). Annual additions of renewables since 2017 have outpaced that of coal. India has emerged as one of the largest renewable auction markets in the world; this has aided domestic developers to attract private investments. In fact, solar and wind-based power generation represent the cheapest sources of bulk electricity generation in the country since 2018, being driven by successful auctions and the declining costs of equipment worldwide (Garde et al, 2020). However, it is also important to take note of the fact that the pace of capacity addition has slowed down in the past couple of years.

While the share of fossil fuel based **electricity generation** in total installed capacity fell from 68"% to 62"% between 2014-2020, coal dominates the generation portfolio (MOEF&CC, 2021). Although total **energy demand** in India has been steadily rising over the past few decades across all sectors, however the per capita energy consumption is much below the world average (International Energy Agency, 2020). The lion's share in terms of energy consumption accrues from the industrial sector followed by residential and transport sectors. In India the industrial sector accounts for 22 percent of GHG emissions and a majority of those emissions are generated by Iron and Steel, Cement and Ammonia sub sectors[30] (National Productivity Council 2017). The source wise and sector wise

30 Available at: https://www.ceew.in/sites/default/files/GHGPI_Industry_Sector_State_Level_Methodology.pdf

bifurcation of electricity generation and demand in India are presented in Figure 4 and Figure 5 respectively.

India has assumed leadership role in promotion of **energy efficiency** and conservation towards addressing global issue of climate change. Government of India has undertaken a two-pronged approach to cater to energy demand of its citizens while ensuring minimum rise in CO_2 emissions. On the generation side, the Government is promoting greater use of renewable in the energy mix mainly through solar and wind and at the same time shifting towards supercritical technologies for coal-based power plants. Efforts are also being made to efficiently use energy in the demand side through various innovative policy measures under the ambit of the Energy Conservation Act 2001 (EC Act).

Owing to the various energy efficiency measures undertaken so far, energy intensity of the country has declined from 0.273 mega joule per INR in 2012-13 to 0.223 mega joule per INR in 2019-20 indicating an efficiency increase of 18%. This will have a direct impact on emission reduction intensity with energy efficiency contributing to 55- 56% of the set target of 33-35% reduction .

The EC Act was enacted in 2001 with the goal of reducing energy intensity of the Indian economy, with the Bureau of Energy Efficiency (BEE) being set up as a statutory body to facilitate implementation of the Act. Several innovative energy efficiency mechanisms and national programs have been successfully designed and implemented like the Perform Achieve and Trade (PAT), Standards and Labelling for Energy Efficient Appliances, UJALA for households, Street Lighting National Programme (SLNP), Energy Conservation Building Codes (ECBC). These endeavours have resulted in electrical energy savings of 145.03 Billion Units (worth USD 12.43 Billion), thermal energy savings of 15.58 Million Tonnes of oil Equivalent (MTOE) (worth USD 4.10 Billion) and total energy savings of 28.06 MTOE. Total cost savings are to the tune of approximately USD 16.52 Billion, while total reduction in CO_2 emissions is around 177.6 Million Tonnes.

The updated Energy Conservation Building Code (ECBC) launched in the year 2017 and its adoption by the states is expected to result in more than 25% energy savings. The standard and labelling (S&L) for appliances has been very successful in aiding the consumer in making informed choices about energy intensive appliances and equipment. The programme covers 28 appliances out of which 10 appliances are under the mandatory regime while the remaining are under the voluntary regime.

The globally recognised industrial energy efficiency programme of India - Perform, Achieve and Trade (PAT) scheme is in its VI cycle now. The schemes cover 1073 energy intensive industries / establishments from 13 sectors. Recently concluded second cycle of the PAT scheme has resulted in energy savings of 14.08 MTOE. The energy savings exceeded the notified target by about 16 %. This saving is to the tune of USD 4.10 Billion and contributed in reduction of 66 Million Tonne of carbon dioxide. Achievements under different cycles of the scheme have been presented in Table 4.

Table 4: PAT Cycles

PAT Cycle	Sectors	Number of DCs	Energy Saving Targets	Actual Savings
PAT I (2012-13 to 2014-15)	**8 sectors**: Aluminium, Cement, Chlor-Alkali, Fertilizer, Iron & Steel, Paper & Pulp, Thermal Power Plant and Textile	478	6.686 mtoe	8.67 mtoe
PAT II (2016-17 TO 2018-19)	**11 Sectors**: 3 new sectors i.e. Refineries, Railways and DISCOMs	621	8.869 mtoe	14.08 mtoe
PAT III (2017-18 to 2019-20)	**6 Sectors:** Thermal Power Plant, Cement, Aluminum, Pulp & Paper, Iron & Steel and Textile	116	1.06 mtoe	-
PAT IV (2018-19 TO 2020-21)	**8 Sectors**: 6 existing and 2 newly added i.e. Buildings and Petrochemicals	109	0.699 mtoe	-
PAT V(2019-20 TO 2021-22)	**8 sectors**: Aluminum, Cement, Chlor-Alkali, Commercial Buildings (Hotels), Iron & Steel, Pulp & Paper, Textile and Thermal Power Plant	110	0.513 mtoe	-
PAT VI (2020-21 TO 2022-23)	**6 sectors**: Cement, Commercial Buildings, Iron & steel , Petroleum Refinery, Pulp & Paper and Textiles	135	1.277 mtoe	-

The LED program being run by Energy Efficiency Services Limited (EESL) requires special mention and has proven to be a source of inspiration for countries across the globe. As of August 2021, it has successfully distributed roughly 36.13 crore LED bulbs across the nation resulting in energy savings of 46.92 billion kWh per year and reduced GHG emissions by 38 million tonnes annually.[31] India has been one of the few countries to design a cooling action plan (CAP) with a long-term vision (spanning a 20-year period from 2017-18 to 2037-38) that addresses cooling requirements across sectors. There is a general consensus amongst key stakeholders that India needs to focus on hard to abate sectors such as cement and iron & steel.

31 Available at:https://pib.gov.in/Pressreleaseshare.aspx?PRID=1598481

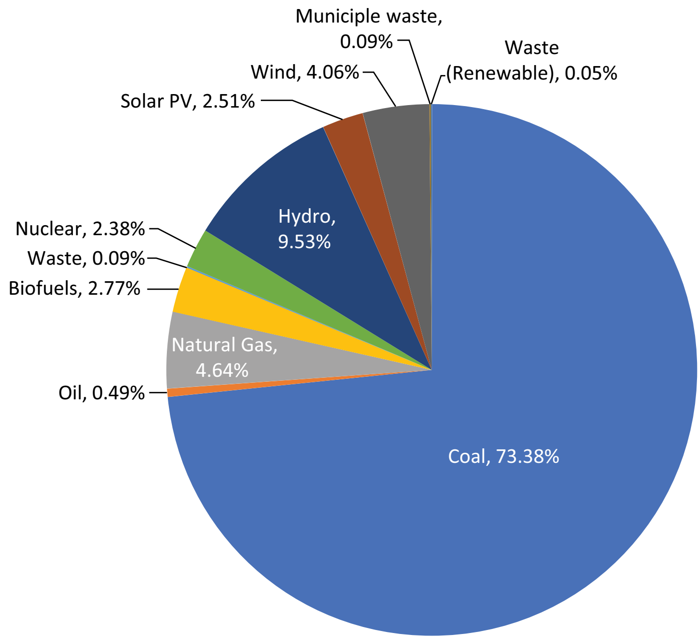

Figure 4: India's source-wise bifurcation of Electricity Generation

Source: IEA Data and Statistics[32]

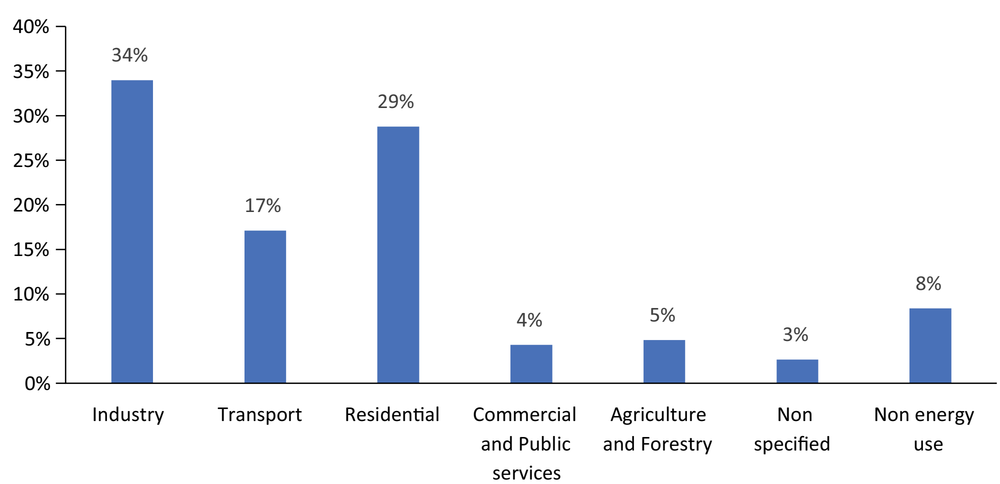

Figure 5: India's Sectoral Share in Energy Demand

Source: IEA Data and Statistics[33]

