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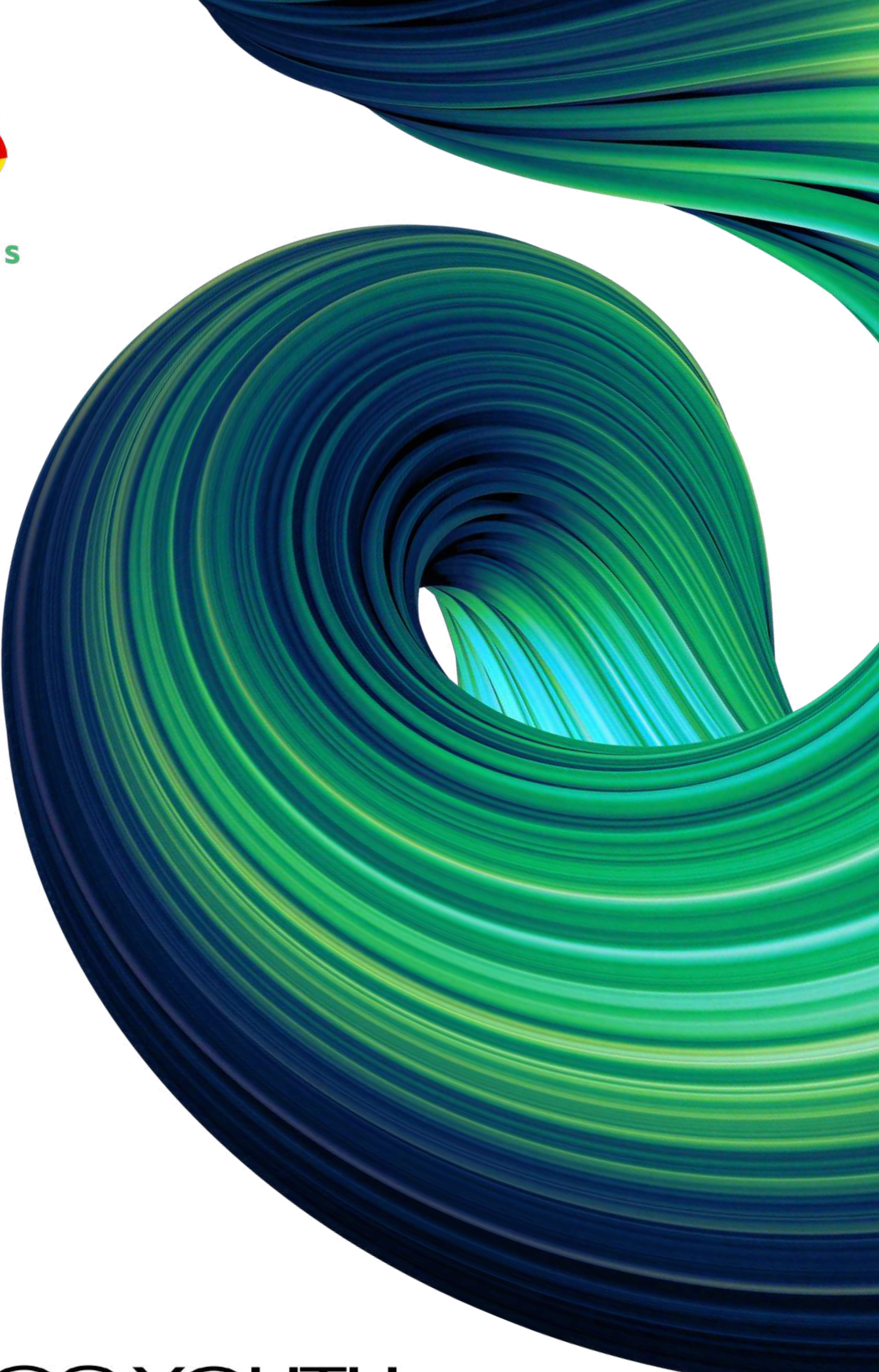

BRICS 2020 YOUTH ENERGY OUTLOOK

BRICS YEA

Introducing

BRICS 2020 YOUTH ENERGY OUTLOOK

The third edition of the leading international research on energy development of BRICS countries prepared by young researchers and scientists

INITIATIVE APPROVED
BY BRICS ENERGY MINISTERS

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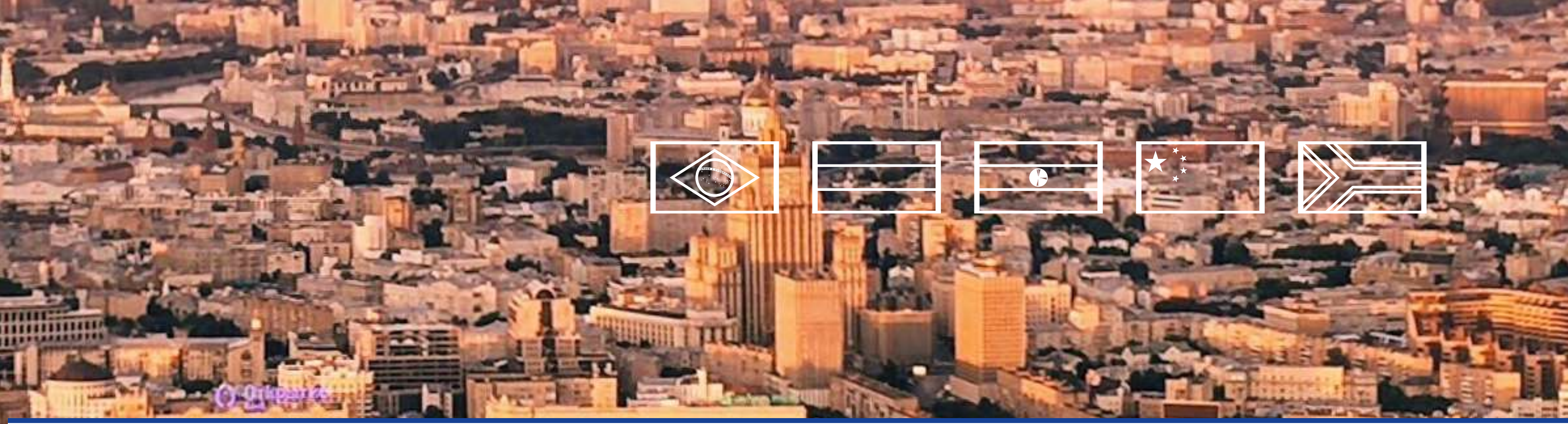

Inside the Outlook

Welcome _

Message from the Chairperson

In front of you a result of hard work of numerous researchers, professionals and students aged 35 and below from BRICS (Brazil, Russia, India, China & South Africa) who believe that there is a future for BRICS energy cooperation.

I will not hide my excitement between the lines and encourage you to read the third edition of our flagship project which is aimed to provide broader understanding of the BRICS energy sectors' pathways for the future. It is obvious that long-term sectoral planning cannot be comprehensive if its developers neglect the standpoint of younger generation of professionals, research fellows and students. We, as BRICS Youth, make a significant contribution to our countries' energy cooperation by sharing today our vision for the future that should help the present leaders make decisions in line with the decisions to come.

The BRICS Youth Energy Outlook 2020 is one of vivid examples that the BRICS Youth stays committed to the decision they made 5 years ago - to cooperate on energy matters and drive this area of BRICS youth cooperation forward. We will stay open to all relevant stakeholders and develop this format of collaborative annual study to meet the highest standards.

As I mentioned, the Outlook 2020 is presented within' the year of the 5th Anniversary of the BRICS Youth Energy Agency. I would like to thank everyone who has been committed to this project throughout the years as you are the reason why the Outlook 2020 is one of the very few international energy studies developed by young people and highly recognized by decision-makers across BRICS countries.

Alexander Kormishin
Chairperson
BRICS Youth Energy Agency

Preface _

Three years ago the BRICS Youth Energy Agency announced a new area of our activities which was aimed at delivering research on the prospective energy trends of BRICS countries from the standpoint of young people. This initiative was supported by a set of core beliefs and our infinite commitment. This year, marking the 5th anniversary of the Agency, we challenged our previous achievements and aimed at significant increase of BRICS Youth's representation in our first-of-a-kind BRICS Youth Energy Outlook. Did we succeed? It is up to you to decide.

All the five BRICS countries, being sovereign, self-sufficient and technologically advanced states, are among the ten largest world economies. There are both energy producers and energy consumers among the five countries, each country has its own advantages in resource endowment and technological innovation. As never before energy, scientific and technological cooperation within BRICS is relevant nowadays. For successful cooperation, it is essential to understand what technologies are the most required now and what common interests and challenges the BRICS countries share. We studied and analyzed the most acute topics of the day relevant to BRICS countries and offered 18 of them to our young researchers.

BRICS has always been an important platform for strengthening cooperation and protecting the common interests of large emerging markets and economies. Thanks to the joint efforts of the five states' leadership, the spirit of openness, inclusiveness and mutually beneficial cooperation, BRICS has become an important group firmly supported by member countries in order to strengthen unity and joint problem-solving. Now it's time for youth to jump in, become active members of the discussions and have their voices heard better and clearer. Contribution to this process is our great mission.

Promoting and strengthening external contacts is one of the key areas for development of BRICS countries, that is why the topics of our research are very ambitious and challenging to discuss. In the Outlook 2020 we tried to unite the vision of our young researchers, namely research fellow and students from leading BRICS universities, members of civil and youth organizations, and the expert point of view aiming to get the best possible outcome. In the beginning of 21st century the BRICS Youth witnessed strong changes in technological and geopolitical landscapes, which may be characterized as the dawn of a new universal technological revolution. The chosen topics are closely related to those changes as the development of Industry 4.0 technologies stimulate countries to achieve national and global goals together. I hope that all the readers will find the present Outlook 2020 a useful contribution to their own discussions and thinking.

Now it takes pleasure and pride to present to you the flagship project coordinated by the Analytical Centre of BRICS Youth Energy Agency. As it was mentioned, BRICS youth energy cooperation is our main focus and this Outlook is the result of many-hours-long research activities delivered by more than 180 immediate developers from all over the world and the BRICS YEA core team.

Due to the impact of the latest challenges we are standing at the crossroad of the pre-COVID and post-COVID eras. The BRICS countries made every effort to overcome the effects of the COVID-19 pandemic and, thus, fully contributed to the economic recovery and created a model for building a new type of relationship between major powers around the world. But how will they manage to drive forward the emission reduction plans? Which role will be attributed to the renewables in the development of energy sector? Is the ecologization of cities still an acute issue? What are the current and future trends in electricity transmission and storage? How will change the traditional energy sources and what is the role of nuclear energy today? If you are interested in discussing of at least one of the questions, you are welcome to start reading and analyzing the Outlook 2020.

Finally, I would like to thank the contribution of the excellent team of our editors, who has done an excellent job of assembling data, interpreting it, building projections and drawing lessons from them, the Chairperson of the Agency and all the rest who supported our great plans. We welcome any feedback on the content and how we can improve it. Enjoy the journey through the pages of the present Outlook!

Y. Delyukina

Yulia Delyukina
Head of Analytical Centre
BRICS Youth Energy Agency

Acknowlegments _

This year's ***BRICS Youth Energy Outlook 2020*** is a result of ambitious effort delivered jointly by the Analytical Centre of BRICS Youth Energy Agency, developers from all over the globe with invaluable support of governments, institutions and organizations. *The Outlook 2020* was prepared by a team led by Head of Analytical Centre Ms. Yulia Delyukina (BRICS YEA) who served as task team leader of the project and coordinated activities at different stages of *the Outlook's* development. The overall guidance was provided by Chairperson Alexander Kormishin (BRICS YEA) who has also took over the design and typographic formatting of the present edition. The present *Outlook 2020* has been developed pro-bono and the printing expences have been covered by the Russian BRICS Chairmanship 2020.

The core team was composed of Arina Lutskaya, Polina Chulkova, Margarita Kuzmina, Maria Gorina, Maria Buyanova, who served as chief regional coordinators for *the Outlook 2020*, executed communication with the developers and edited the submitted research papers. The chief coordinators were assisted by Yulia Plekhanova, Yana Subbotina, who served as editoral coordinators and their mission was to provide their experise for the structing texts in accordance with the base methodology. *The Outlook 2020* enjoyed a media coverage which was delivered by Alexandra Agababova, who was in charge of project's press-secretary. We would also like to thank Alex Smirnov who made Instagram Masks for the present edition and Denis Laskin for assistance in typografic formatting.

The execution of this project is not possible without associate professors, docents, students and professionals who represent 42 universities and organisation from BRICS countries. Especially, we would like to acknowledge the JIS College of Engineering, Thapar Institute of Engineering and Technology (India), University of Pretoria, Senamile Masango Foundation (RSA), University of São Paulo (Brazil) for their committent to the project as two-year participants. We also acknowledge the contributions of teams representing the Indian Institute of Technology (Indian School of Mines) and University of Brasilia for their active approach to the initiatives within the project and EnergyC (Brazil) for a remarkable level of preparations done for their submitted paper.

Also, the core team is grateful to the research groups who represent the other universities and who completed their studies in accordance with the provided methodology that made possible to provide scenario- and strategy-based recommendations: Gubkin Russian State University of Oil and Gas, Kutafin Moscow State Law University, Moscow State Institute of International Relations, National Research Ogarev Mordovia State University (Russia), National Institute of Technology Srinagar, Girijananda Chowdhury Institute of Management and Technology (India), the University of International Business and Economics, Nanjing University of Science and Technology, Sichuan International Studies University, Wuhan Textile University (China), Durban University of Technology, University of Witwatersrand, University of South Africa, University of Kwazulu-Natal, Tshwane University of Technology (South Africa) and University of California (USA), University of Twente (Netherlands), Dalhousie University (Canada).

The Outlook 2020 as a leading energy study for and in the interests of the BRICS nations has been acknowledged by energy and youth policy state authorities. We acknowledge the endorsement of the initiative by the BRICS Energy Ministers following their official meeting on November 11, 2019 on the eve of the 11th BRICS Summit in Brasilia (Brazil). We are grateful, in particular, to the the Ministry of Energy of the Russian Federation and the Department of Mineral Resources and Energy of the Government of the Republic of South Africa who actively participated in the preparations of *the Outlook 2020* at various stages. The team also benefited from endosement of the Russian BRICS Chairmanship 2020 coordinated by the Ministry of Foreign Affairs of the Russian Federation.

We would like to acknowledge a growing support for the project from various stakeholders representing BRICS companies and public organisations who have pronounced their interest in the project and considered cooperation in the years to come, and we are looking forward to it.

Finally, the team apologizes to any individuals or organizations that contributed to this Report but were inadvertently omitted from these acknowledgments.

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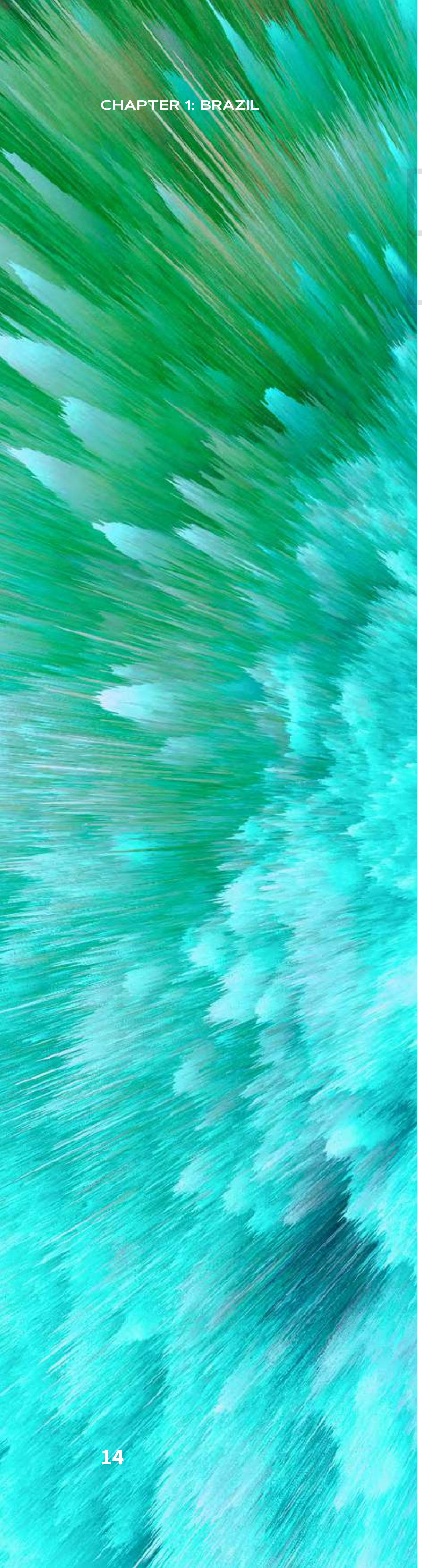
BRAZIL

CHAPTER 1

FEDERATIVE REPUBLIC OF BRAZIL



BRAZIL

Editorial Summary _

Ms. Arina Lutskaya
Coordinator: Brazil
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Brazil has the largest power system in LA and the 9th largest electricity market in the world. In the past few years, new renewable sources, such as wind and solar, grew fast in the country's power generation.

The Brazilian teams chose the following topics: «Energy Storage in Brazil: a first step towards Smart Storage», «The eco-transport of the future. The influence of electric cars on energy efficiency indicators and needed infrastructure for their unimpeded operation» and «Smart city: energy efficient cities. Perspectives, opportunities and problems of creating such cities on the scale of Brazil» because everyone knows that this country is the world's largest player in the renewable energy market (88.8% electric power comes from renewable sources) and the country's economy is becoming more energy efficient. The topics related to non-traditional renewable energy sources, space power stations, air pollution in large cities were not popular, because in these areas everything is stable or the country is not distinguished by special opportunities in it.

Energy Storage in Brazil: a first step towards Smart Storage

Definition

Energy storage is a way of assuring more participation on the renewables in the energy supply, while does not require too much more installed power to do so with reliability. From the distributed generation point of view, energy storage also provides independence from grid connection and resilience for households that are distant from the greater centers. Moreover, it is an innovative technology to increase grid security by integrating new energy resources, replacing outdated infrastructure, and providing backup power during outages.

Smart storage in relation to energy refers to the use of new energy storage technologies. According to MassCEC and Doer, the technologies of stored energy can be classified into five groups according to the form of storage: mechanical, electrical, thermal, electrochemical and chemical. The leading technologies of energy storage in development in Brazil are: (I) Conventional batteries (II) Flow batteries, (III) Fuel cells, (IV) Power-To-Gas (P2G) and (V) Latent heat systems.

The current situation of energy storage in Brazil

Brazil has the largest power system in Latin America and the 9th largest electricity market in the world. In the past few years, new renewable sources, such as wind and solar, grew fast in the country's power generation. In contrast with this Brazilian context, energy storage is still underdeveloped. There is no regulatory framework in Brazilian energy storage, which impacts negatively on the promotion of innovation in the electricity sector. However, in 2015 the Brazilian Energy Quality and Storage Association (ABAQUE) was created which promotes the implementation of energy storage processes in Brazil and stimulates the modernization of the Brazilian Electricity Sector. Moreover, there is no commercial and labor data available about this sector in Brazil.

Brazil is recognized internationally for its integration capacity due to the National Interconnection System (SIN). Recently, Industry 4.0 has been used to make storage "smarter" in Brazil, leading to a better grid balance during periods of high intermittent generation as well as a reduction in its restrictions. Artificial intelligence (AI) is gradually being used for predictive maintenance of fleets of intermittent sources, increasing reliability, and reducing downtime. Through the Internet of Things (IoT), it is already possible to measure the use of traditional batteries, allowing their connection to the users, and delivering performance and functioning reports, as well as allowing the remote monitoring and real-time of all batteries.

Smart Storage: Brazilian Case Studies

After conducting a survey of the main Brazilian companies involved with energy storage it is noticeable that energy storage is expected to become an increasingly strong trend in the coming years. 1)For example, such companies as CEMIG and Alsol opened together the first photovoltaic hybrid plant that combine photovoltaic generation with storage systems in consumer units, which ensures the quality of distribution even at times with higher consumption. 2) The São Francisco Hydroelectric Company (Chesf) developed national technology in solar thermal generation of electric energy, internationally known as CSP (Concentrated Solar Power). Its main advantage is the possibility to store heat, generating electricity further when the sun is no longer available. 3) Eletrobras Furnas will create a hybrid energy storage system consisting in lithium-ion batteries and hydrogen obtained by electrolysis and stored in pressurized tanks, powered by surplus electrical energy from floating photovoltaic panels located on the reservoir lake of the Itumbiara Hydroelectric Plant. 4) In Brazil, the electrical energy supply relies mainly on hydropower plants. The national grid operator (ONS) uses mathematical models to predict the price of energy based on the rain that falls over the rivers and the level of water in the reservoirs or the needs of energy (and water) the population may have. The models used are called DESSEM, DECOMP and Newave. The more digitized the grid is, the better this control will be, and the existent reservoirs can be better used as storage.

However, Brazil could face significant struggles in promoting R&D to create and develop smart technologies for energy storage nationwide, since the level of innovation is stagnated and needs improvements due to the slow recovery of the country.

Current attempts in increasing the participation of energy storage in the Brazilian market are still shy and accurate, though promising. The existing technologies are already satisfactory to make this possible at a lower cost than before and by using resources already available. Brazilian government must now reinforce the importance of the energy sector and acknowledge that energy storage systems must be developed, taking into consideration the commitment taken by international instruments.

The eco-transport of the future. The influence of electric cars on energy efficiency indicators and needed infrastructure for their unimpeded operation

Description and relevance

Electric vehicles (EVs) are considered a key technology for the energy transition in the world. However, currently, the insertion of this technology in Brazil occurs in a slow and macro-regional manner. Electric and hybrid vehicles in Brazil represent 0.03% of the total national road fleet in 2019, mostly represented by the South-Southeast regions. The growth of a country's vehicle fleet is directly related to the level of economic development. This consists of infrastructure problems, household income levels, and legislations that promote the expansion of the EV-market.

Together with the technological advances in lithium-ion batteries, the configuration of hybrid electric vehicles may present a promising trend towards decarbonization, mainly by aligning electricity production with the use of biofuels which subsequently leads to a decrease in respiratory diseases. Among the economic advantages of EVs, some are the reduced maintenance costs and the low refueling costs due to the price/consumption of electricity in the country, which is half of the amount spent on fuels such as ethanol or gasoline.

Risk analysis and perspectives

1) The main risk inherent in the insertion of electric vehicles in Brazil concerns the absence of national public policies and legislation that encourage the development of business models that can sustain the entire EV complex, from its manufacture to infrastructure and circulation on the streets. The high articulation capacity of the sector of sugar, alcohol, and automotive (fossil fuels) in Brazilian institutions delays the prospect of replacing combustion cars with electric and hybrid technology. 2) Another main issue is the power grid infrastructure – it can suffer an impact on the electricity distribution grid. The biggest concern is regarding the highways, where there is the need to install fast-charging points. An alternative would be purchasing EVs for personal use in urban areas. Moreover, due to the presence of garages, planning the charging infrastructure is even more difficult. 3) The instability of the Brazilian currency's exchange rate against the dollar brings insecurity to investors in view of the sudden increase in imports costs of infrastructure components and EVs, therefore discouraging their acquisition on a large scale. 4) In addition, there is low technical workforce capacity for the development and maintenance of this technology in Brazil. 5) It is known that electric vehicles are still substantially more expensive than vehicles with internal combustion due to issues related to battery technology. Although, the sharp drop in the cost of the battery is manageable due to the scale increase and technological development of the battery. 6) another risk observed is the environmental impact of lithium extraction in order to manufacture EV batteries 7) Socioeconomic inequality limits the expansion of technology in less developed regions and with less purchasing power. High cost of EVs prevents mass adhesion by the population, most buy popular cars.

Despite all the benefits mentioned about this technology, the massive adoption of EVs in Brazil is still seen as distant. Having considered particular factors in the country it can be concluded that that one of the best options to insert electric cars and vehicles in Brazil would be using hybrid technology. Ethanol as a fuel used in this technology compensates for the gas emissions, since it also reduces the effect of carbon dioxide on nature through the sugarcane crop cycle in Brazil. One can start using the above-mentioned technology in public transportation, in this manner, cities and consumers would adjust progressively, allowing further a more favorable and appropriate environment for the successful insertion of electric cars in Brazil. Moreover, the main point to increase consumption would be the drop in the final price and it would be essential to stimulate the national production of vehicle components.

Smart city: energy efficient cities. Perspectives, opportunities and problems of creating such cities on the scale of Brazil

Smart Cities, in general, are about solving problems of urbanization in order to provide a better quality of life to its citizens through innovative technologies, while integrating energy, transport, ICT and other fields to that end. Prospects for the development of Smart Cities involving the use of technology must include government effort to provide digital inclusion for the overall majority of the population, a more efficient delivery of public services, the elaboration of new forms of citizen participation in the decision-making of local authorities as well as enhancing transparency and accountability.

Leading cases in Brazil

In Brazil, there is a National Plan of Internet of Things according which IoT features would stimulate a potential economic income of US$ 27 billion. The National Plan concerning Smart Cities is divided in mobility (the Plan of Immediate Actions in Transport and Traffic in Fortaleza14 – PAITT, intends to optimize parking space, reducing traffic jam and GHG emissions), public security (the city of Rio de Janeiro implemented the Rio Operations Center. This center, which has 30 agencies that access cameras and sensors, improving traffic and emergency management), energetic efficiency (Belo Horizonte - the first capital to carry out the modernization of public lighting, which should allow the incorporation of technologies such as wi-fi and cameras) and innovation (In Águas de São Pedro there were smart parking and smart street lightning provided by Ericsson, smart security and surveillance cameras provided by Huawei. ISPM was responsible for IoT Platform and health services, remote monitoring of clinical symptoms and schedule appointments).

Smart city projects are concentrated in some regions, especially in South and Southeast capitals. Among non-capitals, projects are concentrated in São Paulo state countryside and there are much fewer cities from Northeast.

Risks of development

In the Brazilian context there are three groups of limiting factors. The first group embraces the culture of governmental decisions and bureaucracy, which frequently delays solutions acquisition and limits smart cities' market development. Another problem is the lack of regulation in current Brazilian legislation. The second group includes high tax burden, lack of tax breaks, credit and funding lines that could stimulate the market and promote investments. The last group evolves the competition with foreign companies, considering the quality level of products in the country and high input costs due to the dollar exchange rate variation. In addition to that, the sector faces difficulties with the qualified technical staff and expertise on the side of the demand.

It is also necessary to understand the different development levels of Brazilian cities. There are four levels of cities: aspirants, beginners, connected and ready. This classification shows the increasing risk for the smart cities sector according to the lack of human, economic and social development, investments capacity and infrastructure. The aspirants and beginners represent higher risks to the implementation of smart cities solutions whereas the connected and ready cities are potential low-risk markets.

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SMART CITY: ENERGY EFFICIENT CITIES. PERSPECTIVES, OPPORTUNITIES AND PROBLEMS OF CREATING SUCH CITIES ON THE SCALE OF BRAZIL

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Analysis of smart cities in Brazil

1. Describing the topic

The first use of the term ‘Smart City’ dates back to early 1990s, associated with “an urban development more and more dependent on technology and on innovation. More recently, Greta and Cresta[1] discuss the existence of three different perceptions about Smart Cities, one that is (1) techno-centered, with emphasis on new technologies and infrastructure based on ITC [information technology communications], where citizens become ‘end-consumers’ directly affected by the improvements and efficiency of the urban environment (2) human-centered, where attention is paid to human capital (represented by a well-educated citizenry and labour force) as the defining element of a Smart City, and finally (3) integrated, represented by a mixture of the two previous approaches, integrating the technological and the humanist aspect of a Smart City, in order to “create the suitable condition for a continuous and ongoing process of growth and innovation”. The end goal of a Smart City, according to the integrated approach, consists in the use of ICT to enhance the general urban performance and, more importantly, the quality of life of its citizens.

Smart Cities, in general, are about solving problems of urbanization in order to provide a better quality of life to its citizens through innovative technologies, while integrating energy, transport, ICT and other fields to that end[4]. Moreover, a Smart City also has goals that include economic growth, better work opportunities, the establishment of an environmentally responsible and sustainable framework for social development, a more adequate management of public transportation and use of telecommunications technology to address people’s needs, etc.

2. Prospects for The Development of The Smart Cities Until 2035

Prospects for the development of Smart Cities involving the use of technology must include government effort to provide digital inclusion for the overall majority of the population, a more efficient delivery of public services, the elaboration of new forms of citizen participation in the decision-making of local authorities as well as enhancing transparency and accountability.

Other prospects to be taken into consideration revolve around the implementation of two different models of Smart Cities in the foreseeable future. One such model regards the delivery of a specific aspect of a Smart City for a larger number of people (a ‘some for all’ model), while the second model deliver all the aspects and dimensions of a Smart City for a limited amount of inhabitants concentrated in small geographical areas (a ‘all to some’ approach).

In general, according to different authors, a Smart City`s use of telecommunications technology to address the people’s needs is a sine qua non condition to evaluate the success of its implementation[7]. In Sao Paulo for instance, Brazil’s (and

South America’s) largest city, a number of Smart City’s experiments within the state demonstrated “a positive relationship between innovation (science and technology) and the economic well-being”[8] of the people directly affected.

What might come in hand to help expedite the development of Smart Cities concerning the area of telecommunications is the Internet of Things (IoT), a “global infrastructure for the information society that enables advanced services through the interconnection between things (physical and virtual), based on ICTs (free translation)”[9]. In Brazil, this technology is expected to generate an impact of “US $ 50 to US $ 200 billion per year, representing about 10% of the Brazilian GDP (free translation)”.

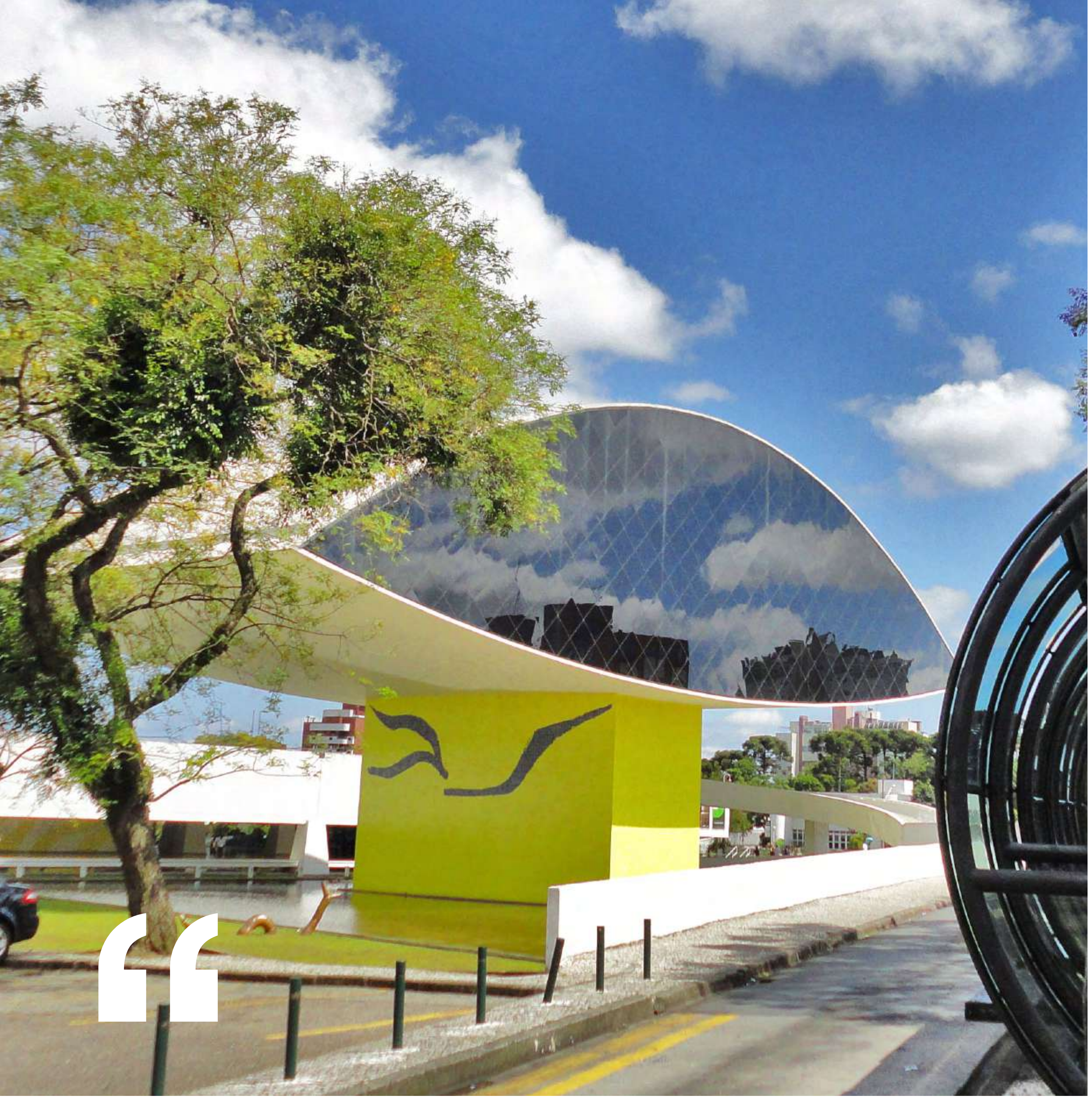
3. Leading cases in Brazil

In Brazil, there is a National Plan of Internet of Things, enacted by Decree 8.234/2014. In order to active this plan, Ministry of Science, Technology, Innovation and Communication signed a cooperation agreement with Brazilian Development Bank (BNDES) to conduct a joint study about IoT, which was carried out by McKinsey and Telecommunications Research and Development Center (CPqD)[11]. According to BNDES[12], cities’ IoT features would stimulate a potential economic income of US$ 27 billion. To support the National Plan, 73 initiatives were mapped, with São Paulo and Rio de Janeiro concentrating 63% of the total[13]. The National Plan concerning Smart Cities is divided in mobility, public security, energetic efficiency and innovation.

With regard to mobility, we can mention the Plan of Immediate Actions in Transport and Traffic in Fortaleza[14] – PAITT, part of Fortaleza Urban Mobility Plan. It has seen, in the last years, an accelerated growth in the car fleet, so that the transport sector was responsible for 61% of the emissions of 2014. Its Urban Mobility Plan, developed with McKinsey & Company, started in 2014. It increased cycle lanes and enacted the Bicicletar project, sponsored by the private sector. It brought bicycles rented through electronic tickets. The plan also contains restrictions on parking, digital parking meters and electronic sensors to identify parking spaces using mobile applications. It intended to optimize parking space, reducing traffic jam and GHG emissions[15].

In terms of security, the city of Rio de Janeiro[16] implemented the Rio Operations Center. This center, founded in 2010, has 30 agencies that access cameras and sensors, improving traffic and emergency management[17]. After "an unusually strong rainstorm hit the city”, which caused “hundreds of mudslides in the city’s famous hillside favelas”, systems have been implemented that allow “representatives of city departments to monitor the city in a large control room, where city officials have access to 560 cameras and other sensors and monitor a detailed computer model of weather forecasting”. The system is showing results, as the number of deaths from mudslides decreased in Rio[18].

Belo Horizonte[19] is a case concerning energy efficiency. All Brazilian cities were forced to take responsibility for the



“Curitiba is the smartest, the most connected and the most virtuous city of Brazil in the state of Paraná. The cities development has always followed the path of sustainability ”

maintenance and modernization of public lighting with ANEEL Resolution 414/2010. Their lack of financial and organizational capacity led to the establishment of public-private partnership. Belo Horizonte was the first capital to carry out this type of operation whose total value was over 991 million reais and started in 2017. The 20 years contract started replacing 182 thousand lighting points by LED luminaires. The installed technology should allow, at a later time, the incorporation of technologies such as wi-fi and cameras20.

Concerning innovation, an important experience has taken place in Natal21 22. The challenges of transforming this city into a smart city were mainly to ensure the right to come and go and improve citizens' participation in public policies. Therefore, Natal City council supported by public and private sectors established a Smart City Consortium, coordinated by Metropole Digital Institute. So, it created a mobile application and an informatics system that stores tourist data and provides ways to manage tourist information. Basically, it consisted in using technologies to deliver touristic services and in exploring Big Data concerning it. The city was one of the host cities during FIFA World Cup 2014 in Brazil and used all the information produced to plan traffic, public mobility, and problem detection.

Also referring to innovation appears Águas de São Pedro, which is a 3,300 inhabitants municipality in the State of São Paulo with high HDI. 560,000 US dollars were invested in 2015. There was no financial support from the city mayor. Among all the features were smart parking and smart street lightning provided by Ericsson, smart security and surveillance cameras provided by Huawei. ISPM was responsible for IoT Platform and health services, remote monitoring of clinical symptoms and schedule appointments. It also involved local startup companies, as well as NGOs 23.

If it is to say, all of these projects have some characteristics in common. These are mainly pilot projects by concessionaires, telecommunication or energy operators, due to the possibility of transferring ownership of these public services and the new public-private partnership models. Among the most common problems, there are issues about security threats and regulation and privacy challenges, which were related by Glancy24, in a study concerning the United States. In Brazil, these problems shall be regulated by the Civil Rights Framework for the Internet and the Law on Access to Information.

More specific Brazilian problems can rely on defining the public-private partnership proposals, in order to search for best results, following a large legislative apparatus. Another challenge is the lack of resources, low technical capacity of municipalities, low capacity for long-term planning and electoral cycles and the predominance of isolated projects that do not demonstrate a strategic vision of public policy.

Smart city projects are concentrated in some regions, especially in South and Southeast capitals. Among non-capitals, projects are concentrated in São Paulo state countryside and there are much fewer cities from Northeast26.

Finally, lack of funding is also an issue. Most of the contributions received by research centres for smart cities projects were up to R$ 100,000. A small portion received above one million reais from public funding agencies, provided by BNDES and FINEP27. About 45% of R&D spending is made by private individuals.

4. Risks of development of smart cities

Risks concerning the development of Smart Cities currently involve, in a political and legal aspect, matters of regulation, public governance and the relationship involving citizens, local authorities and institutions implementing such projects 29. Anand, for instance, argues that “from a political economy perspective […] in a context where access to control of governance institutions is unequally distributed there will be conflicts and Smart City agendas will be captured by those in power for their own advantage”30. In a socio-cultural and economic aspect, on the other hand, Smart Cities face challenges in terms of acquiring the confidence of citizens directly affected by their establishment, as well as regarding the adequate and sufficient financing of innovative, sustainable, and inclusive projects.

As reminded by Anand “in ideal circumstances, Smart City projects are no different to other public infrastructure projects and thus should be subject to cost benefit analysis”31, once financially unsustainable projects might in fact jeopardize the development of Smart Cities in a number of circumstances. Other matters of concern also involve ensuring data security and privacy of citizens who participate in projects of data collection and sharing, as well as how to overcome digital divide and inequality experienced in many countries, Brazil included32.

In the Brazilian context, some executives related to the smart cities sector pointed out, in a research by Getúlio Vargas Foundation, three groups of limiting factors which turn into the referred risks to the sector in terms of supply. The first group embraces bureaucracy, which frequently delays solutions acquisition and limits smart cities' market development in Brazil, and the culture of governmental decisions through which political actors historically hesitate, or do not even consider, in investing on innovative and high-tech solutions to solving urban problems.

Another problem is the lack of regulation in current Brazilian legislation as well as the absence of adequate public policies in this matter. The second group includes high tax burden, lack of tax breaks, credit and funding lines that could stimulate the market and promote investments. The last group evolves the competition with foreign companies, considering the quality level of products in the country and high input costs due to the dollar exchange rate variation. In addition to that, the sector faces difficulties with the qualified technical staff and expertise on the side of the demand33.

According to the analysis of these elements, it is also necessary to understand the different development levels of Brazilian cities in order to identify potential risks to the sector in Brazilian cities. In this concern, the research determined four levels of cities: aspirants, beginners, connected and ready34. This classification shows the increasing risk for the smart cities sector according to the lack of human, economic and social development, investments capacity and infrastructure. The aspirants and beginners represent higher risks to the implementation of smart cities solutions whereas the connected and ready cities are potential low-risk markets to the implementation of technologies related to the smart cities sector.

According to this classification, aspirants include 686 cities with an average population of 10.4 thousand35. These municipalities are largely underdeveloped and have poor connectivity infrastructure, low capacity of investments and absence of favourable environment for innovation. They also do not have any online public service available. This group of cities has no smart cities solutions and any kind of support to implement such solutions.

The beginners are represented by 1762 Brazilian towns with an average population of 13 thousand (11% of the population)36. Albeit the fact that these towns are more developed and have a low to medium connectivity infrastructure, some capacity of investments, they still do not have a favorable environment for innovation. In sum, they may face difficulties in structuring projects and making partnerships.

The connected cities encompass 1.316 municipalities with a population average of 48.5 thousand people and reach 31% of the Brazilian population. It is worth mentioning that five capitals of states are part of this group - Belém, Boa Vista, Maceió, Natal and São Luís37. These cities have good connectivity infrastructure, good investment capacity and an environment of increasing innovation. As an aspect of increasing the environment for innovation, there are universities and more technological companies in these cities. This group represents lower risks for the implementation of smart cities solutions with more possibilities of partnerships and financial support, as well as an unexplored market for such solutions. However, the smart cities project may not be considered as priority in public policies and projects could be at risk of being abandoned if policymakers do not manage to grant continuous financial and logistical support. Other challenges such as the lack of incubators, technological parks, qualification of technology professionals and difficulties in structuring bidding processes for smart city projects can turn into serious risks to the development of the smart cities sector.

In the ready group, there are 243 counties with an average population of 354.8 thousand people and 42% of the Brazilian population. In this group there are 21 state capitals38. These cities have good connectivity infrastructure, high capacity of investments and a very active environment of innovation. These cities concentrate the largest number of technology companies in the country, a greater number of universities, and government departments dedicated to information technology. Despite having favorable features, these cities face some problems of financial availability, difficulties in structuring bidding processes aimed at smart city projects and qualification of technology professionals. Albeit these potential risks that must be tackled by the smart cities sector, the cities have the widest potential on development of smart cities solutions and thus incur in the lowest risks among all the groups mentioned.

Scenarios

Quality scenario analysis of the chosen research topic in Brazil. Analysing smart cities in Brazil in the different scenarios.

Negative

For Brazil, it is essential to have a comprehensive plan on smart cities development, as analyzed above in previews topics. However, it is necessary to highlight some obstacles the country may face in implementing smart cities projects.

In a negative scenario, there are *three main barriers* that undermine the Smart City sector in Brazil. *The first one* is an out-of-date bureaucracy that extends the implementation of new technologies and increases its costs as the majority of local governments cannot afford it. As a result, just a few of them would be concluded with outdated technology. *The second barrier* is the lack of investments. With a low level of investments, which comes mostly from the private sector, they are not enough to develop and effectively introduce smart cities solutions in the citizens' lives. Both Federal and local governments should stimulate the smart cities sector by providing public investments, incentives to the private sector and establishing public-private partnerships. In a negative forecast, the lack of investment also fails to decrease the high costs and suppresses innovation. *The third element* is the lack of a skilled labour force, as in Brazil there are governmental and private investments for training professionals. Hence there are not enough professionals and experts to dedicate themselves in developing new technologies and solutions in this area.

The combination of the above-mentioned barriers, which are interdependent, effectively undermine smart city development and not allow Brazil to develop its own solutions in smart city management and technology.

Conservative

According to the Brazilian Development Bank, "in Brazil, the proportion of households connected to the internet is well below that of developed countries, reaching just 54% of households; and, in rural municipalities, this indicator is 26% (free translation)39". In this sense, many municipalities do not have access to technology and internet because they are not a viable alternative for private investment, leaving part of the country incapable of developing smart city projects.

In this context, it is important to resume, as already mentioned, the inequality between Brazilian municipalities that must be faced by Brazil. On the one hand, there are capitals, mainly, but not exclusively, in the Southeast and South, which have good socioeconomic indicators and enjoy good access to the internet and are capable of making technologies available to citizens. Along with them, there are municipalities of medium size and with reasonable socioeconomic indicators, as well as small municipalities also capable of initiating a digital inclusion process. However, these municipalities are concentrated mainly in the South and Southeast regions.

On the other hand, there are a great number of municipalities in the Northeast, which despite having average socioeconomic indicators, do not have technology. In spite of the inequality among Brazilian regions, it is important to mention that there are poor and economically fragile municipalities with difficulties in providing technologies spread in all regions of the country.

Another aggravating factor is the pandemic generated by the coronavirus, which has been diverting state investments to the health system. Besides, the effects of the pandemic cannot yet be predicted in the country, which has no forecast to end social isolation and resume economic activities. Therefore, part of the state funds should be attributed to the economic recovery.
Finally, mention should be made of the seeming absence of a technological development agenda that provides for federal public investments to expand the area. As well as the liberal trend of the last Brazilian governments, which has not made as many investments in infrastructure when necessary for the development of smart cities.

Taking the factors presented, we have that by 2035 only the metropolises must have developed technologies and could be considered smart cities in Brazil. Thus, such cities must bring their own or state investments, so that we will have the concentration of these cities in the southeastern region of the country, with some highlights for cities in the south and northeast, as mentioned earlier in the present article.

Innovative

The scenario for the further development of Smart Cities in Brazil might be seen as positive when considering some basic observable trends: technology-wise, the number of Brazilians using the internet continues to grow year by year and now it encompasses 70% of the overall population, which is equivalent to 126.9 million people, while in urban regions more specifically, the amount of people connected to the internet accounts for some 74%40. Among Internet users, 48% purchased or used some form of online service, such as Uber, movie and music streaming platform, or ordered food online41. It is safe to assume that due to the pandemics, it is already possible to see a tendency of rise in the e-services industry as well.

Why is it important? Because those numbers demonstrate an already well-based familiarity with internet and/or technologically oriented services by a significant number of Brazilians, especially in city centers, which is the backbone of a great number of Smart Cities' projects worldwide, provided the close relationship between Smart Cities and the use of ICT for the improvement of the quality of life of the citizens.

Another factor that might provide positive prospects for Smart Cities in the near future in Brazil relates to general improvements in human capital or, at least, to the rise in the number of people with higher education throughout the country since early 2000s, provided this fact alone contributes to the generation of a better-educated citizenry and workforce. Data from the Brazilian Higher Education Census has shown that the number of university students in Brazil grew 64% between 2007 and 2017, raising from 5.3 to some 8.3 million people, a trend that, if confirmed, could provide for the betterment of the 'human factor', or the 'end-consumers' of a Smart City, whose openness to innovation through education is a essential element for the integrated approach to Smart Cities mentioned previously in this work.

Strategies to be taken into consideration:

Negative

Considering the above-mentioned problems with an undermining potential of creating negative forecasts for smart city sector in Brazil, public policies to tackle such bottlenecks in a strategic manner should address the following aspects:

A public bidding and formal procedures reform in municipal, state and federal levels in order to conform urban planning to smart solutions, to create public funds on investing in smart cities solutions that favour technology transfer and innovation to develop domestic solutions to local problems. The establishment information and communication technology applied to urban planning and city solutions training and graduate courses as well as expanding the existing ones. In this concern, it is also mandatory that the local governments work together with academia in solutions as well as promoting and sponsoring research and create innovation centers within existing local institutions;

To be able to implement the aforementioned measures, the local governments should create a specialized technical sector inside the governmental structure to formulate strategies, policies and measures according to the local reality and specificity. This sector should also be responsible for establishing partnership with different research and development institutions and the private sector to mitigate budget limitations and expertise scarcity. It can be created as a Municipal Department of Innovation and Technology of the city government or a smaller structure that is subordinated to an existing department.

Conservative

Considering the conservative scenario, and the characteristics presented in this topic, some strategies can be adopted for the implementation of smart cities: The elaboration and implementation of a federal agenda for technological development and implementation of national infrastructure that allow cities and regional governments to develop plans aimed at smart cities. The investment in broadband infrastructure. In this sense, Brazil has the Fund for the Universalization of Telecommunications Services (Fust), "whose purpose is to provide resources to cover the portion of the cost exclusively attributable to the fulfillment of the obligations for the universalization of telecommunications services, which cannot be recovered. with the efficient operation of the service42 (free translation)". The Fust receives 1% of the gross revenue from telecommunications operators per year43. Thus, from 2020 to 2035, given the history, around R $ 30 billion could be raised44 for investment in broadband technology.

The signing of public-private partnerships should be used as a tool for implementing infrastructure projects in cities, aiming at the technological improvement of public services. The Elaboration of municipal planning for the implementation of urban and technological projects that aim to make the municipality a smart city, taking into account the needs of each region.

Innovative

Smart Cities have everything to do with better management of resources, sustainable development, and the improvement in the quality of life of the citizens affected (directly or indirectly) by their implementation. Following the afore-mentioned considerations, strategies for policy implementation that would facilitate the attainment of goals concerning Smart Cities should include the establishment of contacts within the frameworks of public-private partnerships with a view to turn technologies such as the IoT (Internet of Things) as well as 5G available to a bigger share of the Brazilian population, thus facilitating the attainment of data and technology-based Smart Cities; the establishment of monitoring centers, following the example of Rio de Janeiro, throughout different cities and metropolitan areas with the exclusive aim to help combat crime and other unlawful acts; that, meanwhile, having in mind the necessity for a balanced approach between surveillance of public spaces and individual's privacy.

There should also be considerations regarding the improvement of city's connectivity, and the establishment of partnerships with companies and the private sector for the attainment of better overall internet quality access (promoting digital inclusion), as well as fast and reliable public Wi-Fi connection, providing the adequate technological environment for Smart Cities based on data-sharing to operate.

Consolidation of public policies to facilitate and/or easy the pathway for university education for the youth and young adults in Brazil (in the country, up to 2018 the percentage of people between 18-24 years old enrolled in higher educational institutions hovered below 20%), in order to attain the improvement of the 'human capital' factor in urban environments, the 'end-consumers' and main beneficiaries of Smart Cities.

Another important strategy is the implementation of Smart Cities into a state policy, not subordinate to party-politics and/or narrow bureaucratic interests, which could jeopardize its development and thriving. The urban policy is enshrined in the Brazilian Constitution and is dealt by each city through its municipal legislation and the director plan. The general aspects and instruments of urban planning in Brazil are set in the Estatuto da Cidade (law 10.257/2001). Two key instruments established in the law are the directive plan (a city planning ordinance, mandatory for several Brazilian cities) and the operation of urban consortium, whereby, according to article 32 of the law, the government, with the participation of landowners, inhabitants, permanent users and private investors work together to achieve certain structural urban changes, social improvements and environmental value. These operations can include public incentives to impact reducing technologies and save resources.

It is possible to identify a trend towards a broader use, in Brazil, of instruments from this law for the next decades, considering more cities will have to adopt the directing plan and may follow the example of successful operations of urban consortium.

2 The Eco-Transport of the Future. The Influence of Electric Cars on Energy Efficiency Indicators and Needed Infrastructure for Their Unimpeded Operation

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Introduction

1. Description and Relevance

Electric vehicles (EVs) are considered a key technology for the energy transition in the world. Nowadays, the process of electrification has been an important alternative for local governments to encourage energy efficiency, to contribute to reducing pollutant emissions, and diversifying the energy matrix (IEA, 2020). In Brazil, the automotive industry is fundamental to its economy. The country is placed as the 8th vehicle manufacturer in the world, and the 6th with the largest domestic market (ANFAVEA, 2020).

Among the main socio-cultural benefits that the fleets of EVs can offer, the reduction in atmospheric pollution indexes stands out. Besides decarbonization, it is possible to highlight improvements such as noise reduction and noise pollution. It proves a better quality of life to the population and lowers expenditures in public health by governments, mostly related to respiratory diseases (Gauto, 2020).

Therefore, electric vehicles have been presented as an alternative to be used. However, currently, the insertion of this technology in Brazil occurs in a slow and macro-regional manner. It is primarily focused on the South-Southeast regions, which consists of large industrial presence, developed infrastructure, and a higher level of household income and infrastructure (see Figure 1). According to the National Electric Energy Agency's (ANEEL) annual report (2019), the Southeast region has the largest vehicle fleet and highest energy consumption in Brazil, thus being the most favorable region for the adoption of measures and expansion for sales of EVs.

An example worth mentioning is the Via Dutra, which connects the two largest Brazilian metropolises: Rio de Janeiro and São Paulo cities. The highway is considered the largest electric corridor in Latin America, consisting of six charging points. One advantage to highlight is that the electric recharge costs only 25% of what would be spent to supply a vehicle with a combustion engine to travel the same distance between the two cities (Autoesporte, 2018). Moreover, among the economic advantages of EVs, some are the reduced maintenance costs and the low refueling costs due to the price/consumption of electricity in the country, which is half of the amount spent on fuels such as ethanol or gasoline (WWF, 2017).

In general, the demand for electric cars in Brazil is quite low. Electric and hybrid vehicles in Brazil represent 0.03% of the total national road fleet in 2019, mostly represented by the state of São Paulo (30%), followed by Paraná (6%) and Minas Gerais (5%) (Denatran, 2020). Furthermore, it is worth mentioning that there was a 31% increase in the EV fleet only in the first semester of 2020 compared to 2019.

Given the fact that most EVs are imported, and due to the lack of tax incentives and the reduction of import taxes, the price of EVs suffers a significant impact. It is, therefore, possible to affirm that there is a financial barrier for the population in purchasing EVs. The price of batteries is another crucial factor in EVs' final cost, as it is related to their technological development and their large-scale production since their manufacture is rather expensive. Additionally, concerning the socio-cultural parameters, Porchera et al. (2016) suggest that there is a massive lack of knowledge and interest among the population about the environmental benefits and advantages of electric and hybrid vehicles. For this reason, economy cars still lead sales in the Brazilian market due to their affordable prices, despite the fact that electric vehicles are in general smaller and compact vehicles (EPE, 2019).