Initiatives to decarbonise the **transport sector** in the country include improving efficiency, use of cleaner fuels, modal shifts and promoting electric mobility. India is proactively pursuing its green

32 Available at: https://www.iea.org/data-and-statistics/data-tables?country=INDIA&energy=Electricity&year=2018

33 Available at: https://www.iea.org/data-and-statistics/data-tables?country=INDIA&energy=Balances&year=2018

mobility agenda, as an ameliorative step to combat climate change and air pollution. The National Mission for Electric Mobility (NMEM) was launched in 2011, which was followed by the unveiling of the National Electric Mobility Mission Plan (NEMMP) 2020 in 2013. Under the ambit of this program, the Faster Adoption and Manufacturing of Hybrid & Electric Vehicles (FAME) (2015) was approved. Following the success under FAME I the second phase was launched in 2019 with an outlay of INR 1,00,000 million spread across a three year period. The country also recently launched the 'Go Electric' campaign to create awareness about electric mobility benefits, charging infrastructure and electric cooking. Some of the other efforts to promote electric mobility in the country include reduction of GST on EVs from 12% to 5%, revision of customs duty on EV components to boost local manufacturing of parts, exemption of permit for battery operated commercial vehicles etc. As of 2019, more than 3 lakh EVs are operating in India (MOEF&CC, 2021).

Apart from electric mobility, the Ministry of New and Renewable Energy has identified **hydrogen** as a strategic area for development since 2006. The ministry launched the Hydrogen and Fuel Cell Roadmap in 2006, that aimed to develop India as a successful hydrogen economy. India has recently announced a National Hydrogen Energy Mission (NHM) that will draw up a road map for using hydrogen as an energy source. The initiative has the potential to transform the transport sector. The NHM will focus on generation of hydrogen from green energy sources.

India had identified **Carbon Capture, Utilization and Storage (CCUS)** as a priority area in its Second Biennial Update Report that was submitted to the United Nations Framework Convention on Climate Change (UNFCCC). The country is an active participant in the Carbon Capture Innovation Challenge under Mission Innovation (MI). India launched a funding opportunity in 2018-19 under MI for carbon capture (IC3), sustainable biofuels (IC4) and converting sunlight (IC5). The idea was to aid collaboration between Indian researchers and other MI member countries and a budget of USD17 million has been sanctioned for 47 projects (IC3 – 20, IC4 – 14, IC5 -13) across the three themes.[34] The Oil and Natural Gas Corporation (ONGC) and Indian Oil Corporation limited (IOL) have signed an MoU in 2019 to jointly work towards reducing carbon emissions through the implementation of CCUS at the Koyali Refinery in Gujarat.[35] Similarly, Dalmia Cement announced its plans to build a 5,00,000-tonne carbon capture cement plant in Tamil Nadu. It has signed a MoU with UK based Carbon Clean Solutions (CCSL) for technology and operational services for running the plant. Dalmia Cement happens to be the first cement company in the world to have committed to becoming carbon negative by 2040.[36]

Some of the technological needs of India as identified in BUR 3 are presented in Table 5.

34 Available at: http://mission-innovation.net/wp-content/uploads/2019/05/MI-Country-Highlights-2019.pdf.

35 Available at: http://print.acjnewsline.org/?p=8534.

36 Available at: https://carboncleansolutions.com/media-center/news/article/2019/09/dalmia-cement-and-ccsl-sign-mou.

Table 5: Technology Needs

Area	Technology
Solar Photovoltaics	» Crystalline Silicon technology for solar PV installations » Technological knowhow for manufacturing upstream segments in the supply chain such as polysilicon, ingot, wafer etc. » Next generation PV technologies such as Perovskites, multi-Junction Solar Cells, Dye induction PVs etc.
Offshore Wind	» Increase capacity factor of domestic manufacturing units » Modelling and simulation tools to improve forecasting
Advanced Ultra Super Critical Coal Technology (AUSC)	» Materials with high creep rupture strength and resistance to corrosion at high temperatures and pressures.
Light Emitting Diode Bulb	» LED chip manufacturing technology
Room Air Conditioners	» Rotary Compressors
Iron & Steel	» Coke Dry Quenching (CDQ) » Waste Heat recovery generation from low TPD Sponge Iron Plants » Regenerative/ recuperative Burner for Reheating Furnace » Sinter Plant Heat Recovery (Steam Recovery from Sinter Cooler Waste Heat) » Sinter Plant Heat Recovery (Power generation from sinter cooler waste heat) » Coal Moisture Control (CMC) system (Top Charged) » Top Pressure Recovery Turbine (TRT) » Pulverized Coal Injection (PCI) system » Hot stove waste heat recovery » Converter gas recovery device » Ecological and economical arc furnace » Waste heat recovery from electric arc furnace » Regenerative Burner Total System for Reheating Furnace » Energy monitoring and management system » Cogeneration with Gas Turbine Combined Cycle (GTCC) » Low Grade Heat Recovery Using Organic Rankine Cycle » Hot Blast Superheating with Plasma technology » Advanced automation L-3 model online simulation of Blast Furnace » Gas Oxygen refining technology » Converter Gas Sensible Heat Recovery » H2 based iron & steel making technologies » CCS/CCUS (Carbon Capture Storage/Carbon Capture, Utilisation and Storage) technologies, » HISARNA Technology which is being developed under ULCOS Programme.
Hydrogen	» Technologies for type III and type IV cylinders, as well as hydride and carbon materials for hydrogen storage » Catalysts, membranes, and fuel cell manufacturing assemblies » Hydrogen supply chain infrastructure and dispensing stations » Green hydrogen utilization in the industry, including ammonia for fertilizers and iron and steel production.
Lithium-Ion Battery (LiB) & Flow Battery	» Raw materials and technology are barriers to large scale manufacturing of Lithium-Ion Batteries in India

Source: MOEF&CC (2021)

China

Similar to most developing countries, the Chinese economy is largely coal based with roughly 62 per cent of the **total energy supply** arising from this sector. As of 2018, the corresponding shares for crude oil, natural gas, nuclear energy, hydro, wind & solar energy, biofuels & waste are 19.6%, 7.8%, 2.4%, 2.5% and 3.6% respectively. The Chinese government lays importance on investing in renewable energy as it plays a pivotal role in tackling issues of air and water pollution and in mitigating risks of socio-economic instability. The country's **renewable energy** installed capacity as of 2020 is dominated by hydro power, wind and solar energy with 39.6%, 30.1% and 27.1% respectively.[37] The 13th Five Year Plan for Electricity (2016-2020) endeavours to increase the share of non-fossil fuels in electricity generation from 35 to 39 per cent.[38] The Nationally Determined Contribution targets of the country aim at capping carbon emissions by 2030 or earlier and reducing the carbon intensity of GDP by 60-65 per cent by 2030 from the 2005 levels (UNDP, 2019).

Since 2016, the National Energy Administration (NEA) of the country has adopted a warning mechanism for planning and construction coal power plants that evaluates the risk level of new plants on the basis of the economy of construction, the adequacy of installed capacity and the constrain of energy resources. The risk level will be published annually to guide and control the planning and construction of coal power plants across China. Over the years, the warning mechanism has guaranteed China accomplishing the goal of preventing and solving the overcapacity of coal power. Given the declining trend in the cost of renewable technologies and the maturing of markets, China has begun the phasing out of subsidies in renewable energy. In 2019 to 2020, the Chinese government adopted subsidised biding for solar power which accelerated the quitting of subsidies for solar PV projects. From 2021, Chinese government will not provide subsidies to new recorded centralized PV projects and the distributed PV projects for business use.

The total electricity generation in 2020 was to the tune of 7.62 trillion kWh. The source wise bifurcation of **electricity generation** in 2020 is depicted in Figure 6. In terms of **energy demand,** the industrial sector is the largest consumer of energy with roughly 48 percent of the demand accruing from this sector.[39] In particular, the sub sectors of steel, aluminium and chemicals account for the majority of industrial energy demand. The sectoral share in energy demand is presented in Figure 7.

37 Available at: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Jul/IRENA_Renewable_Energy_Statistics_2020.pdf

38 Available at: https://csis-website-prod.s3.amazonaws.com/s3fs- public/171011_chiu_china_Solar.pdf?i70f0uep_pGOS3iWhvwUlBNigJMcYJvX

39 Available at: https://www.iea.org/data-and-statistics/data-tables?country=CHINAREG&energy=Balances&year=2018

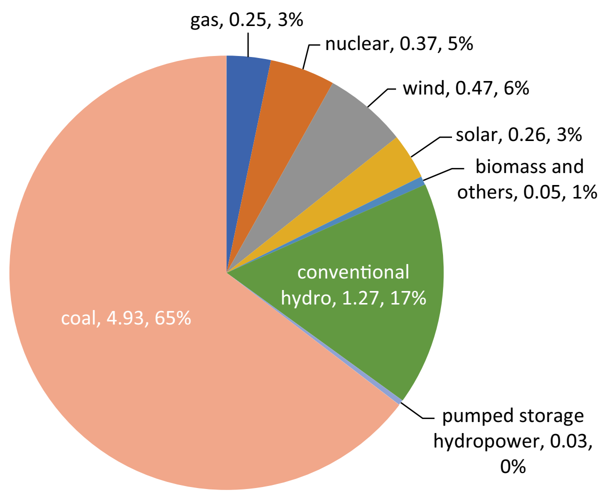

Figure 6: China's source-wise bifurcation of Electricity Generation

Source: IEA Data and Statistics[40]

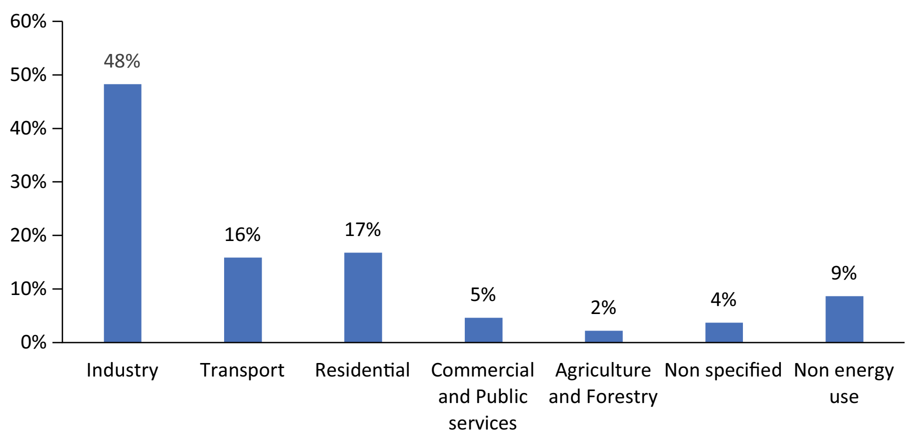

Figure 7: China's Sectoral Share in Energy Demand

Source: IEA Data and Statistics [41]

China has emerged as a global leader in **energy efficiency** and according to the efficiency policy index prepared by the IEA, more than half the world's policy progress between 2000 and 2016 was accounted for by China. The legal basis for energy conservation and efficiency is provided by the Energy Conservation Law that was revised in 2016. It chalks out the responsibilities of government entities and departments and stipulates the obligations of energy consumers and equipment manufacturers. Moreover, the production, sale or import of products that do not fulfil the mandatory energy efficiency standard is strictly prohibited. The Energy Supply and Consumption Revolution Strategy (2016-2030) was launched to provide an outlook till 2030 and send signal to investors regarding the change in policy pace. Additionally, it also capped energy consumption at 6 Gtce[42] and endeavours to reach the global average energy consumption per unit of GDP by 2030. A series of energy efficiency action plans cutting across different sectors have also

40 Available at: https://www.iea.org/data-and-statistics/data-tables?country=CHINAREG&energy=Electricity&year=2018
41 Available at: https://www.iea.org/data-and-statistics/data-tables?country=CHINAREG&energy=Balances&year=2018
42 Giga tonnes of coal equivalent

been envisaged which include upgradation and renovation of coal power plants, green buildings, green development of the industrial sector and green transport. The country is engaged in a number of bilateral and multilateral initiatives (with countries such as the US, Germany, the EU and the LAS) to facilitate co-operation between countries on matters of energy efficiency. Moreover, China has demonstrated world leadership in energy efficiency through the G20 platform as well. (International Energy Charter, 2018).

The Chinese government has implemented a range of policies to support developments in the field of **hydrogen** fuel cell research. Guangzhou city plans to construct an H_2 fuel industrial chain that would cover everything from production, storage, transportation and usage.[43] China has been actively encouraging EfW deployments to manage increasing municipal solid waste as a result of increasing urbanisation and economic development. China today has the highest installed EfW capacity globally (IEA, 2020). EfW, along with solid biomass-based electricity generation (agricultural residue for bio energy), receive feed-in-tariff support. China has also announced a pilot project for coal power stations to begin co-firing biomass.

Since 2007, the country has been enhancing its domestic **CCUS** technology R&D and has promoted industry level pilot projects for carbon capture technologies. Three integrated carbon capture and storage projects in the field of chemical production and natural gas processing have entered the construction or operational phase. The Chinese government issued a notice in 2013 to extend provincial level support to projects in the Shaanxi and Guangdong regions (IEA Clean Coal Center , 2018). Following the success of the emissions trading system (ETS) pilot project in seven regions within China, the country launched its first nationwide ETS in 2017. As per the work plan, the programme is to be launched in three separate phases starting with the electricity sector.[44]

As per the Second Biennial Update Report supported by China, the country has listed out key technology needs. These have been listed in the Table 6 below.

Table 6: Prioritized Technology Needs

Sectors	Technology Needs
Energy	1,000 MW high-parameter & large-capacity ultra super critical power generation technology
	Combined gas and steam cycle power generation technology (150 MW level)
	Shale gas development technology
	Nuclear power generation technology
	Steam turbine systems retrofit
Renewable Energy	Offshore wind power technology
	Thin-film photovoltaic battery technology
Iron and Steel Industry	Smelting restoration technology for iron making (including corex and finex)

43 Available at: https://www.hydrogenfuelnews.com/guangzhou-hydrogen-energy-sector-expected-to-top-200b-yuan-in-a-decade/8540341/

44 Available at: https://ets-china.org/ets-in-china/

Sectors	Technology Needs
Construction Material Industry	Intelligent optimization and control system for cement furnace
Transport	Electric vehicles
	Aircraft engine
	Freight transportation organization model optimization technology
	Road transportation enterprise energy consumption monitoring and statistical analysis technology
Residential and Commercial Buildings	External insulating intumescent fire-retardant paint for foam material and cellulose material
	Self-expanding seal tape for energy-efficient windows
	Heat and moisture exchange membrane for heat recovery from fresh air and exhaust air
Waste	Combined gas-steam cycle for incineration plants and power plants (waste-to-energy and gas turbine, WtE-GT).
	Reheat cycle system
Chemical Industry	Production technology of methanol with high co_2 content natural gas
	CO_2-free pulverized coal pressure conveying technology

Source: The People's Republic of China Second Biennial Update Report on Climate Change (2018)

South Africa

South Africa is a middle-income country that is endowed with rich reserves of natural resources. In addition, the country is also one of the largest economies in Africa. According to the data provided by World Bank[45], the per capita GDP of South Africa equals USD 6001.4 as of 2019.

The country's energy mix is dominated by coal, and around 77 per cent of the **primary energy** needs are currently fulfilled by the same. However, this scenario changed with time, and South Africa diversified towards nuclear, hydroelectricity, wind electricity and others.

The current **energy mix** is dominated by coal in South Africa, constitutes about 90 per cent of the total mix, followed by biofuel and waste, and nuclear energy constituting 5.09"% and 20"%, respectively (IEA, 2020) (Figure 8).

Currently, coal dominates the energy mix of South Africa. There are around 17 coalfields in the country, and most are located in the country's north-eastern part. Majority of the coal is mined from Wittbank and Highveld coalfields, and they account for approximately 75 per cent of the total production[46]. It currently has six refineries, out of which only 50 per cent are operational. [47]

The country relies upon natural gas to power electricity generation to tackle energy poverty in the

45 Available at: https://data.worldbank.org/indicator/NY.GDP.PCAP.CD?locations=ZA
46 Available at: http://www.energy.gov.za/files/media/explained/South-African-Coal-Sector-Report.pdf
47 Available at: https://www.engineeringnews.co.za/article/future-of-oil-refining-in-south-africa-highly-uncertain-2021-04-30/rep_id:4136

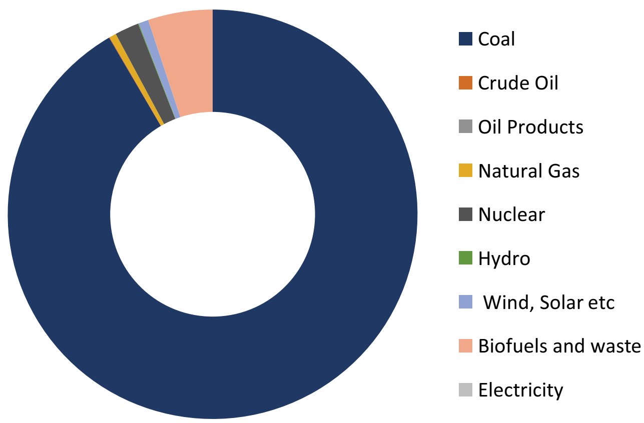

Figure 8: South Africa source-wise bifurcation of Electricity Generation (2018)

Source: IEA (2020)

country. With a power generation capacity of 51309 MW, the newly updated 20 years integrated resource plan outlines a new power generation program till 2030[48].