In order to have a greater penetration of electric vehicles in Brazil, it will be necessary a series of measures to promote conditions for the development of technology, such as infrastructure, regulation, reduction of the acquisition cost, among others. However, this effort to promote development policies for EVs progresses unhurriedly in the country. Not to mention that it comes up against the strong and consolidated Brazilian biofuels industry, which currently presents itself in the political sphere as a more viable energy alternative compared to electric vehicles in the automobile industry.

2. Trends and Perspectives

Now, there are some incentive policies in Brazil that can be analyzed (see Table 1). Among the presented policies, there is the exemption from property tax on motor vehicles (IPVA) in eight states and municipalities, the exemption from Tax on Industrialized Products (IPI), and incentives for research and development (R&D) on electric mobility. In addition, the insertion of electromobility programs in the largest Brazilian cities has become an attraction for the modernization of public transport fleets.

The Brazilian State has acted modestly through public financing instruments. According to the National Bank for Economic and Social Development's data (BNDES, 2018), its R&D fund invested heavily in two EV charging stations projects, located in the South and Southeast regions. Meanwhile, investments in production are directed to manufacturing companies of electronic components. Still, the prospect of producing this technology at the national level is rather uncertain, since the growth of a country's vehicle fleet is directly related to the level of economic development. This consists of infrastructure problems, household income levels, and legislations that promote the expansion of the EV-market in the North, Center-West and Northeast regions (Dargay et al., 2007).

In terms of legislation and regulation, in 2018 the Normative Resolution 819/2018 was established on EV charging for those interested in providing this service, such as distributors, gas stations, shopping centers, entrepreneurs, etc. (ANEEL, 2018). Any interested party is allowed to carry out recharging activities for EVs, including for commercial exploitation at freely negotiated prices, the so-called public recharge (ANEEL, 2018). The local distributor may install charging stations in its area of operation for the public recharging of electric vehicles (ANEEL, 2018).

The Brazilian Electric mix is mostly composed of renewable sources: 64.9% hydraulic, 8.6% wind power, 8.4% biomass and 1% solar (EPE, 2020). Together with the technological advances in lithium-ion batteries, the configuration of hybrid electric vehicles may present a promising trend towards decarbonization, mainly by aligning electricity production with the use of biofuels (Simon, 2013). Also, if comparing the efficiency of the electric motor compared to the combustion engine (80% to 12%-18%, respectively), the former contributes to greater energy efficiency, and thus lower energy consumption (FGV, 2017).

Furthermore, discussions about the insertion of electric cars take into account the total lifecycle economic cost and environmental impact analysis of Lithium-ion battery electric vehicles (BEVs) versus ICEVs to further understand BEVs and their transformative potential.

Since studies consider emissions and environmental impacts from the life cycle of the vehicle itself, as well as from the battery, the main question is: How to use an electric car, where its whole concept is based on the non-emission of greenhouse gases (GHG), but which still uses pollutant electricity generation sources that produce these gases? In terms of emissions and other environmental impacts, it must be considered the operational phase of the vehicle, known as "Tank-to-Wheel" (TTW), and the entire electric energy chain that supplies the vehicle, "Well-to-Grid" or "Well-to-Wheel" (WTW) (Song et al., 2018).

One of the main issues regarding the large-scale insertion of EVs is the power grid infrastructure – it can suffer an impact on the electricity distribution grid. Most residential chargers must be of low-power and slow charging units, which can be managed successfully without causing significant impacts on the network, especially if the residents do overnight charging. The biggest concern is regarding the highways, where there is the need to install fast-charging points. Firstly, most of the intra-national transportation in Brazil is done through the roads. Secondly, fast-charging consumes a large amount of energy in a very short time.

An alternative to the above-mentioned points would be purchasing EVs for personal use in urban areas. Given the greater demand for high-end vehicles in the South-Southeast regions, investing in EVs can be attractive for individuals who circulate mostly in the city and are able to recharge at home. The fuel economy itself might be able to pay part of the additional investment for the EV. However, if small reductions in import tax rates and an increase in the number of fast chargers on highways take place, those would add to the advantages of the EV as inexpensive options for society, which can cause significant increase in the demand for EV.

Therefore, it is necessary to consider that several variables influence the adoption of different electric vehicle technologies in each country. For this reason, one point that Brazil should consider when developing its electric car industry is: which electric vehicle technology would be more appropriate given that the biofuels industry and flex-fuel technology are already spread nationally since 2003 (FGV ENERGIA, 2017).

As a result, unlike other countries, the adoption of EVs is not seen as an urgency to comply with the climate reduction agenda. Moreover, according to the National Association of Motor Vehicle Manufacturers (FGV ENERGIA, 2017), the use of ethanol as a fuel compensates for the gas emissions, since it also reduces the effect of carbon dioxide on nature through the sugarcane crop cycle in Brazil. Thus, regarding ethanol hybrid vehicles or the ethanol cell (SOFC), it can be said that there are "negative emissions" since emissions are offset on two fronts.

Taking this into consideration, one of the most successful alternatives for Brazil, at least for the initial insertion or tran-

Table 1
Incentive policies for electric vehicles in Brazil

INSTITUTIONS	POLICIES
Federal Government (CAMEX)	Reduction of the VE import tax rate from 35% to zero
Federal Government (BNDES)	Financing for R&D: electrical component; batteries; charging stations
Federal Government (ANEEL)	Electric mobility R&D projects
States and Federal District: Paraná, Rio de Janeiro, Mato Grosso do Sul, Maranhão, Piauí, Ceará, Rio Grande do Norte, Pernambuco e Brasília.	Exemption from IPVA; Electromobility programs
Cities: São Paulo, Sorocaba, Indaiatuba e São Bernardo do Campo	Exemption from IPVA

Source: own elaboration. Based on data: ABVE (2016); BNDES (2018); ITDP (2020).

sition phase, could be the case of hybrid electric cars. In this case, Brazil would benefit from both the comparative advantage in the use of the EVs to reduce emissions and the use of ethanol.

The solution for Brazil must then consider all these mentioned perspectives, such as regions, the socio-economic development and the commercial sectors already established. It is essential to analyze from the macro to the micro points of view, including the political, economic, sociocultural, technological, and environmental standpoints if Brazil is to efficiently insert electric vehicles into its market.

Risk Analysis

In order to understand and analyze the EV market in depth, interviews were conducted with different stakeholders, such as government representatives, academic researchers and representatives of large private sector companies. According to the opinion of academy and market experts (Consoni, Barassa, Prado, Oliveira et al., 2020), the main risk inherent in the insertion of electric vehicles in Brazil concerns the absence of national public policies and legislation that encourage the development of business models that can sustain the entire EV complex, from its manufacture to infrastructure and circulation on the streets. According to Mr. Gonçalves Mendes, there is still a lack of regulation and incentives in the country, for instance, in terms of incentives, Brazil is still far behind, especially when compared to European indices.

From the point of view of urban mobility, the failure to update the bidding systems (government purchases), according to the energy efficiency goals coupled with subsidies, becomes another risk by discouraging the adhesion of public transport companies to acquire electric fleets, either buses or medium-sized cars, perpetuating the use of outdated vehicles (Maluf, 2020).

Another risk in the political field and pointed out by the interviewed specialists concerns the capacity of articulation of the sugar and alcohol sector and automobiles in Brazilian institutions, since the policies of incentive to ethanol, as well as the maximization of the pre-salt exploration can delay the prospect of replacement of combustion cars by electric and hybrid technology in the medium and long term (Prado, Maluf, Pereira, and Oliveira, 2020).

The risks are even higher when speaking of the economic sphere, especially due to the volatility of the Brazilian currency's exchange rate against the dollar. This instability brings insecurity to investors in view of the sudden increase in imports costs of infrastructure components and EVs, therefore discouraging their acquisition on a large scale. In addition, there is low technical workforce capacity for the development and maintenance of this technology in Brazil (Gonçalves Mendes, 2020). Mr. Gonçalves Mendes also suggests that despite the uncertainties, in the last few years there has been an evolution in the EV offer market, currently counting on more than 15 electric or hybrid models.

Another important point is the development of infrastructure for EVs. Infrastructure is one of the main elements for the insertion of electric cars anywhere, but in the case of Brazil, this factor proves even more essential due to the organization of the cities. In Brazil, all buildings – houses and residential, as well as commercial buildings – have garages, which is different from countries in the northern hemisphere. shows that in the case of Brazil, planning the charging infrastructure is even more complex. Besides, since the country does not have a rail transport structure, both personal and commercial interstate transport is done by road. Thus, it is necessary to have recharge points in residences and public spaces, in cities and especially on highways. In addition, another infrastructure challenge related to the risk of domestic vehicle recharging is that many residential electrical installations are old and cannot support the consumption of vehicle chargers, said our expert from Electricus.

Another risk is a changing people's custom of filling up their vehicles in the public spaces to doing so in their residence. However, this challenge can be counterbalanced by consumer's tendency to be increasingly participating actively in the way their energy is generated and consumed.
On the other hand, according to E. Lacusta Jr. of CPFL Energia and with data from the Emotive Project (Leite, 2017), simulations carried out by CPFL show that a 5% EV penetration in the total fleet – which is a relatively high number for the current scenario in the world, as no country has yet reached this percentage of VE penetration except Norway. If the growth is

23 de Maio Avenue, view of Obelisco in Ibirapuera Park, São Paulo

gradual and slow, as it is being, it will be easier to deal with specific problems concluded Lacusta Jr.
Even though there are some specific initiatives for EV charging infrastructure in the developed regions of the country, most are private initiatives motivated by large companies that see electric mobility as a profitable business in the medium term, but there is still no national public policy to foster EV infrastructure in Brazil.

In addition, it is known that electric vehicles are still substantially more expensive than vehicles with internal combustion due to issues related to battery technology. Although, according to our interviewed experts and studies, the sharp drop in the cost of the battery is manageable due to the scale increase and technological development of the battery. The scale of production alone – for example, mining – already represents almost half of the drop in battery cost, the other portion represents technological development.

As for the environmental issue, one of the risks observed is the environmental impact of lithium extraction in order to manufacture EV batteries (Lacusta Jr, 2020). The experts also mentioned new technology innovations and applications for the battery. The drop in the cost of the battery represents around 40-50% of the total cost of EV, and thus has a significant impact in the final costs for the consumers (Arioli, 2016).

The increase in the fleet of EVs also depends on economic development. Brazil has numerous socioeconomic and infrastructure problems that limit the expansion of technology, as the priorities of this agenda seem to diverge from the State, hence discouraging greater participation through public resources dedicated both to R&D and national manufacturing (Mendes, Seabra, 2020; Dargay et al., 2007).

Scenarios

Quality scenario analysis and strategy for policy implementation.

Negative

A low and slow insertion of EVs in the Brazilian market, in which the development of EV technology would come up against the political articulation of biofuels and fossil fuels, preventing government and market incentives to scale up EVs.

In this scenario, there is a strong legal uncertainty that negatively impacts investments that reflect the economic and socio-cultural development of electric mobility in the country. Consequently, if there is no safe regulation from a technical standpoint, the lack of dialogue between intersectoral agents hinders progress on topics such as infrastructure, charging stations, energy efficiency, among other points. Bottlenecks related to public policies, such as the cut in incentives and/or the increase in rates, can slow the adoption of EVs in Brazil, turning the focus to other mobility options in the country.

Also noteworthy is the growing supply of fossil fuels, mainly from the growing Brazilian production of oil and natural gas. Petroleum resources can provide energy security through the already-mature and widely consolidated technology in the Brazilian society, which still presents advantages in most cases, and also with low prices on the economic side.

In addition, the political influence of the biofuels sector, which represents a large number of companies with decades of consolidated infrastructure and high investments in projects in operation, is evidenced as a determining factor for limiting the insertion of EVs. In this scenario, the massive development of refined biodiesel from a variety of oilseeds for use in heavy fleets such as trucks and buses would also be emphasized. In short, in addition to energy security through a strongly consolidated industry, biofuels still fill the gap in the environmental problem. For instance, the numerous varieties of ethanol, such as the traditional alternative of sugar cane, second generation ethanol (cellulosic), and even ethanol obtained from cereals such as corn.

Furthermore, the lack of public policies in the country for tax incentives and even subsidies to reduce EV costs and availability of public financing lines are serious barriers. In this scenario, the country has been slowing economic growth in recent years with a reduction in tax revenue, which also reduces investment capacity and undermines more concrete government actions to disseminate technology.

Conservative

The speed of insertion of EVs would remain constant in the current standards, characterized by a gradual and relatively slow penetration of electromobility in the country. As a strategy for implementing policies in a way that the speed of the development of EV technologies and their insertion in the Brazilian market is continuous, it would be necessary that tax policies and incentives – such as exemptions from IPVA and IPI – do not only be constant, but also to have gradual expansion on the others brazilian regions, even if slow. Thus, in the long run it would be possible for these incentives to gradually counterbalance the high cost of EVs in Brazil, the accessibility of economy cars, and the use of biofuels.

The reduction in battery costs should reach 70% by 2030. Considering that, on average, the cost of batteries represents about 40% of the EV and that, with the advancement of technology in EV, the cost of the entire body is reduced by 20% in the same period, we can estimate that there will be a reduction of about 40% in the final price to the consumer in 2030. Under these conditions, the economic viability for light private-use EVs would increase significantly, which should increase consumer demand and accelerate the entry of new manufacturers into the national territory (IEA, 2020).

At the same time, it would be important, in case of an expansion, to also include other Brazilian states and cities, in order to encourage EVs at national level as a whole, and thus, cities would gradually generate a greater demand for infrastructure, while the state could simultaneously provide the necessary public infrastructure, both in cities and on interstate highways. The speed of this scenario is reflecting the pace of the current situation in Brazil.

In the conservative scenario, there is also a tendency to increase the insertion of vehicles powered by biofuels. However, the prospects are that EVs and these vehicles coexist, as both types of vehicles present different consumers and operate in different locations, with no competition between them. The integration of energy demand from EVs with the country's mostly renewable electric matrix would result in a decrease in pollution in large urban centers.

Innovative

It consists of an acceleration in the insertion of EVs in the country due to government support to national industry and the entire electromobility ecosystem. The rapid speed of overcoming the challenges would result in the electrification of the entire fleet in the medium-term.

The strategy behind this would consist in formalizing the guidelines and actions responsible for the National Electromobility Plan. From the legislative perspective, there would be a limitation of the combustion cars' production in the automakers in Brazil and, consequently, the displacement of their subsidies for the production of electric and hybrid vehicles. Subnational incentives would be expanded by exemption from IPVA, as well as through the expansion of public policies for sustainable urban mobility, where small and large electric vehicles would be included in public transport.

In this way, public financing becomes a key factor in this scenario. Greater BNDES participation through credit lines for subnational governments and the EV production chain would be a way of sustaining initiatives in the long-run. Given the ability to access BRICS financial cooperation channels via the New Development Bank (NDB, 2020), the BNDES would raise additional funds in order to sustain not only research and development actions, but also the expansion of the electrical infrastructure.

As part of the National Electromobility Plan, there would be a tax reduction policy for the national manufacture of raw material, equipment, capital, and components to be used in EV assembly lines and loaders, aiming to encourage local industry and market. On the demand side, there would be an incentive to promote residential recharge and also an encouragement to energy self-generation through the distribution of photovoltaic generation systems, thus creating a sustainable electric mobility ecosystem in the country.

Even in a positive scenario, there could be limitations on the adoption of EVs in some regions of Brazil that do not have the geographical conditions to operate EVs, such as the Brazilian countryside that has outdated roads with no conditions to support recharge infrastructures. Therefore, even with the rapid expansion of electricity demand due to the population's adhesion to electromobility, there would be a balance between planning to expand the electricity grid and Brazil's electricity mix in a sustainable – and decarbonized – manner. Urban centers would have a sharp drop in air pollution, an increase in quality of life and a drop in public health spending.

For the purpose of providing a better understanding of the variables and criteria that impact the scenario of electromobility in Brazil, an interactive table was created with the main variables, how they interact with the sector and what are the main recommendations for political actions for further development of electromobility in the Brazilian context.

For each identified variable, a degree of impact that this criteria would have on the policy implementation strategy was assigned. This degree varies from 1 to 3, where 1 is low impact, 2 is medium, and 3 high impact. The evaluation attributed to these variables were defined based on the market study and interviews carried out throughout the project with stakeholders and actors representing three important sectors and decision-making institutions: companies (market), researchers (academia) and policymakers (government).

VARIABLE	IMPACT	CHALLENGE	RECOMMENDATION
POLITICAL CRITERIA *Absence of legislation and regulation for EVs and for EV recharge points*	3	The high articulation capacity of the sector of sugar, alcohol, and automotive (fossil fuels) in Brazilian institutions delays the prospect of replacing combustion cars with electric and hybrid technology	To create regulatory incentives for the development of business models that can sustain the entire EV complex chain. From its manufacture to infrastructure for circulation on the streets, such as: the exemption from parking for EVs, mandatory charging stations in public buildings, etc
TECHNOLOGICAL CRITERIA *Absence of incentives for national EV and battery production*	2	It prevents the national industry development and does not generate income and jobs in the country. It stimulates more imports, where the dollar has a high value in comparison to the devalued Brazilian Real. Plus the high cost of EVs	Policies to encourage national industry and development of innovative technology: R&D, batteries, qualification of technical labor, tax exemption, etc. In short, to promote Decent work and economic growth, and Industry, Innovation and Infrastructure, which are the Sustainable Development Goals (SDGs) 8 and 9, respectively
MICROECONOMIC CRITERIA *Brazilian currency exchange rate volatility against the dollar*	2	The instability brings insecurity to investors due to the sudden increase in costs in the import of infrastructure components and EVs, discouraging their acquisition on a large scale	It would be necessary to stimulate the national production of vehicle components in order to dilute import costs
MACROECONOMIC CRITERIA *Brazilian currency exchange rate volatility against the dollar*	2	The instability brings insecurity to investors due to the sudden increase in costs in the import of infrastructure components and EVs, discouraging their acquisition on a large scale	It would be necessary to stimulate the national production of vehicle components in order to dilute import costs
REGULATORY CRITERIA *Absence of a bidding system for government purchase*	2	This discourages the adhesion of public transport companies to acquire electric fleets, whether by bus or medium-sized cars, perpetuating the use of outdated vehicles	Compulsory measures focusing on Sustainable cities and communities, and commitment to climate action, which are the SDGs 11 and 13, respectively. I.e. command and control to replace the fleet according to energy efficiency and emissions targets, encouraging the purchase of low-carbon technologies, generating demand, albeit incipient, for manufacturers, and stimulating the electrification of the country's fleet.
SOCIOECONOMIC CRITERIA *Socioeconomic inequality*	3	It limits the expansion of technology in less developed regions and with less purchasing power. As well as it limits the Government's ability to create fiscal policies to EV development	Application of multisectoral public policy instruments (income, education and employment). In this sense, encouraging the EV production chain can help in the perspective of better jobs. In addition toIncentives to hybrid technology vehicle for the transition to VE
SOCIOCULTURAL CRITERIA *Consumer cultural experience*	1	Lack of knowledge and interest by the population about the economic benefits (low cost of operation and maintenance) and environmental advantages of electric vehicles (emission and noise)	Public campaigns to disseminate information and knowledge about the importance and advantage of EVs
INFRASTRUCTURE CRITERIA *Recharge infrastructure*	3	Change in the supply pattern from the residences to public spaces, which may take time and should occur gradually The great distances between cities and the need for charging stations for refueling, since EVs still have low battery autonomy	Allow the sale of electricity to the distributor, for example V2G: charge at night (cheapest rate) and sell the energy later (highest rate).
ENVIRONMENTAL CRITERIA *Absence of infrastructure for battery disposal and/or reuse*	1	Lithium recycling is not a significant portion, only 3% of the lithium produced in the world comes from recycling	To have more incentives regarding battery disposal; to develop more studies on the use of second life batteries

Source: own elaboration. Based on interviews with specialists in the sector.

Concerning the absence of legislation and regulation for EVs and charging points, it is attributed with an impact 3 – high impact. Given the increase in the use of renewable technologies and electric vehicles, adapting the supply to the demand for electricity becomes an important and complex issue. Due to the infrastructural and institutional complexity of electrical systems, it is unlikely that the infrastructure for electromobility (smart grids and charging stations) will be implemented only by market forces. Thus, creating regulatory incentives for the development of models that can support the entire EV complex is essential – from its manufacture to infrastructure for circulation on the streets.

As for the technological criteria, Brazil is still extremely dependent on EV imports, and given that, it was agreed that the absence of incentives for national production is of medium impact. As for the batteries, their necessary evolution – mainly in terms of weight and cost – will depend on technological progress. To stimulate the national production of EVs and batteries, actions that encourage R&D combined with the needs of the market, in addition to the qualification of technical labor and tax exemption would allow a larger scale of production and new markets to guarantee market share and cost reduction. Thus, a favorable environment is created for the emergence of new market niches and opportunities, such as the replacement and reuse market for used electric batteries and the market for stationary electric batteries (EPE, 2019).

Regarding the absence of tax incentives for the acquisition of EV by consumers and the volatility of the Brazilian currency exchange rate against the dollar, a medium impact – grade 2 – was attributed. The main point to increase consumption would be the drop in the final price and it would be essential to stimulate the national production of vehicle components. The reduction of inputs has a greater impact on the national industry and may result in greater generation of jobs and the collection of other taxes due to the effect on the supply chain. Furthermore, the absence of a bidding system for government purchase, a low impact was attributed – grade 1. A challenge may also have repercussions in the technological area, mainly because, in the absence of government tenders it may then limit the development of electric public transport to the population. However, in the short-term, it does not present any imminent risks for the development of the electric cars' fleet in the country, mainly light and individual cars.

For the criteria of cultural experience of the consumer, a grade of low impact was assigned. The lack of knowledge and access to information on the benefits of EVs can be solved through information dissemination campaigns. In the variable regarding Brazilian socioeconomic inequality, a grade 3 was attributed to the impact generated due to the weak potential demand, originated by the population's low income level. Inequality ends up influencing the public opinion about electric vehicles. Thus, actions integrated to the Electric Mobility Plan that aim to reduce regional inequality and promote education and economic development, are essential for the sustainable development of electromobility.

Moreover, regarding recharge infrastructures, a grade 3 of high impact was given. Infrastructure is one of the main elements for the insertion of electric cars therefore, the impact of this variable is high. According to a report by EPE (2019), the distribution electric grid must be prepared to interact with the consumer and create incentives to recharge vehicles without overloading the electrical system, mostly during off-peak hours. Thus, actions to enable this to take place and to encourage consumers to join the VE are necessary, such as: the creation of specific rates for each time slot and the implementation of smart networks capable of monitoring, integrated maintenance and advanced measurement infrastructures, and integration of renewable energies with electric vehicles as energy storage in the grid, for example vehicle-to-grid (V2G).

In relation to the absence of infrastructure for battery disposal and reuse, the degree of impact was considered low – grade 1. Although it is extremely necessary to develop actions for the correct disposal of batteries and to have the option of using second-life batteries – in order to avoid several environmental impacts.

When it comes to international cooperation agreements, a degree 2 of impact was attributed, since these agreements can supply demands from the Brazilian Government, such as financing, and could also allow technology transfer to the country. The countries' competitive advantages could be better exploited with common strategies among them. For example, in Brazil, despite recent advances in research on lithium reserves, its exploitation still does not have the representativeness that is found in Brazil's neighbor countries.

Furthermore, possible cooperation agreements between BRICS member countries can be extremely viable regarding the resources required for investments. Currently, these incentives and investment are rather scarce by BRICS governments – except from China. However, as previously stated, these are vital for the implementation of large EV public transport networks.

Another potential for cooperation could be from the exchange between these countries, regarding the technological area, natural resources, government plans, and public policies. The energy integration between the BRICS can assist in the development of technologies in each country, moving a whole local chain of jobs, industries, income distribution and less dependence on resources from other countries. To occur as a form of sustainable complement, the increase in the use of EVs must be conditioned by the greater use of renewable sources in the generation mix. These points were defended by Joaquim Seabra from our interviews.

Conclusion

Despite all the benefits mentioned about this technology, the massive adoption of EVs in Brazil is still seen as distant, and the vast majority of Brazilians do not see this as a national reality in the short-term. MME (2018) considers that EVs in 2050 will represent 11% of the total fleet. This is mainly due to the high cost of EV, the lack of charging infrastructure combined with low battery autonomy, and the certain resistance from consumers. Thus, in order to have a greater economic viability for the diffusion of EV technology, a significant advance in the reduction of battery prices is essential, together with an increase in its storage capacity, in the international scenario.

It can be concluded that the active participation of government entities for the insertion of electric vehicles in Brazil is indispensable. Not only from the legislative point, in which there must be a regulation of the vehicle and its activities, but because this is the only way to make it feasible to insert EVs in an already established market. Having support in the political sphere is also necessary in order to have more public incentives and subsidies for further development of electric mobility in Brazil.

Having considered particular factors in the country, such as the issue of the strong biofuel industry, it can be concluded that one of the best options to insert electric cars and vehicles in Brazil would be using hybrid technology. This option does not necessarily need to be the permanent solution, but rather a transition technology in order to adapt the market to electric mobility in the long-run, especially when considering citizen's personal use. Meanwhile, the country can still enjoy its current infrastructure devoted to biofuels, having time to gradually adapt cities, roads, and consumers to the whole scenario of EVs. Furthermore, another option that can be either considered would be starting this insertion first in public transportation. In this manner, cities and consumers would adjust progressively, allowing further a more favorable and appropriate environment for the successful insertion of electric cars in Brazil.

23 de Maio Avenue, view of Obelisco in Ibirapuera Park, São Paulo

3 Energy Storage in Brazil: A First Step Towards Smart Storage

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Introduction

Energy storage is considered one of the eight most important disruptive innovations that will influence the country's top 10 industries at the end of this decade, especially with the current increase in the share of intermittent sources in the power grid (National Industry Confederation [CNI], n.d.). Although Brazil has a high participation of hydropower plants in its energy matrix (Energy Research Office [EPE], 2019), there is a need to relieve transmission and distribution grids, support isolated systems, as well as address the reduction in precipitation levels in recent years, which could be dealt with smart storage solutions.

More than a climate change strategy, energy storage is a way of assuring more participation on the renewables in the energy supply, while does not require too much more installed power to do so with reliability. From the distributed generation point of view, energy storage also provides independence from grid connection and resilience for households that are distant from the greater centers (Gupta, Bruce-Konuah & Howard, 2019; Klaimi et al., 2018). Furthermore, the concept of smart city itself, that it, a city that uses technology to tackle crucial development problems (Dameri, 2013), counts on energy storage (Al Dakheel et al., 2020).

There is an international commitment to replace fossil energy sources with renewable ones, strengthened after COP 21 (Hinrichs-Rahlwes, 2017). Indeed, the use of a resource that is not limited to reserves across the world is a more intelligent way of managing what humankind has available. Besides, it is a way of ensuring future generations are able to meet their needs as well. Such an expected energy production shift increases the need to store it, since renewable sources have variable patterns of generation (Chase & Berzina, 2018). Therefore, it is necessary to absorb the surplus and release it when supply is low, but there is demand. It also limits the costly downtime of peak generators and helps reduce Greenhouse Gases (GHG) (Crossley, 2013). Finally, it is an innovative technology to increase grid security by integrating new energy resources, replacing outdated infrastructure, and providing backup power during outages (Union of Concerned Scientists, 2018).

Therefore, this article aims to address the challenges and opportunities of developing smart storage in Brazil, since energy storage is not yet consolidated in the country. In order to answer this question, this article will review important definitions for this field of study, then examine the current Brazilian storage environment, trends, and prospects until 2035, followed by five case studies of seven Brazilian companies, selected following the Brazilian Electricity Regulatory Agency (ANEEL) R&D call for projects. Finally, it will analyze the risks and scenarios (positive, conservative, and negative) and provide strategies for the implementation of public policies based on an adapted version of Godet's La Prospective scenario construction method.

Definitions on Energy and Smart Storage

In the past few years, the term "smart" has often been used in many different subjects, but there is no single definition. However, smart storage in relation to energy, in this case, refers to the use of new energy storage technologies, each with its own benefits, to better meet the different energy needs. Thus, according to MassCEC and Doer (2016), the technologies of stored energy can be classified into five groups according to the form of storage, as shown in Figure 1 and Appendix I.

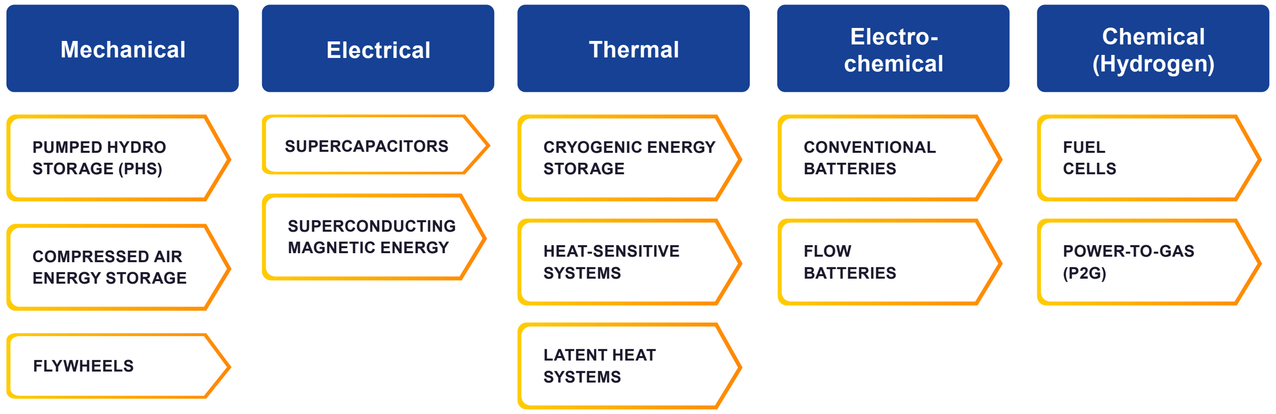

Figure 1: Classification of Energy Storage Technologies
Source: Self elaboration, adapted from MassCEC & DOER (2016)

Mechanical energy storage has PHS, that according to Barbour et al (2016), it's a process that pumps water from a lower to a higher reservoir in periods of low demand. CAES uses compressed air to store energy, and Flywheels, as mentioned in Figure 1, refers to inertial masses that turn around an axis (Bender, 2016).

Thermal energy storage (TES) presents the Heat-sensitive systems, which are based on increasing the temperature of materials, without undergoing phase changes. In the Latent heat systems, the storage is based on the absorption/emission of heat during the change of phase of the material. Also, there is the Cryogenic Energy Storage, a type of storage made at low temperatures (Lopes, 2016). About Electrochemical Energy Storage, there are the Conventional batteries which the most popular are of lead acid (PbA) and lithium ions (Li-ion). Another type of this kind of storage is the Flow batteries as zinc bromide (ZnBr) and vanadium redox (VRB) (Evans et al, 2012).

Chemical Energy Storage presents Fuel cells or hydrogen storage which uses hydrogen as a fuel to react with oxygen (Serra, 2016). The concept of P2G is to feed electrolysers with cheap surplus renewable electricity to produce hydrogen and inject this into the gas grid (Zhang et al, 2016).

As approached in the selected case studies, the leading technologies of energy storage in development in Brazil are: (i) Conventional batteries (ii) Flow batteries, (iii) Fuel cells, (iv) Power-To-Gas (P2G) and (v) Latent heat systems.

Current situation of energy storage in Brazil

Brazil has the largest power system in Latin America and the 9th largest electricity market in the world. In the country, there are two separate markets for energy trade, which are the regulated electricity market (ACR), where generators and distributors can work with bilateral contracts through government auctions, and the free electricity market (ACL), where big consumers can buy energy directly from generators or traders (Griebenow & Ohara, 2018). As the graphic below shows, the Brazilian grid is mostly composed of green energy. In the past few years, new renewable sources, such as wind and solar, grew fast in the country's power generation (Losekann & Tavares, 2019).

In contrast with this Brazilian context, energy storage is still underdeveloped (Delgado, Hage & Leite, 2017), which will be analyzed in the following subsectors:

1. Political and regulatory aspects

The energy sector requires the balance between demand and supply due its centrality in other critical infrastructure sectors. Thus, public policies are strategic in creating the integration of energy storage systems nationwide. An important step for this purpose was the creation of the Brazilian Energy

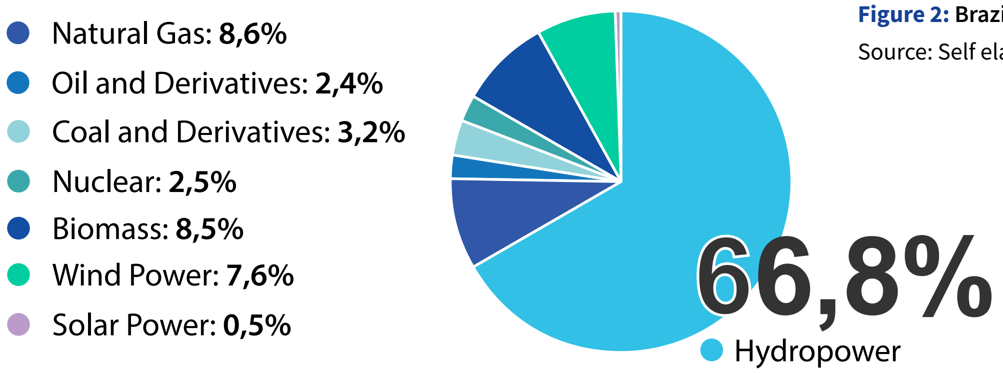

Figure 2: **Brazilian Electrical Grid**
Source: Self elaboration, based on EPE

Quality and Storage Association (ABAQUE), in 2015, which promotes the implementation of energy storage processes in Brazil and stimulates the modernization of the Brazilian Electricity Sector.

Regarding the lack of a regulatory framework in energy storage, Dantas et al. (2018) argues that the country's regulations still focus on pre-defined remuneration, which impacts negatively on the promotion of innovation in the electricity sector, and, thus, on the attractiveness of investments. Another issue is ancillary services, essentials in maintaining frequency, voltage, and power quality on the electric system, making energy storage projects feasible, which also do not have a regulatory framework in Brazil (Weiss & Tsuchida, 2015).

2. Economic and commercial aspects

Energy storage is a global trend as it provides benefits across the entire value chain of energy systems, from the generation to the end user. Despite that, there is no commercial and labor data available about this sector in Brazil. However, it is estimated that the country's storage potential will be 95 GW by 2023 (Brazilian Energy Quality and Storage Association [ABAQUE], 2016).

Moreover, the ion-lithium batteries are the most used technology for energy storage nowadays in the country after hydraulic storage.

2. Technological aspects

Brazil is recognized internationally for its integration capacity due to the National Interconnection System (SIN) despite its continental dimension. Hydropower has been the mainstay of the energy grid, although its share has been in decline for the last two decades. The share of this source with large reservoirs can convey the false idea that the country does not need energy storage. However, the effective storage capacity of hydropower has been decreasing, primarily due to the growing demand for supply and the dramatic reduction in the level of precipitation, especially in the semi-arid Northeast region (EPE, 2019).

Besides, the country has shown itself capable of using other renewable energy sources, especially intermittent ones. Therefore, the need to store electricity generated by non-dispatchable energy sources becomes essential for use whenever necessary. Recently, Industry 4.0 has been used to make storage "smarter" in Brazil, leading to a better grid balance during periods of high intermittent generation as well as a reduction in its restrictions. Artificial intelligence (AI) is gradually being used for predictive maintenance of fleets of intermittent sources, increasing reliability, and reducing downtime (REN21, 2020). Through the Internet of Things (IoT), it is already possible to measure the use of traditional batteries, allowing their connection to the users, and delivering performance and functioning reports, as well as allowing the remote monitoring and real-time of all batteries (Brazilian IoT Association [ABINC], 2019).

2. Socio-environmental aspects

The Brazilian grid is marked by a high proportion of renewable sources, with considerable growth of wind and solar sources in later years. However, there are challenges in terms of maintenance and strengthening of a low-carbon approach brought by international alliances. The most important one in this regard is the Paris Agreement, in which Brazil states it will reduce its GHG by 37% in 2025 and 43% by 2030. This pledge encompasses the Brazilian economy, wildlife and indigenous areas. This raises the challenge of keeping the Brazilian energy capacity from a low carbon-intensive level (Losekann & Tavares, 2019).

Moreover, less than 1% of the Brazilian population does not have access to electricity from the national grid (World Bank, 2018). Therefore, alternative ways of generation and storage of energy in distant locations of the country mean that millions of people will have easier access to energy and all the technologies that require it.

Development Trends for Smart Storage in Brazil

Innovation brings significant impacts on society, be it regional or global. Sustainability has a deep relationship with innovation trends, as it is presumed to look to the future, that is, to trends, risks and opportunities (Zallauy, 2019). Thus, it is not only necessary to look at the present, there is also a need to prepare for changes and innovate.

After conducting a survey of the main Brazilian companies involved with energy storage, it is noticeable that energy storage is expected to become an increasingly strong trend in the coming years (CNI, n.d.).

Storing energy contributes to solving the great challenge of intermittent renewable sources. With the use of storage systems, it is possible that the operator of the electrical system uses electrical energy in a more flexible way, that is, that which would be lost, can be used at other times (Bolt, 2019).

Smart storage: Case studies from Brazil

In this section, the article explores the different smart storage technologies being developed in Brazil by analyzing the case studies of seven large companies from the country.

Battery (CEMIG/Alsol)

CEMIG is the Minas Gerais Energy Company, one of the main electric energy concessionaires in Brazil. Alsol Energias Renováveis is a specialized company in distributed generation of different renewable energy sources. Alsol was a pioneer in Brazil in photovoltaic systems and energy storage and currently has 500 projects in operation (Alsol Renováveis, 2020).

In May 2018, these two companies opened together the first photovoltaic plant with a storage capacity of 1 MW (megawatt) in Brazil. In this project, both combined energy storage and distributed generation with the installation of a 300 kWp (kilowatt-peak) photovoltaic plant and a 1 MW storage system (Power Company of Minas Gerais [CEMIG], 2018). The plant has 1,152 solar panels and has a generation potential of approximately 480 thousand kWh/year, which is enough energy to serve around 250 homes with an average consumption of 150 kWh/month per year (CEMIG, 2018).

According to Ambiente Energia (2018), the investment made has a total value of US$ 6.9 mi - US$ 5.33 mi by CEMIG, and US$ 1.57 mi by Alsol Renováveis. The goal is to build a new business model, based on hybrid plants that combine photovoltaic generation with storage systems in consumer units, which ensures the quality of distribution even at times with higher consumption (Ambiente Energia, 2018). The system was purchased from the Chinese company BYD and the technology used is lithium ion, which provides greater storage capacity and an improvement in the quality of the energy delivered

(Federal University of Paraíba [UFPB], 2018).

In Brazil, plants that had this type of operation before this project generated energy only during the day and wouldn't supply active energy during the night (CEMIG, 2018). In this new plant, the logic is reversed, since it has a combination of sending energy to the grid and storage throughout the day with the presence of the sun. An important piece of information is that this technology allows its potential of 1 MW to be injected into the network for up to three hours. This is a first prototype, but the idea is commissioning another six energy storage units to be installed (UFPB, 2018).

Biogas (Itaipu Binacional)

Itaipu Binacional is a company founded in 1966. At the time, Brazil and Paraguay united to construct a hydroelectric power plant between both countries with an installed capacity of 14 GW. This plant produces 11,3% of Brazil's total energy consumption and 88,1% of Paraguay's (Itaipu, 2019). However, the company has been investing in new forms of storage, focusing on rural producers, who may use the farm's waste to produce biogas (Itaipu, n.d.). The project is enrolled in farms in Paraná, and followed by the research center CIBiogás, supported by Itaipu Binacional (CIBiogás, n.d.). Such initiatives not only help these farms have access to clean energy, but it also decreases their carbon footprint and gives them another product: bio-fertilizers.

The use of biogas in small bioreactors, installed in farms in south Brazil, has shown Itaipu Binacional good results (Itaipu, n.d.) and studies show this is a viable scenario (Freitas et al, 2019). However, there are no specific government policies to encourage producers to take the risk. In addition, though the return is fast, the initial price is not viable for most producers in the country. To increase the number of farmers that choose to have a bioreactor, the government could for example endure the laws of the farm waste disposal, that in many cases today are thrown away irregularly and close to water sources.

In Brazil, around 41% of the territory is dedicated to agricultural proposes (IBGE, 2017). The country owns the world's second-largest cattle herd (United States Department of Agriculture [USDA], 2019) and it is a top exporter of pigs and chickens. Thus, biogas from animal manure is a significant possibility of using a resource already available in the country.

Methane, one of the main components of the biogas, is better to compress than hydrogen (thus better to store) and it is a safer alternative (smaller possibility of explosion). In addition, this gas, if filtered from biogas, can also be inserted on the natural gas grid without restrictions (Ajanovic et al, 2020).

Anyhow, biogas should appear more in the discussions about energy storage and become more available and affordable, so it can have a more significant place in the future of Brazilian energy market.


The Itaipu Dam, Jonas de Carvalho (Flickr)

Concentrated Solar Power with thermal energy storage (Chesf)

The São Francisco Hydroelectric Company (Chesf) is a subsidiary of Eletrobras - the largest Brazilian electric power generation company controlled by the Federal Government. Chesf's main activities are the generation, transmission and sale of electric energy.

The project in energy storage originated in a R&D program launched by ANEEL in September 2015 for the development of national technology in solar thermal generation of electric energy, internationally known as CSP (Concentrated Solar Power), which is in the process of expanding worldwide.

In this technology, a fluid absorbs solar energy (heat) concentrated by mirrors in a focal point. That heat may be stored to later be pumped, at high temperatures, to directly drive turbines or to be used as an intermediate medium to heat a secondary working fluid through stages of heat exchangers and/or energy storage (Mantilla et al, 2016). Its main advantage is the possibility to store heat, generating electricity further when the sun is no longer available. The combination between the CSP technology and thermal storage also provide a greater short-term stability in power generation, increasing the capacity and dispatchability factor of the solar thermal plant.

Chesf's project aims the development of a 1,0 MWth (thermal power) and 250 kWel (electric power) central tower CSP plant with air as working fluid and a thermal storage capable of supplying energy for 7 hours at full load. It will be executed in the Petrolina Solar Energy Reference Center (Cresp). Economically, the relevance of the project is undeniable, which, among some contributions, will form and structure a local supply chain, improving conditions in the region.

Hydrogen (Furnas/ Senai)

Eletrobras Furnas is another subsidiary of Eletrobras that operates in the generation and transmission of energy all over the country with 12 hydroelectric and 2 thermoelectric plants.

Furnas's energy storage project comes from a R&D program launched by ANEEL in August 2016 for the proposition of energy storage systems in an integrated and sustainable way, seeking to create conditions for the development of technological bases and national production infrastructure, and has a deadline of May 2021.

It will be a hybrid energy storage system consisting in lithium-ion batteries and hydrogen obtained by electrolysis and stored in pressurized tanks, powered by surplus electrical energy from floating photovoltaic panels located on the reservoir lake of the Itumbiara Hydroelectric Plant owned by Furnas in the state of Goiás. The system also includes a 300 kW fuel cell for power generation based on the stored hydrogen (Electrical Energy Research Center [Cepel], 2019), through catalyzed electrochemical reactions that have only heat and water as by-products.

This project is the result of a partnership between Furnas and the company Base Energia Sustentável, associated with São Paulo State University (Unesp).

The entire solar plant located in Itumbiara will have a 1000 kW power, of which 200 kWp will come from the floating panels located in the plant's reservoir and 800 kWp from the other panels on the ground. The energy won't be commercialized, it will power the plant's auxiliary services system, such as lighting, sockets, ventilation, etc. The surplus energy will be injected into the grid through the existing infrastructure.

Storage and hydropower (grid operator - ONS)

In Brazil, the electrical energy supply relies mainly on hydropower plants (more than 60% of the grid (EPE, n.d.). To control the whole connected energy system (SIN), the national grid operator (ONS) uses mathematical models to predict the price of energy based on the rain that falls over the rivers and the level of water in the reservoirs.

The models used are called DESSEM, DECOMP and Newave (Brazilian Electricity Consumers Association [ANACE], 2018; Mercado Livre de Energia, n.d.). Therefore, in Brazil, when there is enough rain, the grid operator coordinates a decrease on the use of thermoelectric plants (that depend on fossil fuels) and the price of energy goes down. Water as a resource of energy emits less GHG than oil and coal and it is something that Brazil, as a tropical country, has in a large quantity. Another advantage is that it is a source that allows the grid more flexibility and stability.

A good aspect of hydro plants is that they can also be used as a place for energy storage, by storing water. Along with the mathematical models available for the grid operator, it is possible to predict the needs of energy (and water) the population may have. Thus, when solar and wind become larger players of a hybrid energy generation, water may be reserved and, when there is no sun or wind, released through the turbines and assure there will be no outages (Pimenta & Assireu, 2015; Deng et al, 2019). In addition, this is a renewable source of energy and does not require expensive imported equipment. The more digitized the grid is, the better this control will be, and the existent reservoirs can be better used as storage. This way, the energy transition towards a cleaner production will also come smoother and surer.

One major challenge for this kind of energy storage is that the construction of hydro plants requires the flooding of large areas. Therefore, the reservoirs should be planned to minimize this environmental impact and benefit from the geographical relief as much as possible. The sustainability gains of choosing a certain source of energy should be bigger than the losses and impacts caused by its construction and long-term operation and maintenance.

Analysis on risks for development of smart storage in Brazil

Storage technologies aim to fill time gaps between energy supply and demand. Thus, the lack of a regulation could jeopardize the energy sector in general due to the continuous decrease in energy demand provoked by Covid-19 crisis.

Moreover, the International Monetary Fund [IMF] (2020) stated that Brazil's economy is expected to shrink 9,1%, which is the highest decrease among BRICS countries. This could lead to a decrease of foreign direct investments in the country for the next 10 years due to its slow recovery compared to countries of the group, advanced and developing economies.

Another potential risk for Brazil's development is its performance in the Global Innovation Index (GII). Among BRICS countries, Brazil had the lowest score since 2016 (GII, 2020). This could also represent a risk, especially on the smart storage segment, since the level of innovation is stagnated and needs improvements. Brazil could face significant struggles in promoting R&D to create and develop new technologies for energy storage nationwide.

Lastly, in December 2019, Brazilian President Bolsonaro approved the Pluriannual Plan (PPA) for 2020-2023, in which it rejected the guideline submitting Brazil to UN Agenda 2030 (Câmara dos Deputados, 2019). It is important to highlight that the PPA establishes guidelines, goals and targets for the Union, States and Municipalities for the next four years. Therefore, the projects developed by Brazilian states and municipalities regarding SDG7 could also be impacted by the government's rejection of the agenda.

Scenarios

What the future awaits: scenarios on smart storage in Brazil

Negative

Taking into consideration a scenario of development slow-down, the industry could lose important advances made in the energy storage segment since the country would still be recovering from the impacts caused by Covid-19. With the exposure of structural vulnerabilities of the country, the country would need to focus its efforts in constructing a solid and strong infrastructure to be able to overcome the current situation.

Moreover, the prices of electric power tariffs could grow exponentially due the decrease of demand. In June 2020, ANEEL approved the regulation "Conta-Covid", which dilutes the increases in electric power tariffs over the next five years and preserves the financial situation of companies in the energy sector (ANEEL, 2020). However, these measures might not be enough to prevent the particularities energy SMEs face, as well as marginalized communities, when considered the existing lack of access to electricity in some regions (World Bank, 2018), and their continuous consumption based on diesel power generation.

Lastly, in June 2020, the MME proposed to cut the transport decarbonization target for this year to 14.53 million tons, half of the 28.7 million tons previously foreseen. The Ministry also aims to reduce the GHG emission targets for the next nine years, going from 670 million tons to only 529.85 million tons (Ramos, 2020). This measure could lead to a continuous trend of noncompliance, impacting on the attempts to promote clean energy and clean solutions in Brazil, as well as the efforts to combat climate change.

Conservative

Even though the process of liberalization of the national economy tends to lower the importation costs of storage technologies (REN21, 2020), it is not feasible to expect that the hydropower plants role as the main source of storage will be overcome shortly. Besides, in a conservative scenario, it is expected that fossil fuels and thermal power will continue to play a significant role in times of drought and for the isolated systems, especially with their ongoing decrease in international market prices (International Energy Agency [IEA], 2020).

Without the decrease in the use of fossil fuels, it is expected that the GHG rate, issued by the energy sector, will not have a sharp drop and keep above 300M tons in the coming years (System Gas Emissions Estimation [SEEG], 2018). In terms of storage, Brazil tends to follow the line of battery use, which can be linked mainly to renewable sources of energy generation, such as solar and wind energy. However, batteries have a low power when compared to other storage sources, which can lead to a slow to reach the balance between production and sustainability. In order to leverage the use of batteries and even other sources of energy storage, tax reduction policies would be a strategy to heat up the market for companies in the area of energy storage and even encourage use in homes.

Innovative

Renewable energy sources, such as wind and solar, are expected to continue to grow in the electrical Brazilian grid. For sources that vary so much as those during the day, their growth is tied up with energy storage. The estimation is that, in 2020, the market will reach a storage record with a total of 12.6 GWh of systems deployed (Energia hoje, 2020).

Moreover, the company Wood Mackenzie published a recent study, in which remarked that the post-2020 scenario shows a large increase in hybrid energy storage (Canal Energia, 2020). Looking directly at Brazil, the feeling is that the country will follow the same perspective mainly in the near term, as in addition to already being investing in hybrid energy storage as shown in one of the case studies. Currently, the option for renewables is aligned with the objectives of economic recovery: lower electricity costs, job creation and sustainability.

Strategies to be taken into consideration:

Negative

ANALYTICAL LEVEL	MAIN STRATEGIES
Politics	Implementation of infrastructure measures that promote a profound improvement in the energy sector as a whole. Promote diplomatic dialogue with strategic nations for national interest.
Economy	Improvement of economic performance indicators in order to attract new investments, especially for the energy sector.
Society	Creation of special programs that allow local, rural, traditional and vulnerable communities to use energy storage as a source of income and become a “prosumer”.
Environment	Maintain the decarbonization and GHG reduction targets previously agreed in the Paris Agreement in order to continue to promote climate change and sustainability.
Technology	Implement scientific research in the triple helix model (Etzkowitz & Leydesdorff, 1995) - government, academia and industry - to cover the electrical technological demands.

Table 1: Strategies for the implementation of public policies in the positive scenario
Source: Self elaboration

Conservative

ANALYTICAL LEVEL	MAIN STRATEGIES
Politics	Promotion of R&D projects to speed up the development of energy storage initiatives, by articulating with governments, private sector and universities; Implementation of national programs to strengthen the Brazilian energy sector, as well as the domestic production of energy storage projects. Strengthening of ABAQUE's role in the sector.
Economy	Allocation of funds to enhance the pace in the development of new technologies in order to insert Brazil in the Industry 4.0; The Ministry of Mining and Energy, Ministry of Economy, ANEEL, ONS and other relevant actors must work together in the coordination of resources provision in order to promote better allocation.
Society	Implementation of programs designed for local communities aiming to create jobs opportunities and promote the production and commercial initiatives.
Environment	Implementation of tax reduction policy for sales of storage technologies for companies and households.
Technology	Implementation of tax incentive policy for the establishment of smart energy storage companies in Brazil.

Table 2: Strategies for the implementation of public policies in the conservative scenario
Source: Self elaboration

Innovative

ANALYTICAL LEVEL	MAIN STRATEGIES
Politics	Caring out projects under International Organizations umbrella, such as IEA, BRICS, UN, along with the creation of exchange programs on energy storage studies; Creation of a Superintendence in ANEEL dedicated to coordinate energy storage projects, goals and rules.
Economy	Prevent the depletion of natural resources in general by promoting technological advances. The Ministry of Environment, Ministry of Economy and other relevant actors must work together to coordinate the efforts.
Society	Implementation of energy storage solutions to guarantee the continuation of the access to energy in all territory even during power spikes.
Environment	Promotion of specific plans for cities and states to achieve and respect SDG goals, as well as the inclusion of energy storage as part of SDG 7 targets in 2030 Agenda; Implementation of laws and rules to achieve zero GHG emission and to integrate ancillary services in the energy sector.
Technology	Promotion of international technical cooperation to share knowledge on high quality technologies with other nations.

Table 3: Strategies for the implementation of public policies in the innovative (positive) scenario
Source: Self elaboration

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02

RUSSIA

CHAPTER 2

RUSSIAN FEDERATION

Editorial Summary _

Ms. Polina Chulkova
Coordinator: Russia
Analytical Centre of BRICS Youth Energy Agency

Introduction

Russian teams working on the Outlook-2020 showed interest in the following topics: traditional hydrocarbon energy, new technologies of transport and electricity transmission at a distance, energy supply to remote areas using low capacity nuclear stations with a long fuel cycle.

Russia has a large raw material base of liquid hydrocarbons, which provides the country with the sixth place among the countries that hold reserves. Russia is also one of the crucial countries in the global gas industry. As for electric power systems in Russia, they have developed and continue to develop from isolated local systems to powerful power connections. Since the Russian Federation has a vast territory, the development of technologies for power lines is an important topic for this country. It is also worth noting that Russia has a full range of nuclear energy technologies, from the extraction of uranium ores to electricity generation. Based on all of the above, it becomes clear why The Russian developers of the Outlook-2020 chose those topics.

Now let's take a closer look at the main trends and solutions presented by Russian developers in their works.

Traditional hydrocarbon energy within the sustainable development: current consumption pattern, prospects, search for new solutions and technologies

Russia has faced with energy demand reduction due to the COVID-19. The gas industry was less affected. Hydrocarbon storages are fully filled, which leads to lower gas prices and does not pose any risk.

The probability that conservative scenario will be implemented is primarily a matter of politics and economics. In order to maintain its position in the external markets, new gas pipelines are being built. This is important in a situation where the demand for gas for electricity and petrochemicals increases.

According to a positive scenario, the implementation of government support measures creates conditions for faster growth of the industry. The increase in output will be provided mainly due to the development of petrochemical industries and the growth of the segment of deep processing products.

The most important positions for import substitution in the industry are components and spare parts for the equipment of gas processing plants, which mainly work on the basis of Western technologies. The negative situation on the international political scene puts Russia in a dangerous position, in which there is a risk of a significant reduction in production due to dependence on imported technologies. Tightening sanctions regime will result in a substantial loss: the import of polymer products will decrease and polymer exporting companies will suffer.

The likeliest is a negative scenario, the mitigation of which will be facilitated by the introduction of differentiated tax rates for geological exploration and creating a program of preferential lending to gas chemical companies.

New technologies of transport and electricity transmission at a distance

The implementation of the vision of the strategic plan 2030 of electricity transmission will require additional innovative systemic activities over the next decades. The following cross-cutting activities are highlighted to support technology adoption: inter-operator large-scale experiments in the field of active technologies; inter-operator coordinated actions at the supranational level; research in the field of interoperability technologies.

As for the future prospects of the Russian electricity grid until 2030, the Russian team came to the following conclusions: The "Smart Grid" concept includes transmission systems as an integral part of the future electrical grids in Russia. In reality, electricity transmission and distribution market players will interact more and more with each other in order to solve conceptual problems in the design of the electric power system. The introduction of active and real-time technologies will inevitably make the dynamic processes of the Russian energy system more complex, at the same time effective technologies should facilitate the actions of system operators for the next twenty years.

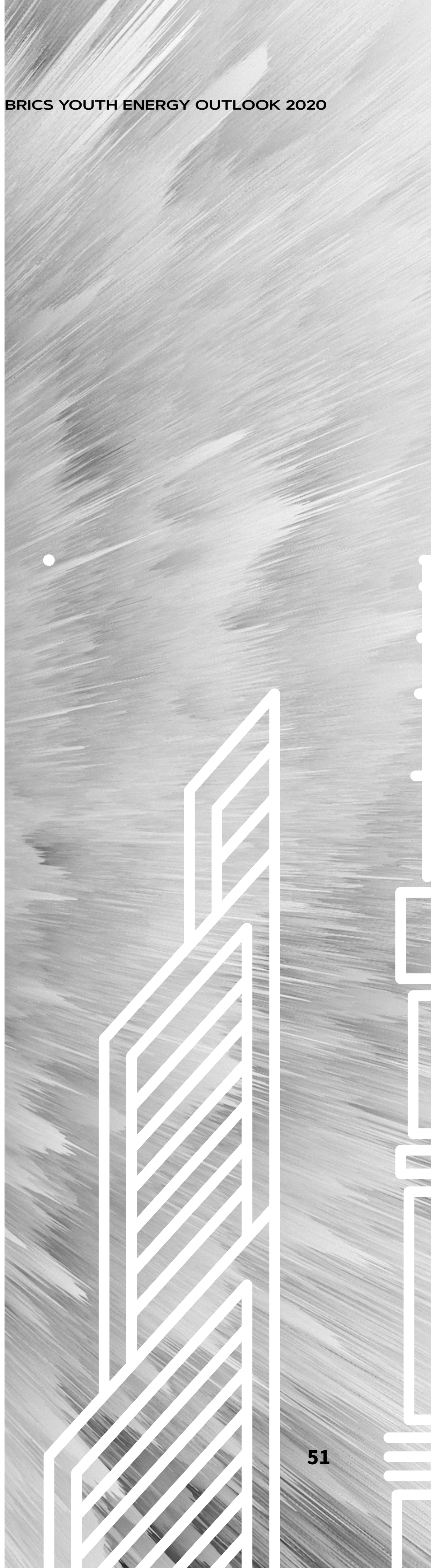
Low capacity nuclear stations with a long fuel cycle to supply energy to remote areas and the areas with a low level of grid development

Today Rosatom adheres to a basic scenario of development. Taking advantage of the availability of ready-made technical solutions for a variety of cases, Rosatom expects an increase in demand for small nuclear power in Russia and the world, concentrating its main efforts on the construction and operation of NPPs of medium and large capacity. This is the easiest and most reliable way, which does not require high costs or risks from the company.

In the framework of an innovative scenario, Rosatom State Corporation must take advantage of its advantages in the international arena in order to prevent the other countries to divide the SNPPs market among themselves, leaving Russia "overboard". Rosatom must realize its main advantage - the availability of real hardware. The availability of the finished product can provide Rosatom with a rich export market in the next decade.

According to developers of the Outlook-2020, a negative scenario looks completely impossible. It could involve completely abandoning the construction and export of SNPPs and ending R&D on all projects. The international nuclear energy market, with an increase in demand for SNPPs and a fall in demand for large NPPs, will oust Russia. Rosatom State Corporation will be on the verge of bankruptcy and will be fully funded from the budget.

Russian team consider that Rosatom needs to switch to the innovative development scenario, which was described above, as soon as possible, and start implementing comprehensive measures on the part of the RF Government.



1 Traditional hydrocarbon energy within a sustainable development: current consumption patterns, the prospectives, the search for new solutions and technologies (extraction, storage, transport, processing, transformation and conservation)

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Introduction

Currently, events in the energy market are unfolding extremely “tragically”. The OPEC+ meeting in March was not able to contribute to a compromise solution, which opened up the possibility of speculatively “playing in the oil market”. According to estimates by the International Energy Agency, at a cost of $ 30 per barrel Brent crude oil world production of 3.8 million barrels oil per day is excessive. With a decrease in the cost of a barrel of Brent up to $ 15 per barrel, there will be an excess of 15.5 million barrels per day of international oil production, of which 8 million barrels per day occur in North American oil [1].

What changes cheaper oil will have on energy balance structures, as well as on “fuel competition”, remains to be analyzed. Nevertheless, it is possible to declare that if this trend continues, the following consequences will arise:

1. The peak in oil demand will shift over time;
2. Investors may reduce interest in renewable energy;
3. The competitiveness of electric vehicles will slow its growth [2].

Analysis of traditional hydrocarbon energy

2.1. Estimation of gas reserves

Natural gas continues to be the most long-term sustainable energy source. Natural gas is the raw material for gas processing, therefore the situation with its reserves, production, export and consumption has a strong influence on the production activity and development of enterprises. The proven global gas reserves are 193.0 trillion cubic meters, of which 79% are in 10 countries. The level of gas reserves relative to the current annual production in the whole world is estimated at 49 years. Natural gas in the long term up to 2040 remains a steadily growing and highest priority energy resource on a global scale (see Fig. 1).

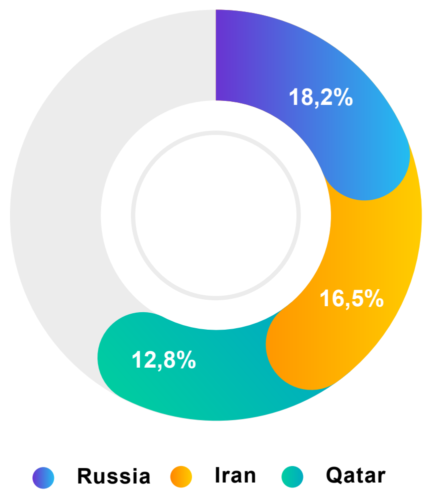

Figure 1: 79% of global gas orders
Source: BP Energy Outlook, 2019

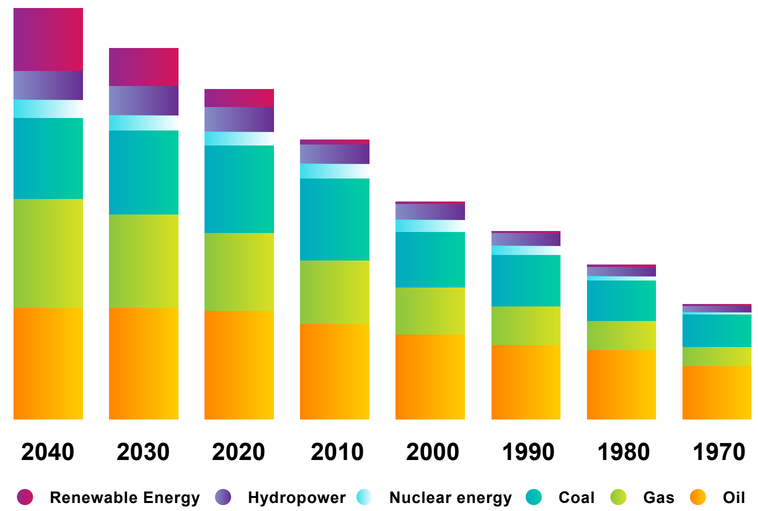

Figure 2: Change in energy consumption by years
Source: BP Energy Outlook, 2019

An important aspect of competition is the creation of gas chemical products with a completely different value added. In the structure of leading oil and gas companies today, a two-three-fold excess of the profitability of the downstream segment over the upstream sector is evident. Therefore, considering the growing role of natural gas as a “golden balancer” in the energy markets (see Fig. 2), as well as the higher margin of refined products, the gas-chemical complex seems to be the most relevant direction in the development of the Russian energy sector [3].

Currently, according to the Ministry of Natural Resources of the Russian Federation, gas reserves in Russia constitute 73 trillion cubic meters. The largest gas accumulation node is the northern part of the West Siberian Plate; there are more than 20 unique fields. Therefore, the main exploration is associated with this region. However, in the Arctic and the Far East, the problem of ensuring growth and development of reserves remains relevant for the economic development of the Russian Federation.

2.2. Impact on the Russian economy

According to experts, it is necessary to increase government funding for geological surveys at least twice to optimally increase hydrocarbon reserves. In 2019, exploration financing amounted to 21.4 billion rubles, but in 2020-2023, further growth in the volume of work in Russia is expected, which will be stimulated mainly due to the interest of oil and gas companies in the search and development of new fields.

Also, in Russia, there is an increase in the volumes of natural and associated gas processing (see Fig. 3), which generally has a favorable effect on the Russian economy, as the demand for gas processing products is growing, and the unit cost of the final product as a whole is increasing.

2.3. The processing of associated petroleum and natural gases

The processing of associated petroleum and natural gases is carried out at gas processing plants (GPPs), where they undergo primary hydrocarbon gas processing. Further, the processed gas can be liquefied to the state of LNG, pumped into the main pipeline as energy fuel, or sent for secondary (deep) processing at gas chemical or petrochemical complexes (GCCs).

Today, only 5% of the natural gas produced in the Russian Federation is used for processing to produce gas chemistry products, 15% is processed at the gas processing plant to produce products of small processing and motor fuels, and the remaining amount of gas is exported to importing countries. On the territory of the Russian Federation, there are 30 gas-processing plants, one helium plant and many GCCs.

2.4. Describing the main products of deep gas processing

The great advantage of gas chemistry processes is that in the processes of deep gas processing the final products of the highest processing are formed. At the GCCs, gas is recycled using gas chemistry processes. These processes include steam methane conversion to produce synthesis gas, catalytic dehydrogenation to produce olefins, thermal pyrolysis in tube furnaces, polymerization of monomers, and much more. The result of this processing is the final product with high added value, which was obtained from gas raw materials. At this stage, the main products of deep gas processing are:

1. **Ammonia:** in total Russia produces 19100 thousand tons per year; is used in the production of mineral fertilizers, nitric acid, polymeric materials and explosives.
2. **Methanol:** 4460 thousand tons per year; is at the same time the final product, ready to be used as motor fuel or an inhibitor of hydrate formation in pipelines in the far north, but at the same time it is an intermediate product for the further synthesis of substances such as methyl tertiary-butyl ether (MTBE), a high-octane additive to gasoline, and raw materials for the production of lower olefins - raw materials for polymerization plants, for the production of formaldehyde, methylamines, acetic acid, etc.
3. **Polymers** (polypropylene, high-pressure polyethylene, low-pressure polyethylene), 5230 thousand tons per year; are widely used in such fields as engineering, medicine, electronics, and construction.

In conclusion, we note the positive role of the state in supporting the gas industry. The extension of the Development Strategy for the gas industry until 2035, the inclusion of measures to liberalize domestic market prices and the adoption of an Action Plan (“Road Map”) for the development of the production of mineral fertilizers for the period until 2025 characterizes the industry as a priority. Subsidizing technology development costs and supporting domestic companies in foreign markets will enable domestic companies to produce competitive products with high added value [4].

HMAO Governor's Press-centre

Scenarios

The preparation of negative and innovative / positive forecasts is formed by evaluating the conservative / basic forecast.

Negative

Economic Aspect

According to a negative scenario, the sanction pressure on the Russian economy will increase. This is explained by the extremely low probability of resolving political contradictions and the unwillingness of opponents to agree to come to a common decision in the new political as well as economic conditions.

The most important positions for import substitution in the industry are components and spare parts for the equipment of gas processing plants, which mainly work on the basis of Western technologies. Therefore, now the share of Russian technologies in gas processing is very small. The negative situation on the international political scene puts Russia in a dangerous position, in which there is a risk of a significant reduction in production due to dependence on imported technologies.

Environmental Aspect

From an environmental point of view, there is a widespread transition to more environmentally neutral projects around the world. Currently, alternative energy sources are actively developing. According to BP, the growth in the share of renewable energy sources will be the most active, greatly exceeding the growth in the consumption of traditional hydrocarbons. Undoubtedly, this “ecological transition” will affect the gas industry, and it should be noted that in the future the gas industry might still expect tougher requirements for the environmental safety of enterprises. Air pollutant emissions will decrease, given the current situation at enterprises, on average, to 1% per year.

It is also worth remarking the pressure from renewable energy sources (RES). According to estimates by major environmental and technology agencies, there has been a growing trend towards explosive growth in technology for renewable energy sources. According to International Renewable Energy Agency (IRENA): global energy transformation; the most promising areas that can replace gas in the energy market are solar and wind energy. Investments in renewable energy in the largest developing countries of the world - India and China, where the greatest demand for energy is expected by 2035, is already an order of magnitude higher than investments in the transition to gas energy. Technologies that are used in the energy sector can offset and smooth out the peak demand for hydrocarbon resources, thereby creating adverse conditions for the development of the industry.

Technological Aspect

From a technology perspective, a negative scenario involves:

- the closure of old factories for the production of gas chemistry in connection with the lack of funds for their modernization;
- the inability to produce gas chemistry products due to limited access to foreign technologies due to sanctions;
- the closure of gas chemical production plants due to a decrease in demand in the foreign market.

Moreover, the development of foreign producer giants with an advantage in the cheapness of financial and raw materials will expand their geographical presence and displace Russian export fertilizers produced from ammonia.

With the decline, the methanol market will also be under the pressure in the long term. It is caused by the following factors:

1. The introduction of environmental and technical safety standards, which may call into question the use of methanol as a fuel and oxygenates due to its high toxicity and explosiveness.
2. The main factor in the competitiveness of Russian methanol is its low price (as methanol is produced from natural gas).
3. The increase in natural gas price will lead to a rise in the price of methanol, which will make its production less profitable and lower competitiveness.

It is worth mentioning that one of the promising industries for the use of methanol is its use as a raw material in the production of olefins: ethylene, propylene (MTO process). Moreover, it is likely that this process will not be able to compete with traditional methods for the production of olefins (gas and gasoline pyrolysis) due to their higher profitability. It will also endanger the development of the methanol industry.

Tightening sanctions regime will result in a substantial loss in all stages of polymer production. The import of polymer products will decrease: pipes, films, stationery that are not produced in the Russian Federation will disappear. Polymer exporting companies will suffer (today 20% of polymers are sold abroad), the lack of sales markets will force them to either reduce production or close plants [11].

Conservative

Describing the hydrocarbon energy

Russia has faced with energy demand reduction due to the COVID-19. The gas industry was less affected by the drop in the demand than the oil industry [5]. Gas demand is declining mainly in industry and in the commercial sector. Hydrocarbon storages are fully filled, which leads to lower gas prices. UGS facilities are 70% full, which does not pose a risk to future gas demand growth.

Also, it should be mentioned that the generation of electricity by burning gas at a gas turbine power plant and combined cycle power plants is more efficient. In addition, the increase in demand for electricity from gas will be stimulated by the transition to hybrid and electric cars using hydrocarbon fuels and the power of power plants that generate electricity by burning gas.

The probability that these scenarios will be implemented is primarily a matter of politics and economics. Natural gas price volatility increased in 2020, as demand reduction caused by losses during the

Covid-19 pandemic brought the market back to its 25-year low of $ 1.55 / MMBtu in early April. In the future, by 2050, prices are expected to remain below $ 4.00 / MMBtu "due to the abundance of cheaper resources. These cheaper resources make it possible to increase the level of production at a lower cost”, says the annual forecast of the International energy agency [6].

It is worth noting that in 2019, the United States has imposed sanctions on investing countries, which participate in the construction of the Nord Stream - 2 pipeline. The conservative projection assumes the preservation of these sanctions and the absence of new ones.

In order to maintain its position in the external markets of Russia, new gas pipelines are being built with a total capacity of over 200 billion cubic meters of gas by 2025. This is important in a situation where the demand for gas for electricity and petrochemicals increases.

Valuable gas products are produced at the GPP and GCC: ammonia, urea, urea-formaldehyde concentrate, methanol, formalin, and various polymers. Consider the prospects of each product in the order.

Development of the ammonia

Ammonia is one of the most important products of the chemical industry, on which the production of nitrogen fertilizers and nitrogen compounds is completely based. Its production is carried out by more than 80 countries. World ammonia production is about 173 million tons / year (2017). Today, Russia has capacities of more than 19 million tons / year (more than 10% of world ammonia production) and is among the world leaders [7].

The potential capacity of the domestic ammonia market could be 19 million tons in 2030. Export opportunities will be 4.8 million tons, and the production level will increase to 25.9 million tons (see Fig. 4).

By 2030, it is planned to commission more than 6 million tons of new ammonia production capacities. Largest GCCs are Phosphorit IG LLC, OTECO JSC (EuroChem North-West JSC), Nakhodka Mineral Fertilizers Plant CJSC, NPP Plateks (National Chemical Group), PJSC UCC Shchekinoazot, LLC YULGA.

Usage of urea and urea-formaldehyde concentrate

The next important components are urea and urea-formaldehyde concentrate. The demand for it is regulated by the consumers (agro-industrial complex and woodworking industry); therefore, during the world pandemic, enterprises are gradually reducing volumes from 5 to 10%. After its completion, project to resume the capacity of woodworking and furniture factories, and demand for the CFC will be restored and gradually increased.

Perspective of methanol

As for methanol, it is used in the preparation of synthetic resins and fuel additives, acetic acid and solvents. In addition to this, methanol has established itself as a fuel and as a raw material for the production of olefins. The volume of methanol production in Russia is 4.4 million tons (about 5.8% of global capacity). Currently, one of the promising areas of methanol use is the production of olefins. This industry can become one of the key in the medium term. By 2025, the world formaldehyde market will amount to 26 million tons, mainly due to the Asia-Pacific region. In Russia the average annual growth rate of methanol consumption will not exceed 1.7%.

Application of polymers

Polymers are polymerization products of unsaturated hydrocarbons. The main segment of polymers is represented by polypropylene (PP), polyethylene high (HDPE) and low (LDPE) pressure. The range of applications is very wide: films, sheets, pipes, toys, stationery, etc.

40% increase in demand for basic polymers is forecasted by 2030, and by 2050 is expected to increase by 60-65%. Consequently, there is a need for the construction of additional capacities or an increase in the old polymers production [9].

Risks

The special attention should be drawn to the influence of potential risks, which was taken into account when a conservative forecast was made. It is necessary to focus on all the risks that can have even the smallest impact on the projects of gas companies:

Environmental risks:

1. Displacement of hydrocarbons from the international market by renewable energy sources;
2. Tighter legislation in the field of environmental oversight.
3. Risks associated with a political factor:
4. Competition between Russia and other exporting countries. This risk lies in the fact that the United States, acting as the main competitor in gas exports, can weaken Russia's position in the global gas market;
5. Lower government measures aimed at supporting the gas industry.
6. Technological risks:
7. Failure by contracting companies to reconstruct, modernize, and build new facilities, which will directly affect the amount of gas chemistry products produced, as a result of which demand may be unsatisfied with the supply, and it may also reduce the share of import substitution.

Positive

Economic Aspect

According to a positive scenario, the implementation of government support measures, with the involvement of the necessary funding in the chemical and petrochemical industry creates conditions for faster growth of the industry. The increase in output will be provided mainly due to the development of petrochemical industries and the growth of the segment of deep processing products [10].

Currently, many countries in Europe are already openly declaring that sanctions against Russia, including the energy sector, must be lifted. In the future, it is expected that sectoral and personal sanctions will be partially lifted and partially weakened. This will lead to a restructuring of the import substitution program and an increase in the degree of international integration of the Russian gas market. The possibilities of ordering high-tech equipment will directly reduce costs by eliminating intermediate links, which in turn will favorably affect the competitiveness of the domestic hydrocarbon sector.

Environmental Aspect

On the subject of ecology, in a positive scenario, the complementarity between gas and renewable energy sources is expected, taking into consideration the unsustainable specifics of solar and wind energy and the deployment of several complementarity options (such as demand-side management, flexible power plants, etc.) that will maintain the balance of renewable energy and gas.

Technological Aspect

In a positive scenario, stable prices and the market for Russian gas and gas chemistry products are forecasted. Such scenario will provide the gas industry with the necessary funds to companies to carry out their activities and develop.

A positive technological scenario involves:

- the emergence of domestic highly profitable gas processing technologies;
- modernization of old plants and, as a result, an increase in the output of high-quality products;
- increase in the proportion of gas used for processing to produce gas chemistry products.

It is worth noting that the developing sectors of its consumption, such as use of an aqueous solution of ammonia in the production of a substance having the properties of absorption of oil spills in fresh and salt waters. Technologies for using ammonia as a fuel are also being developed, for instance, ammonia mixed with acetone as rocket fuel, as carbonless monofuel for ICE and diesel engines, or mixed with motor fuels derived from oil, ammonia as carbonless fuel for diesel power plants and as promising marine fuel. The demand for gas chemistry products also will only increase.

The development of the woodworking, chemical, automotive and gas industries will lead to an increase in demand for methanol. Today, methanol production capacity in Russia is 4.4 million tons, while by 2030 the volume of production will increase 5-6 times.

Promising long-term growth drivers will be spheres such as MTO (methanol-to-olefins) and the use of methanol as a fuel.

while by 2030 the volume of production will increase 5-6 times. Promising long-term growth drivers will be spheres such as MTO (methanol-to-olefins) and the use of methanol as a fuel.

The polymer market is developing very quickly, and with it, the ways of their secondary use are developing. Particularly promising developing sectors are engineering, automotive, instrumentation, 3D printing. By 2035, a big leap is expected in the 3D printing industry, as it allows getting high-quality and high- precision objects. There are also developments on the production of rapidly decomposable brands of polymers, which will give a new leap to the polymer future.

Recommendations to be taken into consideration:

Negative

Fiscal and monetary policies

In case of a negative scenario for the development of the energy sector in Russia presupposes not only the fact of sanctions, but also their extension and tightening. In this regard, the costs of the energy sector company will be increased; the state should revise the fiscal and monetary policies in relation to the oil and gas sector, namely:

1. To structure the legislative framework for taxation;
2. To increase the number of companies using value-added tax (VAT) on hydrocarbon production;
3. To differentiate the tax conditions for geological exploration, exploration and production of crude oil on land and on the continental shelf;
4. To reduce corporate tax rates;
5. Temporarily to eliminate export duties;
6. To create preferential lending programs for companies with differentiated interest rates.

These political actions will allow updating the tax climate in the market for both state and independent companies and making it more “favorable”. It is important to consider the fact that all these measures are temporary and their introduction is relevant only in a negative scenario, since a change in fiscal and monetary policies leads to a temporary decrease in the rate of filling the state budget, but it allows the company to develop its positions, which in the long term contributes to state growth.

Investment

Measures focused on overcoming the negative scenario should be supported not only by political actions of the state, in the form of reforming fiscal policies, but also by a large volume of investments aimed both at updating and replacing technology funds, and developing their own technologies.

The development of technologies in the domestic market is also a measure against import substitution and sanctions; therefore, it can positively affect the investment climate of the state. Improving the investment climate, in turn, will lead to an additional increase in the investment fund, which will result from the formation of an attractive and profitable economic environment.

Amortization policy

Improvements in the depreciation policy and state price (tariff) regulation in the field of transportation will affect the foreign policy of the state, which will strengthen the internal position of gas products and natural gas of the Russian Federation. To implement the innovative depreciation policy, it is necessary to perform a number of sequential actions:

1. Reforming approaches to creating groups of fixed assets and setting depreciation rates for them;
2. Establishment of a separate group of fixed assets;

3. Eliminate the procedure in accordance with which the costs of improving fixed assets are included in gross expenditures;
4. It is necessary to improve the procurement process of goods in the field of activity of natural monopolies and organizations in the field of hydrocarbon transportation.

Thus, based on the above sequential actions, we can conclude that the way out of a negative scenario can only be realized in the case of critical actions. The main ones are reforming the fiscal policy as well as changing the depreciation policy. It is important to note that all these changes are focused on the long term.

Investment

Measures focused on overcoming the negative scenario should be supported not only by political actions of the state, in the form of reforming fiscal policies, but also by a large volume of investments aimed both at updating and replacing technology funds, and developing their own technologies.

The development of technologies in the domestic market is also a measure against import substitution and sanctions; therefore, it can positively affect the investment climate of the state. Improving the investment climate, in turn, will lead to an additional increase in the investment fund, which will result from the formation of an attractive and profitable economic environment.

Conservative

Financial, pricing and tax policies

The conservative scenario assumes that the previous sanctions will be preserved, but no new ones will appear, including limiting the access of Russian energy companies to borrowed capital, the latest technologies and markets. In this case, it will be necessary to change all economic activity in the oil and gas sector - financial, pricing and tax policies. Therefore, for the implementation of this direction it is proposed to carry out the following measures:

- Introduce tax breaks for the development of hard-to- recover reserves and the exploitation of low-productivity deposits and individual strata;
- Reduce export duties for the first years (grace period is expected in the region of 2-4 years) production for new and newly discovered fields (individual layers);
- Support offshore projects: create a special income tax and special export conditions.

Development of domestic gas supply

Also, separately from other measures, it is worth focus attention on the development of domestic gas supply to the regions of Siberia and the Far East, which implies support for the regional gasification program implemented by PJSC Gazprom through tax incentives, which will increase the volume of the domestic gas market and, as a result, increase profits from gas sales to consumers whose role is played by the population [12].

The stumbling block for STP is expensive capital. Today, the policy of the regulator is as follows - much (several times) more expensive capital, and much cheaper fuel costs. This greatly reduces the attractiveness of any areas of scientific and technological progress in the energy sector as a whole and any measures aimed at improving energy efficiency in particular [13].

Contribution to scientific and technological progress

Thus, other measure could be material stimulation of scientific and technological progress in the energy sector, which implies a consistent increase in domestic prices for natural gas since 2020 (while prices for the population should not increase) to levels of equal profitability with its prices on world markets.

The next step may be the necessary to reduce export duties, especially since such a situation with export duties is practiced only in Russia and does not receive recognition from the World Trade Organization (WTO).

Investment efficiency of the energy and the economy

One of the most important and really efficient methods of countering external threats, in our opinion, should be a real boost investment efficiency of the fuel and the economy as a whole. In this direction, we have identified several of the highest priority measures aimed at various industries:

- To increase the attractiveness of the production sharing agreements (PSAs) regime by increasing the limit values for expenses reimbursed to the PSAs participant;
- To pursue a state policy aimed at removing restrictions on the participation of foreign investors in gas projects together with national companies;
- To implement the development of a long-term investment risk insurance system.

Positive

Economic measures

In the case of a positive scenario for the development there are necessary measures of influence in the domestic market, the political measures taken by the state. It is obvious that in the current crisis situation, a positive scenario can occur only after the adoption of certain strategic measures. Recommendations for a positive outlook will be based entirely on additional introductions to the conservative, basic scenario:

1. Price stimulation of technological progress in the energy sector;
2. Reduction of duties on hydrocarbon exports;
3. A radical increase in the investment efficiency of the Russian fuel and energy complex and the energy efficiency of the economy as a whole;
4. Measures to stimulate technology innovation;
5. Business optimization.

Environmental measures

Speaking about environmental measures, the main way to influence the energy sector is to create a national system for monitoring and reporting on greenhouse gas emissions, as well as publishing these results by gas companies, which will ensure that the image of companies depends on their environmental policies. The image of companies directly affects the investment climate of the state, so these measures will help strengthen the strategy proposed above, related to improving the investment efficiency of the fuel and energy complex. Additional environmental measures are:

1. There are even risks of changing climatic conditions during the development of a feasibility study

Mariiskiy Plant, Source: angi.ru

in the energy sector, as well as their compliance with modern environmental standards.

2. Stimulating the reduction of new waste generation and increasing the degree of utilization of accumulated waste from energy enterprises, due to tax benefits and fines that will go to the fiscal reserve;
3. Development of energy saving and energy efficiency technologies.

Energy audit

The next group of measures is tied to the control of companies, namely, stimulating the development of energy audit. The concept of energy audit consists of additional verification of the entire oil and gas complex, which can lead to the successful implementation of innovative projects and the development of the domestic energy sector.

Therefore, in the case of a positive scenario, there will be a favorable investment climate in the country. This will involve an additional vast influx of foreign investment, and government measures will be aimed not so much at tight regulation as at reducing barriers to the influx of foreign capital, technology and stimulating innovative development.

Conclusion

These recommendations serve as the basis for the development and implementation of public policy, depending on different development scenarios. In our opinion, the most likely is a negative scenario, the mitigation of which will be facilitated by the introduction of differentiated tax rates for geological exploration, exploration and production of oil and gas on the shelf and offshore; creating a program of preferential lending to gas chemical companies; stimulation of scientific research aimed at reducing the environmental impact of the fuel and energy complex, improving energy efficiency and energy conservation.

2 New technologies of transport and electricity transmission at a distance

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Introduction

Electricity transmission, in a broad sense, can be defined as the next, or fourth, in a series of similar fundamental structural transformations of the global energy sector.

Within the framework of the existing problems, the decarbonation of the electric power system requires a consistent modernization of the Russian system of transmission and distribution of electricity by means of technical, market and regulatory impacts on the planned, normal and emergency modes of the network.

One can foresee two main complementary courses for such modernization.

- Sustainable expansion of the power grid enabling increased transmission capacity. This can be achieved through a class of innovative and flexible technologies.
- Optimization of existing network funds by operating them closer to the limits of system security. In this case, more advanced technologies and devices are required to monitor and control the regime.

Overall, the current strategic plan aims to educate system operators on the “maturity” deficiencies of each of the technology alternatives under study. In this case, the strategic plan provides 10-year intervals for each technology, which prioritize the solution of key problems during the expected life cycle of the technology until it reaches the so-called “The level of maturity of the system operator”.

A complete list of promising technologies with a justification for choosing each of them was proposed by the REALISEGRID research project and discussed with system operators and stakeholders of the power system. Then the main technologies were subdivided into 4 main groups:

1. Passive equipment

Passive equipment (P), mainly associated with high voltage alternating current (HVAC) transmission devices, which include XLPE insulated underground cables; gas insulated lines (GILs); high temperature conductors (HTCs), also known as high temperature low voltage drop conductors (HTLS), which build on advances in composite materials; high temperature superconducting cables (HTS), which operate at extremely low temperatures and provide very low resistance; high voltage lines equipped with innovative supports.

2. Active equipment

Active equipment (A), capable of actively managing the network while increasing the capacity of the power transmission system to increase the stability of the system or smooth out possible intersystem fluctuations. These technologies include devices such as phase shifting transformers (linear regulators) (PSTs), direct current transmission (HVDC), flexible alternating current transmission systems (FACTS) and short circuit current limiting devices (FCLs).

3. The equipment of the real-time monitoring system

The equipment of the real-time monitoring system (RT) is based on advanced hardware and software components used to detect the loads and operating limits of the characteristic elements of the system in real time, as well as to monitor the general state of the system for dynamic stability. These technologies include a transient monitoring system (WAMS) and real-time heat sensing and monitoring lines (also known as smart lines) capable of dynamically increasing transmission capacity by monitoring conductor temperature.

4. The system operators

The system operators (ITO) operational impact equipment is based on some new technologies awaiting implementation in developing distribution networks and affecting the activities of the system operator: smart metering devices and energy storage technologies. Storage technologies include pumped storage power plants; energy storage using compressed air; kinetic energy storage (flywheel); superconducting magnetic storage; sodium sulfur rechargeable batteries.

It is worth noting that the selected technologies were considered independently of each other, although they could be implemented jointly to further enhance their impacts.

Overview of opportunities for advanced technologies

1. Passive technologies

XLPE insulated underground cables represent great potential for power transmission. Such cables are more and more used for direct current transmission (HVDC) applications. Further commissioning of XLPE-insulated AC cables, despite modern technological progress, is difficult, since the cost barrier compared to traditional solutions is still high and will remain so due to the increased complexity inherent in this technology. The cost barrier can be reduced by considering all types of benefits arising from this technology, namely reduced life cycle losses, lead times for procedures, permits, visual impacts, etc.

Gas insulated line (GIL) is a proven but still not widely used technology, mainly used in small installations (running tunnels, bridges or other existing infrastructure). This transmission line can carry significantly more power than traditional solutions and XLPE cables.

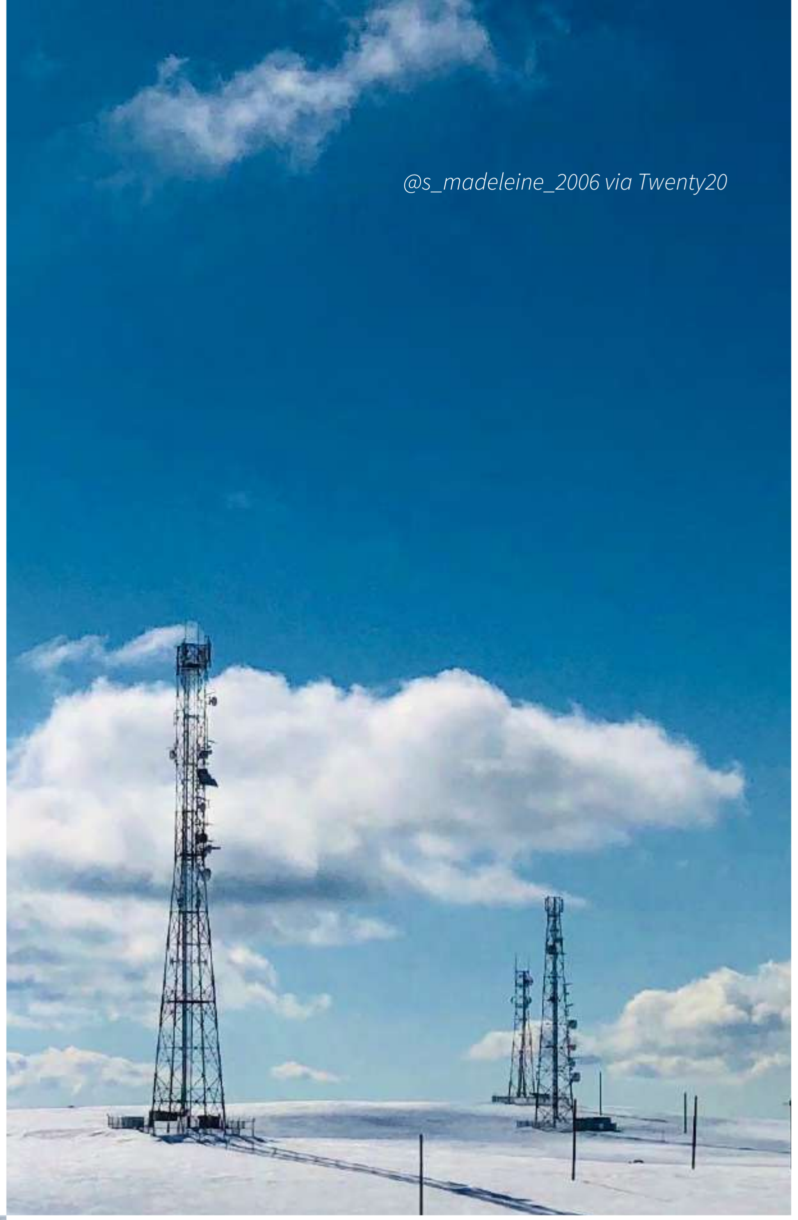
However, this technology faces great environmental challenges in terms of emissions of SF6 gas (sulfur fluoride), which are much more harmful than CO2 emissions. In addition, the costs of production and operation of such lines remain high relative to traditional solutions. The current level of maturity of this technology, based on the expected results of the analysis of its advantages and disadvantages, requires further improvement.

High temperature conductors (HTCs) are able to withstand higher operating temperatures, thus allowing more power to be transmitted than conventional conductors. They can increase the capacity without affecting the established transmission line right of way and, in general, without modifications to the transmission towers.

Among the technologies studied, high temperature superconducting cables (HTS) are the furthest from commercial use. Some upbeat experts are only suggesting the first use of HTS by 2030, thanks to the second generation of materials (yttrium barium copper oxide, also known as YBCO) and advanced coating techniques. The cost and size of cryogenic refrigeration units will remain the main obstacle to the implementation of HTS.

2. Active technologies

Current Limiters (FCLs) include technologies with varying degrees of maturity. When researching new concepts (high temperature superconducting current limiter, solid state current limiter, hybrid current limiter), there are still technological challenges that will have to be faced before commercial operation (especially for the high temperature superconducting current limiter).



The implementation of favorable testing by system operators at EU level could help consolidate information on design types and materials, cost savings and standards.

Phase shifting transformers (PSTs), used to control active power by adjusting the voltage phase difference between two nodes in a power system, are a mature technology used by system operators in Europe to manage power flow. The development of joint PST models by system operators and common standards should facilitate the integration of PST into transmission systems. Along with this, the development of cross-border electricity trade and the integration of renewable electricity will increase the need for such technology, working through coordinated management implemented within the inter-operator focal points.

Direct current transmission (HVDC) technology has proven to be reliable and attractive for long distance transmission of electricity, for deep cable lines (long submarine cable lines) and internal connections of asynchronous systems. AC to DC and DC to AC converters are critical to the development of this technology. The most advanced technology, the self-commutating off-line voltage converter (VSC), is more flexible than the more traditional linear commutated current converter (CSC) as it allows active and reactive power to be controlled independently.

Key advantages of DC transmission lie in the plane of increased transmission capacity of transmission lines compared to conventional AC transmission and improved controllability of the power flow, which, in turn, can improve the reliability of the line operation. Although the investment cost of a DC converter station is higher than that of an AC substation, the total investment cost of a DC transmission line can be lower than that of a corresponding AC line if a certain transmission distance (i.e. . "Break-even distance").

Flexible AC Transmission System (FACTS) equipment is a family of power electronics devices capable of increasing the controllability and stability of an AC system and increasing transmission capacity. Controlled lines are naturally compared by system operators to mechanically driven equipment that provides control functions, such as phase-shifting transformers (simpler, more reliable, reliable and generally cheaper solution, but with limited dynamic capabilities).

Flexible line devices can be classified according to their type of connection (parallel, series and combined). Parallel devices provide adequate reactive power compensation and voltage regulation functions, while series devices offer key benefits in terms of active power flow control and improved transient stability.

Cost, complexity and reliability issues are currently the main barriers to the integration of these technologies from the perspective of European system operators. Until now, lateral compensation devices (eg static, static thyristor compensator) were the most widespread and mature controlled line technologies.

The continued deployment of managed lines will depend on the technological ability of suppliers to overcome these barriers through greater standardization, interoperability and economies of scale.

The main technological problems lie in power electronic topologies (a set of microcircuit connections) and in the development of new types of semiconductors instead of silicon. More user-friendly interfaces and validation of performance through field testing will help build the confidence of system operators in these new technologies. As with the rest of active equipment, controlled lines, DC transmissions and linear regulators will be critical for the future integration of renewable energy sources into the Russian grid.

3. Real-time technology

Lines with Real-Time Thermal Monitoring and Evaluation RTTR lines (also known as smart RTTR lines) represent a fairly mature technology based on real-time line (cable) monitoring. This technology aims to maximize throughput while meeting design operating temperature limits, thereby reducing potential line congestion problems.

The development of this technology is a rather difficult process of solving practical integration problems: integration with other means, interaction and functional relationship with protective equipment, control of smart lines controlled in real time, interaction with the SCADA system (supervisory control and data acquisition, dispatch control and data collection) and the use of real-time outputs at the control level.

The combined use of real-time measurement and weather forecasting can significantly increase the value of RTTR technology for network operations: such use can be a useful opportunity for system operators to achieve higher throughput while maintaining safety and reliability in existing power systems. At the same time, relatively low investment costs come to the fore in comparison with the volume of investments required for the construction of new power transmission lines.

The Transient Monitoring System (WAMS) [3] is an information platform for monitoring and supervisory control. Based on devices for measuring complex quantities of current and voltage (PMUs), the WAMS system allows you to monitor the state of the power system over large areas in order to detect and further counter the disruption of grid stability.

This early warning system improves system reliability by preventing hazardous impacts from spreading over large areas and optimizing the use of available intervention tools in the system. However, some of the critical R&D challenges are signal accuracy and reliability, communication architectures, and data processing. Going forward, the development of WAMS will require standards for data processing, large-scale demonstrations and interoperability with other active equipment to realize the benefits brought by WAMS.

4. Technologies of control actions

While energy storage technologies are not directly under the control of system operators, they can have a significant impact on the planning and operation of the grid. Energy storage can help maximize the stability of the grid in the event of a sudden load / generation surge due to the volatility of power generation from most RES installations.

Storage can also support system operators in reducing CO_2 emissions. Historically, electricity storage has been associated with technologies such as pumped storage and compressed air energy storage. At the same time, other storage technologies are not directly related to solving large-scale system problems.

However, there are still technical and mainly regulatory issues to be faced. From a regulatory perspective, there are unresolved issues related to which market participants should own and operate storage equipment. The implementation of large-scale simulations and tests of energy storage at a European level appears to be a necessary step to validate the benefits of energy storage technologies.

Overcoming Non-Technical Barriers To Accelerate Technology Learning

The transmission technologies discussed in this article show different levels of maturity. Future commissioning will depend not only on their intrinsic strengths, but also on external factors such as:

- the approval and trust of the system operators based on large-scale simulations, experiments and tests in order to find out all the benefits to the system;
- standardization and interoperability of equipment due to a small number of high-tech equipment manufacturers in the international market;
- a shortage of qualified engineers and technicians in the power system, which is a major problem for the power industry;
- financing that depends on the regulatory framework and investment incentives at the location of the transmission systems;
- administrative barriers, such as authorization and approval procedures, are not yet debugged at the EU level.

Therefore, the implementation of the vision of the strategic plan 2030 will require additional innovative systemic activities over the next decades. The following cross-cutting activities are highlighted to support technology adoption:

- inter-operator large-scale experiments in the field of active technologies, including energy storage;
- inter-operator coordinated actions at the supranational (i.e. regional) level;
- research in the field of interoperability technologies.

Conclusion

The above results of strategic planning can serve to describe the future prospects of the Russian electricity grid until 2030. This leads to the following main conclusions.

The “Smart Grid” concept includes transmission systems as an integral part of the future electrical grids in Russia. In reality, electricity transmission and distribution market players will interact more and more with each other in order to solve conceptual problems in the design of the electric power system:

- decentralized "random" generation will grow;
- changes in operating rules and procedures will allow for more manageable loads.

Both changes should not affect the security and reliability of the system.

The introduction of active technologies and real-time technologies will inevitably make the dynamic processes of the Russian energy system more complex. Transient and grid imbalances will be considered in the future short term operational planning of power systems requiring more digital modeling of the interconnected power systems; their complexity will continue to grow in order to assess system security beyond the boundaries of each system operator's control area.

Effective technologies should facilitate the actions of system operators for the next twenty years:

- Smart telemetry at the distribution network level provides the ability to monitor low voltage network operation: it can be linked to smarter substations to provide system operators with better visibility of distributed generation and consumption, which in turn will be useful in implementing demand response approaches to effective peak load management.
- The combination of instruments for measuring complex quantities of current and voltage (PMUs), advanced computing architectures and digital modeling methods will provide reliable, accurate and hierarchical on-line assessment of the Russian system. A security assessment can then be performed every five minutes, including modeling the network's time-domain behavior.
- Large storage facilities for electricity can change the design principle of electrical systems that electricity cannot be contained and stored. From now on, wind and solar energy can be stored and used during peak hours, as well as at any time when it is required. Energy storage equipment can be optimally located close to generation centers.

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3 Low capacity nuclear stations with a long fuel cycle to supply energy to remote areas and the areas with a low level of grid development

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Introduction

According to the International Atomic Energy Agency's (further – IAEA) 2018 global nuclear power growth forecast, a 30% increase over current levels will be achieved by 2030, and capacity will almost double by 2050 [20]. However, at the same time, globalization, urbanization, population growth, aging infrastructure and stricter environmental regulations put today's electricity generation capacity in jeopardy.

Also, there is another problem. Today there are 440 nuclear power reactors in operation in the world [12]. Most of them are located in North America, Europe (including the European part of the Russian Federation (further - RF)), China, Japan. However, other regions practically do not have nuclear thermal and power plants.

Nevertheless, the development of these regions may be associated with the expansion of the extraction of rare metals, the rise in the production of gas, coal, iron ore, the development of the processing industry. However, the development of production is impossible without a stable energy supply. In addition, for the implementation of national projects energy is also needed. There are also problems in the supply of remote military units, border outposts, ports of the Northern Sea Route, stations to support a promising air route over the Arctic Ocean (it is necessary to carry out constant radio control, access to satellite navigation and communication with ground stations). It is obvious that the construction of medium and large nuclear power plants is unprofitable and impossible.

Against the background of these facts, a new promising direction in the development of nuclear power is low capacity nuclear power plants (further - SNPP) based on reactor facilities with a long fuel cycle.

Analysis of low capacity nuclear stations

1. General world analysis

According to the IAEA classification, small nuclear reactors (further - LPR) include plants with a capacity of less than 300 MW [33], the world demand for which until 2040 is from 0.5 to 1,000 units. An IAEA assessment in 2009 under its Innovative Nuclear Power Reactors and Fuel Cycle (further - INPRO) program concluded that 96 small modular reactors could be launched worldwide by 2030 [33]. 56 projects have been added to the Advances in Small Modular Reactor Technology Developments 2018 catalog.

Nowadays, there are 26 operating civilian reactors of low power in the world. It can be noted right away that 3 out of 4 countries using SNPPs are BRICS countries, and Pakistan uses Chinese technologies. This testifies to the relevance of the SNPP`s topic for study within the BRICS Youth Energy Outlook 2020.

Also, the United States is the world leader in the development of LPRs, and Russia and China are in second and third places with a difference of one project. At the same time, the difference in the number of projects under development between the first and second places is 11 units (almost twice as much). This lag is a clear example of several features of SNPPs at once, which we will consider further below.

2. Features of low capacity nuclear power plants

The SNPP system should be based on an alliance of government and private business. Due to the higher unit cost per kilowatt of energy, SNPPs look less promising for the state and entrepreneurs in comparison with more powerful plants. At the same time, LPRs offer private companies the opportunity to develop industrial production in regions with DES, since they can provide an uninterrupted power supply and require less initial investment. However, not all private companies can afford to build even a small nuclear power plant. In addition, companies, to a greater extent, do not seek to invest in unverified projects, and at this stage the experience of using SNPPs in most countries is still not large enough. In order to convince them of the profitability of investing in SNPPs, it is necessary to ensure a low cost of capital (discount rate) at the level of 5% [16]. However, even with all the assumptions, it can be concluded that the introduction of such technologies into the industrial life of private enterprises requires government`s support in the development of promising projects and in their practical implementation. The first helps to maintain healthy competition in the LPRs market, and the second helps to overcome economic risks for private clients.

What about Russia, there are natural state monopolies in the field of nuclear energy. This leads to the fact that private investors have to make compromises with government interests, which they are not always ready to make. In particular, in the Russian Federation, the development and construction of the reactor plant is distributed among the subsidiaries of the State Atomic Energy Corporation Rosatom (further – Rosatom), so there can be no question of competition in the market (Russian companies do not intend to purchase equipment from abroad). Rosatom's activities in the development and construction of nuclear power plants based on LPR are not aimed at providing energy to enterprises of private corporations, but at implementing government programs and strategies in remote regions or for export.

3. Situation in Russia

The average electricity consumption by current and potential consumers of the Chaun-Bilibino energy district is estimated at 6-24 MW, but there is a possibility of a consumer with a load of more than 200 MW. At the same time, the existing and planned for construction power lines (further - LP) have a maximum voltage of 110 kV. Given the existing loads, a huge question arises about the profitability of building a new SNPP instead of the outdated Bilibino NPP. To provide energy and heat to the sparsely populated cities of the Chukotka AO and those few enterprises that are still in service, the joint efforts of coal or diesel power plants with the support of the newest floating nuclear thermal power plant (further - FNPP) Akademik Lomonosov will be enough.

This indicates that the main consumer of electricity from SNPPs in remote regions will not be municipal services, housing and communal services, etc., but enterprises, in particular, for the extraction and processing of minerals. Given the current capitalist economy in the Russian Federation, these enterprises will most likely be represented by private individuals. Therefore, it is expected that the development of a system of SNPPs isolated from the centralized power supply is possible only if there is an increase in industrial production in remote regions.

4. The development of remote regions

However, such a scenario for the development of the Russian Far North, as well as the Far East, Siberia and the Republic of Crimea seems the most undesirable. Insufficient attention to this region has far-reaching economic and political consequences for Russia. Chukotka's mineral resources are estimated at about $ 1 trillion [15]. This amount of mineral resources makes Chukotka an attractive raw material base for other states. Insufficient attention to this problem may result in a weakening of political and economic power in the northern regions of the Russian Federation, which will lead to the economic expansion of these regions.

There is only one way to avoid such consequences – to start the development of remote regions again. It is necessary to draw up state programs aimed at developing the resource base of the northern and other promising regions, as well as their practical implementation, also, it is necessary to create conditions for the development of production by private companies. Anyway, it is required to create a sufficiently powerful energy supply system, which, however, is fraught with certain difficulties: rigorous climate, difficult and expensive conditions of cargo delivery, remoteness from supply centers.

In such conditions, the construction of large nuclear power plants will cost unaffordable amounts for local authorities or private companies. This is where SNPPs, which are less profitable in terms of electricity price per kilowatt, become very promising. This is ensured by their following advantages:

- Short construction time compared to large power facil-

One-of-a-kind floating nuclear power plant (FNPP) "Akademic Lomonosov", Source: rosenergoatom.ru

ities, that will allow, in a shorter time frame, to provide potential consumers with the energy necessary for the development of production and reduce their economic risks;

- Compact size to accommodate remote locations and confined spaces. The entire configuration is a lightweight, transportable and compact reactor, resulting in a significant reduction in the size of the radiation section. Some designs lack main circulation pumps and coolant flow is natural circulation, which reduces mechanical complexity and provides room for other equipment. They can also replace decommissioned coal-fired power plants, the capacity of which is rarely very large;
- Environmentally friendly form of energy. SNPPs consume less fuel, produce less radioactive waste (RW), and in the event of emergencies, the affected area will be much smaller. This is especially important in the conditions of the Russian north with its unique and very fragile ecosystem;
- Minimum initial investment, which leads to lower risks for investors;
- Potentially easier process for disposal of spent nuclear waste. Russian specialists were able to gain experience in the disposal of waste from small nuclear reactors during the implementation of the program to ensure nuclear and radiation safety, which was in effect from 2008 to 2015. The program continues now on the horizon until 2030, so there should be no problems with waste disposal [3];
- Increased reliability. Simplified and at the same time more lasting design improves the reliability of small reactor systems. The increased reliability of LPRs is achieved by: minimizing the number of active components; equipping with modern equipment and widespread use of automation; applying advanced diagnostic and predictive methods; and using the services of highly qualified and well trained operators. The simplified design makes the reactors easier to operate and less vulnerable to operational disruption;
- Improved security. Most SNPPs can be equipped with passive safety systems. Their work is based on the laws of gravity and natural circulation. The ability of passive safety systems to remove residual energy release, emergency core cooling and heat removal from containment eliminates the need for external power supply in emergency conditions and, in turn, ensures a low frequency of core damage;
- Possibility of placement next to the consumer;
- The longest possible period of operation is desirable before reloading nuclear fuel;
- Possibility of fixing the price for products of the nuclear complex for the future;
- Relative ease of integration into the existing power system;
- Multifunctionality. The regional cogeneration energy sector is currently and in the future the largest, highly socially significant and developing sector of the Unified Energy System (UES) of Russia. A large-scale entry into the regions of nuclear cogeneration energy on the basis of specialized nuclear cogeneration power units will be a large, socially significant infrastructure innovation project that will expand the scope of application of nuclear energy sources in the interests of the regional sector. For the far north, heat supply requires no less attention than power supply. In this region, twice as much fuel is spent on heating as on electricity. The Far North is the most heat-consuming regions of the Russian Federation, while occupying almost half of its territory.

5. Perspective technology

There is also a number of promising technologies that can make LPRs even more promising for companies or customer countries. Worth highlighting:

5.1. Small modular reactors (SMRs)

SMRs are defined as nuclear reactors, typically equivalent to 300 MW or less, designed in modular technology using factory production of modules, pursuing batch production economies and short construction times. New technologies include small modular reactors. Thanks to the modular design, the NPP elements are manufactured in the factory and the plant itself is assembled on site, thereby significantly reducing the time of construction. Additional modules can be added to the station as needs arise. SMRs can target niche markets including countries with small power grids. For SMRs, savings will depend on the speed of learning to manufacture and the number of units produced. Cogeneration can also open up additional revenue streams for small modular reactors. The modular design and small size allow multiple units to be created in the same area, and modules can be switched on or off independently of each other in order to ensure a continuous supply of energy of the required power. Due to the use of passive cooling systems, the modular design has a lower threshold for access to cooling water, so the reactors are suitable for remote regions and for specific applications such as mining or desalination. However, there are some problems: it is necessary to monitor several units at once. It is required to train professional personnel, and also to consider issues of cyber security. Higher electricity costs are also expected compared to large NPPs, however, the average estimated cost of electricity generation at SMRs could be reduced by large-scale serial production. Among other things, SMR projects and concepts of work may conflict with laws and regulations and require changes or new documents to be made to facilitate SMR licensing.