Nuclear power has been part of South Africa's energy mix since the 1980s. Currently, the country has two nuclear power plants generating about 5 per cent of its total electricity. The country plans to increase the share of energy generated from this source in its energy mix by 2030. South Africa has outlined plans to increase the existing power of nuclear by 1 GW and extend the operating lifetime of the existing power plant by 20 years (World Nuclear Association, 2020). The country is also attempting to increase the usage of biofuels in its energy mix which dates back to 2007 when the country adopted its industrial biofuel strategy. However, despite such early measures, the biofuel industry in South Africa is still in a nascent stage (Saravanan et al., 2020).

Energy demand in South Africa is dominated by industries (34.41%) followed by the transportation sector (26.93%), residential sector (18.72%), commercial and public services (8.54%), agriculture and forestry (3.08%) and others (IEA, 2020) (Figure 9).

The country is currently undertaking significant changes directed towards reducing emissions from the energy sector. The country promotes renewable energy and energy efficiency interventions in the industrial sector to optimise energy use.

Some of the mitigation strategies that are being adopted in the country are discussed below:

Energy efficiency is one of the pillars for climate mitigation, and South Africa is actively promoting energy-efficient technologies. The goal for augmenting energy efficiency is backed by the Energy Efficiency and Energy Demand Management Flagship Programme, which aims to improve industrial energy efficiency, energy efficiency and labelling standards, integrated demand management programmes, and several other actions (South Africa, 2019). The Energy Efficiency in Public infrastructure and Buildings work package works towards the continuous integration of energy efficiency measures in public buildings.

To improve energy requirements in buildings and the commercial sectors, the country has

48 Available at: http://gasprocessingnews.com/columns/201910/industry-focus-the-future-of-gas-to-power-projects-in-africa.aspx#:~:text=A%20large%20share%20of%20South%20Africa%E2%80%99s%20gas%20supply,Province%2C%20which%20holds%20proven%20reserves%20of%202.6%20Tft3.

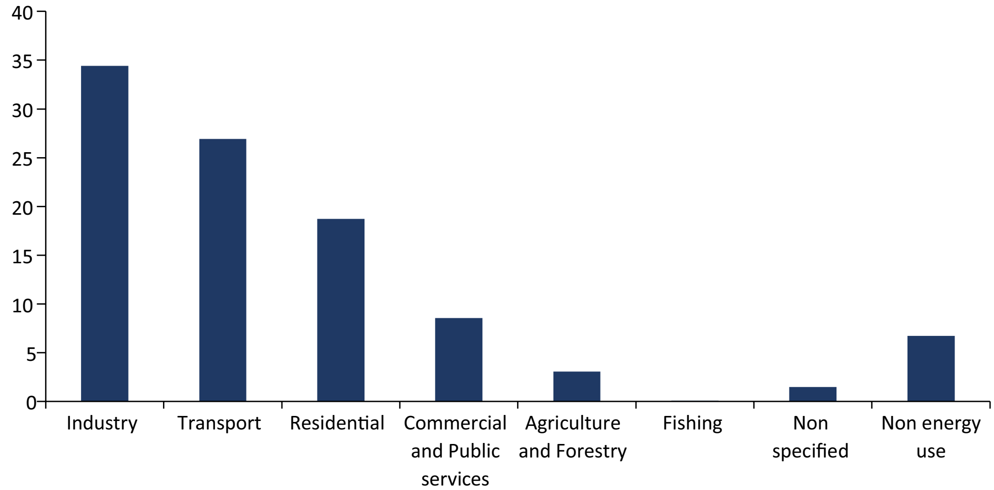

Figure 9: South Africa's Sectoral Energy Demand (2018)

Source: IEA (2020)

implemented the 'Low Carbon, Climate Resilient Built Environment, Communities, and Human Settlements Programme'. In an attempt to reduce energy consumption by the buildings sector the Green Building Council of South Africa launched the Net Zero Building Certification program in 2017. The programme aimed at effective planning of urban centres and the development of green buildings.

Efficient and clean transport strategies are central to transitioning towards a low carbon economy. The government of South Africa implemented the 'Transport Flagship Programme', which aims at integrating rapid public transport networks, biofuels, CNG and encourages a modal shift in case of freight vehicles.

The industrial sector's development is lagging compared to the other sectors in South Africa.

3. METHODOLOGY

In this year's BRICS Technology Report, three demand sectors have been covered, namely – industry, transport and buildings. Both, short-term and long-term needs in technology have been determined in this research for the aforementioned sectors. The primary objective is to identify the critical technologies that are required, deliberate on the next steps that need to be undertaken, explore avenues of joint technological collaboration, recognize potential barriers and inform policy makers regarding the kind of policy push that may be required.

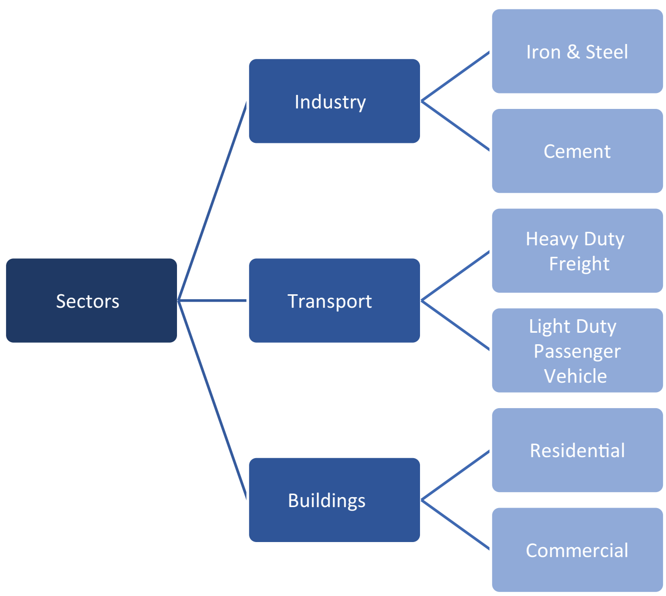

Figure 10: Coverage of Sectors

The questionnaire covers the following key aspects with respect to the technologies:

» Impact of technology development and implementation
» Timeframe of technology development
» Cost parity
» Possibility of commercial deployment and barriers to the same
» Probability of technologies being domestically produced
» Barriers to domestic production
» Willingness to collaborate

A snapshot of the questionnaire is provided below:

Table 7: Questionnaire

Aspect	Questions
Impact	What impact will the development of technology and implementation have on your country such as growth of domestic production, efficiency, cost reduction, emission reduction etc.? For each technology select one of the following: » High impact » Medium impact » Low impact
Time framework	How important is this technology's development in short-term, medium-term or long-term? For each technology you need to select one or more of the following statements: » Short-term (implementation by the end of 2024) » Medium-term (implementation between 2025 to 2028) » Long-term (implementation between 2029 to 2035)
Cost Parity	When would this technology achieve cost parity with conventional alternatives? For each technology you need to underline one or more of the following statements » Short-term (implementation by the end of 2024) » Medium-term (implementation between 2025 to 2028) » Long-term (implementation between 2029 to 2035)
Barriers to Commercial Deployment	Do you think that the following technology can be commercially deployed in your country's fuel and energy complex? For each technology select "Yes" or "No". If "No", what could be some of the barriers for the same? » A – No requirement of the technology » B - Issues with Intellectual Property » C – Low profit margins of the technology » D - The implementation of technology is associated with multiple risks » E - This technology has already been implemented in the industry » F - Other (please write in the comment cell - #F)
Domestic Production probability	In your opinion, is it possible produce the technology in your country? If yes, what is the probability that the technology development and implementation will be completed by the end of 2024, or in the period from 2025 to 2028, or the period from 2029 to 2035? » High probability (probability exceeds 75%) » Medium probability (probability between 25% and 75%) » Low probability (probability less than 25%)
Domestic Production	If the technology can't be produced in your own country, what could be the possible reason(s)? » A – No scientific research » B - There are no companies capable to develop the technology » C - No demand (industrial) for this technology » D – No supportive policy framework » E - Technology is too expensive to produce » F - Foreign companies have already satisfied market demand » G - Other (please write in the comment cell # G) » If massive production support measures are required, please type them in # H)

Aspect	Questions
Willingness to Collaborate	Is your country ready to collaborate in the development of technology? For each technology select "Yes" or "No". If "Yes", type in (# I) codes and in (#J) the names of organizations with which your country will collaborate: » A - Educational organization » B - Research Institutes & Academies » C - Research institutes (industrial) » D - Local equipment producers » F - Local companies (fuel and energy sector) » G - Local service companies » I - Foreign companies (fuel and energy sector) » K – Other » L- All the previous options

Three questionnaires (one for each sector) were circulated among BRICS member countries to elicit their responses on the same. For cases where adequate information was not provided, questionnaire responses were complemented with bilateral meetings for further clarification as well as key reports released by respective countries.

The technologies covered under the previously mentioned sectors are depicted in Tables 8,9,10, 11 and 12 below.