5.2. Transportable nuclear power plants (further - TNPP) and FNPPs

One of the most promising technologies in the direction we are considering is transportable nuclear power plants and nuclear power plants based on floating power units (FPU). The advantages of such designs include:

- minimization of the volume and cost of capital construction in the area where SNPP is located;
- the minimum number of operating personnel;
- performance of the most nuclear and radiation hazardous operations associated with refueling and repair work at a reactor facility, at a specialized enterprise, which ensures a high level of safety and quality of work;
- simplicity of solving the problem of SNPP decommissioning after the development of a technical resource with minimization of environmental consequences;
- small capacity of TNPP creates a lower potential for nuclear risks in comparison with nuclear power of large capacities and, accordingly, a greater prospect of real insurance of such risks at all stages of the life cycle of TNPP.

TNPPs are regarded as installations to be produced in series. It should also be borne in mind that in the future, TNPP will have no operating personnel, or its number will be minimized. In this case, “unmanned” technologies should be used in the TNPP physical protection system, and external rapid reaction forces should be used to solve the tasks assigned to this system.

The electrical capacity of block-transportable SNPPs transported by road does not exceed 2.5 MW. The electric power of the NPP Angstrem project with the SVBR-10 liquid-metal coolant reactor, transported on a special train, reaches 6 MW. NPP includes 9-12 transportable functional modules. Due to the production of all modules in the factory, the duration of installation work on the NPP site is only 1 month. At the moment, the NPP Angstrem project has not reached practical implementation, however, OKB Gidropress has received other orders for the development of small stations based on the SVBR-10 reactors and the more powerful SVBR-100, which indicates the interest at the state and private levels.

Nowadays, only one TNPP project has been implemented in the Russian Federation, but not on a railway or automobile chassis, but on the basis of an FPU. In theory, floating power units can have a wide range of capacities from 3.5 MW (e) (FPU with one ABV-3 reactor) to 70 MW (e) (FPU with two KLT-40S reactors), for FPU with SVBR-75 reactors / 100 declared capacity of 100 MW(e) and an interval between refueling of 7-8 years.

5.2. Small nuclear reactors of ABV type

LPRs of ABV type with electrical power of 4-10 MW are being developed by OKBM Afrikantov. ABVs are unified plants with integral reactors and 100% natural circulation of the primary circuit with a built-in steam-gas compensation system for land-based and floating NPPs. The main equipment of the reactor plant is arranged on a metal-water protection tank into a single steam generating unit. Ensuring a guaranteed level of safety is carried out due to the developed properties of self-protection and passive safety systems. Installation of the unit is carried out in an aggregate manner. To further improve the design, the following optimization areas are envisaged: ensuring the possibility of using reactors in a wider power range of 4-18 MW, increasing the core energy storage up to 3.1 TWh while ensuring the interval between refueling up to 10 years, minimizing the composition of normal operation and safety systems and service systems, flexibility of the composition and design of modules depending on customer requirements. Due to its compactness and a wide range of overlapping capacities, LPRs ABV can be used as an energy source for various purposes.

6. Russian projects

Russia has unique experience in the design and operation of lead-bismuth-cooled reactors for nuclear submarines. At present, low-power reactors of the SVBR type are being developed in Russia to create nuclear power sources in the power range of 10 - 40 MW-el. (SVBR-10) and 100-400 MW-el. (SVBR-100) using a modular power unit construction principle. The SVBR-100 project is at the highest stage of development. The project is being implemented by AKME-Engineering (a joint venture between Rosatom and EuroSibEnergo). The SVBR-100 AKME-engineering project is being carried out in cooperation with OKB Gidropress, VNIPIET, FEI and a number of other enterprises in the nuclear and related industries. The reactors have a high level of passive safety and internal safety, thanks to the use of first-degree lead-bismuth evacuation materials in the body of the monoblock reactor. Reactors can also use various types of nuclear fuel and operate in a closed nuclear fuel cycle.

In coastal areas with lack of railways, it is possible to create a coastal SNPP based on a FPU or a SMR on a transportable reactor block, moved by water and air cushion vehicles. In practice, the FNPP Akademik Lomonosov was created on the basis of a non-self-propelled vessel. The keel of the first floating nuclear power plant named after Academician Lomonosov was laid in April 2007 at Sevmash in Severodvinsk. Mooring trials began in mid-2016, and in May 2018 the vessel completed the first leg of its voyage to Pevek, docking in Murmansk to load fuel. Fuel loading was completed in October 2018, launch - in December 2019, and commercial operation - in May 2020 (full industrial and technological heat supply is planned to be implemented by 2021). However, if necessary, the FPU can be relocated from one site to another. The total lifespan is 38 years: three 12-year campaigns with a one-year maintenance gap in between.

The first power unit will take over the cogeneration aspect with a declared desalination capacity of 40,000 to 240,000 m3 / day, starting at 210 GJ / h. Repair of the station and refueling of fuel will be carried out under the conditions of existing in our country specialized enterprises for technological maintenance of nuclear vessels, which have the necessary equipment and qualified personnel.

7. Floating desalination stations

Separately, it is worth noting the potential of floating desalination stations, which can be located in coastal zones of arid regions.

Small modular power units can be placed under water or underground, including within civilian facilities, which will reduce the cost of plants by 50% by reducing the length of power lines and heating mains, reducing infrastructure and personnel [7]. It will also significantly reduce the cost of constructing the same containment, significantly changing the layout of the building. Both of these options for the location of the power unit provide greater protection against natural or human-made impacts. Such an arrangement of power units will reduce environmental and social risks for cities and natural objects near the station. In addition, such developments have enormous potential for providing energy and heat to military facilities. In these cases, to ensure secrecy, low-power power units can be located directly under the military unit underground, which also significantly reduces the length of heat and power transmission lines.

8. Comparing low capacity nuclear power plants with traditional nuclear power stations

Based on the above facts, it can be noted that in DES zones SNPPs look much more promising options than traditional NPPs. There is also clearly visible interest in such stations all over the world, including in Russia. However, the question still remains unresolved whether they will have an advantage over coal-fired thermal power plants (further - CPP), wind power plants (further – WPP), hydroelectric power plants (further - HPP), geothermal power plants (further - GeoPP), solar power plants (further - SPP), tidal power plants (further - TPP) and diesel power plants (further - DPP) in regions with DES. It should be borne in mind that since low-power installations are cogeneration, it is necessary to consider several markets at once: electricity, heat, desalinated water, etc.

Let us immediately note the low prospects of renewable energy sources (RES) for supplying remote regions of Russia:

8.1. Hydroelectric power plants

Nowadays the potential of such stations in the world is almost completely exhausted. Their construction on small rivers does not make any sense, and the construction of new HPPs on large rivers will lead to flooding of agricultural land and settlements, disruption of the water balance, disruptions in the work of the ecosystem of the regions, climatic consequences. In addition, not all regions have large enough rivers for the construction of such structures, which are not a winning option in terms of the cost of the structure itself and its operation, and also potentially carry the danger of major disasters. It is also worth considering the fact that their use in the Extreme Sevres is simply impossible, since the rivers there are covered with ice for most of the year. The possibility of using damless hydroelectric power plants reduces environmental risks, but creates a relationship between the river flow rate and electricity generation;

8.2. Wind power plants

Wind power on a large scale turned out to be unreliable, uneconomical and unable to provide electricity in the required quantities. Their energy production depends on the strength of the wind, therefore it is unstable, which is not suitable for supplying large industrial facilities and cities. Also, to produce a sufficient amount of energy, it will be necessary to create a complex of wind installations on a sufficiently large territory, which, due to noise and vibrations, cannot be used for anything else. Serious negative consequences of the use of wind energy include interference with air traffic and the propagation of radio and television waves, disruption of bird migration routes, climatic changes due to disruption of the natural circulation of air flows;

8.3. Solar power plants

One of the most important barriers to the expanded use of SPPs as energy sources in DES regions is the low intensity of solar radiation. The practical implementation of the concentration of solar energy requires the alienation of huge land areas. To SPP with a capacity of 1000 MW (El), and 10% efficiency, needs 67 km^2. Also, the land that will need to be allocated for various industrial enterprises that produce materials for the construction and operation of SPPs. It should be emphasized that the consumption of materials, time and human resources in solar energy is 500 times higher than in traditional fossil fuel energy and nuclear energy;

8.4. Tidal power plants

In the 21st century, TPPs can become very promising sources of electricity if they use Gorlov's helicoidal turbines, which can significantly reduce environmental risks by building a station without building a dam. However, TPPs cannot supply power to cities and businesses within mainland Russia. This significantly reduces the scope of their application. However, now there are no ready-made commercial proposals for such stations. All of these factors make the potentially larger scale production of SNPPs more cost effective;

8.5. Geothermal power plants

Geothermal energy has a number of serious drawbacks, characteristic to one degree or another for all RES. These include the impossibility of placing on a variety of sites available for traditional energy sources, low intensity of incoming energy, serious environmental consequences: the possibility of awakening seismic activity in the area of the power plant, the danger of local subsidence of soils, emission of toxic gases, which are dangerous to humans, animals and plants.

9. Some conclusions

Based on all of the above facts, it can be concluded that it makes sense to compare SNPPs only with other traditional energy sources (CPP and DPP). The main difference between nuclear energy and coal and oil-based energy is that NPPs do not use organic fuel. This is not only good for the environment, but also beneficial in economic terms, because a huge part of the costs of CPP and DPP in remote regions falls precisely on the purchase, delivery and storage of coal, gas or diesel fuel. At the same time, most of these costs are taken by the delivery of organic fuel to remote regions due to the required large volumes and long distance.

As an example, let us give the estimatedconstant cost of heat and electricity generated by competing energy sources of the Chaun-Bilibino energies district, depending on the price of fuel. The data presents that at coal prices from $ 200/t. and diesel fuel from $ 700/t. FNPP has a huge advantage over CPP and DPP, making them more winning options in the long run. This is not able to change even the temporary drop in prices for coal and diesel fuel, since the pandemic did not hit the Russian energy industry as hard as, for example, the energy industry in Europe. On the contrary, during the pandemic, nuclear power has established itself as a reliable energy source capable of continuing to supply uninterrupted energy even in the most critical situations. The Energy Information Administration (further - EIA) is projecting a significant recovery of energy prices in the second half of this year, and then a major recovery in demand next year. Thus, the specific infrastructural and geographic features of the remote regions of Russia nullify economic risks due to the higher price per MW of energy than other energy sources have. Taking into account the absence of other significant problems of SNPP, it can be stated with confidence that if there is a long-term contract for the supply of energy, fresh water, hydrogen, etc. in any DES, the prospects for the development of small nuclear power do not carry any risks that could prevent their commercial implementation.

Rosatom's Kaliniskaya Nuclear Plant,
Source: rosenergoatom.ru

Conclusion

In conclusion, we consider it necessary to note that in order to obtain maximum benefits, Rosatom needs to switch to the innovative development scenario, which was described above, as soon as possible. However, this will require comprehensive measures on the part of the RF Government. For this reason, it is necessary to compile a catalog of available LPR technologies and an SNPP "road map" for presentation to the Ministry of Finance of the Russian Federation and potential investors.

Scenarios

The preparation of negative and innovative / positive forecasts is formed by evaluating the conservative / basic forecast.

Negative

With such promising opportunities, a negative scenario looks completely impossible. It could involve completely abandoning the construction and export of SNPPs, ending R&D on all projects currently being developed, and focusing exclusively on reactors for icebreakers, submarines and large NPPs.

This will lead to a drop in interest in nuclear energy in the DES regions, since the construction of large NPPs there is completely unprofitable, a drop in the authority of the Russian nuclear industry and Russia itself on the world stage and huge financial gaps for both Rosatom State Corporation and the budget of the Russian Federation in the whole. Also, negative consequences may occur for the state integrity of the Russian Federation, and the development of remote regions of Russia will slow down so much that by 2035 we will not notice any serious changes in these regions.

The international nuclear energy market, with an increase in demand for SNPPs and a fall in demand for large NPPs, will oust Russia and will be divided between Europe, North America, China and Japan. After investing in foreign countries, the reference of Rosatom State Corporation will fall so much that the company will not have time to restore its positions by 2035. Since export is a priority for Rosatom, the state corporation will be on the verge of bankruptcy and will be fully funded from the budget. In such conditions, the entire domestic nuclear industry will begin to reverse in the development of innovative ideas, then gradually and inevitably cede the domestic market to foreign companies.

Conservative

Today Rosatom adheres to a conservative / basic scenario of development. Taking advantage of the availability of ready-made technical solutions for a variety of cases, Rosatom expects an increase in demand for small nuclear power in Russia and the world, concentrating its main efforts on the construction and operation of NPPs of medium and large capacity both in Russia and abroad.

This is the easiest and most reliable way, which does not require high costs or risks from the company. Most of the projects have been developed since Soviet times, which greatly reduces the cost of research and development work (further - R&D). At the same time, the company will always have a demand, at least in the domestic market, since low-power reactors are used for military purposes under orders from the Ministry of Defense of the Russian Federation, as well as in the nuclear icebreaker fleet. It is enough just to wait until the demand for SNPPs grows due to resource depletion in regions with centralized power supply and there will be a need to develop power systems in previously less developed or completely developed regions.

To implement such a scenario, Rosatom only needs to fulfill military orders and continue the development of already announced projects without additional funding from the budget. When there is interest either from municipalities or from individuals, they can contact the company in order to draw up a commercial proposal. Since Rosatom has no competition in the domestic market, sooner or later, orders for SNPPs will begin to come.

However, the conservative scenario for the development of small-scale power generation in Russia seems akin to a "time bomb", which can cause huge financial losses to Rosatom in the event of an explosion if the company does not switch to an innovative (positive) scenario.

As world nuclear association notes, the Government of the Russian Federation plans to cut funding for Rosatom State Corporation. Under these conditions, the company will have to compensate for these financial losses by making more profits. At the same time, one of the goals of Rosatom is to receive 60% of its total earnings from exports by 2030. Taken together, these two factors mean that relying on the domestic market is a huge financial risk that can be avoided when new export capacity is deployed. However, in the international arena, Rosatom loses its monopoly position and is forced to compete with other states. At the moment, the Russian company is focusing its export on VVER-1200 reactors and other high-power reactors. However, insufficient flexibility in the external market and insufficient attention to LPR and SNPP based on them may lead to the fact that Rosatom's competitors, which are already developing this export direction, will be able to offer client countries more profitable solutions in the foreseeable future, since they will already have experience in serial production and export of LPRs, including TNPP, for which it is necessary to think over issues of international security, change existing international codes and standards, etc. A slight lag now, at the dawn of SNPP development, will lead to a catastrophic gap in the future, when these technologies will occupy a significant part of the market. In the future until 2035 SNPP technologies will become the main trend in nuclear power, at least they will be of interest to states wishing to acquire nuclear power, but do not have enough money to build a large NPP.

Positive

International Relations

In the framework of an innovative scenario, Rosatom State Corporation must take advantage of its advantages in the international arena in order to prevent the United States, China, France, Canada, etc. to divide the SNPPs market among themselves, leaving Russia "overboard". Meanwhile, while England, Canada and the United States are trying to play for a long time, developing innovative solutions, improving the technical appearance and economics of their SNPPs projects, Rosatom must realize its main advantage - the availability of real hardware. Without trying to jump the chasm between today's unit cost of small NPPs and the required one, the state corporation needs to bet on the construction of SNPPs here and now. For example, more than a dozen other countries have already become interested in the FNPPs project: Malaysia, Indonesia, South Korea, Mozambique, Namibia, South Africa, India, Vietnam, and Latin American countries - Brazil, Uruguay, Chile - are considered as a promising market for FNPPs. At the moment, Rosatom is out of competition in the world FNPPs market, since only in Russia there is a similar project implemented in practice. The availability of the finished product is a guarantor for the client countries and can provide Rosatom with a rich export market in the next decade.

Design, production and supply of equipment for the nuclear and thermal energy

Another important advantage of Rosatom is its readiness to make a comprehensive proposal, consisting only of turnkey NPPs but also of fuel, training, infrastructure development, legal and regulatory structures, and so on. Rosatom's subsidiary Atomenergomash offers a full range of solutions in the design, production and supply of equipment for the nuclear and thermal energy, oil and gas industry, shipbuilding and the special steel market. The company fully controls the production chain of equipment for the nuclear island and the turbine hall, from R&D and detailed design to process design and equipment manufacturing. This is supported by significant construction financing in the client countries, as well as the willingness to take on equity participation or build their own BOO production, as in Turkey.

International commerce

For the development of international trade, Rosatom needs to create several more test samples, which should show that in the future, Russian developments will not be inferior to Western or Chinese ones in terms of manufacturability. At the same time, it is also worth making several test commercial proposals so that potential customers can see real numbers as a sign of their willingness to cooperate. A special place in this campaign should be attributed to the Ministry of Foreign Affairs of the Russian Federation (further - MFA). On the one hand, it should continue to expand the network of Rosatom's representative offices in embassies in different countries. In addition, it is necessary to promote Russian nuclear energy at the interstate level through intergovernmental agreements, which also rests on the shoulders of the Foreign Ministry. Do not forget about joint work with other states within various international organizations (IAEA, BRICS, the Nuclear Energy Agency of the Organization for Economic Cooperation and Development (further - OECD NEA), the Commission of the CIS member states on the use of nuclear energy for peaceful purposes, etc.).

However, one should not forget about caution in foreign trade. In particular, Rosatom's export policy should be different for countries with and without nuclear weapons. In particular, it is necessary to consider the issues of radioactive waste (further - RW), processing, since countries possessing nuclear weapons or promising developments in this area can obtain plutonium from spent nuclear fuel (SNF) for their military nuclear program. In trade with such countries, for example, India, it is necessary to remove all radioactive waste left over from the operation of Russian-made NPPs.

Internal affairs

In the domestic market it is necessary to achieve an alliance between the state and business. First of all, the state should stimulate the extraction of minerals in the North and East of Russia by economic and legal methods. Then it is worth contacting the largest companies specializing in the extraction of minerals (Polyus Gold, PJSC Lukoil, Evraz Plc, United Company Rusal, etc.) with a proposal for the construction and operation of ASMM near potential locations of mining enterprises. At the same time, taking into account the successful export policy on the domestic market, at first Rosatom will be able to afford to go into negative territory, but to reduce prices for domestic companies in order to further stimulate their investments in these regions.

Thus, the active industrial development of DES regions will begin, in which, with the growth of cities and the further development of production, new energy capacities will be needed. As a result, a whole network of SNPPs may appear, which will create an autonomous eastern branch of the Unified Energy System of Russia (further - UES), capable of withstanding the load of large NPPs, equipment and building materials for which, under conditions of industrial development, can be produced near the future location of the station. So, it will be possible to move to the complete centralization of the Russian power grids and move from the less efficient (in a centralized power supply system) large NPPs). However, such a development strategy requires an increase in uranium production or exports to fuel the new NPPs.

4 New technologies for the delivery of non-traditional renewable energy sources and traditional energy sources to consumers

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Introduction

In recent years, with the rapid development of the economy, the demand for energy is increasing, and the problem of energy shortage has gradually become a common concern in the world. The development of new energy sources and the efficient utilization of existing energy sources have attracted wide attention. In order to cope with the energy shortage, countries should step up the development of new energy sources. However, in the process of new energy development, various deficiencies begin to appear, such as the new energy development cycle is longer, the cost is higher. In the field of energy utilization, heat exchanger is the most common and important unit heat exchanger. Therefore, improving the heat exchange efficiency of heat exchanger is the fundamental of energy saving.

Analysis of technologies for delivery of energy sources

1. Analysis of the growth of the radius of heat supply of trunk networks in large cities from combined energy sources

The Russian energy sector is the basic branch of the Russian economy, providing energy for the internal needs of the national economy and the population. In the course of the energy reform, the system of state regulation and the structure of the industry changed, and a competitive electricity and capacity market was formed. At the same time, there are a number of problems associated with the activities of generating companies: the imperfection of the regulatory framework; unsatisfactory level of market infrastructure development; low rates of renewal of production assets; incomplete use of the generating capacities of the stations. According to the energy strategy of Russia until 2030 the structure of the installed capacity will change: the share of nuclear power plants will increase due to the commissioning of new capacities and the share of thermal power plants using gas will decrease due to the decommissioning of equipment. The efficiency of energy supply to consumers is determined by the technical level of the main equipment of TPPs. The degree of physical wear and tear of equipment is characterized by age groups. Today in Russia combined heat and power production is carried out mainly at CHP plants. The advantage of this production: 20 - 30% reduction in fuel consumption compared to separate generation; beneficial use of waste heat. Investments are planned in the development of heat supply from combined energy sources for a more complete coverage of the population. The main causes of accidents are severe wear and corrosion of pipelines during operation of heating networks beyond the standard service life and low rates of replacement of dilapidated networks. The social importance of the industry sets more and more stringent frameworks when choosing development paths. District heating systems need serious modernization. The changes being developed today in the model of energy markets and in the methodology for planning energy development should create the right incentives for market participants to create reliable, balanced all types of energy resources.

2. Justification of the growth of heat losses in heat networks

The efficiency of transporting the coolant directly depends on: the length and diameter of the pipeline, the temperature of the coolant and the environment, the magnitude of heat losses and coolant leaks through the insulation. Determination of real heat losses allows to justify the structure of the power supply system, the choice of the temperature schedule, as well as work on the modernization of heating networks It should be noted that heat losses are also included in the tariffs for heat energy and are an indicator of energy efficiency. Thus, the determination of energy losses during the transport of a heat carrier is an important task of energy supply. With competent design and a hydraulically adjusted system of heating mains, the loss does not exceed 5-7%. However, in reality, losses in heating systems are 20% or more. The reasons for deviations from the design operating modes of heating systems are moisture insulation and soil due to a violation of the integrity of the building and insulation structures of heat pipelines, rapid aging and destruction of the types of heat-insulating materials used. The length of heating networks in need of repair is 29% of the total length of all heating networks in Russia. There are several ways to solve the problem of heat loss in heating system: the improvement of the types of pipelines and their insulation and the development of alternative energy sources.

3. Addressing the trend of non-compliance with quality regulation schedules

Recently, there has been a significant gap between the actual and design temperature schedules for regulating heat supply systems. District heating systems were designed using high-quality regulation, with a seasonal load regulation temperature schedule of 150-70 ° C. But, already starting from the end of the 70s, deviations of the temperature of the network water appeared in the actual control schedules, at low outside temperatures. Under the design conditions, the water temperature in the supply heating lines dropped to 85-115 ° C. The lowering of the temperature schedule by the owners of heat sources was formalized as work according to the design schedule of 150-70 ° C with a “cut-off” at a low temperature of 110-130 ° C. The transition to a lower temperature schedule, for example, 110-70 ° C from the design schedule of 150-70 ° C, should entail a number of serious consequences. In connection with a 2-fold decrease in the calculated temperature difference of the supply water, while maintaining the heat load of heating, it is necessary to ensure an increase in the flow of supply water also by 2 times. The corresponding pressure loss through the heating network in the heating network and in the heat exchange equipment will increase by 4 times. The required increase in the power of the network pumps should occur 8 times. Neither the throughput of the heating networks, nor the installed network pumps will make it possible to ensure the delivery of the heat carrier to consumers with a doubled consumption. In this regard, it is quite clear that to ensure the temperature schedule of 110-70 ° C, radical reconstruction will be required, the costs of which are unbearable for the owners of heating systems. Currently, the country is developing heat supply schemes, in which the design control schedules of 150-70 ° C, 130-70 ° C are considered not only relevant, but also valid for 15 years in advance. At the same time, there are no explanations for the provision of such schedules in practice, no justification of the heat load at low outdoor temperatures in real control conditions is provided.

4. Study of the tendency of approaching autonomous power supply sources to a consumer

The most important aspect of the functioning of any production is energy saving. Efficient and reliable operation of consumers is mainly determined by a stable supply of energy carriers. The issue of energy supply is especially relevant for consumers who have facilities remote from the centralized energy system. For most energy facilities, interruptions in the supply of energy are undesirable, due to the large material damage, therefore, the appearance of a duplicated energy source is necessary. It is often difficult to solve these problems. In this regard, autonomous power supply sources have been developed in the energy market. Most of the existing powerful power supply systems (NPP, HPP, CHP) are highly susceptible to wear and tear, which entails a decrease in their reliability. A way out of this situation is the use of autonomous energy sources, as exemplified by gas turbine and gas piston units (GPU and GTU), which allow cogeneration of heat and electricity. The production of our own energy allows you to pay for it at the cost of production, thereby dramatically reducing consumer costs.

The use of GPUs and GTUs for power generation provides the following advantages:

1. reducing the cost of consumed electricity up to 15% for the payback period and up to 35% for the operation period;
2. additional redundancy of power sources;
3. reduction of emissions of harmful substances into the atmosphere.

According to the energy strategy of Russia until 2035, the development and expansion of autonomous energy supply systems for consumers is a priority area for intensifying the country's energy. Autonomous energy will require an increase of 1.2-1.5 times the average annual investment in the energy sector. In comparison with 2015, the required volume of investments in 2035: in autonomous energy will be 3-4 times higher, and the share in the total volume of investments in energy supply will increase from 10 to 16-20%. In 2030, the share of heat produced by CHP plants will decrease from 43 to 35%. Distributed power generation units in the form of gas turbine units and their combination with a heat recovery boiler will be greatly developed. The generating capacity in 2030 will consist of power plants operating on advanced world-class technologies.

The Russian Federation is a typical example of a country with an already developed centralized energy supply system and at the same time having a significant need for decentralized energy sources. The implementation of projects for the organization of autonomous power supply is associated with a number of risks: the uncertainty of the development of events, the impossibility of predicting the main indicators of

Table 1: Risks of decentralized energy supply
Source: Self elaboration

RISKS		
INVESTMENT RISKS	OPERATIONAL	LEGAL RISKS
1. Increase in the cost of equipment and also construction and installation works	1. Changes in market prices for electricity and gas	1. Legislative changes in the conditions of interaction between entities in the energy and gas markets
2. Violation of the delivery time of equipment and materials	2. Impossibility of selling excess energy on the market	
3. Violation of construction technology, design, planning, management mistakes	3. Unfavorable dynamics of internal energy consumption	2. Changes to tax, antimonopoly and other legislation
	4. Natural gas supply disruptions	
	5. Generating equipment failures	

Table 2: Safety functions of decentralized energy supply
Source: Self elaboration

SAFETY FUNCTIONS (COUNTERMEASURES)		
1. Justification of the brand and model of equipment	1. Planning and organizing project approvals	1. Planning and organizing project approvals
2. Obtaining reliability guarantees from component suppliers	2. Control over the quality of supplied energy	
3. Obtaining a long-term contract with a professional company for the installation and repair of equipment	3. Long-term contracts for the supply of raw materials	
	4. Obtaining a long-term contract with a professional company for the installation and repair of equipment	

the enterprise's activity, incompleteness and inaccuracy of the initial information on the conditions for the implementation of the project and related results (Table 1).

At each stage of the project, it is necessary to identify and assess the emerging risks, develop measures to prevent, reduce or compensate for damage from their impact. To reduce the identified risks, security functions (countermeasures) are provided (Table 2).

Based on the foregoing, we can draw conclusions about the need for the widespread construction of autonomous energy sources to reduce dependence on centralized systems.

5. Analysis of the increase in the growth of unconventional energy sources

The development of the scientific and technical complex, which characterizes the modern energy system of Russia, is steadily leading to an increase in the consumption of energy resources. Today, the main energy raw materials for energy production in the Russian Federation are non-renewable sources (oil, gas and coal), as well as non-biospheric energy sources. The use of these sources entails a number of environmental, economic and political problems. This is mainly expressed in the depletion of natural resources and an increase in their prices, environmental pollution, and increased investment in the expensive construction of specialized stations. All these factors make the task of energy supply urgent.

The way out of this situation is seen in the use of alternative energy, that is, in the use of renewable, inexhaustible energy sources. The rapid and widespread development of this type of energy is hindered by the fact that the territory of our country is very rich in natural resources, therefore it is considered not profitable to install expensive equipment where power supply networks have already been installed.

On the territory of Russia, in almost every region there is at least one type of alternative energy sources.

Scenarios

Negative, conservative and positive scenarios for the development of new delivery technologies for consumers.

Negative

Economic aspect: Renewable energy in Russia is following this path with uncertain steps. The only area of alternative energy in the country is the biofuel industry, in particular the production of wood pellets. Russia is the leader in the supply of these products to Europe. In the production of electricity based on renewable energy sources, hydropower has achieved significant development, which accounts for up to 16% of the country's energy balance. The solar and wind power industry is practically at zero. Green energy in Russia should have started to develop thanks to state support. To attract investors to the energy sector, a mechanism has been developed that allows investors to recoup their costs by increasing the cost of their services within 15 years.

In the perspective of the development of RES capacities, Russia has: unique competitive advantages for the development of all types of alternative energy sources, a large number of empty areas that can be used for RES; territories with high insolation, a huge part of off-grid energy, in which there are thousands of outdated isolated diesel power plants. The price of such a generation is incredibly high, so a simple complex solar-wind-diesel installation is absolutely acceptable even in our current economic situation.

Environmental aspect: Emissions from thermal power plants are a significant source of such a potent carcinogen as benzopyrene. An increase in oncological diseases is associated with its action. The emissions from coal-fired power plants also contain silicon and aluminum oxides. These abrasives can damage lung tissue and cause diseases such as silicosis.

The storage of ash and slag is a serious problem near the TPP. This requires significant areas that have not been used for a long time, and are also centers of accumulation of heavy metals and increased radioactivity.

The quality of water in reservoirs is deteriorating. The amount of organic matter in them sharply increases both due to ecosystems that have gone underwater, and due to their accumulation as a result of slow water exchange.

Technological aspect: A characteristic feature of traditional energy is its long-term and good development, it has been tested for a long time in various operating conditions, but taking into account the long time of use without the involvement of repair funds, as well as the introduction of new technologies, this industry has some negative technical aspects:

- high proportion of depreciation of fixed assets;
- the use of outdated technology in the production and transportation of electricity;
- the threat of loss of technological sovereignty;
- low energy efficiency in the production and transport of electricity;
- lack of experience in the design and operation of power facilities based on innovative technologies.

Conservative

Use of a pulse heating system for public and industrial buildings

At present, the potential for the development of traditional heat supply systems in terms of increasing heat transfer is practically exhausted. Replacing shell-and-tube water heaters with plate water heaters was a significant step towards increasing the turbulence of the coolant flow, and, consequently, increasing heat transfer. On the one hand, this made it possible to increase the heat transfer coefficient within 10%, and on the other hand, the tendency to overgrowth, the formation of scale, sludge and other deposits increased, which eventually leads to a decrease in the heat transfer coefficient. In addition, these circumstances hinder their use for independent heat supply systems. One of the cardinal ways to solve this problem is to transfer the circulation of the coolant in the heat supply system from a stationary mode to a pulsed one. In this case, you can use several effects. Firstly, the heat transfer coefficient of the moving stream increases depending on the frequency and amplitude of the pulsations of the velocity of its outflow, secondly, self-cleaning of the heat transfer surfaces of the equipment occurs and, thirdly, it becomes possible to transform part of the available head of the heating medium into the head of the heated one in the case of independent connection heating installations or for circulation of water in a hot water supply system.

Application of microchannel heat exchangers

Microchannel heat exchangers are already used in many branches of science and technology. With the solution of the problems associated with the use of these innovative devices as evaporators, one should expect the transition of all climatic equipment to heat exchange sections of a new type. Traditional plate heat exchangers can also be converted to microchannel technology, provided that the media exchanging thermal energy are sufficiently clean.

The main advantages of microchannel heat exchangers are much smaller dimensions, weight and cost. So, if tubular-finned devices involve the use of copper tubes and aluminum fins, then microchannel ones are made only of aluminum. In addition, due to the smaller thickness of microchannel devices, the pressure loss through the air in them is less by 50%. The innovative heat exchangers feature increased corrosion resistance of the structure due to the use of aluminum and the absence of galvanic corrosion.

The reduced internal volume requires 30% less refrigerant charge, further reducing the weight of the filled unit. The efficiency of microchannel heat exchangers is 10% higher.

Using vortex pumps as an autonomous energy source

The technical policy of most developed countries today includes the possibility of maximizing the use of solar technologies, operating on solar energy and using hydrogen as fuel for cars and thermal power plants. But solar energy has low efficiency. It is not capable of fully replacing traditional fuels, and the burning of hydrogen again leads to the destruction of the earth's atmosphere. The release of large quantities of steam and water during the combustion of hydrogen causes a greenhouse effect.

Devices for the production of thermal and electrical energy based on the energy of air and water are widely used, but without changing their natural state (vortex heat generator and vortex engine).

In a vortex heat generator, the water is cleaned of harmful microbes and bacteria during operation. The efficiency of a vortex heat generator is higher than that of any known electrical or nuclear source of thermal energy. And the efficiency of the vortex engine reaches 97% versus 40% of the efficiency of the DVS, 34% - of nuclear power plants, 12% - of solar batteries.

Description of the device for recuperating excess pressure of the heat carrier

Transportation of working fluids occurs at a pressure exceeding the required pressure for use by consumers. As a result, there is currently a problem of excessive main pressure in heat and water supply systems. With the help of damping devices, the value of the inlet pressure is reduced and, as a result, the potential energy of the overpressure of the main networks is lost.

Through main pipelines, the working fluid moves at a normal pressure of about 9 MPa. However, the value of the working pressure required for the correct operation of the power equipment must be reduced to 2 MPa. "Excess" pressure is throttled.

To prevent potential energy losses associated with the aforementioned throttling, there are methods for converting the overpressure of the line.

Risks of using unconventional energy sources

The activation of the process of developing renewable energy sources in Russia requires a careful approach and study of the risk factors arising during the creation and operation of power facilities, as well as an analysis of the main risk management methods applicable in renewable energy.

Significant world experience in the development of renewable energy projects was the basis for studying the factors and methods of risk management in a number of foreign studies. The main trends in the formation of risks and their management were identified in a study conducted on the basis of the principle of bottom-up analysis of expert assessments of a number of leading experts in renewable energy.

The study showed that, attaching great importance to financial, political and regulatory risks, 62% of respondents consider resource risks associated with fluctuations in the volume of generation of power plants on renewable energy sources to be the most significant for foreign projects.

Positive

Economic aspect: Today, alternative energy provides an increasing part of the energy needs of the world's leading economies. At the moment, a new model of world energy is being built, which implies the gradual replacement of traditional fossil energy resources with alternative energy.

At the moment, in more than 30 countries, the cost of energy from alternative sources is lower than the cost of energy from hydrocarbons, according to the report of the World Economic Forum (WEF). According to the WEF forecasts, another third of the world's countries will soon achieve equal costs of producing energy from renewable sources and from fossil fuels in the next two years. Although conventional energy is still cheaper than clean energy, this gap is gradually closing. In the last 10 years alone, the average price of a kilowatt of wind energy has dropped by almost 60%.

Also, the American consulting company Bloomberg New Energy Finance, which monitors changes in the global energy market, has repeatedly noted in its annual reports the rapid pace of falling prices for non-traditional energy sources. The International Wind Energy Council in Europe predicts that CO2 permits will cost three times more by 2030 than they are now.

Environmental aspect: The ecological characteristics of various types of energy are manifested in the placement of power plants, disposal of waste, pollution of the atmosphere and lithosphere with combustion products. Alternative energy is practically safe for the ecology and the environment, in comparison with traditional sources. The risk of a threat to human health is significantly reduced.

Replacing coal-based power plants will drastically limit the release of nitrogen, sulfur, and carbon dioxide into the Earth's atmosphere, which together contribute to the greenhouse effect and climate change. The accumulation of hazardous radioactive elements in the ash heaps of power plants is prevented.

Comparing the environmental indicators of various types of energy, we can conclude that the least damage to the environment when receiving energy occurs when using renewable sources. Renewable energy sources have the lowest environmental penalty score compared to traditional energy sources.

Technological aspect: Experimental studies have shown that the use of an overpressure recuperation system using the technology of impulse supply of the working medium will guarantee to obtain:

- full automation of the workflow, including emergency situations;
- automated monitoring and system diagnostics;
- increasing the efficiency of operation of the central heating station up to 30%;
- increasing the operational reliability of the main equipment and the resource of the throttle control valves of the central heating station;
- the possibility of using the flow energy converter as an emergency source of electricity;
- the possibility of using the energy of a pulsed fluid flow in order to obtain mechanical energy for thermal units of buildings.

Recommendations to be taken into consideration:

Conservative

Development of alternative energy sources

The importance of alternative energy lies not only in the development of energy, but also in industrial policy and economic development in general. It is a knowledge-intensive, high-tech industry that creates skilled jobs both within and in related industries. Leading countries in terms of installed solar energy capacity (China, Germany, Japan, USA) are also the leading industrial powers. They form a new technological platform in the energy sector. Russia should seriously approach the issue of developing alternative energy sources and take its rightful place in the gigantic world market of new energy, both by increasing the share of renewable energy generation within the country and entering foreign markets with engineering solutions and end products.

Development and application of new technologies

For a long time, the world economy did without innovations in the energy sector. Advances in information technology have been linked to stagnation in energy. Alternative sources did not provide a real substitute for burning hydrocarbon fuels. Biofuels, wind and solar generators did not jeopardize the old energy industry. The development of revolutionary technologies in the energy sector, for obtaining atmospheric electricity or economical autonomous generation, was blocked by corporations. In the coming years, other inventions will appear that will drastically reduce the cost of energy.

Positive

Professional development of specialists

Advanced training is considered as a powerful factor in the economic, political, social and cultural life of the country, as an important link in continuous education, contributing to the successful acquisition and improvement of various knowledge obtained as a result of primary education, as a form of vocational education for adults, ensuring the growth of professionalism and competence of a specialist through improvement professional skills, mastering new professional duties. The system of advanced training is constantly developing and improving, great attention is paid to the quality of education, and the idea of the need to intensify the processes of advanced training is increasingly heard.

Contribution to scientific and technological progress

For three decades until the mid-1980s, Western economic science was almost completely dominated by the concept of technological progress brought into the economic system from the outside, developed within the framework of neoclassical theory. It was proposed and substantiated in the works of R. Solow, R. Harrod, J. Hicks, J. Tinbergen and a number of other famous economists. Scientific and technological progress has a very significant impact on increasing the rate of economic growth, ensuring the conservation of energy and raw materials, the release of labor, the solution of social problems by improving working and living conditions, improving the quality of consumer goods.

Negative

Addressing the issue of the environmental crisis in the energy sector

To reconcile the constant growth of energy consumption with the growing negative consequences of energy, given that in the near future humanity will feel the limitations of fossil fuels, there are apparently two ways.

Energy saving. The impact of progress on energy savings can be demonstrated with steam engines. As you know, the efficiency of steam engines 100 years ago was 3-5%, and now it reaches 40%. The development of the world economy after the energy crisis of the 70s also showed that humanity has significant reserves on this path. The use of resource-saving and energy-saving technologies has ensured a significant reduction in fuel and material consumption in developed countries.

Development of cleaner types of energy production. The development of alternative energy sources, especially those based on the use of renewable sources, is likely to solve the problem. However, the ways to implement this direction are not yet obvious.

Ways to modernize traditional sources of energy generation

An example for obtaining and concentrating energy resources can be: mining, processing and enrichment of nuclear fuel; transfer of resources to power plants; conversion of primary energy into secondary energy using power plants; transfer of secondary energy to consumers.

An archaic view of the development of the economy of alternative energy

Businessmen consider alternative energy to be expensive and uncompetitive in comparison with hydrocarbons. Such stereotypical thinking can destroy all the beginnings of the development of renewable energy and cost Russia dearly. The rapid progress in alternative energy has already made wind and solar power plants competitive. In the short term, alternative energy will become more profitable for most countries, which will result in a new drop in world oil prices.

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CHAPTER 3

REPUBLIC OF INDIA

03

INDIA

Editorial Summary _

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Introduction

In the BRICS Youth Energy Outlook-2020, nine Indian teams analyzed the chosen trends, estimated all current and possible risks, revealed advantages and drawbacks of technologies and projects launched in the country, and presented their own views on prospects of their topics.

As India comes under one of the most polluted countries in the world and has 13 highly polluted cities, all of the developers within the Outlook framework are eager to analyze the current environmental situation using a wide range of approaches and offer new solutions to overcome this particular issue. Thus, Indian teams tend to focus on topics referring to reducing pollution and emissions e.g. CO2, shifting toward renewable and non-traditional energy resources, implementation of electric vehicles, the introduction of digital and smart systems, distributed generation, and finding environmentally positive ways of controlling such spheres as nuclear power and petrochemistry. India engages in the “United Nations Framework Convention on Climate Change” (UNFCCC) which focuses to discover and extend the span of Clean Development Mechanism (CDM) ventures. Moreover, the government and industry leading companies introduce new programmes; nevertheless, the researchers put forward additional initiatives in order to draw attention to the ecology issue and boost the development of all accessible energy systems that India enjoys.

Development of non-traditional renewable energy sources

The location of India enables to use all possible renewable resources for inner and outer purposes. At present, non - traditional RE sources contribute almost 23.7% of the world’s power demand while India contributes around 4.5% of the globe’s entire RE based power generation. The developers consider that wind and solar energy are the leaders of the renewable energy sector in India and have lots of scopes to expand it using new technological developments. Wind energy becomes the leading non-conventional energy source (NCES) for power generation in India because of the enormous coastal region and sufficient availability of velocity of wind. Solar energy technology is the most adequate RE source with extensive applications such as distributed generation, rural electrification on-grid and off-grid, street lighting, agricultural applications, DC network interconnection etc. Interest in the use of bio-fuels worldwide has grown strongly due to the high oil prices, concerns about climate change from greenhouse gas emissions and the desire to promote domestic rural economies. Geothermal energy is a very energy-efficient method to generate a source of renewable energy. Hydro power energy is the most reliable and efficient renewable source of energy which can be utilized in fulfilling the demand of ever-growing power in the country with no fuel cost. Biomass energy is a reliable source but not the preferred because of unavailability of biomass throughout the year. Thus, the developers support the idea of expanding the usage of RE sources and increasing future projects based on them

Energy sources as a solution of environmental issues

RE sources are environmentally friendly, have no or little emission of poisonous gases than traditional power plants. According to the teams’ estimations, investing in digitalization, developing battery storage solutions and efficient power converter, and providing access to local renewable resources can increase the share of RE sources in the energy sector and solve the problem of air pollution. One of the successful methods of reducing CO2 emissions is Carbon capture and storage. CCS can prevent large amounts of CO2 from entering the atmosphere at large industrial point sources and if the fuel is biogenic, CCS can actually contribute to reducing CO2 in the atmosphere. Clean hydrogen can be made by steam reforming of natural gas and by storing the byproduct CO2.

The transition to “digital” is inevitable

Another important issue that the developers showed their interest in was the shift toward digitalization, smart using, controlling and distribution of the gained energy. The researchers concluded that the gradual transformation of the power industry and its digital transition due to the persistent and quick escalation of the power demand is inevitable. Firstly, it has a positive impact on the environment due to having no emissions, generates great employment opportunities and pushes the market to grow as demand, for example in EV, is constantly rising. Electric vehicles can be used as storage devices for RE, improve transport system and reduce dependence on foreign oil import. Secondly, the smart grid is an electrical grid that includes the smart meters, smart appliances and renewable energy resources. The smart meters are installed in a place of the old mechanical meters and they operate digitally. These meters enable the transfer of information between homes and energy providers. They also help in complete eradication of errors due to manual readings. The smart meters allow the consumer to monitor their electricity usage and in turn optimize their consumption. The decentralized power generation which is a part of the smart grid system helps in reducing the dependency on fossil fuels for the generation of power.

The development of petrochemistry: prohibition of the use or recycling

Looking into a debatable question concerning the prohibition of petrochemistry or its recycling, the developers tend to favor the second option. Although petrochemicals can be injurious to the earth's ecosystem, there is a difficulty in finding alternatives to petrochemical products. That is why, the benefits of petrochemicals, especially plastics, need to be recognized by encouraging proper collection, segregation, recycling, and education.

Nuclear stations for diversification of energy balance

Nuclear power stations and their developing for reducing ecology load face several environmental risks such as waste generation, water use impacts and land use impacts. However, the methods for overcoming the negative impacts have been introduced. The waste can be buried deep underground in insulated containers or under the ice sheet of Antarctica, shot into space or sun, changed into harmless isotopes. Moreover, in India, the spent fuel is considered as not a waste to manage but a resource from which Plutonium can be extracted and consequently it has pursued reprocessing as the way of dealing with spent fuel. There is also scope for using water more sustainably in non-electric applications of nuclear energy, in particular in desalination to overcome existing freshwater scarcity.

1 The eco-transport of the future. The influence of electric cars on energy efficiency indicators and needed infrastructure for their unimpeded operation

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Introduction

Electric vehicles, unlike conventional petrol and diesel vehicles, are powered by one or more electric motors rather than internal combustion engines. Electric vehicles contain a battery that is charged by means of electricity supply. The electric energy is then stored and used to run the electric motor.

Electric vehicles are of two types i.e. battery powered electric vehicle (BEVs) and plug in hybrid electric vehicle (PHEVs).

1. Advantages and Global Trends

Being introduced for the first time at the end of the 19th century, electric vehicles gained significant advantages over steam ones along with ease of use and lack of long starting time problem. The advantage over gasoline engines was pollution-free driving of the engines and short-distance urban transport. These facts made huge impact on automotive market when electric vehicles were introduced [2].

Despite of successful models made by Ferdinand Porsche (P1 car was the company's first car to use electric power) and later by Thomas Edison and Henry Ford to develop a cheap electric vehicle for a large audience [3-5], eventually electric vehicles disappeared from the market around 1935 after being hit by vehicles equipped with combustion engines [6] since in the 1920s sales of hand crank and gasoline vehicles increased, especially in the US, due to decline in gas prices across the country and rising gasoline network. Moreover, electricity was not yet available in rural areas at that moment. Nowadays electric vehicles are expected to increase from 2% global shares in 2016 to 22% in 2030 [7].

2. Indian Government's Initiatives

2.1 National Electric Mobility Mission Plan (NEMMP) 2020

Salient points of this mission are listed below:

- By 2020, target of nearly 5 to 7 million electric vehicles to be deployed in the country.
- By 2020, availability of approximately 400,000 battery power electric cars (BEVs) in market – target of reducing 4 million tons of CO2 and usage of 120 million barrels of crude oil.
- Total project investment required is INR 20,000-23,000 corers (approximately 3 billion USD).

2.2 E-Rickshaw

- DeenDayal E-Rickshaw scheme was announced by government of India in June 2014, in order to help the manual rickshaw pullers by providing E-Rickshaws at a reasonable cost with minimum rate of interest of 3%.
- The Motor Vehicle Amendment bill was passed by government in March 2015 as a validation of battery powered E-Rickshaw into commercial transport vehicle.
- According to the bill, three wheeled battery powered vehicles can only carry 4 passengers along with luggage of 50 kg and it can travel less than 25 kilometers in one go.
- The total wattage of all the batteries in three wheeled battery powered vehicles should be less than 4000 Watts due to safety issues.
- In Delhi, there was a steep increase in the number of battery powered E-Rickshaws from 4,000 in year 2010 to 100,000 in year 2014 and became the essential part of the local transportation.

2.3 FAME India Scheme

- “Faster Adoption and Manufacturing of Electric and Hybrid Vehicles in India” scheme was administered by The Department of Heavy Industry on April 1st 2015.
- The primary aim of this scheme is to include the electric vehicles like electric buses, taxis and three wheelers in the local transportation of 11 cities.
- Government of India will provide subsequent amount of subsidy to all the cities which include Delhi, Kolkata, Ahmedabad, Indore, Bengaluru, Hyderabad, Jaipur, and Mumbai along with then Jammu and Guwahati were considered under special category [8].
- All the main nine cities will have 40 subsidized buses whereas Guwahati and Jammu will be supported with only 15 subsidized buses.
- Number of the subsidy taxies and three wheelers given to each city will vary based on the demand of cities e.g. Bengaluru will be provided with 100 subsidized taxies and 500 subsidized three wheelers while Indore will be provided with 50 and 200 respectively [8].
- The total number of subsidized vehicles including buses, taxies and three- wheeler came out to be 1,420.

3. Growth of EVs in India

3.1 Policy objectives

- Every city in India is targeting on increasing the part of electric vehicle in public transportation system by 60-80% before 2030.

3.2 Market size

- India is the largest producer and consumer of the motorized two wheelers in the world. Two wheeler is the first choice of vehicle in Indian market and will continue to remain by 2035 (UNEP, DTU and IIM-A)
- India had $3.1 million market share of motorized two-wheelers in 2019 and expected to grow up to $94 million by 2025.

3.3 Environmental

- India is the third largest producer of greenhouse gases after China and the USA. Out of 20 highly polluted cities of the world, 13 cities are from India.
- It is estimated that high level penetration of EV in India vehicle market could result in 50% drop in air pollution by 2035 (UNEP, DTU and IIM-A).

3.4 Allied opportunities

- Electric vehicle can be used as storage devices for renewable energy as Government of India are planning to install 100 GW solar plant by 2022 [8].
- This scheme will help both solar plants and electric vehicles.

Relevance of EVs with the Title (Economical, Political, Socio-Cultural, Technological, and Environmental Aspects of EVs In India)

1. Environmental Aspects

- Electric vehicles don’t liberate any harmful pollutants to the environment and produce comparatively less noise than standard petrol or diesel vehicles.
- India comes under one of the most polluted countries in the word. India is ranked 10th in the world when comes to death rate due to pollution.
- Indian automobile industry strictly follows the world standards about safety and emissions.
- Indian government is taking various initiatives to larger the market of electric vehicles in India and to lower the carbon particles level in atmosphere.

2. Socio-Cultural Aspects

- EV requires low maintenance and is cost effective which is why it can be considered as an asset for Indian rural society. It will be lucrative to rural market.
- It will generate the employment at rural level and will decrease urbanization.
- As India is second largest populated country in the world so skilled labour is available at lower cost compared to the western world.

3. Economical Aspects

- India is one of the larger importers of crude oil to meet 70% of the demand. Penetration of EVs in India vehicle

market can significantly reduce the consumption of oil.
- Indian government is providing subsequent subsidies to economical weaker people [10] and government has imposed lower taxes to automobile industries to produce EV.
- Many automobile companies have offered various types (cost, luxury, size, etc.) of electric vehicles in Indian market.
- Market of EV potential buyers is increasing at gradual rate.

4. Political Aspects

- India government has developed various new policies to promote electric vehicle, which will initially ensure a smoother transition to small-scale production and further improve cooperation in the automotive industry.
- Government has implemented various schemes like automotive mission plan, FAME, NEMMP and organized various summit like global e-mobility, electric vehicle summit, etc.
- Global E-Mobility summit was inaugurated by Prime Minister Shri Narendra Damodardas Modi on September 7, 2018 [11]. According to new proposal “the government will first begin creating favorable ecosystems in nine polluted cities with a population of over four million, and gradually move to cities with populations of one million-plus”.
- The aim of all the policies regarding EV is to shift one-third of Indian vehicle market from internal combustion engines to electric vehicle by 2030.

5. Technological Aspects

- Every year in India lakhs of efficient graduates passes out which act as biggest asset to the segment.
- There are thousands of local credible supplies which can provide best quality material at cheaper rate and reduces transportation cost.
- India is one of the globally emerging hub of automobile industry and of R&D.
- Indian population has acceptance toward new products in the market, thus increase the rate of consumption of new products.

India Current Scenario for EV Penetration and Support by Government

According to Indian market scenario, EV is expected to have steep rise in long run. Not only government but leading automobile companies like Mahindra and Tata are helping in development of e-mobility industry in India. Indian government is supporting various projects for developing the electric infrastructure. All the subsidies and incentive proved by the government would reduce the cost of electric vehicles, thereby increasing the demand for electric drivers in the Indian market. In September 2017, Government of India decided to buy 10,000 electric cars from Tata Motors to replace the old petrol and diesel cars used by government agencies.

1. Key Developments Driving EVs

- Maruti Suzuki, a renowned Indian automotive company, announced to open a plant in September 2017 to produce lithium-ion batteries in Gujarat, along partnership with Denso and Toshiba with a total investment of 1,700 cr.
- Earlier in 2018, Maruti Suzuki announced that it would work with Toyota to manufacture the electric vehicles. They plan to produce 35,000 electric vehicles per year in India by 2020 [12]. In May 2018, the company announced the investment of $ 14.5 billion in Research and Development. It was the biggest investment in an EV program.
- Hyundai announced in 2018 that it will launch an electric version of the Kona SUV in 2019 which is globally successful into the Indian market. The company will venture in producing luxurious sedan and cost-effective SUVs in Indian market.
- Renault India announced in 2018 that they had ordered an electric motor and its drives from Rico Auto Industries and is seeking EV development at its plant in Chennai.

2. Current Level of Penetration and Sales

The EV sales for 2019 are 759.6 thousand units, including motorcycles (126,000), electric bus (3,600) and electric three wheelers (630,000). The electric motorcycle market saw a growth of 130%. The increase in e-mobility was due to announcement of the government's policy FAME-II (Faster Adoption and Manufacturing of Electric Vehicles).

2.1 Emerging EV Charging Ecosystem

The EV market has grown rapidly with the development of infrastructure and charging technologies. The advancement in the technology of EV charging and the advancement of EV in the distance coverage are important factors for the effective progress of the EV market. In addition, the Indian government has increased its attention towards pollution free environments which are driving the market for electric vehicles. Efficient charging infrastructures are needed to be installed for these types of vehicles. There can be a public charging stations and private charging stations which can be a great asset. Public charging stations can charge up to 8 times faster than conventional household sources. In other words, depending on the capacity of the EV battery, it can charge 100% in 3-4 hours. The figure 2 represents the estimated cost of grow of electric vehicle in market from 2019 to 2027.