Table 8: Industrial Sector - Cement

S. No.	Technology
1	Chemical absorption (partial capture rates, less than 20%)
2	Chemical absorption (full capture rates)
3	Calcium looping
4	Oxy- fuel
5	Novel physical adsorption (using silica or organic-based adsorption)
6	Direct separation Calcination Technology for Carbon Capture
7	Sequester/ mineralise CO_2 in concrete and other inert carbonate materials
8	Calcined clay
9	Carbonation of calcium silicates
10	Magnesium silicates (MOMs)
11	Alkali-activated binders (geopolymers)
12	Direct electrification
13	Concentrated solar power direct heating
14	Partial use of hydrogen
15	Decarbonating calcium carbonate
16	Alternative fuel and raw material use in cement industries

S. No.	Technology
17	Clinker Substitution
18	Waste heat recovery
19	Other capture technologies

Table 9: Industrial Sector- Iron & Steel

S. No.	Technology
1	Blast Furnace: off-gas hydrogen enrichment and/or CO_2 removal for use or storage
2	Blast Furnace: converting off-gases to fuels and chemicals
3	Blast Furnace: torrefied biomass
4	Blast Furnace: Charcoal
5	Smelting reduction with carbon capture, utilisation and storage
6	Smelting reduction H_2 plasma reduction
7	Direct Reduced Iron - Natural gas based with CO_2 Capture
8	Direct Reduced Iron based solely on electrolytic H_2
9	Ancillary processes- H_2 for high temperature heat
10	Electrolysis: Low temperature alkaline
11	Electrolysis: High-temperature molten oxide
12	Sinter Plant Heat Recovery - Steam recovery from sinter cooler waste heat
13	Sinter Plant Heat Recovery - Power generation from sinter cooler waste heat
14	Moisture Control Coking Coal
15	Top Pressure Recovery Turbine
16	Hot Stove Waste Heat Recovery
17	Waste Heat Recovery from Electric Arc Furnace
18	Steel making through Direct Reduction and Electric Arc Furnace Route
19	Reuse of steel making by products
20	Carbon Capture in Steel production
21	Direct charging of hot billets from Continuous Casting Machine to rolling mill

Table 10: Transport Sector - Heavy Duty Freight

S. No.	Technology
1	Platooning: Reduction in Aerodynamic drag
2	Autonomous Trucks: Energy and fuel efficiency
3	Traction Battery Manufacturing: *A Traction battery is a battery used to power the electric motors of a battery electric vehicle (BEV) or hybrid electric vehicle (HEV).
4	Advanced Chemistry Cell Manufacturing (like Lithium-ion Cell, Flow Battery etc.) * Advance Chemistry Cells ("ACCs") are the new generation advance storage technologies that can store electric energy either as electrochemical or as chemical energy and convert it back to electric energy as and when required.
5	Induction Charging of Electric Vehicle (EV)
6	Mega chargers/ High Power Charging for Commercial Vehicles (HPCCV): Electrification
7	Electric road systems: Electrification
8	Traction Motor and Controller Manufacturing
9	Hydrogen and compressed natural gas (CNG) blends
10	Proton-exchange membrane fuel cells (PEMFC): Hydrogen
11	Fuel Switching: Bio Fuels/Alternate fuels (Methanol /Ethanol etc.)
12	Electric Heavy Duty Trucks (HDTs): Electrification
13	Fuel Cell Electric Vehicles (FCEV) HDTs: Hydrogen
14	Opportunity Charging: Electrification *Opportunity charging is a system that permits batteries to be charged several times during the work cycle (such as pantograph charging)

Table 11: Transport Sector: Light Duty Vehicle

S. No.	Technology
1	Traction Battery Manufacturing: *A Traction battery is a battery used to power the electric motors of a battery electric vehicle (BEV) or hybrid electric vehicle (HEV).
2	Advanced Chemistry Cell Manufacturing (like Lithium-ion Cell, Flow Battery etc.) * Advance Chemistry Cells ("ACCs") are the new generation advance storage technologies that can store electric energy either as electrochemical or as chemical energy and convert it back to electric energy as and when required.
3	Traction Motor and Controller Manufacturing
4	Induction Charging of Electric Vehicle (EV)
5	Mega chargers/ High Power Charging for Commercial Vehicles (HPCCV): Electrification
6	Electric road systems: Electrification
7	Proton-exchange membrane (PEM) fuel cells: Hydrogen
8	Fuel Switching: Bio Fuels/Alternate fuels (Methanol/Ethanol etc.)
9	Hydrogen Fuel Cell

S. No.	Technology
10	Hyperloop Transport Technologies
11	Integrated ticketing, pedestrian and bicycle facilities

Table 12: Buildings Sector

S. No.	Technology
1	Envelope: Prefabricated building components
2	Envelope: High performance glass - Double/ triple glazed window units
3	Envelope: High performance glass - Chromogenic/ switchable glazing
4	Envelope: High performance glass - Heat reflective glass
5	Envelope: High performance glass - Low emissivity glass
6	Envelope: Air-tightness/ infiltration control
7	Envelope: External movable shading devices
8	Envelope: Wall and roof insulation
9	Envelope: Cavity walls
10	Envelope: Autoclaved aerated concrete (AAC) Blocks/ Fly Ash Bricks
11	Envelope: Cement Stabilised Earth Blocks (CSEB)
12	Envelope: Phase change materials
13	Envelope: Light pipes/ daylight tubes/ sun trackers
14	Heating, Ventilation and Air Conditioning (HVAC): Low-GWP refrigerant based cooling systems
15	Heating, Ventilation and Air Conditioning (HVAC): Two- and Three-Stage Evaporative cooling (heat & moisture exchanger)
16	Heating, Ventilation and Air Conditioning (HVAC): Desiccant cooling system
17	Heating, Ventilation and Air Conditioning (HVAC): Solar air conditioning
18	Heating, Ventilation and Air Conditioning (HVAC): CCHP/Tri-generation
19	Heating, Ventilation and Air Conditioning (HVAC): District heating/ cooling
20	Heating, Ventilation and Air Conditioning (HVAC): Radiant heating/ cooling
21	Heating, Ventilation and Air Conditioning (HVAC): Earth-air tunnels
22	Heating, Ventilation and Air Conditioning (HVAC): Structure heating/ cooling
23	Heating, Ventilation and Air Conditioning (HVAC): Air-to-water heat pumps
24	Heating, Ventilation and Air Conditioning (HVAC): Ground and water source heat pumps
25	Heating, Ventilation and Air Conditioning (HVAC): Vapour absorption
26	Heating, Ventilation and Air Conditioning (HVAC): Vapour adsorption
27	Heating, Ventilation and Air Conditioning (HVAC): Adiabatic cooling system
28	Heating, Ventilation and Air Conditioning (HVAC): Condensation heat recovery
29	Heating, Ventilation and Air Conditioning (HVAC): Solid-state cooling
30	Lighting: Solid-state lighting
31	Electrical: Thermal energy storage

S. No.	Technology
32	Electrical: Demand response
33	Electrical: Direct Current motors or linear motors for energy efficient equipment
34	Electrical: Automated Building Management Systems
36	Electrical: Smart Home Automation Systems
37	Electrical: Smart Metering
38	Electrical: Cogeneration
39	Renewable Energy Integration: Heliostats with automatic tracking controls
40	Renewable Energy Integration: Solar water heating
41	Renewable Energy Integration: Building integrated photovoltaics (BIPV)

4. ANALYSIS OF RESPONSES

This chapter analyses the responses received from member countries on the questionnaires that were prepared.

Industry

Over the years, pathways for energy transition have surfaced in the context of buildings, power and the transport sectors, being driven primarily through technological advancements and cost reductions. Similar pathways with respect to the industrial sector have just started to be explored in greater detail. Off late, there has been an increasing focus on addressing emissions from the hard to abate sectors that will ultimately pave the way forward for undertaking deep decarbonization of the economy. In the section that follows, responses received from BRICS member countries regarding some of the new technologies that will play a pivotal role in this regard have been analysed.

Cement Sector

In terms of **impact of technology development and implementation**, questionnaire responses have been grouped into ***medium to high*** and ***negligible to low potential*** (with regard to technology cooperation). In case of the former, overlaps in technology listing in these categories across countries have been incorporated. These include technologies such as *calcium looping, oxyfuel, calcined clay, partial use of hydrogen and waste to heat recovery*. These indicate avenues for technology cooperation amongst member countries. In the category of ***low to negligible potential*** those technologies which found mention in individual country responses but were not overlapping have been included. These include:

» Alternative fuel and raw material use in cement industries

» Clinker substitution

» Chemical absorption (partial capture)

» Chemical absorption (full capture)

» Novel physical absorption (using silica or organic-based adsorption)

» Direct separation Calcination Technology for Carbon Capture

» Sequester/ mineralize CO_2 in concrete and other inert carbonate materials

» Carbonation of calcium silicates

» Magnesium silicates (MOMs)

» Alkali-activated binders (geopolymers)

» Direct electrification

» Concentrated solar power direct heating

» Decarbonating calcium carbonate

» Other capture technologies

With regard to **timeframe of technology development** (implementation by end of 2024/ between 2025-2028/ between 2029-2035), responses indicated that in the ***short to medium term*** there are immediate gains from technology implementation in the case of clinker substitution, waste heat recovery, alternative fuel and raw material use in cement industries. The remaining technologies such as calcium looping, oxy fuel, partial use of hydrogen (others mentioned in *low to negligible* category of 'impact of technology development and implementation') have been identified for ***long term*** implementation

Similarly, responses indicate that **cost parity** will be reached in the ***short to medium term*** for technologies such as clinker substitution, waste heat recovery, alternative fuel and raw material use in cement industries. On the other hand, learning curves and economies of scale come into play with regard to technologies such as calcium looping, oxy-fuel, partial use of hydrogen, chemical absorption, calcined clay and all other technologies etc.

In terms of **possibility of commercial deployment**, it has been found that clinker substitution, waste heat recovery and alternative fuel and raw material use are already being implemented. Technologies that are on the anvil and have not yet reached commercialization stages include calcium looping, oxy fuel, partial hydrogen use, chemical absorption (partial & full capture), novel physical absorption (using silica or organic-based adsorption) etc. One of the reasons cited was that the *technology implementation is associated with multiple risks*.

Mixed responses were received in terms of **probability of technologies being domestically produced** across the three timelines. Thus, no concrete inferences could be drawn from the same.

A variety of responses were received with regard to the **barriers to domestic production of technologies** thereby drawing attention to the various stages of technology development. For instance, the most prominent response was the *issue of financing expensive technologies* which was found particularly in the case of technologies that have reached the commercialization stage such as alternative fuel use, waste heat recovery etc. For calcium looping, partial hydrogen use and oxy fuel, the barrier appears to be *lack of scientific research* and *lack of company capability to develop the technology*. This highlights the areas of technology cooperation by way of pilot projects and joint research initiatives. Other nascent stage technologies such as chemical absorption, magnesium silicates, direct electrification etc. *require both finances as well as technology R&D.*

In terms of **willingness to collaborate,** for technologies important in the short term such as waste heat recovery and clinker substitution countries have *expressed interest to collaborate with local equipment manufacturers*. For technologies that require further research, responses indicate willingness to collaborate with *research institutes & academia as well as industrial research institutes.*

Iron and Steel Sector

Similar to the case of the cement sector, in terms of **impact of technology development and implementation**, questionnaire responses have been grouped into *medium to high* and *low to negligible potential* categories. Within the ***medium to high category***, technologies that found mention are as follows.

» Direct Reduced Iron based solely on electrolytic H_2

» Ancillary processes- H_2 for high temperature heat

» Sinter Plant Heat Recovery - Steam recovery from sinter cooler waste heat

» Sinter Plant Heat Recovery - Power generation from sinter cooler waste heat

» Moisture Control Coking Coal

» Waste Heat Recovery from Electric Arc Furnace

» Steel making through Direct Reduction and Electric Arc Furnace Route

» Reuse of steel making by products

» Direct charging of hot billets from Continuous Casting Machine to rolling mill

These aforementioned technologies indicate avenues of technology cooperation.

On the other hand, the following technologies featured under the ***low to negligible potential*** category:

» Blast Furnace: off-gas hydrogen enrichment and/or CO_2 removal for use or storage

» Blast Furnace: converting off-gases to fuels and chemicals

» Smelting reduction with carbon capture, utilisation and storage

» Smelting reduction H_2 plasma reduction

» Direct Reduced Iron- Natural gas based with CO_2 Capture

» Electrolysis: Low temperature alkaline

» Electrolysis: High-temperature molten oxide

» Hot Stove Waste Heat Recovery

» Carbon Capture in Steel production

» Blast Furnace: torrefied biomass

» Blast Furnace: Charcoal

» Top Pressure Recovery Turbine.

With regard to **timeframe of technology development** (implementation by end of 2024/ between 2025-2028/ between 2029-2035) responses indicated that in the ***short to medium term*** there are immediate gains from technology implementation in the case of:

» Moisture Control Coking Coal

» Waste Heat Recovery from Electric Arc Furnace

» Steel making through Direct Reduction and Electric Arc Furnace Route

» Reuse of steel making by products

» Direct charging of hot billets from Continuous Casting Machine to rolling mill
» Smelting reduction with carbon capture, utilisation and storage
» Direct Reduced Iron - Natural gas based with CO_2 Capture
» Direct Reduced Iron based solely on electrolytic H_2
» Ancillary processes- H_2 for high temperature heat
» Sinter Plant Heat Recovery - Steam recovery from sinter cooler waste heat
» Sinter Plant Heat Recovery - Power generation from sinter cooler waste heat
» Top Pressure Recovery Turbine
» Carbon Capture in Steel production.

The remaining technologies not mentioned in the above list have been identified for the ***long term*** implementation.

Responses indicated that **cost parity** will be reached in the ***short to medium term*** for technologies listed under the *short to medium term* category in the previous point (i.e. moisture control coking coal, waste heat recovery from Electric Arc Furnace, steel making through Direct Reduction and Electric Arc Furnace route etc.) On the other hand, learning curves and economies of scale come into play with regard to all other technologies thereby falling under the category of ***long term***.

In terms of **possibility of commercial deployment** mixed responses were received. For instance, some countries indicated possibility of commercial deployment for almost all technologies barring blast furnace: charcoal. On the other hand some countries have identified the primary barrier of technology implementation being associated with multiple risks in case of most technologies. In case of blast furnace: torrefied biomass, blast furnace: charcoal, and top pressure recovery turbine, it has been indicated that these technologies have already been implemented in some countries.

With regard to **probability of technologies being domestically produced** the responses received were as follows:

Probability	Time period	Technology
Low to Medium	By end of 2024	» Moisture control coking coal » Top pressure recovery turbine » Waste heat recovery from Electric Arc Furnace Steel making through Direct Reduction and Electric Arc Furnace route » Reuse of steel making by products » Direct charging of hot billets from Continuous Casting Machine to rolling mill » Ancillary processes- H2 for high temperature heat » Blast Furnace: Charcoal » Blast Furnace: torrefied biomass

Probability	Time period	Technology
Medium to high	Between 2025-2028	» Sinter Plant Heat Recovery - Steam recovery from sinter cooler waste heat » Sinter Plant Heat Recovery - Power generation from sinter cooler waste heat » Direct Reduced Iron- Natural gas based with CO_2 Capture » Hot Stove Waste Heat Recovery » Carbon Capture in Steel production
Low to medium	Between 2029-2035	All other technologies not mentioned in above two cells

Mixed responses were received with regard to the **barriers to domestic production of technologies** thereby drawing attention to the various stages of technology development. For the technologies listed below while some countries identified the barrier to be *lack of companies who are capable of developing the technology* other countries cited the barrier of *technologies being too expensive:*

- Blast furnace: off-gas hydrogen enrichment and/or CO_2 removal for use or storage
- Blast furnace: converting off-gases to fuels and chemicals
- Smelting reduction H_2 plasma reduction
- Direct Reduced Iron- natural gas based with CO_2 Capture
- Direct Reduced Iron based solely on electrolytic H_2

Ancillary processes- H_2 for high temperature heat was identified as *being too expensive to produce*. With regard to electrolysis (high-temperature molten oxide and low temperature alkaline) while some countries considered it to be *too expensive* others indicated that there was *no industrial demand* for this technology. For blast furnace: torrefied in particular, some responses highlighted *lack of scientific research* as the barrier while others pegged the technology as being *too expensive to produce*.

In terms of **willingness to collaborate,** some countries expressed willingness to collaborate on technologies such as waste heat recovery from Electric Arc Furnace, steel making through Direct Reduction and Electric Arc Furnace route, reuse of steel making by products, carbon capture in steel production and direct charging of hot billets from Continuous Casting Machine to rolling mill with local equipment producers. Some of the countries also expressed interest to collaborate will all categories mentioned for all technologies.

Transport

The transportation sector is responsible for a significant share of GHG emissions and accounts for nearly one quarter of the total energy related emissions generated annually.[25] This is also one of the sectors where significant gains in terms of energy efficiency are possible for BRICS nations.

25 Available at: https://www.unep.org/explore-topics/energy/what-we-do/transport

The present transportation system is predominantly based on fossil fuels and there is a need to diversify our dependence away from just a few energy sources. Some of the technologies that would help achieve 'low carbon pathways, energy efficiency and energy security' in the transport sector have been analysed in this section in the context of BRICS member countries.

Light Duty Vehicles

In terms of **impact of technology development and implementation**, questionnaire responses have been grouped into ***medium to high*** and ***negligible to low potential*** (with regard to technology cooperation). In case of the former, overlaps in technology listing in these categories across countries have been incorporated. These include technologies such as

» Traction Battery Manufacturing

» Advanced Chemistry Cell Manufacturing (like Lithium-ion Cell, Flow Battery etc.)

» Induction Charging of Electric Vehicle (EV)

» Electric Road systems: Electrification

» Fuel Switching: Bio Fuels/Alternate fuels (Methanol/Ethanol etc.)

» Traction Motor and Controller Manufacturing

These indicate avenues for technology cooperation amongst member countries.