2.2 Solar Powered Charging Stations

With the growth in the Sale of electric vehicle has led to the demand of more electric vehicle changing stations or infrastructure. This has introduced solar panel charging station to regulate the demand for more charging station.

The growth in the demand for electric vehicles has inspired the automation industry to integrate solar technology into electric vehicles and use renewable energy in their transportation operations. The capacity of solar charging stations is assumed that it will reach about 38,782 units by 2020 and will continue to increase up to 387,542 units by 2030 as shown in figure 3, with a compound annual growth rate of 17.1%. The solar energy availability in subcontinent countries and government various efforts to encourage more effective and environment friendly mobility solution can explain this growth.

Prospects of EVs in India

India has the fourth largest automotive industry in the world. In 2018, the production of all type of vehicle has increased to 5.17 million units and is expected to grow every year in future. By every passing year auto exporter rate of India is growing gradually, in 2018 it had growth rate of 15.54%. In FY2018-2019, there was decline in export of passenger car of 9.64% while there was rise in commercial vehicle, two wheelers and three wheelers by 3.17%, 16.55% and 49% respectively, leading to overall growth of 14.50%. India is experiencing sustained economic growth brought about by various factors such as social and cultural transformation, strong population growth, strong economic expansion, and increased urbanization, etc.

Lately in 2018, Ola launched the real-time monitoring system named "Guardian" to further improve the safety of riding customers traveling on the platform. The project was launched as pilot project in metro cities namely, Bengaluru, Mumbai and Pune. It was the part of Ola’s national Safety Plan “Street Safe”, which is also the first project in the riding industry.
In 2018, Ola announced the establishment of the first social innovation department along with policy research department naming Ola Mobility Institute. The institution will work to use the potential of the “disruptive” movement as the engine of Indian economic growth and innovation.

1. Market Size

Indian market of ride sharing is expected to grow at a compound annual growth rate of 33.86% each year as shown in figure 1. The e-hailing sector is assessed to be one of the largest in terms of value. It is expected to grow from 427.5 million in 2018 to 3,358.9 million in 2025, with a compound annual growth rate of 34.24%. The car rental sector is expected to become the second largest industry, which is assessed to rise to 8.489 billion in 2025 from 978.97 million in 2018, with a gross margin of 25.84.

2. Investments

Indian market of ride sharing is expected to grow at a compound annual growth rate of 33.86% each year as shown in figure 5. The e-hailing sector is assessed to be one of the largest in terms of value. It is expected to grow from 427.5 million in 2018 to 3,358.9 million in 2025, with a compound annual growth rate of 34.24%. The car rental sector is expected to become the second largest industry, which is assessed to rise to 8.489 billion in 2025 from 978.97 million in 2018, with a gross margin of 25.84.

The Recent/Planned Investments and Developments in the Indian Automotive Industry are as follows:

- Ashok Leyland, one of the leading automotive industries

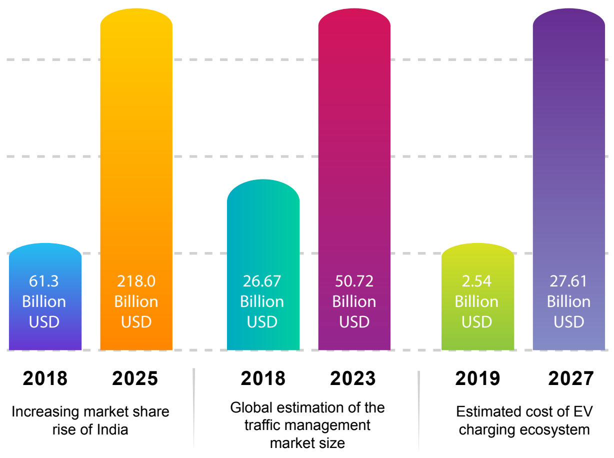

Figure 1: Indian EV Market Profile
Source: Author's calculations

in India, has planned to introduce from 20 to 25 new models of commercial vehicle with an investment of 1 billion rupees (US $ 155.52 million) in 2018-2019.

- By 2020, Hyundai Motor plans a capital expenditure of USD 1 billion in India, along with them SAIC motors has also made an announcement of investing around US $ 310 million in automobile industry.
- Mercedes Benz is one of the leading manufacturers of luxury cars in India has increased the production growth in Chakan plant to 20 thousand annually, which become highest car manufacturing plant in India.
- Mahindra Electric Mobility was opened in November 2018 which is an electric manufacturing center in Bangalore and company invested 100 million rupees ($ 14.25 million) and will gradually increase its annual production capacity to 25,000 units

2.1 Intelligent Transportation System (ITS)

ITS is a "combination of information and communication technologies applied to transportation networks and infrastructure to facilitate vehicle-to-vehicle, vehicle-to-infrastructure communication and transfer of information". It helps in improving the safety of public along with it also helps in managing transportation traffic.

2.2 Effective Traffic Management and Safety

Traffic management is an application of intelligent transportation solutions, which includes first planning, then monitoring and at last control of traffic. It provides guidance to passengers with congestion and suggests them the best route available. Traffic management uses information and communication technology to control road traffic flow, control intersections, measure and manage speedometer and impose speed limits, and detect accidents and emergencies.

The Indian government has gradually invested heavily in the field of traffic management [12]. According to the country's 12th Five-Year Plan (2013-2018), the Department of Transportation plans to invest an additional 30% of $1 trillion in transport infrastructure development. The figure 1 represents the global estimation of the traffic management market size.

Indian Automotive Companies

As far as the production and sales of automobiles and commercial vehicles are concerned, the Indian automobile industry is one of the four largest companies in the world [13]. Electric vehicles provide India with an opportunity to modify the landscape of automobile industry with renewable energy. With the support of the National Electricity Agenda and government-led initiatives, the public and private sectors have begun to shift to electric transportation. In 2017, India tested the first multimodal electric vehicle project in Nagpur, Maharashtra. As of January 2019, the Nagpur Electric Fleet is an electronic rickshaw and electronic cab combination operated by the Ola platform, serving more than 350,000 customers and recording more than 7.5 million clean kilometers. Since its inception, it has saved more than 5.7 million tons of imported fossil fuels and reducing carbon dioxide emissions, reaching 1,230 tons [14]. Pilot projects and subsequent projects (such as National Energy Efficiency Service Co., Ltd. (EESL)) require the introduction of 10,000 electric vehicles [15] which can be attained using various manufacturing companies and modern electric utilities like charging station can be met by partnering with private station owner [16]. In addition to the use of electronic buses by the state government, all measures are also aimed at increasing the number of clean kilometers of Indian convoys.

- Mahindra REVA: It is well known India based company specialized in designing and manufacturing cost effective and compact electric vehicles.
- Ajanta OREVA: "OREVA" is the band name of one of the leading manufacturing company named Ajanta Manufacturing Ltd. It is the one of the prime producers of Compact Fluorescent Lamps and other related products. It also manufactures battery operated bikes.
- HERO ELECTRIC: Hero Eco is a very diverse industry, manufacturing variety of product. It mainly deals in manufacturing electric vehicle, export bicycles, healthcare products, etc.
- TATA MOTORS: It is an Indian multinational automotive company and a subsidiary of the Tata Group, based in Mumbai, India. Its products include passenger cars, trucks, lorries, buses, construction equipment, and military vehicles. It is ranked 17th in the automotive industry, the fourth-largest truck manufacturer, and the second-largest bus manufacturer in the world. The navigation range in Tata Megapixel reaches 900 km, and in combined driving mode, the CO2 emission is only 22 g / km, and the fuel consumption is 100 km / l.

Risk Analysis on Development of EVs in India

Changing travel modes creates new business opportunities. They appear in areas such as charging or discharging infrastructure, services of electric vehicle, and integrated transportation. In India, utilities are entering the mobility industry, some traditional electric companies are exploring the potential in charging and discharging infrastructure, and infrastructure companies are focusing on how to enter the battery business. An important task is to be aware of is the transformation and development of industries with small and medium-sized subsystems and automated components. Many of these smaller industries are diesel/gasoline self-service companies that offers a lot of employment. When electric cars replace gasoline/diesel cars, many of these companies may not be able to survive themselves to new technology. The transition to electric vehicle manufacturing requires careful planning to recruit and support such industries. The expansion of IC engine-based transportation fleets will have a negative impact on the economy, regardless of any adverse health effects. Fluctuations in crude oil prices add uncertainty to the already high import costs and require significant investment in refineries and associated distribution infrastructure. Many studies show that the introduction of electric vehicles has had a positive overall impact on GDP in an economy dominated by fuel import services. A study estimates that promoting the conversion to electric vehicles will increase EU GDP by 1% [17]. Another study estimated that private and social net incomes ranged from US $ 300 to US $ 400 per electric vehicle [18]. In addition to the production of renewable energy, the Indian battery manufacturing industry may exceed the total expenditure of imported crude oil. This will greatly promote the Indian economy. It is expected that the loss of government revenue from taxation in the oil sector will be substituted by higher tax revenues from other economic sectors.

1. Impact on Employment

Efficient electric vehicles will effectively reduce the oil demand globally, the European Climate Foundation forecasts that the number of people employed by 2030 will rise from 5 million to 850,000. Another report predicts that electric cars will generate great employment opportunities around another 2 million by the year 2050. The report also shows that employment intensity in oil production and its distribution will be reduced with only 4 jobs added per million euros in value added in comparison to the 24 jobs added per million euros across the economy. Therefore, changes in outflow from the purchase of imported oil to other spending options will create more employment opportunities. Besides, imported oil when substituted with electricity and batteries, can be used in many ways for battery production, including power generation, power distribution, and battery recycling. In the automotive sector, a significant part of the distribution sector will be moved to the powertrain sector. Traditional suppliers will change from supplying tailpipes and ICE components to battery materials, electric motors, regenerative braking systems. Electric vehicles will generate opportunities for durable and lightweight thermoplastics, which increase demand for electricity, along with the storage facilities, and more. The net effect on employment could be balanced. In addition, battery charging and its replacement will generate great employment nationwide.

2. Impact on Environment and Health

ICE is one of the leading causes of air pollution in the world. It has a negative impact on human health and the environment. Emissions from ICE vehicles account for about two-thirds of urban air pollution. Currently, the ban on old fuel vehicles has had a positive impact on air quality in some cities in India, but only the introduction of large electric vehicles can improve this situation.

Scenarios

Quality scenario analysis and strategy on EVs in India.

Negative

1. To support the EV infrastructure better technology is needed.
2. As compared to conventional vehicles the price of EV is higher.
3. Lack of optimum business model.
4. Shortage of spare parts compared to conventional cars parts.
5. Charging infrastructure is not properly available across all national highways in India.
6. Lack of collaboration between EV manufacturer's e.g. different charging plugs and systems used by different manufacturers.
7. Lack of competition for the segment hence lack of choices.
8. Recharging time significantly greater for an EV than to refill a conventional fuel in car.
9. Energy storage in an EV is dependent on lithium-based batteries, e.g. lithium-polymer and lithium-ion batteries. These lithium batteries emit harmful fumes and are expensive to recycle.
10. Travel range of EV is also limited, and dependent on many operational factors of EV.

Conservative

1. In world market, the demand of EVs is increasing day by day.
2. Government as well as manufacturers providing incentives to attract the buyers.
3. Maintenance cost of EVs is low as compared to other conventional vehicles.
4. Crude oil reservoirs are getting consumed at higher pace than exploration of new reservoirs.
5. No emission of nitrogen or carcinogenic substances.

Innovative

1. As compared to conventional vehicle the EV fuel economy is high and its operating cost is low.
2. Lifestyle convenience of charging your car at home overnight.
3. EV is cheaper to operate.
4. Low running cost for maintenance and recharge environmentally friendly.
5. Government rebates more research and development can be done.
6. Low variable can reduce dependence on foreign oil imports.
7. Can facilitate to earn stronger revenues and profits.

Prospects

Since range of EVs, in a single charge of battery, is the biggest factor deciding fate of electric powered vehicle technology it would be required to facilitate onboard vehicle electricity generation. For example, roof-top of a car installed with 3rd generation flexible solar photo-voltaic cells that could power the drive motors directly during day thereby charging the onboard battery stack simultaneously. During night, battery stack would serve as power unit to drive the drive motors. Owing to changing climatic conditions it would be handy to rely on more than one renewable energy source.

2 Current state, future prospects and contribution of non-traditional renewable energy sources to the solution of the problem of local air pollution in large cities

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Introduction

The impact of air pollution in India is a quite life-threatening and serious health issue in both indoor (household) and outdoor producing a significant impact on the health of citizens as well as the economy. The adverse effects of air pollution are not just restricted to the urban areas but also impact the rural areas, where the majority of the population depends on kerosene and burning of biomass. IC engine vehicles and industry are the main sources of pollution in cities, whereas biomass burning for cooking is the main source of pollution in rural India. Large scale crop residue burning in agriculture fields is the major source of smoke and particulate pollution.

According to the WHO report from 2014, Delhi covered the dirtiest atmosphere of 1,600 cities around the world. Out of 13 Indian cities featured in the 20 cities with the highest level of PM 2.5, Delhi having a PM 2.5 level of 153, six times higher than the WHO safe limit of 2.5[1] Among all the highly polluted cities in the world, 21 out of 30 were in India in 2019. A report in 2016 stated that millions of people in India breathe air that is 10 times or more over the WHO safe limit and 14 of the world's 15 cities with the highest annual levels of air pollution are in India.[2]

In response to the esteemed concerns of poor air quality, lots of alternative energy generating initiatives are taken into consideration of the fact. Renewable energy resources are alternative sources of clean, inexhaustible, and increasingly competitive energy. They differ from fossil fuels in their diversity, abundance, and potential, but the main focusing criteria consist in that they produce neither greenhouse gases nor polluting emissions and reducing pollution, provided that their budgets are dwindling at a sustainable rate, whereas the general cost trend for fossil fuels is in the contradictory path in current global situations.

The most common renewable power technologies include:

- Solar (photovoltaic, solar thermal)
- Wind
- Biogas (e.g., landfill gas/wastewater treatment digester gas)
- Geothermal
- Biomass
- Low-impact hydroelectricity
- Emerging technologies - wave and tidal power

Moreover, social, environmental, and economic problems can be overcome by using renewable energy sources, as they are considered environmentally friendly, having no or little emission of poisonous gases. In account, wind, solar, and hydroelectric systems generate electricity with no associated air pollution emissions. Geothermal and biomass systems emit very fewer air pollutants, though total air emissions are generally much lower than those of coal- and natural gas-fired power plants.

1. Social Impacts

In the context of society, renewable energy sources provide social benefits e.g. improvement of health, according to the choice of a consumer, advancement in technologies, local employment, and job opportunities.

The renewable energy sector will be the largest employee in the future Indian power sector. Already in 2020, 264,000 supplementary renewable energy jobs can be created by shifting from BAU to the NDC scenario. Under the REmap scenario, more than 3.2 million people would be employed in the renewable energy sector by 2050. Biomass and solar energy will be the major drivers of employment with up to 2 million and 1.1 million employees respectively by 2050.

2. Economic Impacts

Renewable energy projects utilize local labour from rural areas, local material, business, shareholders, and services of local banks. In addition, the renewable energy projects have facilitated the communities by establishing a trust fund that aims to invest the money earned by selling electricity in the local economy, which makes it easy for a few communities to invest money on any small business of their own choice. The cost of power selling with renewable sources is much cheaper than that of conventional sources, and the overall economy will be enhanced because there are multiple options to generate power using different renewable energy sources present in that region.

3. Environmental Impacts

Renewable energy production has a positive impact on the environment such as the reduction of particulate matter in the air. The two main aspects of the environment are air and water pollution, normally created by the discharged water from houses, industries, and polluted rain, and discharge of used oils and liquids contains poisonous chemicals and heavy metals like mercury, lead, etc. Along with water pollution, natural resources can be maintained, and the greenhouse effect and air pollution can be mitigated by the proper usage of renewable energy sources.

Oil demand growth slowed in a few years, helping to keep the increase in India's emissions to just 2% in 2019, against an average of 5% per year over the past decade. As an effect of rapid expansion in coal use for power generation, carbon dioxide emissions have doubled in the last 10 years.

Current trends of renewable energy generation

India's energy demand is increasing rapidly with industrialization and increasing population. To reduce fossil fuel emission and improve air quality, India put a huge emphasis on renewable energy production and set a few milestones to be achieved. India has the potential to lead the driving energy transformation with one of the largest renewable energy programmers in the world. By 2022 a target of reaching 175GW of renewable energy production is set, in which 100GW is planned to be produced from solar, 60GW from wind, 10 GW from biomass, and 5GW from small hydropower to meet 20% of energy demand in the country [3]. To reach the target of producing 100GW from solar by 2022, almost 20GW per year solar installations are to be done. Under the scheme of GoI, the National solar mission plans to electrify 300 million people having no electricity by 2019. According to Desert Power India, a target is to achieve 455GW by 2050, two-third of which will be installed in the desert area of the North and West side of India [7].

In the last 10 years, India's Total Final Energy Consumption (TFEC) has been growing at a rate of around 6%. Bioenergy is still the main source of renewable energy in the building and industrial sectors. Solar water heating capacity has reached 6GW by 2014. By November 2019, India reached 86GW of installed capacity from renewable energy [6].

Recent developments in the renewable energy sector

Total installed power capacity in India reached 302GW in 2016 among which 80GW is from renewable including large hydropower, which is about 26.5% of total installed capacity. As on 31st March, 2020, the total installed capacity is 372GW, among which 137.7 GW is from renewable energy sources, which is 37% of the total installed capacity. Among the top five solar parks in the world, three are in India.

India is the seventh largest hydroelectric power producer in the world. As of 31st March, 2020 total hydroelectric installed power capacity had reached 45,699MW for large hydropower. It shares 12.5% of total utility power generation capacity. Besides, a small hydroelectric power capacity of 4,380MW has also been installed.

The installed capacity of wind power in India as on 2018 was 34.293MW. Almost 10% of India's total installed capacity is based on wind power. India has set an ambitious target to generate 60GW of electricity from wind power by 2022.

An estimation says that the potential for biomass energy in India is huge and includes 16,000 MW from biomass energy and a further 3,500 MW from bagasse cogeneration.

Table 1: Installed renewable energy capacity as on 31st March, 2020
Source: L&S p. 208

SECTOR	INSTALLED CAPACITY AS ON 31.03.2020 IN GW	TARGET 2022 IN GW
Solar	34.62	100
Wind	37.7	60
Biomass and Waste to Energy	10	10
Small Hydro	4.6	5
Total	87	175

Table 2: Year wise Renewable Energy Generation in GWh
Source: L&S p. 208

SECTOR	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20
Solar	4600	7450	12086	25871	39268	50103
Wind	28214	28604	46011	52666	62036	64639
Biomass	14944	16681	14159	15252	16325	13843
Small Hydro	8060	8355	7673	5056	8703	9366
Large Hydro	129244	121377	122313	126134	135040	155970
Other	414	269	213	358	425	366
Total	185476	182736	202455	225337	261797	294287
Total Utility Energy	1105446	1168359	1236392	302904	1371517	1385114
% of Renewable	16.77839	15.6404	16.37466	17.29498	19.08813	21.24641

Waste to energy

Waste generation is expected to increase in India in the near future. About 55 million tons of solid waste and 38 billion litres of sewage are generated every year in India. Additional waste is also generated by industries.

India has had a long involvement with anaerobic digestion and biogas technologies. India has established a wastewater treatment plant to generate renewable energy from sewage gas.

Details on leading companies with generation amount (by type of RES)

1. Solar Energy

It has been observed that solar power in India is one of the fast-developing industries. As on 31 March, 2020, India reached an installation capacity of 37.627GW by solar.[1]

Table 3: Sector wise Growth in Renewable Sector
Source: L&S p. 208

SECTOR	INSTALLED CAPACITY (GW)		% GROWTH
	AS ON 31.03.2014	AS ON 29.02.2020	
Renewable Energy (Excluding Large Hydro)	35.5	86.8	145
Solar	2.6	34.4	1223
Wind	21	37.7	80
Biomass, Small Hydro, and Waste to Energy	11.9	14.7	24
Large Hydro	40.5	45.4	12
Nuclear	4.8	6.8	42

India has the lowest capital cost per MW globally to install solar power plants.[2][3] Some companies of India generate the maximum amount of energy like Acme solar 2300MW, Adani 1970 MW Azure Power with 1591MW, Tata Power with 1388MW, renew power with 1241MW, etc, according to the latest data compiled by the International Energy Agency and CEEW.

2. Wind Energy

In the case of wind energy generation, India has significantly increased in recent years. As of 29 February 2020, the total installed wind power capacity was 37.669MW, the fourth largest installed wind power capacity in the world. In India, there are some companies that generate maximum energy. The top three developers, Renew Power had 2637MW, Greenko Energy had 2156MW, Sembcorp had 1365MW of generation capacity at the end of May 2019.

3. Hydroelectric Energy

India is positioned seventh in the world in Hydropower generation. As of 30 April 2017, India's installed utility scale hydroelectric capacity was 44,594 MW or 13.5% of its total utility power generation capacity. [8] In India, there are several companies that produce the maximum amount of energy. These companies are National Hydroelectric Power Corporation (NHPC) with 3290 MW, North Eastern Electric Power Corporation (NEEPCO), THDC India Limited with 1400MW, Satluj Jal Vidyut Nigam etc. [9]

4. Geo-Thermal Power

Geothermal energy is generated through the natural hot springs as a form of thermal energy. Geothermal energy installed capacity is in the experimental phase in India; however, the potential capacity is more than 10,000 MW. The most promising geothermal energy sites in India include Tattapani in Chhattisgarh, Puga in Jammu & Kashmir, Cambay Graben in Gujarat, Manikaran in Himachal Pradesh, Surajkund in Jharkhand, Chhumathang in Jammu & Kashmir. [10] The important geothermal companies are Tata Power, Thermax, NTPC, Avin Energy etc.

5. Biomass Energy

Most of India's Biomass Electricity is being generated in Andhra Pradesh, Maharashtra, Tamil Nadu, Karnataka, and Rajasthan. Other companies are Nuchem Ltd, Indus Green Bio Energy Pvt Ltd, Globus Spirits Limited etc.

Risks of Technological Development of Renewable Energy in Indian Scenario

From the inception of the 21st century researchers emphasise the advancement of the use of Renewable Energy Resources in practical scenarios. The first aspect of the development of the Renewable energises has stood the Conventional Energy industries in the face of annihilation. The second aspect is that for the developing countries like India, the process of switching the peoples from the use of Conventional energy to non-conventional Energy has been quite slow due to the lack of infrastructure.

To overcome the risks associated, local governments can:
1. Assess the availability of local renewable resources
2. Consider the costs of different renewable technologies
3. Examine the aggregate costs and benefits of on-site green power
4. Consider permitting requirements for locations where the facility could be sited
5. Involve local stakeholders, particularly concerning siting
6. Assess available sources of financing and other incentives

Barriers

1. Solar Energy

Land: It suffers from the base problems like protests against augmentation of land acquisition of parks, accession of roads, demarcation of land areas within solar parks remain incomplete after the completion of the project which incurs financial losses for that project

Shares: Lenders and equity investors consider it is risky to invest in renewable energy because of the uncertainty regarding the potential buyers of the electricity.

Forecasting Problems: Power generating from solar and wind is intermittent and forecasting levels are weak that makes it an unattractive endeavour for the power generation companies to switch to renewable energy resources

Economic: India faces the hindrance of moving 25 percent of its population out of poverty. Without an annual energy availability of four tonnes of oil equivalent per capita, it's arduous to attain a Human Development Index of 0.9 which suggests high life expectancy, income, and education.

High-Initial Cost: As the solar industry is capital-intensive, the cost of power generated by the solar is more than conventional energy. In addition to this, the overall cost of imported solar modules has risen as the government has raised the duty for solar imports. Steep duty has resulted in cranking up the overall cost for solar power developers.

Failure of Grid: Immense proportion of renewable makes a grid unstable which may cause the fluctuation of operation voltage or frequency in the Grid that results in a failure of the grid.

2. Wind Energy

2.1. Off-shore Wind Power:

High Capital Cost: An ample amount of Initial Investment is required to develop the requisite infrastructure like supportive vessels, trained manpower

Requirement of adequate Data Collection: It entails a colossal amount of data collection before inaugurating the power plant.

Retrogressive Aspects in the Tourism Sector: The tourist spot within 26 miles from Offshore Wind Plant has degrading property values.

2.2. On-shore Wind Power:

Seldom power generation: Due to poor wind speed or physical blockage it cannot produce the Wind power all over the year.

Sound Pollution: Noise generated by the wind turbine produces an enormous amount of sound pollution.

3. Tidal Energy

Dependency on Tides: Due to the gravitational forces of the moon, the tidal cycle appears every 12 hours. But Wind Speed and Direction directly affects the height of the Tides. To grab enough power from tidal energy, the height of the tide should be at least five meters. So due to this Environmental impact, the power generated by Tidal power is inflexible in nature.

High Capital Cost: Huge investment is required

4. Geo-Termal Energy

Environmental Hazards: Geothermal energy can precipitate several environmental hazards like on-site noise, emissions of gas, and disturbance at drilling sites, disposal sites, roads and pipelines, and power plants during its development.

Air Pollution: The steam contains hydrogen sulphide gas and causes air pollution. The minerals in the steam are also toxic to fish and they are corrosive to pipes, and equipment, requiring constant maintenance.

Strategies for renewable energy growth:

It has been observed from the analysis that India has got remarkable growth in the Renewable energy sector in the past few years. A lot of policies have been planned and executed successfully. To keep this momentum in future, the following strategies may help:

Promotion of Hybrid Solar and Wind Plant and build ancillary market

Hybrid projects have much higher capacity utilization factors and eliminate intermittency challenges. Moreover, it shares the same transmission line. Ancillary markets would provide backup services to smoothen out the variable nature of energy supply.

Build enhanced evacuation infrastructure

Huge investment is needed to transfer a bulk amount of energy over a distance efficiently and quickly through high voltage transmission lines. This scenario is very important where the storage solution is not adequate.

Invest in digitalization

In this age of digitization, an optimum design of the entire infrastructure is possible with software-based algorithms.

Develop battery storage solutions

The battery storage system is an integral part of renewable energy production. During low demand, the power extracted by renewable sources can be stored in batteries efficiently using power electronic converters and during peak demand, this stored energy can fulfil energy demand.

Develop Efficient Power Converter

For the integration of different renewable energy in the grid, an efficient power converter is needed to store renewable energy in the battery and later with the help of power converters this energy can be delivered to load. Thus, the entire integration depends on an efficient power converter.

Reformation of distribution companies

Due to outdated power distribution infrastructure, a quarter part of total power is lost during transmission, which results in different faults, leakages etc. Weak monitoring of an infrastructure is another cause.

@ponsulak via Twenty20

3 Distributed generation as a trend: how is it implemented in India, and how does it affect the industry?

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Introduction

The Indian power sector is under revolution from the past few years with high penetration of renewable energy sources [1]. With inadequate conventional energy sources, it made a possible entry of distributed energy (DE) resources in the Indian power sector. Every energy supply penetrating to the grid at the distribution level is termed as DE. The centralized control of Indian grid system is shifting towards decentralized mode with the inclusion of these DE resources. The growth of this decentralized energy network will be realized by a central control station (CCS). The CCS allows several decentralized plants to combine and function as a single one. It works on a cloud-based platform and administers various decentralized power plants using distribution routes and load centers. DE plants can be distantly functioned using CCS. The CCS comprises of DE resources, distribution & transmission companies and electricity market. Technical CCS operates at distribution & transmission levels, whereas commercial CCS runs the DE units based on demand and generation potential. CCS facilitates DE and communicates with technical CCS and commercial CCS. DE resources include controllable loads, electric vehicles (EV), solar PV units, natural gas turbines, small power plants, fuel cells and energy storages.

Various functionalities of CCS like distributed asset monitoring, asset analytics, distributed asset control, renewable energy management, energy storage management, EV charging asset management, and demand response management are anticipated to influence the adoption of CCS in the Indian power sector.

Furthermore, favorable government policies and regulations are likely to play an important role in the adoption process. Vehicle electrification policy of the government, as part of Faster Adoption and Manufacturing of EVs (FAME) and National Electric Mobility Mission Plan (NEMMP) 2020, will require the development of EV charging infrastructure. Implementation of CCS can help in effectively managing the charging stations spread across the country and control the load on each charging station. Furthermore, successful implementation of five-minute scheduling policy can be possible by using CCS.

However, the large scale implementation of CCS in India can be prevented by a number of challenging factors such as weak regulatory framework. Various utility companies are hesitant to join the CCS architecture owing to issues regarding grid safety, stability, operational efficiency, and pricing. Threat of cyber-attacks significantly challenges the virtualization of power plants. Maintaining security and privacy of the enormous data generated from consumers and prosumers becomes a considerable challenge of the CCS market.

DGs are playing an important role in the global electricity paradigm. In India, DGs are contributing for the Indian power sector. The renewable energy resources because of its advantage and pollution-free electricity towards making Indian power sector neat and clean (green country). With the use of DGs either grid-connected or in stand-alone mode, there are some issues that should be resolved for making DG system more efficient and reliable.

Leading Companies in India

Conventional power stations, such as coal-fired, gas, and nuclear powered plants, as well as hydroelectric dams and large-scale solar power stations, are centralized and often require electric energy to be transmitted over long distances. In contrast to that, distributed energy (DE) systems are decentralized, modular, and more flexible technologies that are located close to the load centers. DE systems are however having a lower rating of power capacities. These DE systems can comprise multiple generations and storage components; in this instance, they are referred to as hybrid power systems.

1. ABB

ABB, formerly ASEA Brown Boveri, is a multinational corporation operating mainly in robotics, power, heavy electrical equipment, and automation technology areas.

ABB is a pioneer in technology, solutions and execution with 25+ years of experience in innovation and technology leadership and is a reliable and proven portfolio with 40+ successful executed projects and with global and sales network.

ABB provides Comprehensive products and solution portfolios when it comes to DG as:

- Consultancy and Design
- EBoP and Plant Automation
- MICROGRID Control System
- Energy Storage and Grid Stabilization
- Power Protection and Distribution
- Solar PV Inverters
- Substations
- Remote Monitoring and Service

Some of the cases of ABB which illustrate the trends in Distributed Generation are:

ABB powers and automates the world's largest solar power project

ABB has been able to support the country's clean energy vision and push for solar power through a number of solar projects. One such project is Adani's solar power plant in Kamuthi, located 90 km from Madurai city in southern India. ABB provided the electrification and automation systems for the Adani solar project. The project is the world's largest solar plant in a single location, surpassing the California-based Topaz Solar farm which has a capacity of 550-megawatts. The massive 648-megawatt Adani solar project, with five separate plants, contributes to the country's renewable energy vision, with the overall aim of diversifying the energy mix to meet growing demand while minimizing environmental impact. The facility spreads over 2,500 acres (10 sq. km) and will enable a clean power supply for around 150,000 households, based on an average national per capita consumption, and accounts for about 10 percent of India's solar power.

IIT Roorkee partners with ABB to enhance smart grid development

The two will construct a smart energy distribution and management system to be piloted under the Smart Cities Mission programme. The project will demonstrate how smart cities in India can use smart grids and automation to optimize management of power networks. The smart grid system will integrate the campus' various energy resources with demand-side management measures, to help the institute lower energy costs by reducing dependence on electricity from the main grid.

ABB energizes the first phase of India's most advanced UHVDC power link

ABB, the leading power and automation technology group, has energized the first pole of the North-East Agra 800 kilovolts (kV) Ultra-high voltage direct current (UHVDC) transmission link, which will supply clean hydropower from north-eastern India to a substation in Agra, and from there, feed it across north India. This completes phase one of the project, which enables the transfer of up to 1,500 megawatts (MW) of electricity along with this link, across a distance of 1,728 kilometres. This region has abundant untapped renewable resources, but load centres are thousands of kilometres away and power must pass through a 22-kilometer wide corridor of land bordered by Nepal and Bangladesh on either side.

2. TATA Power

2.1. Tata Power and the Rockefeller Foundation Announce Breakthrough Enterprise to Empower Million of Indians with Renewable Microgrid Electricity

Tata Power and The Rockefeller Foundation announced the launch of a major new initiative to set up Microgrids, which will address one of the most pervasive challenges in modern India: the lack of access to affordable, reliable electricity for millions of rural homes and enterprises. By scaling up an innovative Microgrid model to be implemented in collaboration with Smart Power India (SPI) and the Institute for Transformative Technologies, TP Renewable Microgrid Ltd. will provide clean power to nearly 5 million households, directly impacting the lives of 25 million people over the next decade.

2.2. Tata Solar Power –Capacity Expansion to cater to the growing demand

The company operates in three segments —solar cell and module manufacturing; engineering, procurement and construction (EPC) services for solar power projects; and development of innovative solar products. Tata Power Solar has executed over 140 MW of rooftop projects across India. Over the past year, the company has installed nearly 40 MW of rooftop solar projects, with the majority of its customers belonging to the industrial and commercial segments. In addition, the company has installed a number of prominent rooftop projects such as a 4.45 MW project for Asian Paints, a 1.2 MW project for Gujarat Energy Development Agency, a 2 MW plant for Murugan Textiles and a 1.25 MW project for SASTRA University, along with multiple residential and industrial projects.

3. Siemens India

Siemens is a market leader in power distribution worldwide. The company has been developing efficient, reliable, flexible power distribution systems since the invention of the dynamo machine.

3.1. Siemens, BECIS to accelerate the rollout of distributed energy in the Asia Pacific

Combining its financial expertise with intelligent energy solutions and services, Siemens has entered the investment and framework agreements with Berkeley Energy Commercial Industrial Solutions (BECIS).

Together, they will provide customers access to distributed energy solutions via a flexible 'Energy as a Service' (EaaS) model, allowing customers in the Asia Pacific market to pay for energy services without the need for any capital investment.

At the same time, Siemens Smart Infrastructure (SI) will contribute technical expertise from its existing footprint in energy and performance services (EPS) projects to BECIS, complementing the latter's experience in distributed energy generation solutions. EaaS is a business model that allows customers to partner with a solutions provider such as BECIS and pay for an energy service over time, without the need for any upfront capital investment. The long-term asset ownership resides with the solutions provider in this business model, in addition to the responsibility of deploying, constructing, operating and maintaining the assets.

3.2. Distributed Power Generation: Future Energy (By Siemens)

The new MVDC PLUS solution (medium-voltage direct current) from Siemens closes the gap between HVDC and local distribution grids connects autonomous systems, increases the efficiency of power transmission, and simplifies decentralized power trading.

The key features of this plan by Siemens are:

- MVDC based on proven technology
- MVDC PLUS connects islands, autonomous systems and regional medium-voltage networks
- MVDC allows power to flow in all directions
- The future of electricity transmission is complex and decentralized.
- MVDC PLUS technology is revolutionizing the electricity market.

4. PANASONIC

4.1. Panasonic and Indian Utility Team up to Roll Out Urban Microgrids

Panasonic and Indian electricity utility group BYPL recently installed four solar-plus-storage-based urban microgrids on rooftops at the utility's offices in the Delhi region, piloting what development partners expect will be many more to come. Panasonic anticipates installing 60 MWh of smart battery energy storage capacity in partnership with BYPL over the next three years.

According to Panasonic, urban microgrids can make a big contribution to the decentralization and de-carbonization of India's power system. Additional Microgrid energy services will be rolled out over time to improve utility grid stabilization and overall management capabilities. Microgrids will be used to avoid network congestion and bottlenecks and provide ancillary grid services, such as voltage regulation.

4.2. Panasonic Claims Highest Conversion Efficiency of 16.09% for Perovskite Solar Panel

Panasonic Corporation has announced that it has achieved the world's highest energy conversion efficiency of 16.09% for a perovskite solar module by developing a lightweight technology, which uses a glass substrate and large-area coating method based on inkjet printing. This was carried out as a part of the project of the New Energy and Industrial Technology Development Organization (NEDO), which is working toward the development of technologies to reduce power generation costs for high performance and high-reliability PV power generation to foster the growth of renewable energy, especially solar power generation. An interesting part of this innovative technology is that it uses an inkjet-based coating method that can cover a large area and is cost-effective. In addition to this, this latest technology allows for generating solar power at locations where conventional panels are hard to install.

5. Schneider Electric India Pvt. Ltd.

5.1. Net Metering via Rooftop Renewables

One of the key benefits of microgrids is that the grid becomes a source of income for the person who installs any sort of renewable energy plant in his home. Schneider Electric in its Microgrid drives introduces Net Metering.

Net metering refers to a billing mechanism that credits solar energy system owners for any electricity they add to the Grid. If a residential customer owns a photovoltaic (PV) system on his/her rooftop, this may generate more electricity than required during daylight hours. A net metering agreement allows the owner of the PV system to sell excess solar power to a utility company or purchase deficit power from this company by using a smart meter in tracking the energy exchange. The latter occurs when solar energy generation is less than what the home requires in the early morning, late evening or during the night. During afternoon hours of peak sunshine, excess energy is supplied back to the Grid. Customers are then credited or debited as per net meter readings over the designated period.

Risks of development

Distributed generation in simpler terms means to generate electricity close to the demand side rather than transporting the electricity from far off locations. The main reason for this advancement is to meet the local demand with the locally available source of generation rather than utilizing tons of resources on generation at different places and the cost of building up a network to transport electricity from that place to the place it requires thus increasing the cost of project and associated losses all year.

Distributed generation is very simple to propose but the implementation requires planning and how electricity will be generated locally and would that generation be enough to cater to the needs of that area.

In distributed generation system local demands are catered by using renewable methods of energy generation. Solar plants, wind turbines, small hydro power plants or gas or coal plants are installed to meet the demands thus reducing the cost incurred on designing and transportation of electricity.

In India, demand in electricity has increased from 8,30,594 MU in 2009-10 to 12,91,010 MU in 2019-20. While the requirement has increased the generation too has increased but never actually met the requirement completely. One of the reasons for the difference is the centralized generation system put in place which requires a lot of infrastructures to be put in place to meet the demand and in case we are able to generate a surplus, we require a grid system to reach the farthest corner of our country. With problems such as these, distributed energy system in India is a strong structure to already setup energy system in India.

The Electricity Act, 2003 of India emphasis on decentralized energy generation particularly through non-renewable sources of energy. With electricity reaching to villages with minimum infrastructure the country's rural area will step into the direction of positive growth. With each passing day the country is stepping up the renewable energy generation and decentralized energy generation is boosting the setup.

Government is pushing for distributed generation in towns and cities, a house owner is asked to pay for the solar panels at a subsidized cost and then two-way meters are installed so that the surplus energy generated by owner is fed to grid thus decrease in electricity bill and improved electricity.

Distributed generation will eventually create a self-sustaining electricity model in India with each household generating for its own use (better solar panels installed). Renewable plants are increasing day in day out with India targeting 175GW renewable energy generation by 2022. With distributed generation, electricity reaching every part of the country, awareness campaigns and different political activities can be forwarded throughout the country. It can be provided through audiovisual equipment running on electricity, thus building a strong foundation towards nation building.

With DG, we can save the existing natural resources, for example in case of centralized generation a power plant needed to overwork juicing every ounce of natural resources of a particular place of which a lot would end up in losses while transmission and other losses. But with distributed generation at different places of need, limited resources will be used to feed electricity to that population.

Scenarios

Quality scenario analysis and strategy on EVs in India.

Negative

1. Renewable energy technologies have been popular in different parts of the globe in regions where demand exists and DG systems have been found to be economically viable and more easily implemented. But at the micro level victory was seldom scaled up for a number of technical, regulatory and financial reasons addressed.

2. Maintaining power quality standards, the issue with the DG is that the DG system can also affect the system's power quality as much as the system can. The electricity boards, therefore, have no hesitation and concern about the energy performance of the DG systems. While new technologies are available, electrical utilities rely heavily on conventional security methods (frequency, under/over-voltage) to increase the capital costs of DG plants

3. People in remote communities have limited opportunities to invest in clean energy technology such as solar lighting systems due to limited cash flows. Access to credit is therefore extremely important to allow access to clean energy technologies such as DG systems, as they are capital-intensive. The poor have always been outside the mainstream in accessing renewable technology such as biogas plants, solar home lighting and much more, due to burdensome processes involved in the access to structured loans and banks ' unwillingness to lend the poor for their energy needs. Banking institutions seldom establish any DG package in rural areas because the villagers cannot provide the required credit agreements.

4. The financial institutions and the banks in India have limited knowledge of the RE technologies and since these options don't directly lead to immediate income-generating activities, it is difficult for FIs and banks to justify loans to rural consumers for these schemes/packages. Lack of adequate knowledge and long-term period Likewise, a local rural energy social entrepreneur who wants to enter the DG market does not have sufficient information and statistics, which prevents them from setting up small DG systems in their villages/districts. The interconnection procedures are another issue which creates an artificial barrier for small DG operators. Interconnection and implementation costs are seldom well specified and standardized, irrespective of the installation

size, which renders the Electricity Board officers ' time consuming to seek concrete answers

5. Most of the Indian programs were developed and planned by the Ministry of Power (MoP), Ministry of New & Renewable Energy (MNRE) and local agencies. The central government is responsible for procurement, planning, priorities, policies, and program implementation plan, the participation of agencies and system design management and monitoring. This leads to very optimistic goals that do not consider the ground realities and issues that lead to poor execution of the programs. One of the stated goals of the Jawaharlal Nehru National Solar Mission (JNNSM) was, for example, to develop a robust indigenous manufacturing sector and transform India into a solar hub. To achieve this goal, the Government implemented the Domestic Component

6. Requirement (DCR) for solar cells and solar modules for crystalline silicon-based solar photovoltaic projects. The systems were distributed equally between thin and crystalline silicon pv in lot one, but in lot two the installations of thin film rose to 59% while the crystalline silicon PV decreased to 41%. This was because the designers preferred thin film since it was excluded from DCR and thus the local manufacturing industries did not improve efficiency. Tariff Fixation Networked domestic and agricultural consumers are subject to tariffs set by the relevant regulatory commission, which is typically below average supply costs in that region. This is because of the cross-subsidizing impact that High Tension customers create on the distribution companies ' total revenues as a result of the payment of high tariffs. Nevertheless, the tariffs are mutually agreed between the electricity provider (using DG generation means) and the customer in the DG system deployment, commissioning and generation scenario. The lack of subsidies electrified by DG networks in remote areas leads to higher prices for domestic consumers.

7. Regulatory issues Local resistance to the introduction of DG projects against grid linked projects can exist in some areas. Often, it takes time and boring to find the right company to perform pre-feasibility studies. The acquisition of land for project development and forestry clearance is another obstacle for each DG developer. The above challenges hinder the progress of the application of the DG. Public utilities and electrical boards do not adapt to the new technology and do not take the on-field situations into account when designing DG implementing schemes and programs in India.

Conservative

1. DG should play an integral role in meeting the country's ever-growing energy requirements. The transition will be hard initially to adjust, but the end result could be that a significant number of consumers receive reliable electricity.

2. The unilateral stream of power will start flowing bilaterally to and from the end user with the introduction of DG. For order to take full advantage of the introduction of the DG, the present Indian grid system needs to be improved.

3. A smart grid could be one of the best options currently available. This paper presents an impression and viability analysis in the Indian sense of decentralized distributed generations. In spite of the numerous obstacles, DG is the key to clean and efficient methods for the future. It is better than the current procedures of power stations. The economic side and the incentives addressed by the DG help its introduction in the Indian power sector. DG is certainly a way forward for India with an estimated addition of 17.800 MW in the near future, combined with innovation in solar, wind, small hydro and biomass. This would benefit both the customers and power generators.

4. The DG has been given the much-needed boost in India by the 2003 Electricity Act. The government of India announced the need for DG based on renewable energy, in order to satisfy the ever-increasing energy needs and provide power to remote villages. It can be inferred that there is enormous potential for exploring renewable sources available in India that can be turned into electricity. In India, a number of resources and various forms of renewable energy are available

5. India is on right track to pursue the development of Distributed Generation with the unbundling of the power sector utilizing captive and co-generation, besides putting all-out effort in harnessing various forms of new and renewable energy. In fact, two Ministries of Government of India are involved in the overall progress of Distributed Generation. While Ministry of Power is interested in rural electrification, Ministry of New and Renewable Energy (MNRE) is for the development of DG, thus fulfilling the need of each other. Liberalization of Government policy vis-à-vis support as well as regulatory mechanism in place is helping to create a conducive atmosphere to achieve the target set in this direction. However, there are challenges that are being attended to with utmost sincerity with Distributed Generation.

Innovative

1. Distributed generation will be the backbone of electricity model in India. With the demand in electricity increasing day after day, the efficiency and innovation in the field is increasing.
2. While the government is doing everything, it can push the model towards renewable energy, distributed generation is helping it. With small consumers increasing their solar device installation and two-way meter (as explained earlier) demand for energy through grid will slowly decrease thus letting natural resource take a break.
3. In coming years for any area, compulsory renewable energy intake for any consumer would be made compulsory thus renewable energy will be further scaled up.
4. Solar panel efficiency will be further increased, group generation will be incorporated. A person with a large area will put up solar panels generating energy locally and profiting from it by supplying it locally to group consumers.
5. With this model India, will emerge as one of the biggest energy producers in the world.

Strategies to be taken into consideration:

1. DG systems are found to be economically viable, but at micro level implementation was hindered due to a number of technical, regulatory and financial reasons. We can overcome this by providing statistical data of financial and technical improvements with DG technologies to the central, state and local regulatory authorities.
2. The Indian government has already set many policies in regard to the development and implementation of DG. Few of such are “National Solar Mission”, “Power for All – Vision 2022”. In this regard, the ongoing “Smart City” proposal can be further upgraded with ‘Vehicle-to-Grid’ technology.
3. The government agencies should compulsorily integrate DG in their power system and more private players should be encouraged to participate in consuming power from DGs. Thus DGs will be further scaled up.

4 Development of Non-traditional Renewable Energy sources (NRES): Pricing, Management of Operating Modes of NRES and Increasing the Efficiency of Power Plants based on them

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Introduction

Electricity from renewable energy sources has seen a rapid growth worldwide and is considered as one of the major areas of research. Technological developments are contributed throughout the world to expand the electricity share from sustainable Renewable sources [1-3]. Over a decade, India has set up a positive attitude for business and technical enhancement in the area of generation and supply of renewable energy (RE). Major portion of rural areas are not connected by electricity in the conventional way. The reason being electricity from RE technologies is utilized to fulfil the basic needs of cooking, lighting etc. which is termed as decentralized energy generation [19]. Thus, in an isolated area, the correct way of electrifying is distributed generation by RE sources [14 – 16]. India is rich in renewable energy such as solar, wind, small hydro etc. but it is not consistent throughout the various parts of the country. India's population stands at the 2nd position worldwide with a share of 18% of world's total population which is utilizing only 6% of the world's primary energy [2, 18]. The status of power generating capacities through RE as on 30.04.2020 is shown in Figure 1.

India has come up with India's largest RE expansion program of 175 GW till 2022 [20]. It contributes around 4.5% of the globe's entire RE based power generation [18]. India is observed to be among the developing nations having enormous prospective for RE technology. At present, non - traditional RE sources contribute almost 23.7% of the world's power demand [10].

Non-Traditional Renewable Energy Sources: Prospects, Development and Relevance to the present global outlook in Indian Context

India is now globally at the 5th position for overall installed RE capacity. Its total power generation (including grid connected RE sources) has been expanded from 1110.46 BU during 2014-2015 to 1390.47 BU during 2019-2020 [10]. The category wise generation performance during the year 2019-2020 was as: thermal reduced by 2.75 %; hydro increased by 15.48 %; nuclear increased by 2.90 % renewable increased by 9.12 % with an overall growth rate of 0.95% [18]. Apart from these, there are some new RE technologies which are equipotential and sustainable for countering the ozone layer depletion and air pollution risk to the earth. These emerging RE technologies comprise of small hydro energy (SHE), geothermal energy (GTE), hydrogen energy and many more. The next section will include prospects, development, pricing and mechanism of some leading non – traditional renewable energy sources (RES) used in India.

1. Wind Energy

Wind energy becomes the leading non-conventional energy source (NCES) for power generation in India because of the enormous coastal region and sufficient availability of velocity of wind. India has an aggregate wind energy potential of 68,500 MW out of which 37000 MW has been harnessed so far. The MNRE has facilitated execution of exhibition and private segment projects through feasible and economic programs and schemes. A self-governing organization in Chennai, Tamil Nadu named "Centre for Wind Energy Technology" (C-WET) under MNRE was established for growth of wind energy based power generation. Total 1244 number of wind monitoring and mapping stations are established under "Wind Resource Assessment Program" in India [12]. Also, C-WET aims to prepare Indian Wind Atlas collaborating with Denmark's Riso National Laboratory. In North- Eastern region (NER) of India, total 20 wind monitoring stations have been sanctioned by MNRE.

1.2. Economic Aspects:

Wind farms can provide electricity 24/7 unlike solar energy. Operational cost is also very low as it doesn't have any fuel expenses or air pollution control equipment. Wind energy projects have also many economic benefits for neighboring communities such as job creation, an additional source of revenue for ranchers and farmers in the form of land lease payments etc. [9]

1.3. Political Aspects:

Waiving off the transmission losses and charges by the Indian government, for the interstate sharing of wind power, will help to meet the RPO requirement of the non-windy regions by purchasing wind power from windy states. Moreover, to speed up this process, bidding has been introduced to attract more customers and in order to realize a suitable price calculating mechanism for transactions of wind power among states.

1.4. Socio-cultural Aspects:

Citizens' health issues will be reduced because of green energy produced by WTG.

1.5. Technological Aspects:

The average size of a wind turbine has been considerably increased and is such that it involves severe constraints depending on testing locations and size of testing facilities for turbine blades and other components. With increasing wind power penetration, additional network requirements and plant functionalities have been developed, bringing new corresponding test and verification procedures.

1.6. Environment Aspects:

Wind energy is arguably the cleanest source of RE. It is seen that placing wind turbines offshore has resulted in the destruction of marine life habitats. However, these effects are extremely minimal and can be resolved. The turbines themselves may act as an artificial reef.

1.7. Relevance to the present BRICS outlook:

Wind energy is the leader of the renewable energy sector at present and has lots of scopes to expand it using new technological developments.

2. Solar Energy

Solar energy Technology is the most adequate RE source with extensive applications such as distributed generation, rural electrification on-grid and off-grid, street lighting, agricultural applications, DC network interconnection etc. Geographically India is located in between the tropic of cancer and equator and receives an average temperature ranging from 25 °C to 27.5 °C annually. With this beneficial geographic location, India receives a global solar radiation of 1200 kWh/m2/year to 2300 kWh/m2/year [9]. Indian south-east coast is measured to be the sunniest region compared to the rest. The MNRE has a target to commission power plants for solar generation up to 20 GW by the year 2022 and significant weight has been given to harnessing electricity from solar energy by implementing National Solar Mission [6].

2.1. Economic Aspects:

- Operational cost of solar plants is low. Small scale solar grid helps self- dependent and uninterrupted power delivery in rural and remote areas. Roof topped solar generation and other standalone PV utilities help in tariff saving of individual utilities and attract small vendors in the generation process which indirectly contributes to the economy.
- Solar electric vehicles, electric trains and aviation systems will reduce the dependency of traditional oil-based transportation systems and markets which will contribute significantly to India's economy directly.

2.2. Political Aspects:

- Solar grid may alleviate the tension of water-war between two states or countries.
- Air, soil and water pollution due to use of conventional sources and problems created by hydro plants in downstream regions especially in the agriculture sector, often ignite political tension in the suffering region. Solar energy sources alleviate this kind of issue.
- Solar based international grouping like, "International Solar Alliance" etc. As well multinational solar projects may help in building geo- political stability besides global economic growth.

2.3. Socio-cultural Aspects:

- Resulting economic benefits would positively impact poverty alleviation and support mitigating water, sanitization, food and other socio-economic challenges in rural India.

Technological Aspects:

- Technological development for low cost storage devices and improvement in efficiency of PV panels is an important issue. This creates scope for researchers and opportunity for industries.
- Better utilization of solar power is important and possible through developing technologies to design domestic, industrial, agricultural land medical appliances, and also in transportation sectors.
- Smart controlling and reliable transmission of quality power generated through solar energy sources are the other areas available for research and development.

2.4. Environment Aspects:

Traditional fossil fuel-based generation creates pollution and global warming. Making the energy sector eco-friendly is an important step for meeting the goal of 2015 Paris agreement to limit the increase in global temperatures to below 2 degree Celsius and solar energy can share major contribution to fulfill the goal [18].

Relevance to the present global outlook:

India's major initiatives like creation of 'World Solar Bank', 'One Sun One World One Grid' project and formation of various international bodies based on solar energy are the reflection of changing trend and future of global energy sector.

3. Biomass

Govt. of India has set up programmes on Biomass promotion titled "Programme on Energy from Urban, Industrial, Agricultural Wastes/Residues and Municipal Solid Wastes (2019–2020)" scheme to support promotion of biomass based congregation in sugar mills and other industries for power generation in the country (1.05.2018 to 31.03.2020) to encourage setting up of projects for harnessing energy in various forms such as Biogas, BioCNG, power from agricultural and industrial waste etc. and thermal use through gasification in industries and also to promote biomass gasifier for feeding power into the grid or meeting captive power and thermal needs of process industries; to promote biogas based Decentralized RE sources of power generation (Off-Grid) [5]. Over the last few years, India has witnessed rapid increase in the biomass power generation (BPG) capacity as the government focuses on promoting RE generation. If this rate continues, India is likely to surpass the target of 12 GW by 2020, way ahead of the target year of 2022.

3.1. Economic Aspects:

Use of biomass energy resources like agricultural and municipal solid waste can reduce net energy costs. Income generated through the sale of waste products can benefit individuals in rural economies.

3.2. Political Aspects:

The use of indigenous and cheap resources like biomass allows for a stable fuel price, making it a serious alternative to the fluctuated imported fuel cost. Furthermore, it helps easing tensions between countries to enjoy a better international climate.