In the category of ***low to negligible potential*** those technologies which found mention in individual country responses but were not overlapping have been included. These include:

» Mega chargers/ High Power Charging for Commercial Vehicles (HPCCV): Electrification

» Proton-exchange membrane (PEM) fuel cells: Hydrogen

» Hydrogen Fuel Cell

» Integrated ticketing, pedestrian and bicycle facilities

» Hyperloop Transport Technologies

Few countries also indicated impact of technologies such as proton-exchange membrane fuel cells (PEMFC): hydrogen and hydrogen fuel cell and autonomous trucks to have ***medium to high impact***.

With regard to **timeframe of technology development** (implementation by end of 2024/ between 2025-2028/ between 2029-2035), responses indicated that in the ***short to medium term*** there are immediate gains from technology implementation in the case of fuel switching: bio fuels/alternate fuels, traction battery manufacturing, electric road systems electrification. The remaining technologies such as traction battery manufacturing: basic cell development, advanced chemistry cell manufacturing: basic cell development, induction charging of electric vehicle etc., (others mentioned in *low to negligible* category of 'impact of technology development and implementation') have been identified for ***long term*** implementation. For the ***short term*** timeframe, significant interest was also shown by few countries for technologies such as advanced chemistry cell manufacturing (like lithium-ion cell, flow battery etc.), traction motor and controller manufacturing, mega chargers/ high power charging for commercial vehicles: electrification.

Similarly, responses indicate that **cost parity** will be reached in the ***short to medium term*** for technologies such as fuel switching: bio fuels/alternate fuels (methanol/ethanol etc.). Significant achievement on cost parity parameter in *short to medium term* was also shown for technologies such as electric road systems: electrification, traction motor and controller manufacturing, traction battery manufacturing. On the other hand, cost parity is expected to be reached in the ***longer term*** for the remaining technologies.

With regard to **possibility of commercial deployment**, it has been found that technologies such as traction battery manufacturing, advanced chemistry cell manufacturing, electric road systems, fuel switching: bio fuels/alternate fuels, traction motor and controller manufacturing can be commercially deployed.

Technologies that are on the anvil and have not yet reached commercialization stages include traction motor and controller manufacturing, induction charging of electric vehicle, mega chargers/high power charging for commercial vehicles: electrification, proton-exchange membrane fuel cells: hydrogen, integrated ticketing, pedestrian and bicycle facilities, induction charging of electric vehicle, hyperloop transport technologies, hydrogen fuel cell etc. one of the reasons cited was that the a) there was no need of the technology and b) profit margins for the technologies were low.

For **probability of technologies being domestically produced** by 2024, technologies such as fuel switching: bio fuels/alternate fuels (methanol/ethanol etc.), integrated ticketing, pedestrian and bicycle facilities, traction battery manufacturing, mega chargers/ high power charging for commercial vehicles: electrification, electric road systems: electrification were shown to have ***high probability***.

However, mixed responses were received in terms of **probability of technologies being domestically produced** across the other timeframes. Technologies which overlapped were traction battery manufacturing, advanced chemistry cell manufacturing (like lithium-ion cell, flow battery etc.), fuel switching: bio fuels/alternate fuels and were found to have ***high probability*** *of being domestically produced*.

With regard to the **barriers to domestic production of technologies,** barrier associated with technologies such as induction charging of electric vehicle, hydrogen fuel cell, hyperloop transport technologies was *lack of scientific research*. Whereas for technologies such as traction battery manufacturing, advanced chemistry cell manufacturing (like lithium-ion cell, flow battery etc.) mega chargers/high power, charging for commercial vehicles: electrification, electric road systems: electrification; countries have identified *lack of industrial demand of these technologies* as the primary barrier. Proton-exchange membrane fuel cells: hydrogen saw *unavailability of companies which are capable to develop the technology* and the *technology being too expensive to produce* as the key barrier. This highlights the areas of technology cooperation by way of pilot projects and joint research initiatives.

Countries showed **willingness to collaborate,** on technologies such as traction battery manufacturing, advanced chemistry cell manufacturing, traction motor and controller manufacturing, electric road systems, fuel switching, hydrogen fuel cell, integrated ticketing and proton-exchange membrane fuel cells. In many of these cases, collaboration partners identified included research institutes & academies, local service companies and local equipment producers.

Heavy Duty Vehicles

Similar to the case of the light duty vehicles, in terms of **impact of technology development and implementation**, questionnaire responses have been grouped into *medium to high* and *low to negligible potential* categories. Within the ***medium to high category***, technologies that found mention are as follows:

» Traction Battery Manufacturing,

» Advanced Chemistry Cell Manufacturing

» Induction Charging of Electric Vehicle

» Electric road systems: Electrification

» Proton-exchange membrane fuel cells

» Fuel Switching: Bio Fuels/Alternate fuel

These technologies indicate avenues of technology cooperation. Significant impact of technology was also shown for autonomous trucks by few countries. On the other hand, all other technologies featured under the ***low to negligible potential*** category.

With regard to **timeframe of technology development** (implementation by end of 2024/ between 2025-2028/ between 2029-2035) responses indicated that in the ***short to medium term*** there are immediate gains from technology implementation in the case of traction, battery manufacturing, electric road systems: electrification, fuel switching: bio fuels/alternate fuels. The remaining technologies not mentioned in the above list have been identified for the ***long term*** implementation.

Responses indicated that **cost parity** will be reached in the ***short to medium term*** for fuel switching: bio fuels/alternate fuels. On the other hand, learning curves and economies of scale come into play with regard to all other technologies thereby falling under the category of ***long term***.

In terms of **possibility of commercial deployment**, some countries indicated possibility of commercial deployment for technologies such as traction battery manufacturing, advanced chemistry cell manufacturing traction motor and controller manufacturing, fuel switching: bio fuels/alternate fuels, fuel cell electric vehicles. On the other hand some, with respect to remaining technologies countries have identified the barrier of technology implementation being associated with low profit margins and absence of demand of technology.

Technologies with *medium to high* **probability of being domestically produced** *by the end of 2024* include traction battery manufacturing, fuel switching: bio fuels/alternate fuels, traction motor and controller manufacturing. There was no clear overlap of technologies in the *low* *probability* category.

Technologies with *medium to high* **probability of being domestically produced** *between 2025-2028* includes technologies such as traction battery manufacturing, advanced chemistry cell manufacturing. All remaining technologies were identified as having *low to medium* probability of being domestically produced *between 2029-2035*.

With regard to the **barriers to domestic production of technologies**, induction charging of electric vehicle was shown to have a clear overlap among the countries. The key barrier was identified as *lack of demand for this technology*.

In terms of **willingness to collaborate,** some countries expressed interest to collaborate on technologies such as traction battery manufacturing, advanced chemistry cell manufacturing (like lithium-ion cell, flow battery etc.), traction motor and controller manufacturing, induction charging of electric vehicle, fuel cell electric vehicles: hydrogen, electric road systems: electrification, proton-exchange membrane fuel cells: hydrogen fuel switching: bio fuels/alternate fuels. Some of the countries also indicated interest to collaborate with all categories mentioned for all technologies.

Buildings

The buildings sector is responsible for a significant share of GHG emissions and accounts for nearly 32 per cent of the global final energy consumption and 19 per cent of the energy-related CO_2 emissions accrue from this sector (IPCC, 2014). Thus, to adapt to a low carbon development pathway, the building sector provides avenues for adopting mitigation strategies. Some of the technologies that would help achieve the same have been analysed in this section in the context of BRICS member countries.

In terms of the **impact of technology development and implementation**, the questionnaire responses have been grouped into *medium to high* and *low to negligible* impact categories. The technologies having ***medium to high*** potential include, smart metering, solar water heating, desiccant cooling systems, smart home automation systems, building-integrated photovoltaics, cavity walls and others as enlisted below. The technologies with ***low to negligible*** potential include chromogenic/ switchable glazing, phase change materials, district heating/cooling, and radiant heating/cooling.

» Prefabricated Building Components

» Air-Tightness/Infiltration Control,

» External Movable Shading Devices,

» Solid-State Lighting

» Autoclaved Aerated Concrete Blocks/Fly Ash Bricks,

» Cement Stabilised Earth Clocks,

» Air To Water Heat Pumps,

» Ground And Water Source Heat Pumps,

» Automated Building Management Systems

» Demand Response

Mixed responses were obtained for Combined Cooling, Heat and Power/trigeneration; hence inferences could not be drawn for the same.

With regard to the **timeframe of technology development**, the responses indicated that in the ***short and medium-term***, the deployment of technologies like, low-Global Warming Potential refrigerant-based cooling systems, two and three-stage evaporation, cogeneration, and others as depicted in the aforementioned list .

The technologies like chromogenic/ switchable glazing, phase change materials, solar air conditioning, district heating/cooling, earth air tunnels, and heliostats with automatic tracking controls have been identified for ***long term*** implementation.