3.3. Socio-cultural Aspects:

Biomass plant makes it possible to shift towards a distributed generation (DG) model in which each zone or locality can pursue its own generating plant and creates employment for the local population.

3.4. Technological Aspects:

The biomass technological strategy is multi-pronged which focuses on improving efficiency of traditional technologies, enhancing supply chains, introducing advanced technologies in order to provide reliable energy services at competitive prices and establishing institutional support.

3.5. Environment Aspects:

Plants that are used to make biofuels (such as oil palm trees and soybeans for biodiesel and sugarcane and corn for ethanol) absorb CO2 as they grow and may offset the CO2 emissions when biofuels are produced.

3.6. Relevance to the present BRICS outlook:

Interest in the use of bio-fuels worldwide has grown strongly in recent years due to the high oil prices, concerns about climate change from greenhouse gas emissions and the desire to promote domestic rural economies.

4. Geothermal Energy

Geological Survey of India (GSI) maps the geo-thermal resources in India. There is an anticipated estimate of 10 GW geo-thermal power potential in India. At this nascent stage, efforts are being made to introduce competitiveness on geothermal activities in India. Geothermal energy (GTE) can be used for heating purposes or can be transformed into electricity. The GTE present within 10000 metres of the surface of the earth crust is estimated to contain 50000 times more energy than in fuel resources around the globe [8, 11]. Initially, the electricity generation cost from GTE is expected to increase and will drop through 2050 [11]. One of the major decisions was taken at the 21st United Nations Framework Convention on Climate Change (COP21) that aims to promote a capable atmosphere to be a focus for investments in GTE; offer modified support and sustainability to sectors and nations with GTE potential.

4.1. Economic Aspects:

Most of the costs involved in GTE plants are related to resource exploration and plant construction, Operational cost is negligible.

4.2. Political Aspects:

There is no widely accepted strategy for scientific and commercial promotion of GTE development so far. Only a few rich countries have given importance on it.

4.3. Socio-cultural Aspects:

Accessing suitable building locations is a challenge. Hydro, solar and wind energy sources are well accepted and established; these factors make traders decide not in favor of GTE.

4.4. Technological Aspects:

Drilling costs are a major technological constraint, which alone account for half of the entire project costs.

4.5. Environment Aspects:

Sometimes, GTE plants produce a small amount of mercury emissions. Scrubbers produce a watery sludge composed of the captured materials, including silica compounds, sulfur, vanadium, chlorides, mercury, nickel, arsenic and other metallic compounds. This toxic sludge is hazardous for the environment.

4.6. Relevance to the present BRICS outlook:

Generating electricity is one of the major uses of geothermal energy. It is a very energy-efficient method to generate a source of renewable energy. It does not emit harmful gases while generating power.

5. Hydrogen Energy and Fuel

Hydrogen Energy and Electricity from it is at a very initial stage in India. The authority, MNRE initiated a R&D programme on Hydrogen Energy and Fuel [20]. Projects and schemes are supported in industrial, academic and research institutions to deal with challenges in development of hydrogen from RE sources. This has resulted in development and demonstration of internal combustion engines, two wheelers, three wheelers, and mini buses that run on hydrogen fuel. Hydrogen, having high efficiency, is termed as the fuel of the future. Efficiency can be increased with water as the exhaust component only. Indian Oil is going to fuel India's first hydrogen dispensing facility at R&D Centre. The durability, efficacy of fuel cell technology will be tested with vehicle being subjected to long trials for mobile or portable applications. Despite hydrogen being simple and abundant, it is difficult to find hydrogen occurring as a gas on planet Earth and can be observed combined with other elements. Although the other forms of RE cannot be harnessed all the time, hydrogen can be stored and transported like electrical energy to different locations required [18].

5.1. Economic Aspects:

Hydrogen energy will facilitate creation of support infrastructure through public-private partnership involving major stakeholders including government, industry, research and user groups. These actions will offer solutions to many challenges in creating infrastructure developing technologies and achieving the economic levels to make affordable hydrogen applications.

5.2. Political Aspects:

Setting up of adequate infrastructure for hydrogen production, storage, supply and applications will need large investments. This would require funding from the government as well as involvement of private sectors to achieve commercially viable application of hydrogen energy.

5.3. Socio-cultural Aspects:

The social issues include acceptance of hydrogen energy and its applications by a common man. This would require efforts to create public awareness about the benefits of hydrogen as a safe and efficient fuel.

5.4. Technological Aspects:

Technological development to provide low cost and preferably carbon free hydrogen is an important aspect. Hydrogen generation technology will develop fuel cells, which is emerged as a promising power source for various applications.

5.5. Environment Aspects:

Hydrogen energy can help India in achieving energy security through reduction in import of fossil fuels and also reduction in urban air pollution.

5.6. Relevance to the present BRICS outlook:

Fuel cells are expected to serve the needs of distributed power generation when cost effective products are available, mainly due to the fact that fuel cells inherently have higher energy conversion efficiency as compared to IC engines.

6. Small Hydro Plant (SHP)

The potential of SHP in India is estimated to be approximately 21,000 MW as per the Government of India. Several schemes are undertaken to encourage the State Government sectors and Independent Power Producers (IPPs) to set-up new SHPs so as to realize the aggregate resource potential in phased manner with an instant mission is to encourage IPPs to initiate new projects of total installed capacity of 1000 MW so as to achieve the target of cumulative capacity of 6000 MW by the year 2022. On the basis of generation capacity below 25 MW, SHP falls in the category of RE source. The MNRE has set a target of 5000 MW with SHP by the year 2022 [3, 6]. This energy is treated as inflation free due to no fuel cost and highest efficiency and developed technology with operational flexibility.

6.1. Economic Aspects:

- SHPs are sustainable and cost effective; it has simple construction, smaller in size, and its operating equipment is cheaper compared to large plants. The cost of electricity generation is free from inflation and the financial return happens quickly.
- There is a good scope for installation of SHPs in remote and mountainous areas. The use of these types of renewable sources of energy in such areas allows for development in economic and social aspects.

6.2. Socio-cultural Aspects:

SHP contributes to the development of the locality through irrigation, fishery, water supply, tourism, and prevention of flood.

6.3. Technological Aspects:

- SHP projects can provide cheap, off-grid power easily to rural areas. The World Bank on the other hand is making an effort to convince about the risk of SHP to the developing nations. The collective impact of SHP plants may outweigh single large dams.
- SHP can be built in a few years and has a longer life cycle.
- As an electricity generation technology, it is a very efficient energy technology because electricity is generated directly from the shaft power.

6.4. Environmental Aspects:

- SHPs do not have large reservoirs and the adaptation of the local population with the project does not have many impacts.
- SHP being a renewable energy source reduces GHG emissions.

6.5. Relevance to the present BRICS outlook:

Hydro power energy is the most reliable and efficient renewable source of energy which can be utilized in fulfilling the demand of ever-growing power in the country with no fuel cost and thus, clean energy is ensured.

Mapping with Nontraditional Renewable Energy Sources with political, Socio - Cultural, technological and environmental factors; Scenario analysis and Criteria analysis

This study is carried out to determine the status of Renewable Energy Sources in the context of India. The status is analyzed by providing weights to the different aspects such as Political, Economic, Socio-Cultural, Technological and Environmental as explained in Section 2.

Table 1 shows the rubrics for mapping criteria to establish weights to RES in Indian context. Table 2 thereby rates the different aspects corresponding to the RES explained.

Leading companies in India: The giant conventional and emerging Energy Providers

1. National Hydro Electric Power Corporation Limited (NHPC)

Profile: NHPC Limited has become the largest group for hydro

Table 1: Mapping Criteria to establish weight to RES in Indian Context
Source: Self elaboration

FACTORS	WEIGHT				
	5	4	3	2	1
Economic	Low Installation cost & low operational cost	Medium installation cost &low operation cost	High Installation cost & Low operation cost	High Installation cost & medium operation cost	High Installation cost & High operation cost
Political	Highly focused & Implemented	Focused & Implementing	Focused but not implementing	Still to be focused	No plan to focus
Socio-cultural	Well accepted and Highly benefitted	Accepted but not highly benefited	Not Accepted initially but benefitted	Neither Accepted nor benefitted	rejected
Technological	Highly developed	Developed	Developing	Under developed	Not developed
Environmental	Green and Clean	Green only	Clean only	Neither green nor clean	Very harmful

Table 2: Rating of Various NRES based on selected factors
Source: Self elaboration

	NTRES	Economic	Political	Socio-cultural	Technological	Environmental
1	**Wind Energy**	4	4	4	4	5
2	**Solar Energy**	3	4	5	3	5
3	**Biomass**	5	4	5	3	2
4	**Geo-thermal**	2	2	3	2	2
5	**Hydrogen Energy**	2	4	4	2	4
6	**Small Hydro Plant**	3	5	3	5	5

energy generation and growth in India, with adequate expertise in development till commissioning in context to setting up of hydro power projects. NHPC Limited has also extended its ventures in the field of solar & wind power Technology.

Recent Accomplishments: Kambang (3 x 2 MW) and Sippi (2x2 MW) Small Hydroelectric Projects in Arunachal Pradesh (A.P), Kambang Project (6 MW), A.P, Sippi Project (4 MW), AP. Few other small hydro projects already completed by 2020 are: Kalpong (Andaman and Nicobar) – 5.25 MW, Sippi (AP) – 4 MW, Kambang (A.P) – 6 MW, Devighat (Nepal) – 14 MW; NHPC Limited is the only nodal agency appointed by the Ministry of Non - Conventional Energy Sources (MNES) for exploitation of Geothermal Energy in the nation.

2. North Eastern Electric Power Corporation Limited (NEEPCO)

Profile: NEEPCO is a viable power generation company in the Indian North Eastern Region and beyond since 1976, working in parallel with the Ministry of Power and the north eastern states to work in their best interest in beating the enormous power potential of the region and the country.

Recent Accomplishments: SHP projects successfully completed: Assam (Dima Hasao) – 25 MW, Nagaland (Doyang) – 3*25 = 75 MW; Government has entrusted upon setting up Geothermal units at several locations of the Country such as Gujarat, Maharashtra, Assam, Uttar Pradesh.

3. National Thermal Power Corporation Limited (NTPC)

Profile: NTPC is the largest energy corporation in India with its ancestry planted way back in 1975 to accelerate power development in India. From generating electricity from fossil fuels, it is now into power generation using hydro, nuclear and renewable energy sources.

Recent Accomplishments: Singrauli (Small Hydro Power) – 8; Dhukwan SHP (3 X12) (THDC).

4. Adani Power Limited

Profile: Adani Renewables (Adani Green Energy Limited), is the pioneer in clean technology and is one of the giant renewable energy Industries in India which is helping India's paradigm shift to renewable power technology. It deals with utility scale grid connected solar and wind projects. With a mission to reach a renewable power generation capacity of 10 GW by 2022, Adani Green Energy is contributing substantially in narrating India's goodness story.

Recent Accomplishments: 40 MW Solar Power Plant at Bitta, Gujarat.

5. Tata Power

Profile: One of the largest integrated and indigenous power industries of India is Tata Power, which combining its subsidiaries and jointly coordinated sectors, has achieved an installed capacity of 12,742 MW. The clean and green technology of Tata Power which includes its renewable energy assets in solar and wind amounts to 36% of the company's portfolio.

Recent Accomplishments: 25 MW solar rooftop at Mithapur, Gujarat; 150 MW Solar generation at Pavagada, Karnataka; 12 MW solar rooftop at Beas, Punjab; 99 MW wind generation at Tamil Nadu, Damodar Valley Corporation for a 1050 MW mega power project at Jharkhand, first 4000 MW ultra mega power project at Mundra (Gujarat) based on super-critical technology.

Conclusion with developmental status of Non-Traditional Energy Sources

Electricity from solar and wind technology is a developed process in India. Power plants are running successfully with all the mentioned economic, political, and environmental aspects. The limitations considered in these two technologies are less as compared to others as there is a technological advancement within two decades. Government of India has set a target of reducing the carbon emission by 20 – 25% by 2020 and simultaneously achieves a target of 175 GW of RE installed capacity [10]. In the relevance of ASEAN nations, a political term "low-hanging fruit" is referred to indicate the share of RE as 30% of total power generation across the globe [18, 20]. The reasons being a lesser percentage in spite of immense potential can be stated as economic, socio-cultural, environmental and technological limitations which cannot be avoided and goes hand in hand. Concentrated Solar Photovoltaic (CSP) technologies require reflections with superior intensity to receivers, which are located at a distant place from the reflectors [3]. Thus, there exist chances of high transmission and distribution losses. Diffused radiations and intensities degrade the performance of CSP to harness electricity from solar energy. The Geothermal System (GS) is prone to small earthquakes or landslides in localities which are prepared for developing wells. GS may cause minor environmental air and water quality issues if the power plants are not designed effectively and maintenance is poor [8]. Biomass energy is reliable but not the preferred renewable energy source because of unavailability of biomass throughout the year [5]. Biomass from agricultural wastes is available only after the harvesting season which stays only for 2 -3 months every year. Thus, there is a huge requirement of storage for producing electricity for KW to MW range. The process of tidal energy conversion is still in a pre-marketable phase and only limited developments have been done so far so that it can be tested at full scale in the ocean and hence not considered in the discussion [4]. The SHP programme presently in India is being accelerated by private investment Industry/sectors. The private sectors have shown the direction out of competitiveness that electricity from SHP energy is highly in demand due to less tariff, etc [12]. The challenge is to improve reliability and quality at reduced costs. The realization of geothermal energy harnessing is a challenge at this stage of development in India. But with the results coming out of industrial, academic and research institutes, it might be easy to set up a plant with an installed capacity of KWs to few MWs.

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5 Non-traditional renewable energy sources vs traditional power system: The change of the established foundations by renewable generation

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Introduction

Production of energy is of crucial importance to the world. We have always aimed to produce more and more energy in the most efficient manner possible. However, the traditional sources of energy had their own shortcomings, which called for the exploration of new sources of energy. The requirement was further intensified by the fact that these sources of energy cannot be replenished, and their production and usage took a toll on the environment. Renewable sources of energy were presented as an alternative to the situation. They are comparatively cleaner and have lesser adverse effects on nature. The world is observing a shift from the traditional sources of energy to renewable sources of energy.

The cardinal forms of renewable sources of energy are solar energy, wind energy, hydroelectric energy and geothermal energy. Each form has its own infrastructural requirements, output capacity, precise specifications, for instance, solar energy functions through the solar cells which trap the energy-rich sun's rays [6-8]. The hydroelectric energy is obtained through the kinetic energy stored in moving water, whereas turbines are used to capitalize on the energy of the fast moving winds.

India is endowed with resources that are indicative of the enormous potential which, if effectively tapped, will put the country as a leader in the energy sector. It is noteworthy that the development of systems running on renewable sources of energy depends on several factors. There is a requirement of technology and equipment which can both produce and handle large amounts of energy. To facilitate this, economic investments need to be made, and policies formulated that expedite the process of development. Thus, it is foremost that a careful study should be made on the various dimensions of the development ranging from the state of technology, environmental conditions to probable risks involved and thus carve out a well-formulated plan to reap the best fruits.

Plans and Policies

With its geographical diversity, robust demand, and political potential, India presents to be a great project site for renewable resources. The government has taken keen measures to formulate policies that can sufficiently and adequately exploit the resources. The government of India is bent on shifting to the usage of cleaner sources of energy and is rapidly investing in several large-scale sustainable power projects and the promotion of such energy sources. Besides, it is expected that renewable energy can garner employment opportunities at all levels in general and the rural areas capitalizing on the country's abundant human resources. The Ministry of New and Renewable Energy (MNRE) has aimed to set up the renewable energy capacity to a total of 175 GW by 2022, which would comprise 100 GW by solar, 60 GW for wind and the remainder will be contributed by hydro, bio, etc. [12].

India has been blessed with a wide area under solar radiation, which is equivalent to more than 5000 trillion kWh/yr. As of June of 2018, the government of India had aimed to achieve 225 GW of renewable energy capacity 2022, implying that it would be ahead of the requirements settled for in the Paris Agreement. India's renewable energy sector has gleaned the interest of many investors, and it is expected the investments will be made of around 80 billion in four years. About 5,000 Compressed Biogas plants will be set up across India by 2023. Under this policy of shifting the resources, targets have been set to 49 percent of the total electricity generated from renewable energy by 2040. This will be a consequence of the usage of efficient batteries, which will further cut the solar energy cost by 66 percent of the current value. The entire avenue will save Rs. 54,000 crores annually and renewable energy will contribute to about 55 percent of the total installed power capacity by 2030 [13-14].

Biomass has been on the rise as an energy source and represents around 14% of the world's final energy consumption. By the year 2050, we can expect that about 15-50% of the world's primary energy use can come from biomass. Biomass power generation in India is rapidly growing and is manifesting itself as a trustable source of energy, as a result of which investments of around Rs. 600 crores are made every year which are generating more than 5000 million units of electricity and sustain more than 10 million man-days in rural areas. There are several hydropower projects which fall under the category of Small Hydropower (SHP) (a station capacity of up to 25 megawatts). 11% of the estimated 15,000 MW SHP potential has been tapped so far, and efforts are being made in this regard [15-16]. Wind power is another potential energy source. In the fiscal year 2017-18, 52.67 TWh was generated, which accounts for around 10% of India's total installed power generation capacity. As much as 70%, most of this power is for five months (May to September) of the Southwest monsoon season [17]. Other sources of energy, such as biogas and geothermal energy have assumed a rather subsidiary role in the current energy mix. However, they are being looked at as a valuable source that can contribute significantly to the future.

1. Economic Factor

The significant contribution of the economic force is necessary for the support of infrastructure, skilled labor, integration with current systems, etc. India's energy demand will increase significantly out to 2035, driven by economic growth, urbanization, rising incomes, and industrial activity. The energy consumption is forecast to grow at around 4.5 percent annually to 2035 (up from 3.5 percent from 2000–2017). India has considerable scope for growth despite starting from a low base for relative per capita energy consumption. On a per-capita basis, India's domestic production of fossil fuels is the weakest among major emerging markets [18]. Still, India relies on fossil fuels for around 75 percent of its energy requirements.

India imports crude oil but is also a significant net exporter of refined products, this reflects the sheer scale of its refining capacity. India's future energy mix is challenging to predict because of rapid technological change. However, even taking account of enhanced domestic energy supply and greater energy efficiency, India's dependence on energy import could still rise from the current 36 percent to as high as 55 percent by 2040 [19, 20].

2. Environmental Conditions

The traditional energy systems are notorious for producing a lot of harmful gases and residues which affect the surroundings in general. Non-renewable sources of energy, such as fossil fuels, are known to produce several toxic gases, which can trigger environmental problems such as acid rain, greenhouse effect, global warming. Thus, it is imperative that parallels be drawn between the spin-offs of the renewable and non-renewable sources of energy [24]. A check should be done on probable unfavorable impacts that the renewables might bring along.

Non-renewable energy typically releases harmful gases into the atmosphere. Carbon Dioxide and methane are major greenhouse gases. Sulfur dioxide, Nitrogen oxides, and Particulate, which contributes to respiratory illnesses, lung disease. Heavy metal in residual causes neurological and developmental damage in humans and other animals. Oxides also cause acid rains, smog, and haze. The extraction processes of non-renewable resources can have detrimental effects on fertile land. Surface mining needs the removal of large amounts of rock and soil to access the coal underneath. This can thus pose a threat to biodiversity as their habitat may be mangled, and they will be required to relocate. The acid mine drainage in coal and effluent water in oil refineries pollutes water. It directly affects agriculture and fishing in that area. Accidents like an oil spill, mine fire, well fire, and nuclear meltdown can seriously harm people, animals, and the environment.

On the other hand, renewable sources also have environmental impacts. Wind energy requires a more considerable amount of land to produce a substantial amount of energy. Wind turbines create noise, which can be mitigated. Solar energy conversion into electricity efficiency is shallow and requires 3.5 to 10 acres per megawatt. Hydropower plants can generally produce more electricity per acre compared with the above sources [27, 28]. Dams and reservoirs are utilized for various purposes like agricultural irrigation, flood control, and recreation, and affect adversely to the wildlife. Flooding the land for a hydroelectric reservoir has severe adverse effects: it destroys the forest, wildlife habitat, and agricultural land. Geo-thermal generally emits hydrogen sulfide, carbon dioxide, ammonia, methane, boron, and heavy metals. Biomass energy has similar problems like fossil fuel energy, but agricultural waste, manure, forest products, and urban waste are used. Wave and tidal power are in the early stage of development. These sources cause damage to marine life and habitats [29].

As there will be an increase in the consumption of renewable energy resources, there will be a corresponding decrease in harmful environmental impacts. Renewable sources of energy are clean sources of energy that assist in bringing down the residual waste. With the reduction in waste, there'll be a decrease in the carbon footprints rate, promoting a greener and cleaner environment.

3. Development and deployment of technology in energy sector

The Indian government has set up an exclusive ministry for the development of renewable energy, the Ministry of New and Renewable energy (MNRE). In 2015, India announced its intention to achieve 30-35% less emission intensity per unit of GDP by 2030, compared to the 2005 level as a part of its Nationally Determined Contribution (NDC). The primary sources of renewable energy in India are solar, wind, hydropower, biomass, and biogas. As of March 2020, the country's installed capacity of solar, wind, and Hydroelectric power reached 37.627 GW, 37.669 GW, and 46 GW respectively [30].

Technical advancements, innovation, and discoveries have been major factors in establishing solar energy as a popular source of power on the renewable energy front. As we become more environmentally cautious, countries are hunting for affordable solutions to maximize the output from solar energy. Photovoltaics (PV) and concentrated Solar Power (CSP) are major technologies that dominate the solar power systems. Research is being conducted to improve over the core concepts of these technologies [31]. In addition, India is developing off-grid solar energy for local energy needs under its large-scale grid-connected solar photovoltaic (PV) initiative. It is evident that for developing nations like India making solar technology cost-competitive is the only key to boosting its deployment.

Wind energy generation capacity in India has significantly risen in recent years. Wind power systems account for 10% of India's total installed power capacity. Various advanced technologies are already developed, and many more are under developing stage for harnessing the efficient wind energy. Kite-Gen and MARS (the Magenn Air Rotor System), two major technologies in the under-developing stage, are 3.3 times more efficient than the synchronous wind turbines. Hydroelectric power generation capacity in India has significantly increased in recent years. The hydropower capacity of India is around 1,45,000 MW, and at 60% load factor, it can meet the demand of about 85, 000 MW. It is well established that geothermal energy can contribute to meeting ever-growing energy demands. Gujarat will be the first state in India to use geothermal energy to produce electricity [32, 33]. The various technologies used are dry steam power stations, flash steam power stations and binary cycle power stations. The GSI (Geological Survey of India) has identified 350 geothermal energy reservoirs in the country. The estimated potential for geothermal energy in India is more than 10000 MW.

MNRE estimated that every year around 500 MT of Biomass, including agro residue and forestry waste, is generated in India. Still, only 25–30 % of it is available for power generation. Many modern biomass conversion technologies are now available, enabling the conversion of biomass to modern energy forms such as electricity or gaseous, liquid, and solid (briquette) fuels [34]. Alternative Green Fuels also hold the high potential to provide a clean and reliable source of energy that can be used in a wide range of applications, including the transportation sector. Hydrogen energy, compressed Bio-gas, Bio-CNG, and Biodiesel are environment friendly and don't have much carbon emissions. The Ministry of New and Renewable Energy (MNRE) has been supporting a R&D program on Hydrogen Energy, Compressed Bio-Gas, and other alternative green fuels for domestic cooking and transport applications.

4. Social dimension

India is currently suffering from dreadful energy poverty; more than 240 million Indians have no access to electricity. And even if we consider the 75-80% of rural households connected to the national grid system have only 6 hours of electricity supply, then more than 550 million people in India can be categorized as electricity poor. India is mostly dependent on coal and fossil fuels to meet its energy demands, most of the rural population is still deprived of energy services [35]. The shift of energy from traditional to non-traditional power systems is challenging, complex, and multifaceted. The transition of energy not only has technological and economic impacts, but it also has a social dimension. India is a developing nation with one of the most lucrative renewable energy markets and is attracting foreign investments to ramp up the government in renewable energy systems. It is anticipated that this renewable energy sector will produce many opportunities for economic, technological, and social development. The Ministry of Human Resource Development (MHRD) has been developing very strong renewable energy education and training systems.

The adoption of renewable energy technologies has a strong potential for employment generation. According to IRENA, Worldwide, this sector has already employed 11 million people at the end of 2018. It has been predicted that the renewable energy sector will engage more and more people as the economies become strong and stable [36]. The continuous development in the industry can decrease poverty and increase the employment rate in India.

Risks of development

Many companies are expanding their investments in the renewable energy sector. But still, funding is a particular challenge, especially for a developing nation like India. This development also has to overcome business and strategic risks, such as the risk of obsolescence in technology [50]. The non-traditional power sector is a very capital-intensive sector, which involves the use of high-end technology. Sound risk management is very critical in securing funding. As projects grow, financial risk also rises with it. The capital risk has several aspects, including raising the capital for infrastructure development and covering the payments on the debt in the initial years of development and operation.

Political and regulatory risk is another significant risk as it is related to the support of the government for renewable energy. Proper regulation and policies are to be exercised for increased penetration of Renewable energy. There are so many consumer related challenges that need to be addressed, apart from low consumer awareness, there is lack of access to credit as well. Renewable energy projects are vulnerable to changes in regulatory framework, the lack of competition means that these projects will generally be dependent on a regulatory framework to proceed, which include access to electricity grids and purchase guarantees of their output [51]. These projects are often located in socially sensitive areas, with larger solar and wind projects, land usage and requirements can be very significant. The high costs of renewable energy technologies as compared to traditional energy power systems pose a risk to these technologies.

Different renewable power systems have different barriers and risks due to various specifics and maturity. Geothermal systems involve key risk issues of drilling expenses, exploration risks, and critical component failures. Wind power systems also have to overcome the upfront costs (planning, permissions, and construction costs) and wind resource variability. Fuel supply availability and environmental liabilities associated with fuel handling and storage are the significant risks of biomass and biogas power systems.

The opinion of society could be determinant to decide which technology and resources the government should invest; policies are generally linked to social tendencies. If some project is not accepted by society and citizens, the government could set a barrier to that technology and lead to the implementation of another power system.

Factors affecting the pace of development

There can be several kinds of factors affecting the development of the new system in several ways. On one hand there are factors which accelerate the speed of development, on the other there are factors which act as obstacles on the path of development.

India's government has started focusing on Renewable energy; over $42 billion is being invested in this sector in 4 years. New business spaces have been merged, and foreign investors are entering the Indian renewable energy market for collaborations. Tariff costs on solar and wind power have also been significantly reduced. A waiver on energy transmission charges is also provided. MNRE stated that not only clean energy targets will be achieved but also be exceeded [54]. The major problem in shifting from non-renewables is the cost of setup and cost of distribution. However, the prices of renewable energy are being reduced, especially solar and wind power.

To shift renewable technology in baseload, we need cheap, scalable, and efficient energy storage. Lithium-ion battery prices have decreased by 50% since 2014, and prices will fall further as large battery factories are built. The India Energy Storage Alliance (IESA) has estimated over 70 GW and 200 GWh of India's energy storage capacity by 2022 as our energy supply mix gets cleaner with renewables. But we cannot entirely rely on renewable sources; it's not always necessary that the intensity of the wind and solar energy would be enough to meet our energy requirements. The energy storage is currently not efficient enough to be cost-effective. However, utilities and power operators discover new ways that these resources can offer more value to the power grid across the board [55]. The increased competition has reduced bids for solar PV and wind projects by 30-40% in just two years. Domestic renewable energy tariffs are now two-thirds of the cost of local coal-sourced power tariffs and half of the new imported thermal power costs. Over the period of 2017-22, average generation costs are estimated to drop by approximately 25% globally for utility-scale solar PV and almost 15% for onshore wind further [56]. The Indian government is imposing taxes on imported products to make Indian manufactured solar cells competitive. But the duty has neither reduced imports nor potentially improved the Indian solar cell market. Instead, it has decreased the installation of solar cells in India. The government should assist the domestic markets and incentivize them for exports as well.

Strategies for non-traditional energy development

After a detailed analysis of the present scenario prevailing in the country, we must carve out a plan to realize the envisioned clean energy generation in India. The investments in the renewable energy systems in India have grown by 22% in the first quarter of 2018-19 compared to 2017-18. India should make such policies that will attract foreign and local investors. Relaxation should be given to the investors, and a reduction in tariffs costs of the project should be made [58]. Skilled labor force and competitive business climate also play an important role in attracting investors. Reducing restrictions on foreign direct investment (FDI), providing dependable conditions for all firms, whether foreign or domestic, will also help in increasing the investments. Flexible markets and protection of intellectual property rights will also play a pivotal role in achieving the shift to cleaner energy [59].

Social acceptance is a significant issue in the Indian energy scenario; people prefer trusted and cheaper sources of energy. Indians have to accept the change because a shift to clean energy is inevitable. Moreover, India should take the initiative to spread awareness regarding renewable power systems and motivate people to use more of it. Seminars and campaigns should be organized to drive people to use fewer fossil fuels and more non-traditional energy sources [60]. The sudden shift to renewable systems is not economically feasible and socially acceptable. Specialized training systems should be developed to enable the laborers to perform their duties effectively. The laborers may also be given some degree or certificate in their related field, where they were completely able to garner the skills and training needed to pursue their profession. Better education and training should be provided to make them more productive.

Renewable energies are very uncertain and often are not available at the time of demand. Solar and wind energies are highly variable and depend on climatic and atmospheric conditions and therefore are unpredictable. Improper modeling often leads to the overestimation of wind and solar energy systems. Better energy storage systems should be made, batteries with high life and efficiency should be available at cheaper costs. Energy transmission systems should also be improved as energy is transmitted at farther locations from the wind farms. Distribution and transmission losses should be reduced, and transmission capacity should be increased [61]. Highly efficient energy transmission and distribution networks will prove a boon to renewable energy transmission.

6 The policy of reducing CO2 and other greenhouse gas emission: global trends, capture and storage technology and the prospects

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Introduction

Greenhouse gases like Carbon dioxide (CO_2), Nitrogen dioxide (NO_2), Sulphur dioxide (SO_2), and various gases of these substances are becoming a threat to our global industries nowadays. For this reason, Carbon Capture and Storage technology (CSS) for reducing CO_2 emission are becoming the subject of debate [1]. There are various technologies available which can convert electric vehicles to smart grids. Thus, this technology can be efficient for the purpose of limiting the temperature within the target value and useful for increasing energy security [1]. A Literature Survey has been carried away to study the development on the basis of CCS technology. The main purpose of this report is to calculate the amount of stored CO_2 for India as well as global perspective.

From the published work in this area, it is found that there is an increasing interest in this CCS technology in India from 2008. Basically, an integrated assessment is done on five sets of methods. These five methods are:

- Commercial availability of CCS technology
- Economic assessment
- Storage capacity assessment
- Life cycle assessment
- Stakeholder analysis

The aim of this report is to investigate thoroughly and compare accessible energy capacity for India. An analysis is also done to investigate CO_2 emission. The main purpose is to replicate the present situation of CCS technology in India. A Life cycle analysis assessment is also done to access the possible environmental impacts of CCS technology. From the International LCA database, basic datasets like mining, transportation and generation are taken to analyze this LCA assessment [1, 45].

Literature Survey

This present investigation is performed on the current progress on clean energy deployment. A complete study on different topics can be described from this report [1] which are mentioned below:

1. The link between energy security and low carbon energy
2. The complexity of the energy system in future
3. Need for flexible electricity systems
4. A combined system of smarter grids, energy storage and flexible generation
5. Role of hydrogen in the energy system in the near future
6. And finally, whether it is possible to achieve the 2°C target by the available technologies by 2075.

This study presents some opportunities for emerging poly generation schemes for the electric power sector [2]. It represents an analysis of the knowledge system for the society that can assist India's contribution to the management of the climate change effect [3]. There are various issues associated with CCS development and greenhouse gas reduction technology which were discussed in this work [4]. The LCA assessment is carried out for major energy resources and technologies in this work. There is the dynamic equilibrium analysis carried out for LCA assessment. It can be seen from the results that the shift to an efficient frontier can be made at a very low cost by the introduction of technologies that moderate local air pollutants like SO2, NOx etc. [5]. A geo-modelling study is done where the recent developments in CCS technology is found. This work examines the various options for CO2 fascination and the possible role of geo-modeling studies [6]. Another study deals with the CO2 reduction methods in India with the usage of CCS technology and the prospects and challenges of this technology. From this work, we can understand that more research work is required on this technology in India [7].

This investigation shows us the role of this technology in justifying both energy security risks for India and global climate change risks. It estimates future CO2 emission projections from a large point source in India [8]. A global comparison is done on the development of three different countries across the world. The main point of this comparative study is CCS technology in developing countries, Brazil, South Africa and India [9].

Another study discusses the Carbon storage capacity in uneconomic coal beds in Alberta, Canada. It deals with the global methodology, potential and site identification. It also measures the theoretical CO2 storage capacity on the basis of CO2 adsorption on coal samples, and it varies between approximately 20 kt CO2/km2 and 1260 kt CO2/km2, for a total of approximately 20 Gt CO2 [10]. Environmental Life Cycle Assessment (LCA) methodology is discussed in this work which also describes how the environment plays a vital role in the CCS technology across the world [11]. Another study is also found on the issues of the 21st century. From this investigation, it can be seen that there are various problems to enrich the CCS technology in the market. Thus, we have to study the problems for this technology and should try for a better solution to overcome these obstacles [12].

This work particularly deals with the survey about coal mining, combustion of coal etc. It also discusses how coal combustion is destroying the environment in different countries and as well as worldwide [13]. European Union (EU) demonstration program for CCS technology is mentioned in this study and it is seen that Zero Emission Fossil Fuel Power Plants (ZEP) is a broad alliance of stakeholders united in their support for Carbon capture and storage (CCS) technology as a key technology for fighting climate change [14]. Again, the promotion of sound management of the Indian petroleum and natural gas resources having balanced regard to the environment, safety, technological and economic aspects of the petroleum activity is discussed in detail. It also presents the review of the work programme and budget of all exploration blocks and fields under PSC's:100 Blocks & 33 fields [15].

It can be seen that various investigations have been carried out to avoid the pollution caused by greenhouse gases from coal-fired power plants. Here the three hard coal IGCC concepts of the future are evaluated by applying emerging technologies and various carbon capture methods [34].

This report represents the combined cycle of integrated shale coal based on gas purification system enables high temperature Singas coolers to be able to evaporate at high pressure. That's why two approaches have been proposed [35].

- Singas coolers Replaced by "partial water quench".
- Gas shift (WGS) configurations.

It is observed that Coal India has shifted its focus to overburden removal. Excessive pressure will accelerate coal production to Coal India Limited (CIL) whenever demand arises and supply coal to its customers on short notice. 95% of CIL's coal production comes from the company's 171 open cast mines. Coal consumption has dropped by about 30 percent because of sudden fall in demand for coal. In a report of Central Electricity Authority, they said that As of April 30, 2020, India had 50.69 million tonnes of coal reserves in its power plants, which lasted for 31 days [36]. This study shows us some implications of CCS technology in the context of two major countries. Norway and Brazil are the two most progressive countries in terms of CCS deployment. The CCS has been applied as a strategic tool for economic competition rather than a climate change mitigation option. It has important implications for policy making [37]. The purpose of the assessment is to carry out an incorporated valuation of CCS technology alternative methods to significantly reduce CO2 emissions in the future. The most crucial precondition which has occurred is to measure consistent storage capacity based on specific geological data [38]. In Table 2, geological ranking and cumulative CO2 emissions in India is presented.

The main purpose of this report is to perform an estimation to decrease the value of CO2 emission for which five assessments are chosen. If the CCS is built within 2050, then the coal power plants can capture the CO2. The storage protection can be decreased by technological, officially permitted, economical and common acceptance factors [39].

Table 1: Geological ranking and cumulative CO_2 emissions in India
Source: [21], L&S p. 208

SERIAL NO.	NAME OF THE STATE	GEOLOGICAL RANKING	CAPTURED CO2 EMISSIONS	MAJOR COAL FIELDS
1	SIKKIM			YES
2	TAMIL NADU	GOOD	5.3	
3	ANDHRA PRADESH	GOOD	4.5	YES
4	KARNATAKA		0.2	
5	MAHARASHTRA	GOOD	7.5	
6	GUJARAT	GOOD,FAIR	4.7	
7	MADHYA PRADESH			YES
8	ORISSA	FAIR	2.8	YES
9	JHARKHAND			YES
10	BIHAR			YES
11	WEST BENGAL		4.1	YES
12	TRIPURA	GOOD		
13	MEGHALAYA	GOOD		
14	MANIPUR	GOOD		
15	ASSAM	GOOD		
16	NAGALAND	GOOD		
17	ARUNACHAL PRADESH	GOOD		
18	JAMMU AND KASHMIR			YES
19	RAJASTHAN	GOOD, FAIR		

Coal excited power plants are the most effective source to increase the carbon emission to the environment. It is found that CCS technology is the only solution to reduce CO2 emission [40]. It is also seen that SO2 and NOX are also the thread for the nature. Therefore, to control this effect, there are basically two ways:

1. The wet Flue Gas Desulphurization (FGD) for SO2

2. Hot side Selective Catalytic Reduction (SCR) for NOX.

Climate action is a very difficult task and many uncertainties are present in the climate. For this reason, some real option to play a helping role to make a decision in climate action is evaluated. Real option plays a very big role in cost analysis. This real option valuation is made by Scholes method [41]. Another assessment report of Intergovernmental panel deals with the near term cost of reducing carbon emission. Nowadays combined cycle is used in India to reduce the carbon emission. As this combined cycle is used, the cost of reducing carbon emission will be lower in India in future [42].

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Numerous life cycle assessment (LCA) on the environment for electricity generation with CCS have been conducted [43]. The results show that the three significant parameter sets are:

- Power plant efficiency
- CO2 capture and purity
- Fuel origin and composition

Therefore, for effective use of clean energy and CCS technology various points were determined such as [44]

- Energy penalty has been increased due to post-combustion of coal.
- Integrate with solar energy can reduce this penalty by supplying the solvent regeneration.
- This can lead to economic benefits.

Conclusions

From this report, the necessity of carbon reduction technology for the benefits of our society and for the betterment of the world is clearly understood. This again describes how India and the rest of the world can be benefitted by this CCS technology. Here, a geological ranking detail of various states of India is provided to understand the scenario of the country. Therefore, from this report, it is clearly understood that there is an urgent need for developing this CCS technology across the world.

7 Development of Petrochemistry: Prohibition of the Use or Recycling

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Introduction to Petrochemistry

Petrochemicals are an integral part of society and our day to day lives. It plays an essential role in virtually all critical sectors of the economy, including agriculture, infrastructure, healthcare, textiles, entertainment, and consumer durables. Petrochemicals are derived from carbon compounds, mainly from hydrocarbons such as crude oil and natural gas. The primary feedstock for the industry being naptha, gas oil, and kerosene. The Petrochemical industry, which entered the Indian industrial scenario in the 1970s, is growing at a significant rate of 1.5 times the country's GDP. Demand is growing at a CAGR of 8%-plus over the last five years (as of 2018) [41].

Current Scenario of Petrochemical Industry in India

The Indian economy is heavily dependent on petrochemicals, but the sector receives far less attention than it deserves. Petrochemicals are one of the critical blind spots in the energy debate, especially given the influence they will exert on future energy trends as more and more percentage of a barrel of crude oil will be used in the materials sector (materials are non-combustible uses of liquids such as petrochemicals, lubricants, and bitumen) [2]. India's market is full of potential and investment opportunities, thanks to the economic reforms initiated in 1991. India currently stands third in polymer consumption globally after China and the US. It has a well-developed Processing and Manufacturing Industry related to the field of petrochemicals.

Discussing the statistics of petrochemical demand in India, the country as of 2018, consumed 42.25 MMT of petrochemicals and produced about 36.86 MMT of petrochemicals, with a total import and export of around 12 MMT and 6 MMT respectively - making the country net importer of Petrochemicals. The following table narrates the details:

Table 1: Production share of primary petrochemicals
Source: [6], L&S p. 208

MAJOR PETROCHEMICALS	PRODUCTION SHARE (2017-18)	NET IMPORTER/EXPORTER
Polymers	25%	Importer
Olefins	24%	Exporter
Aromatics	14%	Exporter
Fibre Intermediates	13%	Importer
Synthetic Fibres/Yarn	10%	Exporter
Aromatics	5%	Exporter
Synthetic detergent Intermediates	2%	Importer
Synthetic rubber	1%	Importer

About 30% of significant petrochemicals demand is met through import, with the need for polymers growing at 11% CAGR [6]. The gap between petrochemicals demand and supply is continuously increasing, especially in the intermediate petrochemicals sector - the critical link between the production of petrochemicals and specialty chemicals. Talking about the downstream Petrochemical Industry, the demand for plastics is growing at the rate of 8-10% in the last five years. Till 2018, there are more than 50,000 processing units in the organized & unorganized sector, with 153,500 Plastic processing machines with a total processing capacity of 45.1 MMT per annum. [6]

Need for Development

Demand for plastics – the most familiar petrochemical product – has outpaced that of all other bulk materials and will continue to proliferate, at least in the case of BRICS nations. The demand for plastics in India is expected to reach 24 Million tons by 2022-23 and 35 Million tons by 2027-28 (i.e., about three times from now), with the processing industry, expected to invest $10 billion during the next five years [9]. Although India stands third in global petrochemical consumption, it has the lowest per capita consumptions (about 10kg per capita) of petrochemical products in the world compared to the worldwide average of 30kg per capita, thus giving a big room for developing the quality of people's life [41].

The following paragraph will discuss how the development of petrochemicals in India would affect different aspects.

1. **Economy:** As of 2018, India's GDP is valued at 2700 billion USD, and the petrochemicals market contributes only 0.74 percent i.e., 20 billion USD, indicating significant headroom for growth. It is anticipated that the sector can grow at the pace of 1.5 times the country's GDP, making it 70 billion USD market at the end of 2030 [41].

2. **Politics:** China is the highest consumer of petrochemicals in the world. The theory of gravity model of international trade suggests that India can fill the gap of demand & supply in China with a lower transportation and manufacturing cost; thus, building the countries' trade relations.

3. **Socio-Cultural:** The socio-cultural aspect of the Petrochemical Industry is significant and has started growing recently with the top Indian companies like RIL making several domestic products such as high-quality clothing materials, pillows, and sportswear. Other companies need to follow this trend as more and more people are moving to cities in search of a better lifestyle.

4. **Technology:** A significant step to technological advancement in the field of Infrastructure (Plastic roads and parks, windmills, solar panels, & telecom poles), Pharma & Healthcare (Medicine blister packs, syringes, blood bags, IV bottles & lab coats for doctors), Transport & Automotive (Metro, cars, mass transport, & tires), Water storage and supply (Water storage tanks & PVC pipes), Agriculture (Drip irrigations, pond linings, sprinklers, mulching) can be led through developing the petrochemical industry in India and integrating it with the recycling industry to have a sustainable technological advancement.

5. **Environment:** Petrochemicals lead to environmental damage, e.g. due to littering of plastics in India. However, it can also help curb significant sources of air pollution by reducing overall GHG emissions in the automotive and construction industries through innovative solutions and applications. [56]

The Indian Path- Prohibition or Recycling of Petrochemicals

Petrochemicals can also be injurious to the health of living beings and the earth's ecosystem. The difficulty in finding alternatives to petrochemical products for many applications completely ignores the possibility of the prohibition of petrochemicals for several decades. As it is said, the benefits of each resource should be acknowledged, thus similarly, the benefits of petrochemicals, especially plastics, need to be recognized by encouraging proper collection, segregation, recycling, and education. With the ongoing global trend of recycling and efforts to curb single-use plastics, India, as well as other BRICS nations, are putting efforts into recycling, although these efforts are being far outweighed by the increase in the consumption of petrochemicals (and thus disposal).

Government of India: Policies and Institutional Framework

The growth in the petrochemical sector, including ingenious R&D and human resource development, needs to be encouraged to achieve global competitiveness, world-scale operation, increased value addition, and substantial growth [61]. As India does not have access to cheaper crude and feedstock like gulf countries, India has to focus on value addition in the downstream industry, namely on the production of value-added products from polymers [61].

Government policies aim to:

1. Achieve environmentally sustainable growth in the petrochemical sector through better plastic waste management, recycling & development of bio-, photo-degradable polymers, and plastics.
2. Promote research and development in petrochemicals and human resource development.

Infrastructure Development

As per the world, industry estimates poor infrastructure is the primary constraint for attracting investments in India [61]. In order to address the issue of quality infrastructures, the following initiatives are being proposed:

Petroleum, chemical and petrochemical investment regions (PCPIRs)

The government has decided to attract significant investment, both domestic & foreign, by providing a transparent and investment-friendly policy and facility regime under which PCPIRs may be set up [61]. The PCCPIRs would reap the benefits of co-sitting, networking, and greater efficiency through shared infrastructure and support services. They would boost manufacturing, augmentation of exports, and generation of employment [62].

Development of Plastic parks as an integrated part of PCPIRs: The plastic industry is a primary foreign exchange earner thus to boost the export of value-added petrochemicals the government will evolve the feasibility of setting up of dedicated plastic parks to promote a cluster approach in the areas of development of plastic applications and plastic recycling [62,56].

National program on petrochemical development

This program was proposed to improve the existing petrochemical technology and research in the country and promote the development of new applications of polymers and plastics. The major components of the program would be as follow:

- Petrochemical Research and Development Fund (PRDF) would cater to the projects of R&D, waste management, recycling, and development of biopolymers, and biodegradable polymers were proposed to be formulated [61].
- Plastic Development Council will work for the sustained development of the plastics processing sector [61].
- Centers of Excellence in Polymer Technology will be set up in existing educational and research institutions working in the field of polymers to strive towards the development of bio-and photo-degradable polymers, recycling process technology, and the development of recycled products [61,35].

Analysis of Leading Companies in India

Reliance Industries Limited (RIL) is the largest integrated petrochemical producer in India and one of the top ten largest producers globally. Their B2B businesses include a broader range of polymers, elastomers, polyesters, aromatics, fibre-intermediates, and advanced materials (composites) [57]. Reliance claims that their healthy earnings from the Petrochemical sector are due to their timely investments and a sound business model interlinking the refining and petrochemical chains, feedstock flexibility, and comprehensive product portfolio. Due to their fully integrated operations, RIL has minimal dependence on external sources for raw materials, and this provides cost competitiveness [5].

Haldia Petrochemicals Limited (HPL): Haldia Petrochemicals Limited is a naphtha-based petrochemical company with a capacity of 3,50,000 TPA polymers. HPL manufactures chemicals such as naphtha and butadiene derived from low-density polyethene (HDPE), nonlinear low-density polyethene (LLDPE), and polypropylene (PP), as well as naphtha cracker (total capacity: 700 KTA ethylene) [23]. HPL is the second-largest producer of polyethene with a total capacity of 700,000 tons per year. The final published annual report of the product summary of the naphtha cracker unit and the polymer is shown in Table 2.

Indian Oil Corporation Limited (IOCL) focuses on the system-

Table 2: Production summary of different plants
Source: [22], L&S, p. 208

PLANT	PRODUCTION (TONS)			
	2012-13	2013-14	2014-15	2015-16
LLDPE Plant	233,166	217,204	79,338	349,799
HDPE Plant	244,893	205,029	92,794	317,667
PP Plant	237,532	205,828	83,173	329,819

atic expansion of its customer base and innovative supply logistics to increase its presence in domestic markets as well as in foreign ones. The Corporation provides a full slate of petrochemical products and intermediaries under the PROPEL brand name [49]. Indian Oil's PROPEL brand of petrochemical cover plastics has an 80% full spectrum application and is exported to over 70 countries [37].

Indian Oil is involved in several projects and plans to:

- invest in the Plastic Park in Paradip, and a joint venture has been launched with the Odisha Industrial Development Corporation [37];
- invest in Paradip Refinery, an ethylene glycol project. The project will help strengthen the Corporation's polyester business through the production of mono ethylene glycol (MEG).
- set up an acrylic / oxo-alcohol project in Damad, Gujarat that will help manage supply-demand for petrochemical products in North India and reduce Indian imports of butyl acrylate.
- set up an R&D-2 campus in Faridabad. It is expected to combine alternative energy, petroleum, nanotechnology, biotechnology, pilot/ performance / semi-commercial scale-up units, Petrochemical, catalytic and chemical industries [43].

Supreme Petrochemicals Limited (SPL) is the largest producer and exporter of Polystyrene (PS) in India with a market share of about 50% and business links with 93 countries across the globe. They also produce Expandable Polystyrene (EPS), Speciality Polymers & Compounds (SPC), Extruded Polystyrene Foam Boards (XPS), Styrene Methyl Methacrylate (SMMA) [68]. Their state-of-art Polystyrene facility has a production capacity of 270,000 TPA along with a 17000 TPA capacity colouring and compounding facility located at Nagothane, 100 Kms South of Mumbai [8].

IG Petrochemicals Limited (IGPL) is the largest producer of Phthalic Anhydride (PA) in India, with about 50% domestic market share. They claim to be one of the lowest costs and top 5 manufacturers of PA globally. PA serves as a raw material for many industries like plasticizers (used in PVC), CPC pigments (used in photovoltaic cells), alkyd resins (used in the manufacturing of paints), and unsaturated polyester resins (used as thermostats). IGPL also produces Maleic Anhydride (MA), used in spandex production, unsaturated polyester resins, and lubricant additives [30].

Risk and Challenges

A company is exposed to risks arising out of the macroeconomic and internal business environments. Fluctuations in crude oil prices, global slowdown, geopolitical tensions, and trade uncertainties can impact the company's performance. IMF April world economic outlook projects global growth in 2020 to fall to -3 percent due to the COVID-19 pandemic [31]. The lack of a regulated market-pricing system and the lack of healthy competition among the diversified conglomerates continue to hamper the petroleum industry's performance.

Increasing pollution near refineries and oil fields is a big problem for the industry. Petrochemical products, such as plastics and Vaseline, are derived from natural products, such as crude oil & natural gas. Extraction and production costs must be determined or adjusted according to environmental pricing principles [42]. The key challenge faced by the petrochemical industry is handling various processes like storage of raw material, transportation of finished products, over the years, the Indian Petrochemical industry had taken the best environmental protection standards to meet the regulations laid down by the government of India [29].

A Graphical Approach

The following paragraph deals with predicting the future of the petrochemical industry in India till 2035, considering three approaches: Negative growth, Conservative growth, and Positive growth. The growth of any sector is proportional to its demand i.e., consumption. With the rise in demand, more investment in R&D, and a rise in production capacity occurs, leading to the overall development of the sector.

Consumption data of petrochemicals in India from 2002-2018 [3,2] is shown in figure 1 through dots. By curve-fitting and extrapolation, a blue dotted line until 2035 is plotted, following a consistent growth approach. As the petrochemical industry's current rate of growth is 1.5 times India's GDP, the dotted blue line represents development at a rate of 1.5 times the GDP. Similarly, the solid red line represents a total of 1.8 times of GDP, solid grey at 1.6 times, solid black 1.4 times and solid green 1.2 times of GDP. According to our analysis, the area between red and grey lines represents a range of growth, between grey and black, represents a range of conservative growth and between black and green represents negative growth. Thus, Figure 1 helps to determine the petrochemical scenario in these three approaches to growth.

An attempt to determine the import, export, and production in India in 2035, following the same rate of growth as today (i.e., conservative), is made through Figures 2 and 3.

According to Figure 1, the consumption of petrochemicals in 2035 can be found through the curve equation (1). Thus, the expected consumption of petrochemicals considering the conservative growth will be 78 MMT.

y = 2E+06x - 4E+09… …. …. (1)

According to Figure 2, the production of petrochemicals in 2035 can be found through the curve equation (2). Thus, the expected output of petrochemicals considering the conservative growth will be 62.5 MMT.

y = 1E+06x - 3E+09… … …. (2)

According to Figure 3 (see L&S, p. 208), the difference between import and export is continuously growing and will reach 33 MMT using the equations (3) and (4) for import & export, respectively.

y = 30906x2 - 1E+08x + 1E+11… … …. (3)

y = 2187.1x2 - 9E+06x + 8E+09… … …. (4)

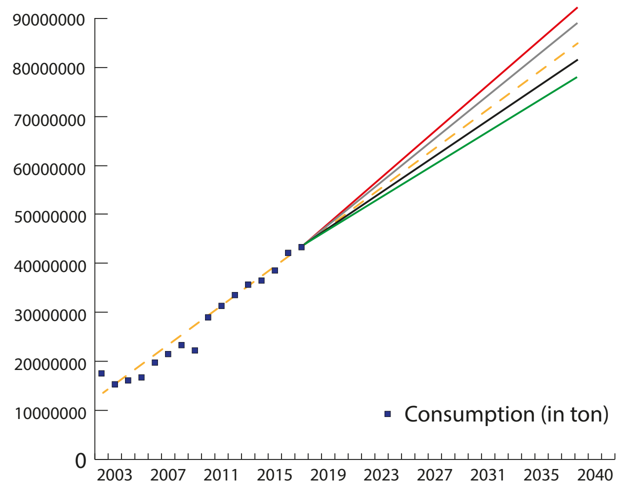

Figure 1: Consumption of Petrochemicals in India
Source: ceicdata.com

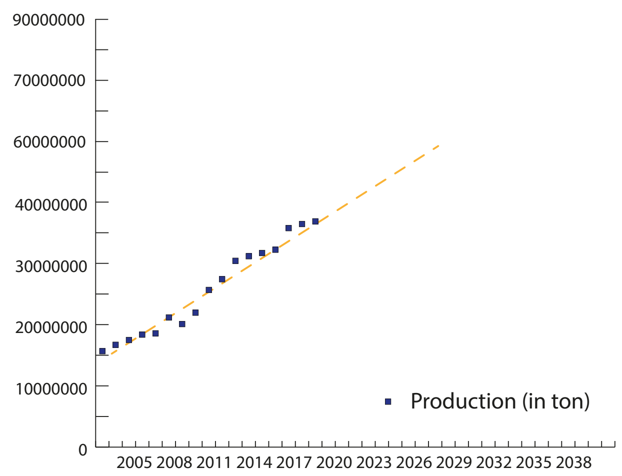

Figure 2: Production of Petrochemicals in India
Source: ceicdata.com

Scenarios

Quality scenario analysis and strategy of petrochemistry in India.

Negative

Risk: While measuring the probability and magnitude of the loss, it appears that another significant risk for the petrochemical industry is the halting of production due to a decrease in demand. This may be due to the emergence of alternative fuels and market differentiation due to economic and political factors [44]. Along with fluctuations in crude oil prices, global recession, geopolitical tensions, and trade uncertainty also affect the development of petrochemistry [42]. India has poor physical infrastructure, and the speed of construction of this infrastructure for trade is also deficient. The growth rate of electricity generation in India is not equal to the growth rate of demand. Therefore, the Indian petrochemical sector faces power shortages and unexpected power cuts. This power problem/power shortage is a significant challenge for a developing country like India, which faces high competition from other countries [13].

Economics: There has been a rising tide of public backlash and concern regarding the use of plastics, particularly "single-use" plastics. Government policies incentivizing the recycling and replacement of plastics is expected to decrease the demand for petrochemicals like ethylene, propane, polyolefin & polyester [28]. The petrochemical industry is investing in high capacity production units, and if demands fall, we will witness a grossly oversupplied market with reduced profit margins [70]. Most of the Indian petrochemical companies are not fully integrated and depend on international supply chains for their raw materials. The fall in domestic prices, inspired by lesser demand or the fall in global prices due to currency devaluation and rising environmental concerns, can impact these domestic companies' profit margins.

Technology: In India, high sinking cost-failure of R & D projects can lead to a significant number of losses to stakeholders, so firms believe more in importing the tested technologies. Thus, India's petrochemical sector's development takes a hit when it comes to world-class R&D and unique game-changing indigenous technological development [42]. Lack of research intensity leads to the loss of brilliant human resources to foreign R & D giants. The manufacturing units functional in India, mostly use the obsolete format of technology and are not able to produce optimally [5]. Thus, there is a necessity for the modernization of equipment.

Ecology: The petrochemical industry releases large quantities of toxic and deleterious substances as effluents into the atmosphere and generates solid waste that is difficult both to treat and to dispose of, e.g., aromatic compounds present are significant environmental pollutants [27]. Plastics are one of the most significant risks to the environment, with a profound impact on marine life. As per Un-Plastic Collective (UPC), a voluntary multi-stakeholder initiative to eliminate plastic pollution in nature, India generates 9.46 million tonnes of plastic waste annually, of which 40 percent remains uncollected, and 43 percent is used for packaging, most of which are single-use. More and more increasing concerns on health and the environment led to the passage of several legislations in India, which will affect petrochemical and energy production and processing for the foreseeable future. The days of single-use plastics are already numbered with many states in India banned plastic carry bags, eventually making a profound impact on the petrochemical industry.

Conservative

Risk: The petroleum industry in India is struggling with a shortage of raw materials, i.e., petroleum crude. Crude oil is a natural resource, so its supply is limited. To keep the sector competitive, Indian companies must find new reserves [42]. However, public sector companies like IOCL, MRPL, GAIL, and private companies RIL, HPL, and Mitsubishi Chemicals are already in the sector and are expanding their existing capabilities through the Brownfield and Greenfield projects. The government is keen to develop and facilitate the petrochemical sector. Independent petrochemical plants sometimes face feedstock supply risks, which can be overcome by setting up plants with oil refineries, a significant feedstock, or near natural gas pipelines. India may become a petrochemical hub soon by capitalizing on its refining capacity. This helps in reducing the cost of transport units and reducing the risks associated with transport raw materials [33].

Economic: The Indian petrochemical industry is expected to grow at a rate of 9.3% against the global average of 5.2%, primarily driven by the increased urbanization and reduction in poverty levels [15]. During the case studies of the petrochemical companies operating in India, we observed that the primary challenge faced by them was the lack of integration. Except for Reliance Industries Ltd. rest of the companies depend on international companies for their raw material supply, which often experiences disruptions due to geopolitical tensions and currency exchange rate fluctuations. India's import of petrochemicals has grown from Rs 1000 crores from 2004-05 to Rs 1.21 lakh crores in FY 2018-19 and expected to rise to Rs 5 lakh crores at current rates [8]. However, the Government of India is now pressing for a self-reliant India [18]. If current development rates continue, the Indian petrochemical industry is expected to be more integrated by 2035 and reduce its economic dependence on foreign supply. The circular economy is expected to save India about $624 Billion by 2050, and the petrochemical industry will be a significant contributor to this initiative.

Technology: India’s petrochemical sector considers science and technology (S&T) a significant contributor to its economic growth from its beginning. Generally, technical resources are domestic in small or downstream petrochemical companies. This is contrary to medium and large-scale companies that import technologies from foreign agencies. Due to technological innovations in the petrochemical sector, the use of low-density polyethene in India is being replaced by linear low-density polyethene. India’s leading petrochemicals company has launched its HDPE (High-Density Polyethene) / LLDPE swing units. The inequality in favour of licensing foreign technologies and hence their equity participation increased with their R&D efforts. Progress in processing technologies is playing a significant role in refining and integrating petrochemical facilities. In a changing scenario, the integration of petroleum refinery and petrochemical production is critical for increasing the utilization of by-products and improving the overall economy of the petroleum refinery.

Ecology: In the last few years, the governments & the citizens in developed countries have grown aware of environmental impacts that are going to be much more significant 15-20 years from now. The developing countries like India & China have more relaxed environmental restrictions to encourage cheaper production. The major industries operating in India are gradually adopting environment-friendly measures via circular economic ideas. According to a report, the circular economy benefits can bring about a 44% reduction in greenhouse gas emissions in India by 2050.

Positive

Risk: India continues to invest heavily in bulk petrochemical capacity to move closure to self-sufficiency, yet additions to capacity address only a fraction of the demand as by 2025, a shortfall of as much as 25 million tons a year could emerge [64]. Limited, thus costly availability of feedstocks, the volatility of crude oil prices, and geopolitical tensions pose a significant challenge for the Indian petrochemical industry [71]. India's overall infrastructure for petrochemicals remains at a relatively early stage of development.

Economics: The petrochemical industry in India already accounts for a significant share of the country's GDP and employs millions. To steepen the growth curve, the Government of India has made policies to support investment in infrastructure, ensuring feedstock supply and strengthening of R&D in the industry [48]. The successful integration of the concepts of circular economy with developing technology can help maximize profit while saving the environment. The National Mission for Enhanced Energy Efficiency (NMEE) has been established to help heavy industries reduce their power consumption. Under this mission, the petrochemical sector has increased its energy efficiency by 6% and aims to be further efficient to reduce operational expenditures [15]. With the increasing use of alternative energy sources, the demand for oil and gas is expected to reach a plateau soon, which can be beneficial for the petrochemical sector.

Technology: Petrochemicals have been the fastest growing industries in India and are expected to reach $100 billion by 2020 [40]. Over the last two decades, the focus of the Indian petrochemical sector has shifted from being technology-dependent to becoming a self-reliant global competitor. Indian Petrochemical Corporation Ltd has developed the process for the production of the Para-diethyl benzene (PDEB) catalyst, which is closely held technology available to select few companies and holds an American patent for this technology. IPCL has also developed and commercialized a process for removing fluoride from an effluent plant, thus facilitating the recycling of water, import-substituting grades of packaging films named biaxially oriented polypropylene (BOPP) [51]. The petrochemical industry contributes about 30% to India's chemical industry, which is likely to become $250 billion by 2020 [40].

Ecology: In the coming years, the Indian petrochemical companies are expected to increase their investments in sustainable projects that will be more eco-friendly and economical. India has a huge urban population and waste generation, particularly in the form of discarded plastics, is a significant issue. 80% of total plastic in circulation is discarded and ends up choking sewers and landfills [32]. The primary challenge faced during the recycling of these wastes is that the different grades require different recycling procedures and cannot be melted together [72]. Future development in technology is expected to increase the efficiency of these processes and provide the impetus for further growth of the industry.

Strategies to be taken into consideration for policy implementation:

Negative

The Government of India provided tax relaxation of up to 200%, to promote the quantity and quality of the petrochemical sector if it outsources projects to academic institutions but the impact of these schemes on the Indian petrochemical sector has been marginal. Poor administration of direct and indirect tax incentives on R&D, and fewer research grants, to significant players, are resisting the competitiveness of the sector [42]. Thus, the policies regarding R&D have to restructured to boost indigenous R&D capability to achieve global competitiveness to meet the 2035 objectives. Indian firms need to find new reserves to keep the sector competitive.

Conservative

Research funding in India is aimed at technology self-sufficiency, not global competition. Indian petrochemical companies need government policies to compete with foreign ones. India needs a skilled workforce to seize the benefits, and we need specialized institutions like the Central Institute of Plastic Engineering and Technology (SIPET). In order to meet the global demand and international competition, the Indian petrochemical industry needs to revive non-financial and financial instruments, promoting policy through strong governance to encourage further research and development projects.

Positive

Chemicals and Petrochemicals Secretary P Raghavendra Rao stated that the attempt of Government of India is the redraft the existing petrochemical policy that was formulated in 2007, and develop an integrated policy framework for chemicals and petrochemicals in a bid to streamline and synchronize the key industrial sectors of chemicals and petrochemicals to meet the demand of 2035 [4]. To boost the domestic production of petrochemicals and make India a manufacturing hub of chemicals and petrochemicals, the Government of India is also planning to increase the capacity utilization from the current level of 75-80%, cut unnecessary imports and increase total petrochemicals installed capacity from 22 million tonnes to 31-32 million tonnes by 2025 [18].

Source: rrpcl.com

8 Nuclear plants for diversification of energy balance, reduction of ecology load due to thermal generation in densely populated Countries with sustainable growth of demand on electric power

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Introduction

Nearly two decades back, India had a motivational slogan, "Power for All." It has now graduated to 'Power for all 24X7', and will soon transform to Quality Power, and on to Green Power. The twist in the slogan only indicates the successful journey India has traversed and the aspirational imperatives of the future. To meet the growing energy needs, Nuclear energy will play an important role. India's first Atomic Energy Commission (AEC) was established in 1948 under the guidance of Dr. Homi Jehangir Bhabha, one of India's famous Nuclear Physicist. Later India built its first nuclear reactor in 1957 named 'Apsara nuclear research reactor' with assistance from the UK. India's domestic uranium reserves are limited; hence it imports most uranium from Russia, Argentina, Mongolia, Kazakhstan, and Namibia.[25]

Currently, nuclear power in India is the fourth-largest source of electricity, with 22 nuclear reactors operating in 8 nuclear power plants. The total installed capacity of nuclear power in India is 6780 MW, which produces 30,292.91 GWh of electricity. India is a leader in thorium-based research. It is by far the only nation to use thorium fuel.[13]

Technology

In January 2015, a compromise made between Indian Prime Minister Narendra Modi and President Obama and a new deal made. The new deal helped resolve differences over the liability of the suppliers to India in the event of a nuclear accident and for the material supplied to the country tracking its whereabouts was demanded by the U.S. Modi, and Obama reached an understanding of the aiding parties liabilities if they wanted to help India realize its nuclear goals. A ten-year framework was agreed upon by both the leaders for deals on cooperation and defence ties.[27]

1. The 3 Stage Program

First Stage
The first stage involves Pressurized Heavy Water Reactors (PHWRs), in which natural uranium used as a fuel. Natural uranium comprises of just 0.7% of Uranium235, which releases the energy of about 200MW per atom on its fission.[22]

Second Stage
The second stage involves Fast Breeder Reactors (FBRs), in which a mix of Plutonium239 and oxide of Uranium238 used as a fuel, which recovered from the fuel spent in the first stage by reprocessing.[22]

Third Stage
The program's third stage aimed towards the following goals:
1. Commercial-scale utilization of Thorium as a fuel.
2. By the time Thorium is available, sustenance of the massive nuclear power capacity developed for a long time, in the second stage.
3. Compared to alternative energy generation options, achieving economically good performance.[22]

2. Current Scenario

Currently, nearly all of India's 5 GW of nuclear power is powered by PHWRs, although the low natural abundance of uranium in India represents the natural end to Stage 1 of this program.[5] Developing Stage 2 FBRs is the goal for the next 4-5 decades in order to produce enough fissile material to begin Stage 3. Currently, having overcome its hurdles in development, India has about 21 nuclear reactors with an installed capacity of 4,480MW, which produced about 2.6 percent electricity of the country, in 2010. Installation of 6 additional reactors with 15 other units of additional capacity of 14,000 MW was planned for this year, i.e., the year 2020.[27]

3. Future

It has projected India's energy consumption rising by 156% between 2017 and 2040. It predicts that the country's energy mix will evolve slowly to 2040, with fossil fuels accounting for 79% of demand in 2040, down from 92% in 2017. In actual terms, between 2017 and 2040, primary energy consumption from fossil fuels is expected to increase by 120%.[23]
Table1: -Electricity Generation – Fuel Mix (Including estimated captive power generation)[16]

Environment

The need of the hour is to bring a change in the composition of India's energy portfolio with a premium on clean energy. Among the choices available for India's growth, the contribution of nuclear energy as a source of stable, non-fossil load power needs to uplifted. The Intergovernmental Panel on Climate Change (IPCC) which called for keeping global warming 'well below' 2°Celsius (C) and above pre-industrial temperature levels. It also brought out the cost of different adaptation and mitigation measures. It underlines the need for decarbonization of the global economy.[17]

In October 2012, a UK-funded program of the Department of Energy and Climate Change (DECC), ran a scenario to minimize costs to the energy system to 2050. A reference case with no future CO2 emission constraints; As per its reference scenario, India's total installed capacity of nuclear power in 2035 is 36 GW, and in 2050 is estimated at 43 GW, which is far less than what we have assumed. These estimates prove that there is an urgent need to shift from thermal power towards nuclear-based generation.[19]

1. Risks

1. **Waste generation:** Non-radioactive waste generates from nuclear power generation, but other energy industry supply chains also generate various non-radioactive wastes. In some cases, this waste is disposed of in landfills, whereas in the case of waste containing toxic and hazardous elements, special handling, treatment, and disposal are required. If not managed appropriately, this waste can cause harm to the environment and human health.
2. **Water use impacts:** SDG 6 on Clean Water and Sanitation. Around 44% of the operational nuclear reactors in

Table 1: Electricity Generation – Fuel Mix (Including estimated captive power generation)
Source: Self elaboration

YEAR	NUCLEAR		Hydro-carbon		Coal		Hydro		Non-Conv Renewable		Total	Per Cap Elec Gen
	TWH	%	TWH	%	TWh	%	TWh	%	TWh	%	TWh	kWh
2002	19.24	3.01	125.08	19.6	425.74	66.69	65.66	10.29	2.66	0.42	637.85	614
2022	206	10	345	17	957	44	460	21	162	8	2154	1620
2032	441	13	572	18	1630	47	600	17	197	6	3485	2454
2042	978	18	9320	18	2673	49	600	11	237	4	5438	3699
2052	2044	26	1250	16	3774	47	600	8	289	4	7957	5305

India situated on the coast. Potential changes in ocean temperatures not deemed radical enough to affect the cooling capacity or trigger regulations related to heat discharges. Inland NPPs are more vulnerable to heat and drought events. Older plants tend to use once-through cooling systems, whereas more recently built NPPs use closed-cycle cooling systems in response to high water withdrawal and stringent regulations on water discharges.[18]

3. **Land use impacts:** SDG 8 on Decent Work and Economic Growth, SDG 12 on Responsible Consumption and Production, and SDG 15 on Life on Land. Opposite to the excitement shown by governments for nuclear power generation, plans for every new nuclear reactor have faced opposition from local groups. One setting where the opposition has recorded consistently has been at public consultations to discuss Environmental Impact assessments (EIA) of nuclear facilities, a necessary step for any project to be accorded environmental clearance.

Politic factor

The scope for civilian atomic business increased significantly, from the beginning of September 2008, following the Nuclear Suppliers Group (NSG) India-specific agreement. The bilateral accord for peaceful, civilian nuclear cooperation allows India to have nuclear commerce with the Nuclear Suppliers Group, without being required to sign the NPT. We were the third-largest producer as well as the third-largest consumer of electricity in the world. We attained our 63% of overall energy within our country in 2017.[10]

1. Prediction for future nuclear development

In order to have an eco-friendly and sustainable future, the Planning Commission had produced an online tool called India Energy Security Scenarios (IESS) 2047 in 2015, which developed in consultation with the UK DECC, TERI, C-Step, and Prayas Energy. The model allows users to choose the future scenario in terms of different progress rate and energy choices and view the resultant outcomes in terms of carbon emissions, import dependence, and land use. The demand and supply scenarios have projected under four different scenarios:[1] 'Least Effort' Scenario, 'Determined Effort' Scenario, 'Aggressive Effort' Scenario, 'Heroic Effort' Scenario

The 'Least Effort' scenario approximates the continuation of past trends and assumes no major policy announcements or other measures for increasing nuclear development. On the other end, the 'Heroic Effort' scenario estimates what can be achieved by pushing the physical limits of what could guide the growth of a particular component of the energy supply until 2047.After a 'Heroic Effort' nuclear capacity rise to 78 GW in 2047.[1]

2.Political Risks

1. **Human rights violation:** A small district of India 'Haripur' had witnessed opposition to uranium mining, where the state has confronted by several legacies (the local communist rule).
2. **Democracy and Citizenship:** The Indian government's plans for nuclear energy profoundly affect India's citizens and development. Cases such as Haripur, Khasi Hills, and Jadugoda urge the need for a proper and well equipped democratic institutions, such as courts of law and other policy instruments, to have the relationship between the government and citizens. In contrast, the government is neglecting the essential need for nuclear development.[10]
3. There is a protest against almost every new Nuclear Power Plant coming up, and according to CBI report, these protests are funded by outside agencies through channels like Greenpeace NGO (Indian government sanctions Greenpeace to send a menacing message).

Economic factor

Share of nuclear power in total electricity generation:

According to the IAEA, India ranks 27th in terms of the share of nuclear power in total electricity generation. In terms of installed capacity, India (6.7 GW) is ranked 12th. In India's case, nuclear power provides roughly two percent of installed electricity capacity currently.[24]

Risk of Development:

1. Nuclear power, which requires high capital expenditure and long gestation, will not attract investment unless incentives are given.
2. The financing of nuclear projects is challenging given the highly capital-intensive nature of such projects, their resulting sensitivity to interest rates and construction durations, and the uncertainties.[7]
3. Raising money from the market is difficult when the power sector has significant non-performing assets (NPAs) estimated at around 17-18 percent.
4. The government does not favor the privatization of the nuclear sector, nor does the Atomic Energy Act allow it.

Development Prospect Under 2035:

India has indicated its intention to ramp up nuclear power capacity 10-fold by 2030 to 63 GW. Currently, the country has an installed nuclear power capacity of 6,780 MW (201617), contributing to about three percent of the total electricity generated. Construction of an additional nine reactors is in progress, which will ramp up nuclear capacity to 13,480 MWe of power. The government has also approved an additional 10 PHWR reactors of 700 MWe each, which will boost the domestic nuclear industry. Two reactors of 1,000 MWe each have been approved for construction at Kudankulam, thus taking the total capacity to 22.48 GW by 2031.[17]

Socio-cultural factor

- ***Safety:*** Amongst all the technologies used to generate power, nuclear energy has the maximum possibility of disaster. A similar incident took place in 1986 in Chernobyl, but other accidents hampered public health as well as the environment.[26]

- ***Accidents:*** All nuclear stations are designed, constructed, and operated in adherence to strict quality and safety methods. Thus, India's safety record has been excellent in over 260 reactor years of operation of power reactors and various other applications. The record is not as excellent as this statement projects. Practically all nuclear reactors and other facilities associated with the nuclear fuel cycle operated by the DAE (Department of Atomic Energy) have had accidents of varying severity.[11]

- ***Public perception:*** People in India is much dependent on natural resources like Land and water, which impact the livelihood of the local people. Reactors require cooling water and Land, which are essential for agriculture, thus affecting the farmers and discharge of hot water and radioactive effluents into the water bodies, affecting fishers. These factors also drive opposition to large hydroelectric dams, thermal power plants, and automobile factories.

- ***Employment:*** The cost-profit margin and availability to energy sources are factors providing situations for jobs and decent work. Improving the economic wellbeing of citizens is essential in sustainable development. A nuclear Power Plant creates many jobs in various sectors. Employment and other economic impacts of nuclear power have received less attention, in contrast to the large volumes of people dealing with issues like financing and waste management. In India, there is a vast majority of the younger population searching for jobs, and this is a sector that can generate employment.

Companies

(Due to the lack of companies with sufficient information, R&D organizations and supporting companies have also been included)

1. ***The Nuclear Power Corporation of India Limited (NPCIL)*** is an Indian public sector undertaking situated in Mumbai, Maharashtra, which is owned by the Government of India under the development of nuclear energy for electricity. It has 22 commercial nuclear power reactors having a capacity of 6780 MW. The reactor fleet consists of two Boiling Water Reactors (BWRs) and 18 Pressurised Heavy Water Reactors (PHWRs), including one 100 MW. India prospects to get to the nuclear power capacity of 63,000 MW by 2035 with installing 16 indigenous PHWR. With almost 50 years of experience in safety standards, having the aim of 'Safety first and Production next,' it ventures around the value of ALARA (As Low as Reasonably Achievable). The releases of radioactive effluents are regulated to make it significantly low.

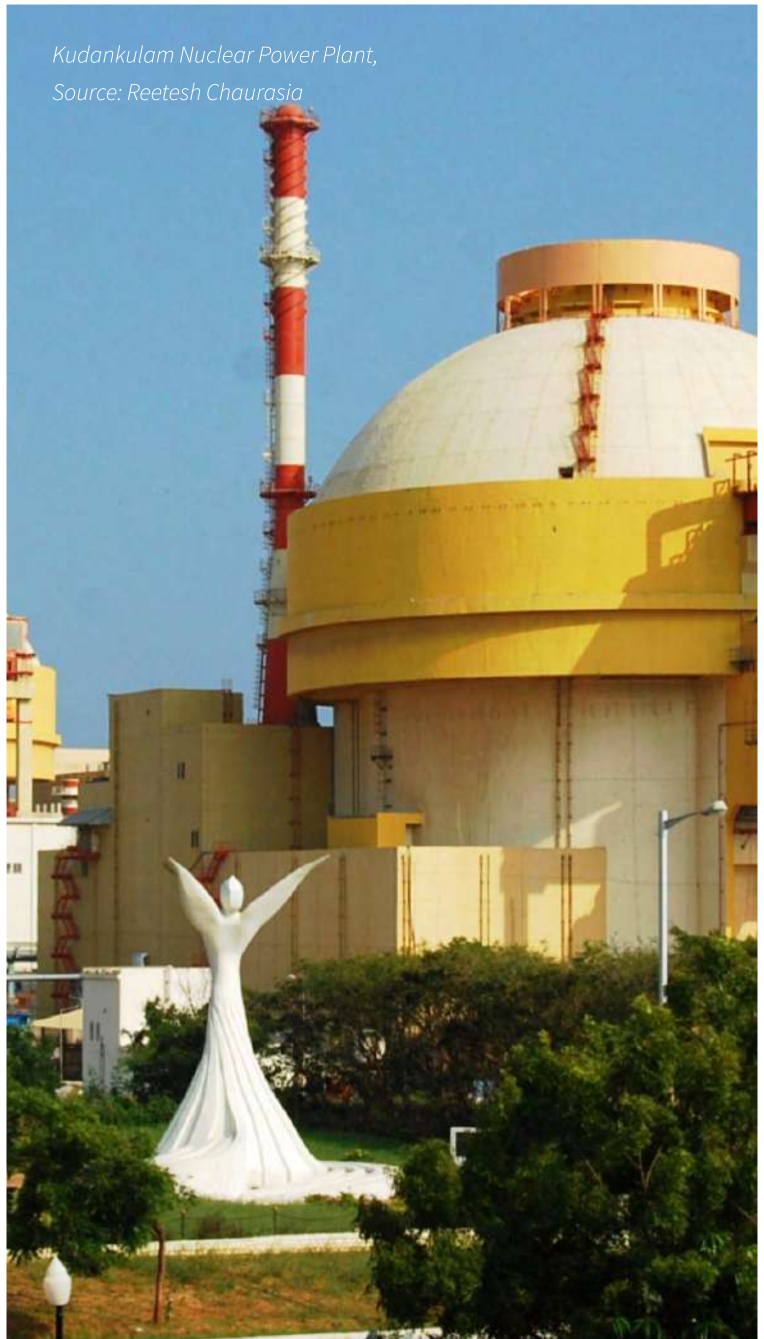
2. ***Bharatiya Nabhikiya Vidyut Nigam Limited (BHAVINI).*** For construction and operation of fast breeder reactors (a part of India's three stages nuclear program), BHAVINI, a public sector undertaking under the department of atomic energy, was incorporated on Oct. 22, 2003. Pro-

totype Fast Breeder Reactor of 500 MW (PFBR) is the first commercial reactor being constructed by BHAVINI in Kalpakkam. Technical Details: A fast breeder reactor is a nuclear reactor that generates more fissile material than it consumes. The Kalpakkam PFBR is designed to use Uranium-238 to breed Plutonium in sodium-cooled fast reactor design.[3] The surplus Plutonium from each FBR can be used to set up more such reactors and grow the nuclear capacity in tune with India's needs for power.[4]

3. ***Indira Gandhi Centre for Atomic Research (IGCAR)*** is among India's important nuclear research centers located in Kalpakkam, Chennai. It has ventured with IIT Kharagpur in developing research for the development of Fast Breeder Reactors (FBRs) which will provide impetus to the second stage of India's nuclear program and are necessary for security and sustainability energy, with a further aim to develop indigenous FBRs for commercial development of nuclear power.[9] IGCAR has played a vital role in India's share to the $25 billion International Thermonuclear Experimental Reactor (ITER) by developing the indigenous cryostat base providing the needed fabrication of trapping Sun's energy by fusion.

4. ***Electronics Corporation of India Limited (ECIL)*** is a Government of India Enterprise under the Department of Atomic Energy, to fulfil the demand of electronics in the industry, thus promoting self-reliance in the field. ECIL also has a significant role in indigenous Electronic Security, Communications, Networking, and e-governance domains. The Company has initiated measures to adopt CSR as a tool for systematic growth. Societal applications of Technology: Community Development the Company has been working on technological solutions for the benefit of society, especially the poor. Increasing the green belt in and around the factory premises by tree plantation drives. Installation of solar power in place of conventional heating systems in areas like the Canteen and Guest House. Installation of effluent treatment processes for the disposal of used hazardous chemicals and other effluents.[6]

5. ***BARC*** is the parent company of many R&D institutions that research nuclear and accelerator technologies such as IGCAR, RRCAT, VECC, and also many industrial establishments such as NPCIL, NFC, and ECIL leading nuclear power production, electronics & instrumentation, materials technology. BARC maintains eight research reactors and is engaged in reactor design and development (including MOX and thorium-fuelled Advanced Heavy Water Reactors (HWRs) and Fast Breeder Reactors (FBRs)), fuel reprocessing; radioisotope production; seismic stations; plants for the manufacture of uranium metal and nuclear fuels; basic research in materials, chemical, physical and biological sciences; pilot plants for the production of heavy water, titanium and zirconium production; radiochemistry and isotope laboratories; waste immobilization and a thorium plant.[2]



Kudankulam Nuclear Power Plant, Source: Reetesh Chaurasia

Scenarios

Quality scenario analysis and strategy of petrochemistry in India.

Negative

Technology: The first stage of the three-stage program involving the indigenous Pressurized Heavy Water Reactors (PHWR) has gained maturity commercially and the Fast Breeder Reactors (FBRs) of the second stage have been implemented commercially with the Fast Breeder Reactor (FBR) of 500MW capacity at Kalpakkam. The third stage's commercial technology development is currently underway. Due to the abundance of Thorium reserves in India, putting it into a unique position, India needs to harness its Thorium effectively. The nuclear power program's third stage depends mainly on Uranium233-Thorium232 systems. Reactors based on Uranium233-Thorium232 systems are not able to provide as practical breeding as the FBRs. Thus, the deployment of large-scale Thorium will take a few decades from now.[21]

Political:

1. India refused to be part of the Non-Proliferation Treaty in 1970, which significantly impacted India's nuclear development for the next 34 years. India lost significant technical advancement and several global opportunities that could be crucial for today's energy diversification.
2. India and China are both the first emerging countries with rapid growth in their energy sector. Both countries see nuclear power as an essential ingredient of sustainable development. However, for nearly four decades, China is leading the Nuclear development and energy generation war with India and has a different international status, with the benefits of being party to the Nuclear Non-Proliferation Treaty (NPT), while India excluded from those benefits, despite its scrupulous conformity to its thorium reserves.
3. India's plan for nuclear energy development significantly affects India's citizens and development. Places like Haripur, Khasi Hills, and Jadugoda lack the necessary infrastructure, whereas the government focuses on nuclear development.

Economic: According to the annual World Nuclear Industry Status Report (WNISR), the overall progress of the nuclear sector in India had been slow. In 2009, India decided to increase nuclear power's contribution to total electricity generation capacity from 2.8% to 9% within 25 years. By 2020, India's installed nuclear power generation capacity was expected to increase to 20 GW. However, currently, the capacity has not exceeded 7 GW.[17] Limited Imports of Uranium, Land Acquisition and selection of location, Lack of Funding, and Lack of Trained Workforce are the reasons for Slow progress.

Conservative

Technology: In parallel to the indigenous 3 stage program, based on imports, are added for faster nuclear power capacity addition. In cooperation with the Russian Federation, two 1000 MW capacity Light Water Reactors (LWRs) are under construction at Kudankulam. These additionalities will make faster capacity addition possible. Thus, it will help India to meet its near term electricity needs, as the fuel cycle linkages govern capacity addition through the sequential three-stage program.[5]

Economic: Nuclear power will continue to play an essential role in the overall energy mix of the country. Currently, the government is providing Rs 3000 cr per annum as funding for ten years for building a ten-reactor fleet of indigenously produced PHWRs. Such an ambitious program has the potential of converting India into a hub of nuclear energy manufacturing creating high technology jobs and making the country exporter of nuclear power equipment.

Positive

Technology:

1. Due to the indigenous nuclear power program's sequential nature and involving the lead time at every stage, the direct utilization of Thorium requires a sufficiently large amount of time. To facilitate the time crunch and to boost the efficiency work on the innovative design of reactors for the direct utilization of Thorium is underway in parallel to the 3 stage program.[15]
2. The Accelerator Driven Systems (ADS) and Advanced Heavy Water Reactor (AHWR) are some frontier technologies that are under development. In ADS, high-energy particles used for fission, which is essentially a sub-critical system.[15] The advantage of ADS is a significant reduction in the production of waste due to burning out of Actinides present in ADS in comparison to the existing reactors. AHWR is supposed to act as a bridge between the initial (first) and final (third) stage, which will boost the direct utilization of Thorium without undergoing the second stage, using heavy water as a moderator and light water as a coolant.

Political:

1. India currently has 21 operating nuclear reactors at six locations across the country, generating a total of 5.8 GW. Its civil nuclear strategy has proceeded mostly without fuel or technological assistance from other countries for more than 30 years.
2. Due to the trade bans in the past and lack of commercially available uranium, the Indian government has taken the initiative for developing a nuclear fuel cycle to exploit its thorium reserves.
3. Indian is seeking technical support from the US, Russia, France, Australia, and Kazakhstan in order to increase its nuclear power generation to 2.8 GW till 2035.

Economic: To meet the 7-9% GDP growth, India is planning to add around 20,000 Mw nuclear power generation capacity over the next decade. Cabinet has approved a 7000 MW "Make in India" project, which will also generate over 33000 jobs in direct and indirect employment, which will help India deal with poverty and unemployment issues. To reduce the cost of generation, India has also entered into a fleet mode of construction.

Strategies to be taken into consideration for policy implementation:

Technology

1. For India to achieve its conceived nuclear power program targets, the fruition of international cooperation is necessary, which will enable India to develop its resources, and a plethora of opportunities will also open up in the export of nuclear services, equipment, and goods.
2. For energy security by the available local fuel, India's best hope is the Fast Breeder Reactor Programme (FBR), and early development will be a significant achievement. Faster evolution is needed in the Indian nuclear power sector and industry to meet the challenges associated, and the way to a faster evolution is keeping the available technology up to date.
3. The indigenous Pressurised Water Reactor (PWR) designed by the DAE is a significant step ahead, but to use it with maximum efficiency, the design needs to bring to production and operation within a committed frame of time.
4. Investing in minor shares of a foreign nuclear equipment producer or acquiring a foreign nuclear energy company would open up the passage to increase the existing production capacity and also help achieve technological insights in the field or acquire technology itself.
5. The UAE and UK models are great examples to learn from; they have been successful in attracting equity in exchange for long-term basis operatorship from international equipment vendors. India could implement this innovative approach by amending the Atomic Energy, thus, help reduce its resource gap and better the risk-sharing.

Environment

1. **International emission trading:** A country earns carbon credit by investing in such projects which will emit a lesser amount of GHGs).
2. **Clean Development Mechanism (CDM):** Certified emission reduction units - Annex b investing in emission reduction project in Non-annex countries - most of them in India and China - sustainable development while giving industrialized countries some flexibility in doing emission reduction targets and foreign investment and technology transfer for the host country.

Political Aspect

1. The protest and the opposition for the nuclear energy generation should be taken seriously, and the government had come up with a safety program to educate people about the safety and benefits of nuclear energy development.
2. Despite losing the early game while refusing the Non-Proliferation Treaty in 1970, Nuclear manages to be the fourth-largest source of electricity in India. With the help of the bilateral accord that allows India to have nuclear commerce with the Nuclear Suppliers Group, in future India has a different policy for increasing nuclear development like India Energy Security Scenarios developed with the support of the UK DECC, TERI, C-Step, and Prayas Energy.

Economic Aspect

1. Proper planning, financial resources, and a rational tariff structure are needed to speed up the progress.
2. Reduction in the cost of construction is required to ensure that nuclear power continues to be affordable in the future. For this nurturing optimum manufacturing capacity is required where there is not only good competition but also a confidence about the continuity of work orders for a competitive industry.
3. A Levelized tariff plan for nuclear power should be considered.
4. Nuclear power should also be given incentives as provided to the renewable sector. Without this facility, there will be a steep increase in tariffs to recover high capital costs.
5. India should also aim at emerging as a global manufacturing hub for nuclear equipment and material.
6. Indian companies should form strategic tie-ups with international majors to be part of the international supply chain; Foreign vendors should be allowed to invest in the plant and operate it for significant periods. The government should give a clear sign to other PSUs to form a joint venture with NPCIL.
7. India should move forward to emerge as an exporter of its hugely successful and cost-competitive PHWRs.
8. A massive increase in trained human resources is required, which is a challenge as well as a boon to employment generation.

9 The transition to "digital" is inevitable: how the power industry is changing with the introduction of digital and smart systems

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Introduction

A reliable, economically affordable and environmentally friendly electric system is the base of modern society. The 4th industrial revolution mostly depends on the digital revolution and combines multiple technologies that are leading to unprecedented paradigm shifts in the economy, business, and society. [33]

In order to exist in this competitive market, power industries must provide uninterrupted power supply with the efficient load distribution and minimize breaks with timely maintenance. As a result, technology innovations such as machine learning algorithms and artificial intelligence are entering the power distribution business at a drastic pace. The innovations in the battery storage, internet of things (IoT), is also providing a great scope for the power industries.

The reduction in the cost of the batteries and the increase in their performances are the result of the research in storage technologies. The demand varies not only daily but also seasonally and annually. The advancement in battery storage technologies can be effectively used to tackle the peak demand. Meeting the peak demands is quite expensive as the utilities either must build new power plants or buy power from other power producers at high cost during the peak time. But if the batteries are connected to the grid, they can effectively inject the required power into the grid at the right time to meet the demand. [20]

Even the emerging electrical vehicles are creating a great demand for the batteries, IESA (India Energy Storage Alliance) estimates the market for energy storage would grow to over 300GWh during 2018-25. India's Union Cabinet chaired by Prime Minister Narendra Modi has approved the 'National Mission on Transformative Mobility and Battery Storage', with a focus on local manufacturing across the whole supply chain for electric vehicles (EV) including battery and cell manufacturing. [7]

The planned capacity target for lithium-ion battery-manufacturing base has been raised to 50GW from 40GW. The government is in the process of opening to tenders to set up a 50GW battery manufacturing base at around US$50 billion investment. To support this, the government is offering financial incentives in the form of subsidies and duty cuts, which could include a reduction in minimum alternate tax to half and import and export duty waivers or cuts for eight years. The successful bidder companies will have to set up production facilities by 2022 and can apply incentives until 2030.

India expects to have an all-electric fleet by 2047 instead of the government's earlier target of achieving this by 2030. The initiative has given a major push to the automobile market to manufacture batteries in India. Currently, the ecosystem lacks large lithium-ion battery plants. Due to this, most batteries are imported, leading to high cost. This, in turn, impacts the cost of vehicles. [22] [27] [2]

Smart grid

Nowadays smart grid is evolving as a new concept in India. The smart cities project that is being implemented in some places in the country is based on the effective utilization of the available resources. These smart cities are to be equipped with smart grid technologies.

The Indian power ministry had released a smart grid vision and road map for India on September 10, 2013. The main vision behind it was to utilize digital technologies effectively and involving the active participation of the stakeholders as well as using renewable energy sources. [25]

The smart grid is an electrical grid that includes the smart meters, smart appliances and renewable energy resources. The smart meters are installed in the place of old mechanical meters and they operate digitally. These meters enable the transfer of information between our home and our energy provider. They also help in complete eradication of errors due to manual readings. The smart meters allow the consumer to monitor their electricity usage and in turn optimize their consumption. According to recent industry reports, distribution utilities globally are expected to spend $378 billion in smart grid technologies by 2030, where India is estimated to install 130 million smart meters by 2021. [5]

Energy Efficiency Services Ltd or EESL have successfully installed 1.10 million smart meters. Some DISCOMs that are using smart meters have increased their per-meter, per-month revenue by Rs 200 (when the national average bill is about Rs 450, assuming average consumption of 90 units per month at Rs 5 per unit), said Saurabh Kumar, managing director at EESL. This increment is due to the improved monitoring efficiency of the per unit electricity supplied and due to improved billing.

The EESL is working to install the pre-paid model of a smart meter in Bihar. In this pre-paid model people can pay in advance for the energy they would like to consume in near future. This will benefit the DISCOMs in having working capitals.

Tata Power Delhi Distribution Ltd (TPDDL), a joint venture of the Delhi government and Tata Power, would make it possible to install meters and launch a mobile app for Android with the Internet of Things (IoT) for the first time in India. Initially, north and north-west Delhi decided to install 2.5 lakh smart meters. By 2025, it seems that 16 lakh smart meters will be ready to serve human needs.

Tampering will be detected by the sensor, then the information will be stored to the meter and will be communicated to a central server. It enables the DISCOM to disconnect power supply remotely. Hooking and other tampering of distribution lines will be detected by wireless power sensors. To solve India's perpetual utility crisis, smart meters can play the role of a game changer after it comes. The technology is capable of controlling electricity thefts, one of the most important problems which is the solution India has been looking for a long. According to the Indian government, the aggregate technical and commercial losses (AT&C), which replicate transmission and collection efficiencies, came down to 18.75 per cent from 20.7 per cent in FY16. According to electricity demand growth projection, the plan is to decrease these losses to below 12 per cent by 2022, and below 10 per cent by 2027.

In India, the implementation of smart metering is obsessed with the urgency to diminish the current aggregate, technical and commercial (AT&C) losses. To deal with these issues, the government of India launched the Ujwal DISCOMs Assurance Yojana (UDAY) scheme, aiming to persuade the operational and financial turnaround of state-owned DISCOMs by reducing AT&C losses to 15 per cent by FY19. According to the plan, a target is set by the government to fast-track the roll-out of 35 million smart meters by the end of 2019. In addition, it declared a plan to reinstate all electricity meters in India with smart prepaid meters in the next three years. The government has decided to ramp up its plan to make smart metering mandatory for bringing more efficient management of energy. To meet these requirements, the Ministry of Power (MoP) had advised manufacturers to scale up the production of smart prepaid meters and work towards bringing down their prices. [32] [6]

The decentralized power generation which is a part of the smart grid system helps in reducing the dependency on fossil fuels for the generation of power as in this method each house can have its own generation of power by using the renewable sources like the solar rooftop panels. Even the excess power generated can be transferred to the grid using the net metering; it not only reduces pollution but also provides a scope of earning. Net metering is a mechanism that allows domestic or commercial users who generate their own electricity mostly from solar to export their surplus electricity back to the grid. In the net metering, the owner has to pay the bill for the net energy that is used.

The Kerala State Electricity Regulatory Commission (KSERC) issued new regulations called the 'Kerala State Electricity Regulatory Commission (Renewable Energy and Net Metering) Regulations, 2020' in which the state has directed the distribution licensees to constitute an in-house renewable energy cell to promote renewable deployment in the state within one month. [13]

The main challenge of net metering in India is slow implementation. Tamil Nadu does not allow net metering for HT consumers. [4] Despite all these challenges, the net metering system is environmentally friendly because it involves electricity generation from renewable energy sources that cause no or less pollution.

Even the concept of peer to peer (p2p) electricity trading is becoming popular. Peer to peer electricity trading is buying and selling electricity from other users who produce and store surplus energy. The trading of energy is done through a secure platform, often using technology like blockchain. Blockchain is a database technology that processes and stores information, such as transactions of assets. These assets can be in the form of renewable energy credits, which can be traded through the database. [11]

Energy trading is the buying and selling as well as moving of the bulk energy from where it is produced to where it is needed. The two exchanges -Indian Energy Exchange (IEX) and Power Exchange of India Limited (PXIL) are in operation in India which facilitates an automated on-line platform for physical day-ahead contracts. [29]

The government of Uttar Pradesh has introduced the blockchain technology to its rooftop solar power segments. It is the only state that allows controlled peer to peer energy trading in India. The UP government is one of the first in the world to formally recognize blockchain as a mechanism to make energy markets more efficient. [21]

A new economic growth model, aligned with global technological and developmental trends, has been embarked. 175 GW of electric power is generated from renewable sources of energy of which 100 GW will get from solar power, building 100 smart cities, rejuvenation transformation of around 500 existing mid-sized cities having a population of around 100,000, digitizing India, and making India a global manufacturing hub are some of the pillars on which the new growth model rests. [31]

According to data provided by the ministry, the greatest number of projects (about 28%) proposed by the city pertain to cleanliness, followed by the economy (24%), inclusion and environment 23% each and about 2% underwater. The 100 smart cities have already initiated the process of implementing 100 impactful projects. The initial estimates of ministry reveal that the 100 projects would mean plantation of 1 lakh trees, 80 new smart classrooms, over 100 green public spaces, 2 lakh trash bins, 1.25 lakh new LEDs streetlights and over 100 new community toilets. [30]

The Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) emphasizes that the baseline estimates of the "consumption loss" (not the same as GDP loss) of taking mitigation action in buildings, transport and the industrial sector combined would be negligible – 0.06% on an annualized basis till 2100 to meet the target of less than 2°C temperature rise over pre-industrial levels or up to 450 ppm of CO2eq of GHGs. [19]

Leading Companies in India Embracing the Smart Grid System

1. **ABB [9]:** ABB is one of the largest power and automation technology companies in the world. They are making their first SCADA project implementation in India with MFTDMA VSAT communication. It is connected to 867 locations across INSAT 3A with communication bandwidth of 11.5 MHz and another 450 locations added subsequently.
2. **CDAC [9]:** Centre for Development of Advanced Computing(C-DAC), Bangalore has developed the COPS SMART ProGate Protocol Converter. The ProGate uses the C-DAC Multi Agent Framework (CMAF) for self-healing from any logical port failures. The product has been developed in adherence to standards and compliance to IEC 60870.
3. **Capgemini [9]:** They have strong presences in the energy and utility segment. Recently they have launched Smart Energy Services, a new global service line that will provide a full spectrum of smart metering, smart home solutions, smart grid across the globe.
4. **POSOCO [9]:** Power System Operation Limited is a wholly-owned subsidiary of Power Grid Corporation of India Limited (PGCIL). They are implementing various projects on Synchrophasors/WAMS in India. One pilot project is already operational at National Load Despatch Center, New Delhi.
5. **Schneider Electric [9]:** The recent acquisition has given Schneider a good hold in the global distribution market and enhanced its Smart Grid Vision. The Company has moved from Smarterhomes to Wiser homes where it integrates smarter home solutions with the multimedia infrastructure in the home. In India, Schneider Electric is headquartered in Gurgaon and has four manufacturing plants and established its first global R&D Center in Bangalore, India.
6. **Telvent [9]:** Telvent industries is one of the largest global IT solutions. Telvent has recently announced that it is going to partner with Larsen and Toubro(L&T) for Smart Grid Projects in Maharashtra State Larsen & Toubro is a USD 9.8 billion technology, engineering and construction group, with global operations. It is one of the largest and the most respected companies in India's private sector.
7. **POWERGRID [9]:** Being the largest transmission utilities in the world with over 72,000 km transmission lines in India POWERGRID has more than 45% power generation in India. Now they are focusing on Smart Grid in India and it will be one of the major Smart Grid industries in the country.

Analysis of risks of development of Incorporation of Smart and Digital Systems in the Power Industries until 2035

A paradigm shift in global power industries is inevitable, considering the persistent and quick escalation of the power demand. One small data might suffice to give an idea about this unstoppable rise: India's power demand would go up to 14,500 TWh/year (terawatt hour per year) by the year 2050 [24]. It is impossible for the conventional generation-transmission-distribution system, i.e. the power system, to fulfil the insatiable appetite and unquenchable thirst of power of this rapidly growing world; not to mention India's case is nothing different. After the 2012 Northern Grid failure which caused an almost two days long blackout in many parts of the country, it should not be expected that the present system would be enough to meet the demand in future. The Government of India (GoI) has taken some initiatives in order to meet the demand, such as the National Smart Grid Mission (NSGM) which has been in operation since January, 2016 [15]. However, the roadmap to transform the conventional system into this proposed smart system is not so straightforward. There are multiple hindrances on the way to achieve this goal; most of those seem to be insurmountable at times but instead in fact those problems can be solved by implementation of proper supports. The major problems are discussed below.

1. Incompetency of Grid Infrastructure [12]:

As mentioned earlier, the grid system of India is still very much conventional. Thus, it is going to be a tough job to transform the whole system into an "intelligent" one keeping the system alive at the same time.

2. Inefficient Metering System [12]:

In earlier days the metering was used to be done using electrodynamometer type energy meters. Every single house used to have one such meter and at the end of the month, the readings were recorded manually. Now, those energy meters work based on mutual magnetic reactions between the fixed and moving coils which can never be free from error. Tiniest distortion in the magnetic field is capable of changing the readings. It was even common malpractice among the users to place or suspend magnets on or beside the meter to manipulate readings or even bypass the meter connection to avoid metering altogether. Although in the last few years, the distribution companies actively changed those analogue type meters with digital ones. Still, that is not smart enough to be used for things like energy trading etc.

3. Decentralized Grid System [12]:

Currently, India is divided into five regional power grids, viz. Northern, Eastern, Western, Southern and North Eastern. The first step towards a smart grid would be centralization. GoI is working on that, for example, the Finance Minister of India Nirmala Sitharaman talked about One Nation, One Grid concept in her maiden union budget in 2019. She added that it was a part of the central government's scheme known as Saubhagya inaugurated by Prime Minister Narendra Modi in 2017[3].

4. Power Theft [12]:

Last but not the least and probably the biggest impediment on the way of a smart power system is not in the system, rather it lies within the consumers who steal power from the LT overhead lines. It is mostly seen in rural areas. Just by bribing local influential persons, many poor people steal power from the lines. This is commonly known as hooking and due to this kind of theft; a major part of the generated power does not reach the distribution section. The distribution companies have responded to this by insulating the overhead lines with thick insulators in recent years.

It is quite clear that smart grid is going to be the heart of the smart power system of the future. Another very important and integral part of this futuristic idea is going to be the smart battery-operated systems, be it vehicles or house electrification. For example, the policy think tank of GoI, known as the Niti Aayog, has stated that within the next two and a half years India requires 50 GWh (Gigawatt hour) of battery storage in order to succeed the EV transition. According to a scientist of the Department of Science and Technology, Mr. Sajid Mubashir, the existing EV batteries are not very suitable for the tropical climate. It is recommended to use these batteries not above 35°C; otherwise, it could lead to explosion [8]. Also, the regular Li-ion batteries usually lose approximately 15% of its capacity after about 3,000 cycles when it is used at 25°C but if it is used at 45°C, which is quite common in India in summer, it loses about 23 – 25% after only about 1,600 cycles [1]. So, extensive research is to be done to develop EV batteries which would work perfectly even under these circumstances.

Personal statement by the authors

India is marching towards a smart power network and in the near future, we can expect India to emerge as one of the leading countries in this prospect.

A common area of concern in most parts of this analysis came out to be the distribution section. Yes, the other two sections need improvement as well, but the distribution sector is in dire need of upgradation.

Many of the major problems in this section have one common root cause, i.e. the macro grid system. Whenever this grid comes under any sort of problem, it causes problems in the hierarchy and eventually the consumers get affected. Instead of this, if a micro grid system is implemented, the systems would stop being over-reliant on the main grid.

Smart meter is another aspect of a smart power system. Usage of smart meters instead of regular energy meters will not only make the system more efficient but also reduce power theft.

The term that inevitably comes after 'Smart Meter' is 'Energy Trading'. The prepaid system can be started in the energy sector too and smart meters will be the heart of this system. Like prepaid plans for cell phones or broadband services, consumers will be able to purchase a certain amount of power at the start of the month. If they consume more than that preset level, they will have to pay more next month. There will also be a provision of selling surplus power back to the grid. If customers consume less than the amount they purchased, they will be allowed to sell the remainder of power back to the grid and an equivalent amount of money would be deducted from their next month's payment.

Distribution transformers are sitting at the heart of the distribution system. Unfortunately, apart from some minor structural changes, being one of the most important instruments of the system, these transformers have not seen much improvement ever since they were incorporated in the system. India is still using the regular analogue type distribution transformers. On the contrary, another BRICS nation, Russia is having digital transformers. Implementation of such transformers in India is urgently needed in order to make the system more efficient and less faulty.

Yes, it is not affordable for all types of consumers as the initial installation charges are pretty high, considering the economic condition of a large section of the common people but still, even they can make most of it using aforesaid facilities like smart metering, energy trading etc.

Scenarios

Approach classification in the Indian power industry

Negative

New report of the MIT Energy Initiative warns that EVs may never achieve the same sticker worth until lithium-ion batteries will be relied on, the energy storage technology that powers most of today's consumer electronics. In fact, it is likely to take another decade to eliminate the difference in the lifetime costs between the vehicle categories, which factors in the higher fuel and maintenance expenses of standard cars and trucks.

The findings sharply contradict those of other research groups, which have concluded that electric vehicles could achieve price parity with gas-powered ones in the next five years. The lingering price differences predicted by the MIT report could stunt the transition to lower-emission vehicles, requiring governments to extend subsidies or enact stricter mandates to achieve the same adoption of EVs and cuts in climate pollution. [14]

The battery segment is going to take off, the EV sector is on the wait and watches scenario. Lithium-ion batteries are gaining major acceptance in the industry due to falling battery prices and new markets emerging such as electric vehicles and energy storage systems (ESS). However, there are a few aspects which the EV battery segment needs to focus on. In this segment, there are a lot of investments as well as production facilities in China. On the contrary, investment stakes are much higher in India. However, once an investment is made, investors are not sure who will buy their product since there are multiple OEMs – all fighting for the same market pie. [28]

However, this technology may not be the most suited for the country like India that has poor mobile and data connectivity not only in remote and rural areas but also in large cities. Even EESL would avoid having to pay for the instalment of new infrastructure, new meters may be out of date every time 5G (fifth-generation) or newer technology comes in leading to the requirement of fresh expenditure. Also, GPRS-based meters would have monthly repeated costs to be paid to the telecom companies. [10]

One of the biggest challenges which are associated with smart meters is their high cost. As per estimates, the average cost (including infrastructure and software) of a smart meter is Rs 4,000-Rs 6,000. Given the weak financial health of DISCOMs, arranging funds for smart meters is a challenge. While government grants under schemes like the IPDS are helpful, they can only go so far. EESL's model of bulk procurement, demand aggregation and savings monetization seem promising. EESL has been able to achieve a 20 per cent reduction in smart meter cost through this approach. Another challenge in smart metering is the limited number of smart meters manufacturers. In addition, there are only a small number of certified testing laboratories for smart meters. There is also a need for adequate cyber security and technological infrastructure. [23]

Conservative

There have been a few attempts which kept the speed of development maintained. Those are as follows:

1. Chandigarh Engineering Department (CED) is working on a smart grid project. The area of implementation of this project is The Chandigarh subdivision area no. 5.

With the implementation of the project, there will be a reduction of AT&C losses. The availability of power supply will be improved. As a result, the peak load will be reduced. And also, they are improving the billing and collection efficiency.

There will be some key functions appearing in this project that are substation automation including SCADA, there will be an integration of solar rooftop. The infrastructure of the substation will have an advanced metering process and moreover, there will be the distribution of transformer monitoring.

It is a project under the National Smart Grid Mission (NSGM). The total budget of this project is 28.58 Cr INR and there will be a market share of 8.574 Cr. INR from NSGM. The funding will be provided through NSGM. [16]

2. A mega smart grid project is going on in Ranchi City under Jharkhand BijliVitran Nigam Limited (JBVNL).

The infrastructure of this project is fully based on advanced metering. The grid will be fully based on mobile like anyone can operate it from anywhere but it's only for the workers of the substation. There will be a reduction of AT&C losses. They are also working on improving the billing system and collection of bills with efficiency. They will provide better consumer relationships with members of the substation.