Similarly, responses indicate that **cost parity** will be reached in the ***short to medium term*** for technologies such as cavity walls, autoclaved aerated concrete blocks/fly ash bricks, cement stabilised earth blocks, low-Global Warming Potential refrigerant-based cooling systems, solid-state lighting, demand response, automated building management systems, cogeneration, and solar water heating. On the other hand, learning curves and economies of scale come into play with regard to technologies enlisted below which were identified for the ***long term***:

» Phase change materials

» Light pipes/ daylight tubes/ sun trackers

» Desiccant cooling systems

» Solar air conditioning

» District heating/cooling, earth air tunnels

» Thermal energy storage

» Direct Current motors or linear motors for energy-efficient equipment

» Heliostats with automatic tracking controls

» Double/ Triple Glazed Window Units

» Chromogenic/Switchable Glazing

» Heat-Reflective Glass

» Low Emissivity Glass

While the majority of the enlisted technologies can be **commercially deployed** in the BRICS countries, the implementation of technologies like chromogenic/ switchable gazing and air-tightness/ infiltration control were identified as being risky.

Technologies with a *medium to high* **probability of being domestically produced** *by the end of 2024* include, external movable shading devices, wall and roof insulation, cavity walls, autoclaved aerated concrete blocks/ fly ash bricks, cement stabilised earth blocks, prefabricated building components, low-Global Warming Potential refrigerant-based cooling systems, two and three stage evaporation cooling, solid-state lighting and others are same as the aforementioned list.

The technologies with a *medium to high probability* of being *produced between 2025 - 2028* are earth air tunnels, solar air conditioning, desiccant cooling systems, thermal energy storage, and Direct Current motors or linear motors for energy-efficient equipment. The technologies with *medium to high* probability to be implemented *post-2029* are light pipes/ day light tubes/ sun trackers, district heating/cooling, radiant heating/ cooling, heliostats with automation tracking controls, and building-integrated photovoltaics.

Majority of the technologies enlisted can be produced in BRICS countries barring a few exceptions such as air-tightness/ infiltration control, phase change materials which are too expensive to be manufactured locally. Several other technologies like thermal energy storage, heliostats with automatic tracking controls, and building integrated photovoltaics lack local policy support to be produced on a mass scale.

In terms of **willingness to collaborate**, the countries have expressed interest in collaborating on most technologies. The collaboration could be between educational organisations, research institutes (academics and industrial), and local equipment producers.

There is an increasing need to adopt low carbon technologies for BRICS countries to develop into a low carbon economy on the demand side. Thus, the need to decarbonise the building sectors is more pressing than before. The sector needs significant investment and policy backup to achieve the goal.

5. FUTURE WORK

Based on the analysis, the technologies that have emerged as areas of mutual interest with potential for immediate gains in the short to medium term, from the perspective of energy demand include the following:

Sector	Technology
Industry - Cement	Clinker substitution
	Waste heat recovery
	Alternative fuel and raw material use
Industry – Iron & Steel	Moisture Control Coking Coal
	Waste Heat Recovery from Electric Arc Furnace
	Steel making through Direct Reduction and Electric Arc Furnace Route
	Reuse of steel making by products
	Direct charging of hot billets from Continuous Casting Machine to rolling mill
	Smelting reduction with carbon capture, utilisation and storage
	Direct Reduced Iron- Natural gas based with CO_2 Capture
	Direct Reduced Iron based solely on electrolytic H_2
	Ancillary processes- H_2 for high temperature heat
	Sinter Plant Heat Recovery - Steam recovery from sinter cooler waste heat
	Sinter Plant Heat Recovery - Power generation from sinter cooler waste heat
	Top Pressure Recovery Turbine
	Carbon Capture in Steel production.
Transport	Electric road systems: Electrification
	Fuel Switching: Bio Fuels/Alternate fuels
	Traction Battery Manufacturing
Buildings	Air-tightness/ infiltration control
	Air-to-water heat pumps
	Automated Building Management Systems
	Building integrated photovoltaics (BIPV)
	Cement Stabilised Earth Blocks (CSEB)
	Cogeneration
	Demand response
	External movable shading devices
	Ground and water source heat pumps

Sector	Technology
	Light pipes/ daylight tubes/ sun trackers
	Low emissivity glass
	Low-Global Warming Potential refrigerant based cooling systems
	Prefabricated building components
	Smart Home Automation Systems
	Solar water heating
	Structure heating/ cooling
	Two- and Three-Stage Evaporative cooling (heat & moisture exchanger)

The aforementioned technologies may thus form the stepping stone to further work under the BRICS Technology Roadmap. BRICS member countries may begin by identifying specific projects where collaboration is possible.

Financing of many of the technologies was found to be a common barrier for member countries. Cooperation in matters of economy and finance is one of the most prominent pillars of cooperation among BRICS countries. The New Development Bank (NDB) which has an objective of mobilizing resources for infrastructure and sustainable development projects in BRICS countries may be roped in for addressing this barrier. BRICS may also consider establishing a joint platform for mobilizing investments in technologies which are critical. With regard to technologies that are already at the commercial deployment stage, collaborating with equipment producers is perhaps the next logical course of action. While for those which are still at the testing/ pilot phases, collaborating with educational institutes and academia will facilitate in speeding up the process.

The next question that arises is that of determining the mode of collaboration. One way forward could be to begin with technologies that have been identified as important in the short to medium term, wherein BRICS member countries would be playing the key role. For the technologies that have been classified under the category of long term implementation, perhaps it would be a good idea to first develop country level policies, assess the demand and wait for the technology to mature further. In the meantime, examining mutual best case scenarios with regard to deployment policy, manufacturing policy etc. may prove to be fruitful. Moreover, the BRICS Research Directory that has been prepared this year by the Indian Presidency, can be put to use for understanding the importance of short term technologies and their adoption in differing country specific contexts. It will also aid in exploring long term technologies by delving deeper into discovering supportive policy structures needed, identifying conditions under which technologies were able to mature etc.

REFERENCES

China. (2018). *The People's Republic of China Second Biennial Update Report on Climate Change* .

Garde, R., Jain, A., Jaiswal, S., Gombar, V., & Traum, D. (2020). *India's Clean Power Revolution: A success story with global implications*. Bloomberg NEF.

IEA. (2020). *Bioenergy Power Generation*. Paris: IEA.

IEA. (2020). *World Energy Investment 2020*. Paris: International Energy Agency.

IEA Clean Coal Center . (2018). *Reducing China's Coal Power Emission with CCUS Retrofits*. IEA Clean Coal Center .

International Energy Agency. (2020). *India 2020: Energy Policy Review*. IEA Publications.

International Energy Charter. (2018). *China Energy Efficiency Report*.

IRENA. 2017. REMAP 2030: Renewable Energy Prospects for the Russian Federation. Abu Dhabi: IRENA.

Lucon O., D. Ürge-Vorsatz, A. Zain Ahmed, H. Akbari, P. Bertoldi, L.F. Cabeza, N. Eyre, A. Gadgil, L.D.D. Harvey, Y. Jiang, E. Liphoto, S. Mirasgedis, S. Murakami, J. Parikh, C. Pyke, and M.V. Vilariño, 2014: Buildings. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA

MOEF&CC. (2021). *Third Biennial Update Report to the United Nations Framework Convention on Climate Change*. Ministry of Environment, Forest and Climate Change, Government of India.

National Productivity Council. (2017). *Best Practices Manual for Reducing GHG Emissions in Iron & Steel (Sponge Iron) Sector*. National Productivity Council.

South Africa (2019). *South Africa Third Biennial Update Report to The United Nations Framework Convention on Climate Change* .

UNFCCC (2020). Report on the technical review of the fourth biennial report of the Russian Federation

UNDP. (2019). *Emissions Gap Report 2019*. United Nations Environment Programme.

ANNEXURE I

Outcomes of India's BRICS Presidency

This year the Presidency has tabled three key outcome documents namely:

» BRICS Energy Report

» BRICS Energy Technology Report

» BRICS Energy Research Directory

Numerous meetings were convened over the course of the past few months, namely the Workshop on Energy Efficiency & Clean Energy, First and Second Senior Energy Officials' Meeting, Working Group meeting on Energy Efficiency and many more. Member countries also expressed their interest of leading/co-leading priority areas with regard to 'Roadmap for BRICS Energy Cooperation up to 2025'. These have been tabulated below.

Table 13: Priority areas of cooperation within the BRICS ERCP and country leads

Type	Priority Area	Expression of Interest
Cross Sectoral	Research on energy sector development of BRICS countries	Russia
	Technology	Russia
	Energy Efficiency	Brazil and India
Sectoral	Natural Gas, including Liquefied Natural Gas (LNG)	Russia
	Renewable energy	Brazil, India, China
	Bioenergy and Biofuel	Brazil
	Sustainable Transport	India
	Smart Grids &Storage	India, China
Newly Proposed	Standards and Regulation	
	Hydrogen	Proposed by Russia and Brazil
	Financial support for Energy RD&D cooperation	Proposed by India

Topics for which member countries did not evince an interest included Digitalization, Capacity Building and Coal. Three topics were then newly proposed in lieu of the same.