The total budget that is a cost in this project is 228.69 Cr. INR. As the funding will be provided by NSGM, there will be a market share of 68.61 Cr. INR from the side of NSGM. [17]

3. In Rourkela City, under Odisha Power Transmission Corporation Limited (OPTCL) there is a smart project that is fully based on SCADA.

The project covers 0.87 lakh of residential and commercial consumers. The current AT&C losses stand 32%. The infrastructure is fully based on the advanced metering procedure. Through this project, there will be a great increase in efficiency in the operation of substation and improvement of billing and collection.

The whole project is funded by NSGM. The total budget cost in this project is 96.97 Cr. INR. There will be a NSGM share of 29.09 Cr. INR. [18]

4. In Gujarat, there is a smart grid pilot project going on under Uttar Gujarat Vij Company Ltd. (UGVCL).

The project started in the month of March 2017 and is still under construction. It covers 22,230 consumers in Noida. The main functions that will be provided are load forecasting, power management & outage management that will highly impact on the utility of the consumers. The main objectives of the project are Advanced Metering Infrastructure-Industrial (AMI-I), Advanced Metering Infrastructure-Residential(AMI-R), PLM, OMS, Power Quality etc. [9]

5. In West Bengal implementation of AMI has been going on since June 2015 Under West Bengal State Electricity Distribution Company Ltd (WBSEDCL).

The proposed project area is covering 5,265 consumers with two no. of 11kV feeders and 46 DTs. The overall consumption is about 7.46 MUs per annum. They are focused on the improvement of AMI-I, AMI-R, PLM. The contractors engaged in this project are M/s Chemicals & M/s CMS Computers Ltd.

Till now they have done the site survey, DRS for Smart Meters & DCUs are approved. FAT for 1000 single phase meters is in the progress in CMS, Mumbai. [9]

Positive

The innovative approaches made so far can be fundamentally divided as follows:

1. **Department of Science and Technology (DST)** [9] supported energy storage and smart grid projects at national as well as international (e.g. US, UK, Netherlands) level.
2. **Science and Engineering Research Board (SERB)** [9] has supported projects like – cooperative control of micro grid, control and coordination of micro-grid systems with renewable resources and storage.
3. **MNRE or Ministry of New and Renewable Energy** [9] is the supervisory body of all the renewable resources related matters. This ministry has a goal of fulfilling the demand for power by developing and deploying renewable resources.
4. **National Smart Grid Mission (NSGM)** was established by the Ministry of Power (MoP) [9] in 2015. Since establishment MoP supported 12 pilot projects related to the smart grid in state level utilities.

Smart Grid Initiatives

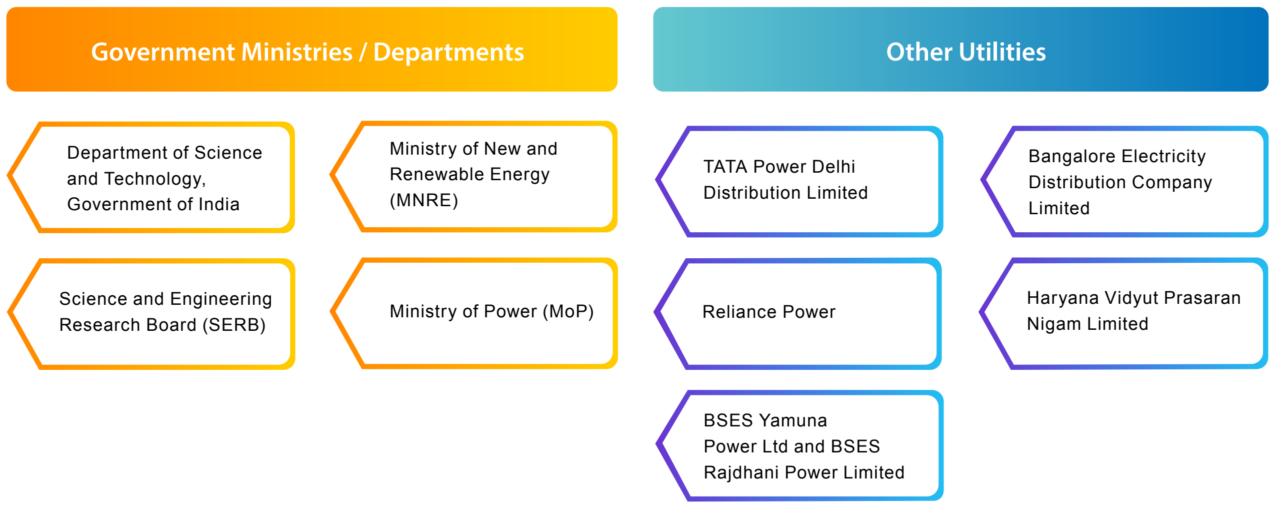

Figure 1: Smart Grid Initiatives
Source: India Country Report on Smart Grids by Government of India [34]

There are five utility projects supporting smart grid researches:

1. **TATA Power Delhi Distribution** [9] has initiated a smart grid project involving radio frequency mesh communication. It will cover an area of 510 sq. km. in the north and north-west Delhi. This project will help TATA Power DDL to serve their consumers better by increasing efficiency, reducing outage time and better control. They are collaborating with Landis+Gyr, a pioneer in global energy management, to fulfil this project. It will cover supply, testing, design, commissioning etc. in order to support advanced metering infrastructure (AMI), distribution automation (DA), automated demand response (ADR), distributed energy resources (solar), street light management, and grid substation automation solution (GSAS). This project will have 2 million endpoints, deploying smart meters and supervisory control and management systems like SCADA, ADMS and SAP.

2. **Bangalore Electricity Distribution Company Ltd** [9] is working on a smart grid electricity network as well. It possesses digital technologies, more efficiency, less cost as well as energy consumption, reliability and transparency and last but not the least, minimized chances of health hazards.

3. **Reliance Power** [9] is having one of the most efficient power systems in the country. About 9% of its energy resources are renewable. Also, their distribution network is highly efficient and reliable, having an approximate loss of 9.5%. Reliance Power has set a goal to enter the trend of smart grid in near future.

4. **Haryana Vidyut Prasaran Nigam Limited** [9] has two basic targets for the betterment of the power situation in the city of Gurugram (also known as 'Gurgaon') – firstly, to provide uninterrupted power supply to all the consumers and hence, secondly, to eradicate usage of diesel generators in the city within a year. After achieving these two goals, they will strive for turning this system into a smart grid.

5. **BSES Yamuna Power Ltd and BSES Rajdhani Power Ltd** [9] has started promoting 'net metering' and installed 185 roof-top solar panels across the city, each having a production capacity of 88 kW. These panels are associated with smart meters to measure net power consumption and sell surplus power back to the grid. This system has a sanctioned load of 6.6 MW so far and the company is eyeing another 1.37 MW by installing 30 more of such panels. The consumers are saving from ₹1,800/month to ₹1 million/month, depending on the sanctioned load. Each kW of capacity requires about 110-120 sq ft area.

Smart Grids Dynamics
Source: Global Smart Grid Federation (GSGF)

“

India is marching towards a smart power network and in the near future, we can expect India to emerge as one of the leading countries in this prospect.

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04

CHINA

CHAPTER 4

PEOPLE'S REPUBLIC OF CHINA

Editorial Summary

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The Chinese teams believe that by adopting the suggested policies within different scenarios, the development of DG will speed up in the near future.

Introduction

The Chinese teams which worked on the Outlook-2020 were interested in the following topics: the policy of reducing CO2 and other greenhouse gas emission; distributed generation in China and other BRICS countries. The issues of new sources of energy and ecology are of the first priority for Chinese government and citizens.

As greenhouse effect is a global problem, China wants to make its contribution to the protection of the Earth. Nowadays coal is the most popular source of energy in China, however, it's well-known that CO2 emissions cause irreparable damage to the atmosphere and ecology in general. Both of chosen Outlook topics are relevant to the current situation and can greatly contribute to the development of Chinese economy, especially its energy sector.

Distributed energy as a trend

China now is at the beginning of an energy transition with the aim of building an energy system for the future. The main direction of development is the usage of photovoltaic power. Its production is growing each year and is likely to continue to rise. With the continuous decline of the cost of renewable energy such as photovoltaic and wind power, related investment is increasing rapidly, especially with distributed photovoltaic. There are 5 biggest companies involved in the distributed energy: Weineng Group, Chint Electric Co., Baofeng energy Co., Titan Wind Energy, China Resources Gas Co. All of them have made a great contribution to the development of distributed energy in China; many of them also focuse on migrogrid technologies and invest in building new plants and infrastructure. Speaking about the prospects of future development, China has a good economical, resource and technical potential. Although price mechanism relies too much on government subsidies, private investments tend to grow. Nevertheless, the industry still has some shortcomings such as the problem of sufficient distribution of energy to all the regions or the lack of technologies.
To sum up, the industry of distributed energy is developing rapidly. The government adopts laws to support the production, many researches are carried to introduce new technological advanced in this sphere, the costs are getting lower.

The policy of reducing CO2 and other greenhouse gas emission

At this point, China is facing the same problem as the world in general: unsustainable production and CO2 and other greenhouse gas emission. The country sets up goals for itself to make their massive production of goods less harmful for the people and the environment. Actions of political agents and international cooperative policies can greatly affect the trend of the greenhouse gas emission growth. Still, the policies and uses of the instruments that political forces possess are too different to reverse the general emission tendencies.

Some change can be brought by using technologies, and there are already 4 approaches being adopted globally. The methods are – improving energy efficiency, increasing usage of low carbon fuels, deploying renewable energy, and applying geoengineering approaches.

Generally speaking, China's negative effect on the planet's environment is massive – it produces a variety of gases (CH4, N20, CO2) from its agricultural and livestock production. Technology is constantly striving to add more techniques to the aforementioned 4 approaches, such as CO2 capture and separation technologies, CO2 transport, CO2 utilization, and use of microalgae. China in particular is keen on using biomass power. But all those technologies are yet to be deployed. Although China still relies on fossil fuels in both commerce and industry terms, the president of China, Mr. Xi, states that the CO2 emission peak will come around 2030 and 20% of energy would be renewable by then, so it can be said that China is on its way to a sustainable future. Developing nations will need huge increases in low-cost energy to power their economic development, with that they will also get more means to reduce pollution.

China should now put energy conservation and emission reduction in the first place, improve energy efficiency by introducing relevant policy standards, put in more effort to make the country's agriculture eco-friendly. All of this sums up to optimizing the economic structure and energy management of the country.

Conclusion

Summarizing everything that was said, we can say that China tends to develop new sources of energy and pays a lot of attention to the environmental problem. Having such a rich energy potential, China have all chances of becoming one of the leading countries in the field of renewable energy.

1 Distributed generation as a trend: how is it implemented in China, and how does it affect the industry?

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Brief description

China is at the beginning of an energy transition with the aim of building an energy system for the future.

1. Natural gas distributed energy

Natural gas consumption increased by 18% in 2018, with a total volume of 282 billion cubic meters (bcm), 10% higher than natural gas production growth rate. China's natural gas production reached 160 bcm and its import dependence rose to 45.3%.

2. Distributed renewable energy generation

2.1. Distributed photovoltaic generation

According to industry statistics, the installed capacity of new photovoltaic power generation in 2019 was 30.11 million kilowatts, down 31.6% from the same period last year, including 17.91 million kilowatts for centralized photovoltaic (a decrease of 22.9% over the same period last year) and 12.2 million kilowatts for distributed photovoltaic (an increase of 41.3% over the same period last year). The cumulative installed capacity of photovoltaic power generation reached 204.3 million kilowatts, an increase of 17.3% over the same period last year, of which distributed photovoltaic was 62.63 million kilowatts, an increase of 24.2%.

The vast majority of the systems are grid connected, with the off-grid market remaining very small in comparison. While over 34 GW of solar PV was connected in China in 2016, almost 90% of this was utility scale. The remainder consisted mostly of commercial PV (IEA, 2017a).

2.2. Distributed wind power generation

In China decentralized wind power generation started at 2011. By the end of 2018, the installed capacity of distributed wind power in China was nearly 400x104 kW. Among them, 15 demonstration projects with a network scale of 76.2x104 kW are mainly located in Shaanxi Province.

Although energy such as biomass is also included in distributed renewable energy, according to extensiveness, convenience and flexibility of projects, distributed photovoltaic is and will be the main body of DG of renewable energy practices in China at present and in the future.

3. The trend of distributed energy in China

Technological progress has improved the economy of distributed energy by reducing its cost. With the continuous decline of the cost of renewable energy such as photovoltaic and wind power, related investment is increasing rapidly, especially with distributed photovoltaic.

The Reform in the market accelerates the process of distributed Energy Grid connection. DG market-oriented trading pilot has applied direct sale and thus expand the innovative business model, which is expected to improve both profitability and stability. Also, a regional power generation and distribution system can be established through DG projects of incremental distribution investors.

4. Case study in China

4.1 Weineng Group: representative enterprise of gas DG

Table 1: Actual and Predicted Revenue Distribution
Source: Predictions from China Calm International Group Limited

ANNUAL ACCOUNT: 12/31 IN MILLION HONG KONG DOLLAR	2018	2019	2020 PREDICTED	2021 PREDICTED	2022 PREDICTED	2019-2022 COMPOUND ANNUAL GROWTH
REVENUE						
SI operations	1,579	1,757	1,836	1,942	2,090	6.0
IBO operations	842	1,038	1,311	1,766	2,200	28.5
In total	2,421	2,794	3,147	3,708	4,289	15.4
REVENUE DISTRIBUTION						
SI operations	65.20	62.90	58.30	52.40	48.70	
IBO operations	34.80	37.10	41.70	47.60	51.30	
In total	100.00	100.00	100.00	100.00	100.00	

At present, Weineng Group International Holding Co., Ltd. (Weineng Group) is mainly engaged in (1) system integration (SI) of gas and diesel generator sets; (2) gas distributed generation through investment, build and operation (IBO) in Southeast Asia and other developing countries/regions.

The company pays close attention to the development of microgrid technology. As microgrid involves both the traditional power supply mode and new DERs it's of the first priority for the company.

We expect the operating income from SI operations to be relatively stable, while the revenue from IBO operations will continue to rise. Specifically, the proportion of IBO operating revenue will increase from 37.1% in 2019 to 41.7%, 47.6% and 51.3% in 2020-2022 respectively (see Table 1). As IBO operations are relatively more profitable, with the rise of the proportion of such operation, the company's total gross margin will also move up.

4.2. Chint Electric Co.: representative enterprise of photovoltaic DG

As one of the world's leading low-voltage electrical appliances and photovoltaic products suppliers, Chint has strong competitive advantages in cost, technology, distribution channels and brand building.

The changing asset structure of photovoltaic power station leads to the boom of distributed generation capacity. Since 2017, Chint has actively embarked on its purchase of distributed assets. At the same time, it sold some centralized ones. For this reason, in 2018 the installed capacity of the company's centralized photovoltaic power station had decreased from 1604MW at the end of 2017 to 1012MW, while the distributed installed capacity had increased from 571mw to 919mw, and the structure of operating power stations had changed significantly. The revenue from the company's photovoltaic business in 2019 reached 11.919 billion. Also, the operating revenue of distributed power stations was 2.444 billion, 25.21% higher than 2018.

4.3. Baofeng energy Co.: a representative enterprise of photovoltaic DG

Baofeng energy, as one of the leading enterprises of high-end coal-based new materials, was successfully listed in May 2019, and thus its strength was further enhanced.

DG projects guarantee high quality development: 90 MWp market-oriented transaction pilot project of DG + potential for a second base. In 2019, the company built Baofeng energy Ningdong 90MWp DG market trading pilot project, with a power generation scale of about 150 million kwh / year.

We are optimistic about further development of the Baofeng. In 2019, the company's operating revenue was over 135.68 billion yuan (+3.95% YoY) and the total profit was over 4,385 million yuan (+2.38% YoY). Thanks to Baofeng energy Ningdong 90MWp DG market trading pilot project, the company

greatly reduced the cost of power generation, with annual net interest rate at 28.0%.

4.4. Titan Wind Energy (Suzhou) Co., Ltd.: a representative enterprise of wind power DG

New and smart energy development allows the company a bright future. In 2019, Titan Wind Energy developed wind farms on a scale of 215 MW that are connected to the grid. By the end of 2019, the total scope for connected wind farms was 680 MW, up 46% YoY, while the number for the wind farms under construction was 179.4 MW.

Since the first distributed wind power plant owned by individual was successfully connected in 2016, the company has been performing well with its new energy sector. It also accumulated rich experience for the operation, maintenance and DG use of wind farms. In terms of products, in 2018, the company drew on its independent R & D for its product release, including microgrid series products, power quality series products and energy storage product BMS.

4.5. China Resources Gas Co., Ltd.: representative enterprise of gas distributed generation

Huadian (Xiamen) distributed energy Co., Ltd. is committed to develop natural gas distributed energy projects, a successful practice of which is Xiamen Jimei Huadian DG project, with an installed capacity of 31.7 MW, annual clean power supply of 225 million KWH, heating (steam) of 300 thousand tons, the actual annual output value adding up to 246 million yuan.

The company is faced with high technical threshold and high requirements for operation and maintenance, as DG projects require sophisticated technologies, including gas distributed tri-generation technology, industrial waste heat recovery and utilization technology etc. Thus, it has invested in SCADA data acquisition and monitoring system, video monitoring system and GIS geographic information system in its information operation in order to hone its technical ability in the construction and operation of DG projects.

Development prospects (by 2035)

1. Assessment of resource potential

Five types of resources, including urban and rural residential roofs, industrial and mining land roofs, railway expressways, tidal flats, reservoirs and ponds, and agricultural greenhouses are mainly considered in the assessment of the potential of distributed photovoltaic resources. According to the calculation, it is estimated to be 50×108kW in China, and that of decentralized wind power resources is expected to be 4×108kW.

2. Assessment of technological potential

According to preliminary estimation, the potential of distributed photovoltaic technology in China will be 12×108kw in 2025; in 2030, it will reach 15×108kW. The potential of distributed wind power technology will be 2.5×108kW and 3×108kW in 2025 and 2030 respectively.

3. Assessment of economic potential

Based on existing technology, it is important to consider the cost of kilowatt hour, power grid reconstruction, and system balance to determine the scale of distributed generation with commercial possibility. Preliminary estimation is as follows: in 2025, the potential of DG technology in China will be about 16×108kW, among which photovoltaic power, wind power, natural gas power generation and biomass account for 79.9%, 15.5%, 3.1% and 1.5% respectively, and the economic potential was about 2×108kw. In 2030, the figure for DG technology potential will arrive at 20×108 kW, with economic potential to be 5×108 to 8×108 kW, considering the growth of available construction area of photovoltaic power generation, the basically unchanged land type of wind power, and the increase of both natural gas supply capacity and the proportion of gas used for power generation.

Risk analysis

1. Policy risks

1.1. Affordable development of renewable energy policy

As the willingness for government to subsidize distributed photovoltaic power generation projects is going down, the establishment of further projects will be more market-orientated, and thereby will undoubtedly face greater investment risks in the future development.

1.2. Restrictions on third party access and regulatory difficulties

In practice, it is difficult for DG projects to obtain reasonable revenue by selling electricity to the grid. For example, in China, due to the insufficient disclosure of information, it is difficult for investors to make a reasonable asset evaluation. Also, insurance companies are blocked to get involved in the process due to the absence of risk-sharing mechanism.

2. Economic risks

2.1. Price distortion

In China, for renewable distributed energy sources such as photovoltaic and biomass, the current price mechanism relies too much on government subsidies and does not form a competitive price mechanism with internalized external benefits. The current price mechanism has the following defects: there is no spot market price discovery mechanism; unable to effectively avoid the risks of both parties to the electricity contract; unable to provide an effective solution to the deviated electric quantity; when the government takes the lead in direct power purchase, the scale of direct power purchase can be expanded at will.

3. Technical risks

3.1. The lacks a flexible way of exchanging electricity between regions

For a long time, China's power grid has suffered from low flexibility in exchanging electricity inter-provincially or inter-regionally. In the northwest, northeast China, electric power is abundant, while southeast relatively scarce. Furthermore, the country also falls short in: excessive short-circuit current, vulnerable power grid, and the risk of large-scale power failure.

3.2. The impact of grid management technology

Take photovoltaic power generation as an example, it is difficult to manage the overall power grid after DG projects are connected to the grid, due to the fact that the current power exchange system in China integrates the collection, storage, transmission, control, distribution and management of photovoltaic power generation.

4. Environmental risks

4.1. Problematic site selection

Given that the current site selection algorithm in China is not perfect, it is difficult to select the ideal place for DG projects. One of the existing site selection algorithms is to determine the location of the base station in the case of a given number of base stations, but the objective basis for determining the number of base stations is insufficient and lacks mathematical model. Another existing algorithm involves high computational complexity, and due to the randomness of the algorithm, the results of the site selection are also problematic.

Conclusion

Through the analysis of policy implementation strategy of DG projects of natural gas energy, photovoltaic energy, and wind energy, which are the main body of DG practices in China, we found that the effects of polices have the potential to be strengthened when placed together, like the administrative instructions and financial support can complement each other. To sum up, we believe that by adopting the suggested policies in different scenarios, the development of DG will speed up in the near future.

Scenarios

Scenario analysis of the development of distributed generation in China

Negative

Natural gas energy distributed generation

Two major technology constraints in Core components:

1. Power and energy conversion equipment. At present, energy storage batteries still need to be improved in terms of capacity, efficiency and life span.
2. Primary and secondary energy-related technologies, including the optimization of natural gas and pipeline transportation technology.

Distributed generation of photovoltaic energy

Regional development is uneven: As of the first half of 2019, certain provinces dominated in the installation of distributed photovoltaic. According to statistics, in the first half of 2019, Shandong added 720MW, Zhejiang 670MW and Jiangsu 520MW, accounting for 41.7% of the country's distributed increment. The problem is that mature markets have been over-developed, while other areas still fall short of such development.

Distributed wind power generation

Economy-related barrier: cost and investment: There is still difficulty of raising capital nowadays in China because that large state-owned enterprises are reluctant to invest in smaller distributed wind energy, major player in the market are small enterprises or a natural person. Also, Investors of distributed wind power generation are faced with great uncertainty due to the high threshold of such investment and its excessive dependence of the subsidy. Also, they can only borrow money from commercial banks, which dampens their willingness to invest in this area.

Conservative

Natural gas energy distributed generation

The absence of laws and regulations, the lack of a standard industry technical standards: As the Renewable Energy Act primarily focused on the legal perspective of natural gas DG projects, effective regulations related to “comprehensive utilization of resources” are nowhere to be found. Therefore, it is high on the agenda for the “comprehensive utilization of resources” to be included in laws, to replace the Opinions on Further Developing the Comprehensive Utilization of Resources in the State Council’s no. 36 Document issued in 1996.

Distributed generation of photovoltaic energy

Grid connection of distributed wind power: Due to the particularity of distributed wind power and the limitation of technology, the cost of ensuring the stability and security of the power grid is relatively high. As a result, grid companies are reluctant to provide timely grid connection services.

Positive

Natural gas energy distributed generation

The strong support of the Chinese government: Take Shanghai as an example, in March 2013, Shanghai issued the Special Support Measures for the Development of Natural gas Distributed Energy Supply System and Gas air conditioning. Some provinces and cities, such as Tianjin, Shaanxi and Guangzhou, have also completed their development plans for natural gas distributed energy during the 12th Five-Year Plan period.

Distributed generation of photovoltaic energy

Breakthroughs in battery technology: Photovoltaic cell is the core component of photovoltaic power generation, directly related to the conversion efficiency between light and electricity, so its development is particularly critical. At present, there are mainly three types of photovoltaic cells and China hopes to take the lead in the thin film cell technology.

Distributed generation of wind energy

The cheap and stable prices of onshore fans in China: In 2016, China and India had the lowest costs of onshore wind project as compared with a typical one charged between $1,050 and $2,000 per kilowatt around the globe. Still, average investment costs are expected to fall by about 7% by 2022 (IEA, 2017A).

Strategies to be taken into consideration for policy implementation:

Negative

Distributed generation of photovoltaic energy

Further improve relevant standards: The national standard GB/T 19964-2012 should be timely revised to improve the functional requirements of anti-island protection and low-voltage crossing coordination of photovoltaic power generation system. In addition, endeavors should be made to speed up the approval of national standard Photovoltaic power generation grid inverter Technical Requirements, and improve grid adaptability in terms of frequency, voltage, and quality.

Distributed wind power generation

Ease financing conditions for small wind plants: It is suggested to introduce preferential loan policies and establish a financial support system. Firstly, China Development Bank shall provide policy-based loans based on financial credit, and provide diversified wind power loans with convenient conditions. At the same time, banks and other financial institutions are encouraged to provide diversified wind power with loan services that pledge the power collection right or assets of the project.

Conservative

Distributed generation of natural gas energy

Expand financing channels and build a mechanism for sharing risks: The financial institutions should give preferential policies on loans and interest to distributed energy projects, while the government should give targeted subsidies for loans and interest to some distributed energy enterprises. In addition, in terms of expanding financing channels, qualified enterprises are encouraged to issue corporate bonds and support their financing and listing on SMEs board and GEM markets.

Distributed photovoltaic power generation

For the arrival of the "post-subsidy" era: switch subsidy target: At present, the state subsidy has gradually regressed to almost none. Centralized power stations will realize power-generation parity in most areas of China by the end of 2019, while distributed power stations are still struggling with that issue. The government should start to consider how to shift the focus of subsidies to DG projects. Also, it has to deal with the problem of energy storage, power grid transformation and gradually push the connection to grid at an equal price.

Positive

Distributed generation of natural gas energy

Follow the 14th five-year Plan, improve the types of policies, and form a set of unified and coordinated policies: The Guidance on Developing Distributed Natural Gas Energy And Ensuring Energy Security was issued on 18 June 2020. It is proposed that relevant technical standards and laws and regulations such as return on investment should be formulated as soon as possible

Distributed generation of photovoltaic energy

Breakthroughs in battery technology: On the one hand, increase the purchase and reserve of crystal-line silicon in the short term to ensure a stable supply of battery materials, but at the same time, pay attention to the problem of excess production capacity of solar cells; On the other hand, enterprises must seize the opportunities to develop emerging photovoltaic technologies, such as advanced thin film and organic cells.

Distributed generation of wind energy

Improve the offshore wind power industry: In order to improve the efficiency and reduce the cost, Chinese offshore wind turbine selection should be based on its existing wind resources, rationally standardize the capacity of foreign wind turbine, select the appropriate technical route, determine a batch of stable models, and give priority to meet the basic requirements of economy and reliability.

2 THE POLICY OF REDUCING CO_2 AND OTHER GREENHOUSE GAS EMISSION: GLOBAL TRENDS, CAPTURE AND STORAGE TECHNOLOGY AND THE PROSPECTS

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Description

1. Economic

The global economy, people's health, development and employment opportunities depend on the availability of natural resources and healthy ecosystems.

At the same time, the costs of unsustainable resource use continue to rise. Roughly 7 million people die of air pollution every year. By data collated by WHO, the health impacts of China's air pollution are valued at more than 10 percent of GDP.

The whole world is significantly under-estimating the benefits of cleaner, climate-smart growth. Bold climate action could deliver at least US$26 trillion in economic benefits through to 2030, compared with business-as-usual.

There are real benefits to be seen in terms of new jobs, economic savings, competitiveness and market opportunities, and improved well-being for people worldwide.

China has used local pilot studies to perform policy experimentation on many issues, most recently including emissions trading schemes, and could adopt similar approaches to establish national or subnational targets for reducing non-CO2 GHG emissions.

Such an experimental approach can help target the application of mitigation technologies in selected sectors or regions and identify best practices that can then be scaled up.

2. Political

CO_2 and other greenhouse gas emission reduction is critical for global climate, air quality and human health. More and more countries are engaging in international cooperation on reducing CO_2 and climate change. However, the current climate and energy policies to reduce CO_2 and other greenhouse gas emission are too weak to reverse the trend of increasing global emissions. And there are factors affecting CO_2 emissions and policy making, among which political factors cannot be ignored.

3. Political

Until 2020, non-renewable resources are still the biggest source of worldwide primary energy. To reduce CO2 emissions, researchers have summarized following main 4 approaches that are adopted by various countries.

- improve energy efficiency and promote energy conservation;
- increase usage of low carbon fuels, including natural gas, hydrogen or nuclear power;
- deploy renewable energy, such as solar, wind, hydropower and bioenergy;
- apply geoengineering approaches, e.g. afforestation and reforestation; and CO2 capture and storage (CCS).

4. Environmental

Relevance of the topic: With China being the largest production and consumption of greenhouse gas in the world, environmental causes play a big role in affecting the big picture. Speaking mainly of the agricultural area, it alone makes up 15.4 percent of China's total GHG emission in 2005, including 84% of nitrous oxide and 47% of CH4, making it the largest contributor to non-GHG emission (ICTSD,2009). The main sources of agricultural greenhouse gases come from three parts: nitrous oxide(N2O) from animal manure management, methane (CH4) from livestock and farms, and CO2 fertilizer application, which emitted 529.2 MtCO2e and 290.8 MtCO2e, respectively. (Bo et al., 2016) On the other hand, the Intergovernmental Panel on Climate Change (IPCC) report that reducing non-CO2 GHG emission, accounting for one-fifth of China's total GHG emission, can limit global warming to 1.5 Celsius degree, otherwise it will become a major concern for climate scientists. (Ambrose, 2019)

Current trend: In order to address all goals set in the Paris Agreement and the promise to peak its CO2 emission in 2030 or even earlier than expected (Gabbatiss, 2019), China is now taking steps to improve the situation, such as implementing more effective irrigation and farming systems. Improving livestock management can present a huge opportunity for reducing non-CO2 emission; measures include "use of appropriate feed and the conversion of manure to compost" (Lin et al., 2019).

Development prospect of environmental till 2035 & risk of development: In the China 2050 Demand Resources and Energy Analysis Model (DREAM), it depicts a framework where the national energy-related agriculture inventory is 830 in 2014 and will decrease to 724 in the 2050 DREAM result, taking in account of most non-CO2 GHGs such as CO2, CH4, N2O, HFCs, PFC, and SF6(Lin et al., 2019).

Cases illustration

1. COFCO- Circular economy

COFCO (China Oil and Foodstuffs Corporation) is not only China's largest food processor, manufacturer and trader, but also a 'Green Practitioner' in the agriculture industry. 30% of global greenhouse gas emissions originate from agriculture and food systems. The company is focusing on developing circular economy which aimed at eliminating waste and the continual use of resources. Each specialized company under the COFCO Group promote the circular economy by promoting the recycling of waste materials and the use of renewable energy. In June 2016, the State-owned Assets Supervision and Administration Commission of the State Council awarded COFCO the honorary title of "Excellent Enterprise for Energy Conservation and Emission Reduction".

2. NIO-Technology

NIO (WEILAI) is a leading Chinese automobile manufacturer specializing in designing and developing electric vehicles. Although Compared with traditional internal combustion engine vehicles, electric vehicles generate more greenhouse gases in the production stage. Considering only the use stage, the use of electric vehicles to completely replace internal-combustion vehicles and the use of clean power stations would reduce

3. YANCON GROUP- Research

YANCON GROUP is the first state-owned asset authorized operation enterprise and a key state-owned coal enterprise in Shandong Province. The annual greenhouse gas emissions produced by the mining industry range from 1.9 to 5.1 billion tons of carbon dioxide equivalent. Most of the mining industry's emissions originate from Escaping Coalbed Methane (150 to 460 million tons) released during coal mining. The company has the cooperation with high-end scientific research teams such as the Chinese Academy of Sciences and Tsinghua University to optimize the three-terminal control technology, and can tailor the complete set of clean coal technology and ultra-low overall emission in different regions.

4. SHOUGANG Group- Management

SHOUGANG GROUP is a super-large enterprise group with cross-regional, cross-ownership, and transnational operations. The production of steel and aluminum generates approximately 42 billion tons of carbon emissions per year. So, the company use a very systematic way to deal with greenhouse gas emission challenge. Based on the existed management system, they go further standardize emission management system and process, improve the market response speed, and strengthen the capacity of carbon emission management, and improve the carbon asset concept of all relevant units. At the same time, it guides the steel factory to plan carbon emissions early, including basic work such as policy research, historical carbon inventory, and carbon emissions system learning and establishment.

5. CHN ENERGY- Cooperation

CHN ENERGY is a large-scale energy company ranked 107th in the 2019 Fortune Global 500 list. The coal combustion in the power industry produces approximately 1 billion tons of carbon dioxide. CHN ENERGY cooperated with China National Petroleum Corporation to explore the capture of the carbon dioxide emitted by the Ordos Coal Chemical Company of Shenhua Group and transport it to the Changqing Oilfield for oil displacement. The purpose is improving the recovery rate and will ultimately achieve the goal of carbon dioxide storage. It is a win-win choice for enterprises to accelerate transformation and upgrading and sustainable development.

Risk analysis

1. Technology

Leung et al [1] have discussed various techniques to buttress 4 approaches, that were already mentioned, including CO2 capture technologies, CO2 separation technologies, CO2 transport, CO2 utilization, etc. These are very mature techniques in many years.

Besides, some innovative techniques are newly developed by many researchers. Microalgae has emerged as a promising option for biological CO2 fixation and intensive research has been carried out to develop feasible systems for removing CO2 from industrial exhaust gases. Biochar production and bioenergy are also very popular and are well discussed by Lenton [2].

In China, biomass power is currently a very popular subject. A SWOT analysis was produced by Zhao and Yan [3], the impact and cost-effectiveness were also evaluated by Lin and He.[4] Noticeably, China's main subsidy funds for renewable resources is from surcharges of electricity bills, which is hard to afford a large-scale renewable project. [5] CCS, which comprises a portfolio of technologies that can massively reduce CO2 emissions, faces the same situation, it is yet to be widely deployed, mainly due to its high cost. Technologies are there, now we need to bring it to land. Further R&D is still required to achieve commercialization.

2. Legal

Global environmental problems, such as ecological degradation, resource crisis and major natural disasters, seriously affect the development and people's well-being of all countries. International organizations have taken environmental protection as the main topic to carry out in-depth discussion in order to obtain the right to formulate global environmental governance regulations.

As a cooperation mechanism between emerging market countries and developing economies, BRICs countries have been making continuous voices in international rule-making around issues such as "international economy and politics" and "cooperation among developing countries", and have become an important force in improving global governance. Facing the increasingly severe environmental situation and the needs of development and transformation, BRICS countries should further strengthen environmental cooperation, build a platform for environmental cooperation and capacity building among BRICs countries, effectively improve the level of environmental governance, promote green development, and study and formulate environmental rules in line with the interests of developing countries.

HCFCs are the main ozone depleting substances. From 2000 to 2012, the emissions of HCFCs in Brazil, India and China continued to increase, with annual growth rates of 1.99%, 10.20% and 8.29%, respectively. The emission of HCFCs in Russia showed a significant stage characteristic. Before 2008, HCFC emissions increased sharply, and then began to decrease year by year. South Africa's HCFC emissions are relatively stable, showing a slight upward trend. It is worth noting that the emissions of HCFCs from BRICs countries decreased significantly in 2013 compared with 2012. This shows that the BRICs countries have gradually transformed and their pollution emissions have begun to decrease.

In view of the unsustainability of economic growth and environmental utilization of extensive development mode, BRICs countries have proposed to promote the transformation of economic development to energy-saving and environment-friendly economic growth mode.

3. Environmental

Although BRICS countries have made some progress in the field of environmental cooperation, the cooperation potential still needs to be further explored. The BRICS countries are linked with Asia, Europe, Africa and the Americas. The diversified environmental and resource endowment of the five countries provides a solid foundation for further strengthening environmental cooperation in the future.

Located in East Asia, China is rich in biodiversity and is one of the countries with the richest biodiversity in the world. China has proved 157 kinds of mineral resources, among which the proven reserves of tungsten, antimony and rare earth occupy the first place in the world. China has rich experience in manufacturing and infrastructure construction. The diversified resources and environmental endowments of BRICS countries provide good conditions for promoting in-depth environmental cooperation.

The demand and advantage differences in response to environmental problems provide ample space and opportunities for BRICS countries to deepen environmental cooperation, which is conducive to the sharing of knowledge and technology within BRICS, and is the driving force for BRICS countries to deepen environmental cooperation.

4. Commercial

China still heavily relies on fossil fuels on both commercial and industrial terms. The president of China, Mr. Xi, said the CO2 emission peak will come around 2030 and 20% of energy would be renewable by then (Huang, 2014). A recent Massachusetts Institute of Technology (MIT) study shows that the peak of 10 billion metric tons will come sometime between 2025 and 2035 with increasing carbon and coal taxes (Zhang et al, 2014). In addition, if China keeps implementing cost-effective technologies for commercial air conditioners and commercial and industrial refrigeration, it will likely fix the leakage problem and reduce CFCs production. With further incentive mechanisms, China is on its way to a sustainable development future.

Conclusion

From technical view, all three scenarios require emission reduction. So, to implement the policy, we can examine following aspects: a. renewables should make up at least 30% of total global electricity generation; b. no new coal-fired power plants be built anywhere, all existing coal plants begin being retired; c. Invest more on R&D, and make sure all development can be used in reality; d. Advocate electric vehicles, doubling of mass-transit utilization in cities; e. Cut emissions in Heavy industry (who cost most)

We have a vanishingly small remaining carbon budget, requiring global emissions to be net-zero within a few decades without the large-scale removal of carbon dioxide from the atmosphere. While the challenge is immense, focusing on communication, ambition and optimism can be useful.

Cooperation is also one of the important aspects of policy. The greenhouse gas emission reduction can be achieved only when a wide range of companies, institutes, organizations, people working together. Emission reduction needs a high-power efficiency machine, reliable energy supply, intelligence manufacturing process, condition-based maintenance strategy. These need lots of companies and institutes working together, to push the technology boundary and science exploration. People should recognize how difficult and how important it is. In some cases, emission reduction means GDP reduction or life quality reduction. At least there are some inconvenient thing that will happen. In this situation, it is important to make people stand with technology and science exploration.

In order to form strategies in accordance with the current environmental trends in China, it is recommended to first regulate deforestation since forests play a vital role in eliminating GHGs and improve air quality. Besides this, China can put in more effort to make the country's agriculture eco-friendlier. For example, avoiding overuse of nitrogen-based fertilizer and switching to organic fertilizer derives from animal manure can set the tone for a sustainable farmland.

Scenarios

Scenario analysis of CO_2 reducing policy in China

Negative

As the world's largest coal consumer and leading greenhouse gas emitter accounting for approximately 27% of global GHG emissions (excluding LULUCF), China has huge pressure on CO_2 and other greenhouse emission reduction and addressing climate change. In this scenario, it assumes that the development of emission reduction develops slowly, it may bring risks in various fields and have great impact on policies implement.

In the economic field, while achieving environmental protection, China must also maintain economic growth, achieve sustainable development of a green economy, and enter the "new normal". As mentioned above, China is still dominated by coal energy. If the development of carbon emission reduction technology cannot adapt to industrial upgrading, the high cost of clean energy use will put tremendous pressure on China's energy industry, and it will also be detrimental to China economic development as the energy industry is one of key pillars in Chinese economy. What's more, although coal consumption in China has shown a downward trend since 2014, the coal consumption still exceeds that of other countries in the world combined. In 2017, coal accounted for 60.4% of China's energy use. If there is no strong technology of CO_2 and other greenhouse emissions reduction, it will make it more difficult for China to actively implement the Paris Agreement, which is related to whether China could become a leader in sustainable development as well as bring potential risks to the construction of the national image in global stage.

Conservative

This scenario takes the assumption that the speed of technology development will be maintaining the same. This will bring a new question- what is the speed of technology development for now? Many researchers go to find out a quantity answer for this question from different aspects. The three indexes can give a profile of technology development speed for now.

The first index is the article account. After the founding of the People's Republic of China, it published a total of 2,362 papers in the three major journals. In 2018, it published 332 papers in these three NSC journals, accounting for 15.4% of the published article.

The second index is the number of technology-related people. The total number of scientific and technological personnel in China has reached 6 million.

The third index is the output of applied technology measured by patents. Patents are divided into invention patents, utility model patents, and appearance design patents. Invention patents are the most relevant to the level of science and technology. In 2014, the Five Bureaus (European Patent Office, the Japan Patent Office, the Korean Patent Office, the State Intellectual Property Office of China, and the United States Patent and Trademark Office) received 2.3 million invention patent applications, of which the largest number in China, which is as high as 928,000, accounting for 40%.

Speaking about the conservative scenario, there will be low risk if the development speed can maintain at the same level as was mentioned in the previous section. However, there is a huge risk of the speed of technical development going down. This is because the reduction of greenhouse gas emissions is highly dependent on technology development. Technology is the most important factor in greenhouse gas emission reduction. This makes the assumption become a position in a specific area.

Technology will show an aggressive trend in the short term while fluctuation in the long term. As the previous section said, the technology development speed for nowadays is relatively high. Researchers and capital are eager to enter the technology area to achieve more things. While for the long term, other industries will raise because of multiple reasons. The researchers and capital will transfer to these areas from the greenhouse gas emission reduction program. This will make some decrease happen. However, the new area cannot increase permanently. It still exists bottleneck as any area in the world. When the development speed of new areas shows a decreasing trend, the researchers and capital will back to the greenhouse gas emission area. So, the long-term fluctuation will happen.

The policy is highly based on risk, technology, economy, and other parameters. As the previous paragraph discussed, the risk will be set at a low level and technology shows short term Aggressive long-term fluctuation. The policy regarding greenhouse gas emission will be prudent and focusing on adjustment for the long term. This means the situation is better than the prediction. The policy does not need to do too much in this area. The policy can focus on how to accelerate the transfer rate from technology to industries and make the market grow healthily. However, the long-term policy is more complex. As the greenhouse gas emission reduction will show fluctuation in the long term, sometimes it can even show a bad market. Hence, the policy should focus on adjustment. It gives moderate stimulate when the signal shows people and capital leave the greenhouse emission reduction industries. Moreover, it also takes care of the overheat of greenhouse emission reduction industries. This can make the fluctuation at an acceptable level.

Positive

It is worth mentioning that many people argue that CO2 could be helpful. There are some interesting findings mention that CO2 can be good for food supply. Early back from 1987, scientists have done an experiment on two cultivars commercial wheat and calculated a linear regression equation that determine the positive correlation of CO2 level and the mean grain yield of the two wheat cultivars. The scientific reason behind this finding was that CO2 is one of the two raw materials (the other one is water) that are required for photosynthesis.

Ecologically, once the CO2 emission is reduced or we can better utilize it, ecological impact would be tremendous. Firstly, our planet would be much cleaner to offer us safety water, food and air, which in return would benefit our human beings eventually. Secondly, if we can balance the development of environment and society, we can protect biodiversity better. In recent decades, many species became extinct because of the climate change.

Economic growth also has strong relationship with CO2 emission. From the figure below, we can assume that if we expect to thrive in the long-term future, we need to reduce CO2 emission. Although there is a threshold at around 20,000 GDP per capita, we are still below this threshold. However, with the growing speed we will shortly touch this line. So, on the positive side, we can assume to maintain at a high-speed level as well.

Recommendations to be taken into consideration for policy implementation:

Developing nations in Asia, Africa, and Latin America will need enormous increases in low-cost energy to power their economic development and lift their citizens out of poverty. Fossil fuels—notably coal, natural gas, and oil—which currently supply more than 80 percent of the world's energy, will remain indispensable.

As countries grow more affluent, they will also acquire greater means to reduce pollution. Indeed, it is precisely the wealth unleashed by industrialization that enables societies to invest in modern technologies and other practices that clean up the environment. Quixotic policies that are aimed at limiting global warming by making fossil fuels prohibitively expensive, would condemn much of humanity to wretched conditions unimaginable in developed nations.

In terms of policy recommendations, China should now put energy conservation and emission reduction in the first place, which will ultimately promote a downward trend in carbon dioxide emissions. In addition, China should further promote the low-carbon transition of the energy system and improve energy efficiency. It is possible to consider formulating and implementing higher energy efficiency standards in the fields of industry, construction, and transportation through the introduction of relevant policy standards. These standards will tap energy saving potential by optimizing the economic structure and energy management, thereby further accelerating the optimization of China's energy structure and vigorously promoting CO2 emission reduction.

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05

SOUTH AFRICA

CHAPTER 5

REPUBLIC OF SOUTH AFRICA

Editorial Summary _

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Introduction

The South African teams are more interested in the topics connected with biofuel and nuclear energy as the country aims to reduce energy emissions and develop green energy policy. However, topics about traditional fossil fuels were the least popular due to lack of these resources in the country. The main goal of the government is to achieve the goal of enabling electricity access for 100% of the population and 93% with access to clean cooking by 2040.

Development of nuclear energy

To enable this aims Southern African countries try to cover half of the demand by nuclear energy. One more advantage of nuclear plants is using them for desalination of water. "Nuclear desalination has been demonstrated and eyed as a viable option to meet the growing demand for potable water and provide hope to areas with acute water shortages in many arid and semi-arid zones". Nuclear desalination is defined to be the production of potable water from seawater in a facility in which a nuclear reactor is used as the source of energy for the desalination process. In recent years, the option of combining nuclear power with seawater desalination has been explored to tackle water shortage problems. Desalination can play a major role for big coastal cities in South Africa such as Cape Town, Durban and Port Elizabeth. South Africa has been experiencing water crisis over the past few years, that is why the desalination of seawater using nuclear energy in the South African's coastal cities is a feasible option to meet the growing demand for potable water.

Problems, with which nuclear energy faces

However, nuclear projects face economic, legislation problems. Firstly, the case for nuclear often seems to lose lustre when the capital costs of new nuclear builds are presented. The installed costs of nuclear power stations were significantly higher than alternative technologies because of the specific safety systems that were part of the build Rothwell further deliberated that the costs of nuclear are determined by the phenomenal construction costs ($/kw) often represented as overnight costs . However , some scientists claims that the lifecycle costs of nuclear power plants make nuclear power an affordable form of electricity because as soon as the construction costs are amortised, NPPs can provide the lowest cost electricity among all other types of energy sources on the grid. The second problem is corruption and unfair behavior of official administrations. The lack of consistency in the resolve to implement the nuclear agenda across successive political administrations has highlighted the political divide in endorsing the new build of NPPs, causing implementation delays.

The third problem is concerned about nuclear energy among nations. The human health aspects that are synonymous with the nuclear energy discussion because of the impacts of nuclear waste and radiation have prompted debates on the social impact of the energy resource. The fouth problem is lack of high qualified specialists eager to work on the plants and construct special tool for it. This is a risk to the country's public procurement policies that support local content requirements to promote local production of materials required in a capital-intensive project such as a NPP and the national drive to significantly reduce technology imports in favour of local technologies.

Development of non-traditional sources of energy

South Africa also wants to develop non traditional sources of energy. Wonderbag, is a company which can convert municipal solid, medical, abattoir, sawmill and agricultural waste to energy (electricity, gas and/or heat). They can also change plastic and waste oil into diesel and offer a waste-to-energy and waste-to-water solution tailored for islands. The City of Johannesburg has a clean energy project which captures methane from 5 landfills to produce clean energy for the city. The company produces green energy through biogas. Green Cape is a non-profit organisation, which helps push the technological frontier by engaging with businesses, investors, government and academia on ways to promote a greener economy, and help acting as the middleman between ideas and implementation. They provide information for foreign investors to understand the local market, help inventors source funding and aid the government with developing standards, policies and regulations. Moreover, South Africa has iplemented some new bio fuel projects. For example, sugar industry where bagasse is used as feedstock for coal-fired boilers. The sugar refineries where the bagasse is used are considered to have an installed generation capacity of about 245 MW equivalent

Concept of smart city

What is more, South African has adopted a plan- Smart City to achieve the main goals of reducing emissions and giving access to lean energy for everyone. A smart city is a place where traditional networks and services are made more flexible, efficient, and sustainable with the use of information, digital and telecommunication technologies, to improve its operations for the benefit of its inhabitants.
We can mention four possible categories of Smart City opportunities in South Africa: waste projects, renewable energy, smart transportation (construction, electrification, manufacturing), street and road lights optimization.

Conclusions

Summarising everything written, we can say that South Africa tends to develop biofuel energy and nuclear energy. However, the production of such fuels is very expensive, that is why the implementation of these projects is slowing down. Speaking about traditional sources of energy, South Africa is one of the main importers of it. That is why to reduce cost South Africa has to produce new shortages and transportation tools.

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1 Smart city: energy efficient cities. Perspectives, opportunities and problems of creating such cities on the scale of South Africa

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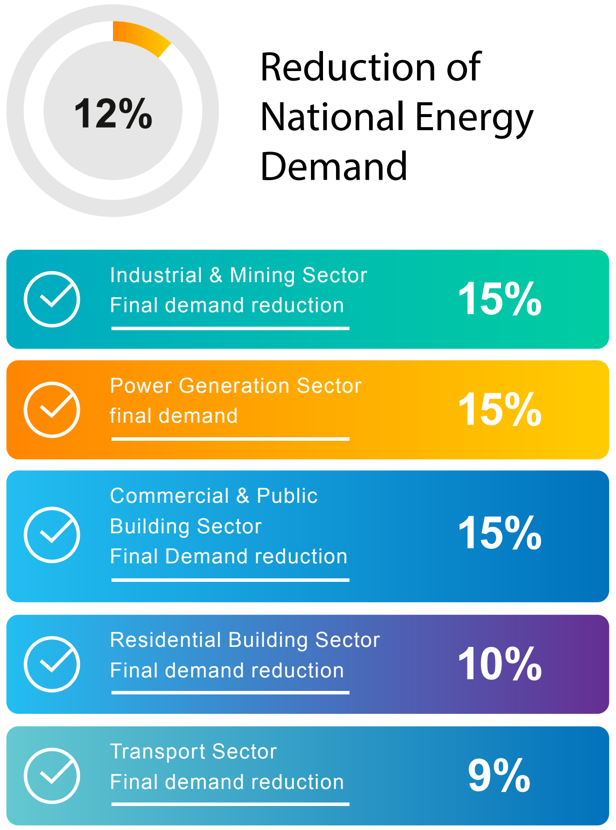
Introduction

The last several years there has been explosive growth of information and communication technologies (ICTs) due to advancement of hardware and software designs. The use of ICT in cities in various forms for different city activities has led to the increased effectiveness of city operations and these cities have been labeled using many terms such as "cyberville", "digital city", "electronic city", "flexicity", "information city", "telicity", "wired city", and "smart city". A smart city is a place where traditional networks and services are made more flexible, efficient, and sustainable with the use of information, digital and telecommunication technologies, to improve its operations for the benefit of its inhabitants. World population has increased significantly in the last decades and so has the expectation of living standards. It is predicted that around 70% of the world population will live in urban areas by the year 2050. At present cities consume 75% of the world's resources and energy which leads to the generation of 80% of greenhouse gases. Thus, in the next few decades there can be severe negative impact on the environment. This makes the concept of smart cities a necessity. The creation of smart cities is a natural strategy to mitigate the problems emerging by rapid urbanization and urban population growth. There are four core themes for a smart city, namely society, economy, environment, and governance. The society theme of a smart city signifies that the city is for its inhabitants or the citizens. The economy theme of a smarty city signifies that the city is able to thrive with continuous job growth and economic growth. The environment theme of a smart city indicates that the city will be able to sustain its function and remain in operation for current and future generations. Speaking about South Africa experiences with this concept are still limited. The precondition for a smart city initiatives is the ability to access the internet and availability. In the country, this is constrained by high cost of data that excludes poor people. A provision of free Wi-fi could be one of the first initiatives that could be done by the municipalities in public spaces as it is implemented in the City of Tshwane.

1. Energy Efficient City Development

The South Africa power structure is currently inefficient, unsustainable and majorly comprised of old infrastructure, with an unreliable electricity grid that is prone to brownouts and blackouts. The high transmission losses, poor power quality, inadequate electricity supply discourage the integration of distributed energy sources. The total rejected energy is a measure of the limitation of an energy source to produce purposeful energy e.g. 2/3 of energy in coal powered station is lost as heat (2019). South African energy sector is undeniably having negative impact on greenhouse gas emissions, which continually grow on due to large power generating facilities running mainly on coal and natural gas. The world energy report (2014) reported the state of the art plants coal-based power plants energy conversion efficiency of 35% to 45%, while natural gas plant efficiency of combined cycle plants can be as much as 60%. Based on the sectoral electricity supply and demand, industrial sector demand sits at 49% comparable to supply of 43,7% (IDC, 2018). Energy efficiency becomes more important solution to mitigate further increase in energy demand, the more the energy demand the more pollution and heat in the city parts all activities arranging city life require energy, such as transportation, job activities, security, airconditioning, catering, entertainment and commerce. The South African government has implemented number of policies and interventions towards promoting energy efficiency in various sectors of the economy and that promotes smart cities initiatives. South Africa energy policy was published in 1998 and subsequently revised in 2012 (DME, 1998). The department of energy (DOE) responded through National Energy Efficiency Strategy (NEES) in 2005 aimed at increasing energy demand alongside a growing commitment to improving resource and reducing national environmental footprint, by setting the target illustrated in Figure 1 (DME, 2005).

A National Energy Efficiency Action Plan was developed in



2012 describing the implementation of the strategy. Energy Efficiency Target Monitoring System was established in 2014 to monitor the progress made towards meeting the original targets (based on a year 2000 baseline) (DOE, 2016). The results of the analysis, confirmed the significant progress made between year 2000 and 2012 in improving energy intensity (DOE, 2016).

2. South African Smart Cities Initiatives

South Africa comprises of nine provinces governed by 9 metropolitan municipalities, with 44-districts municipalities and 205 local municipalities (Brand SA). The following municipalities and district municipalities have embarked on the smart city projects and are at the various level; examples are City of Johannesburg, eThekwini, City of Cape Town, City of Tshwane, City of Ekurhuleni. The mostly and commercial nerve centre is City of Johannesburg which presents opportunities for the creation of energy efficient cities.

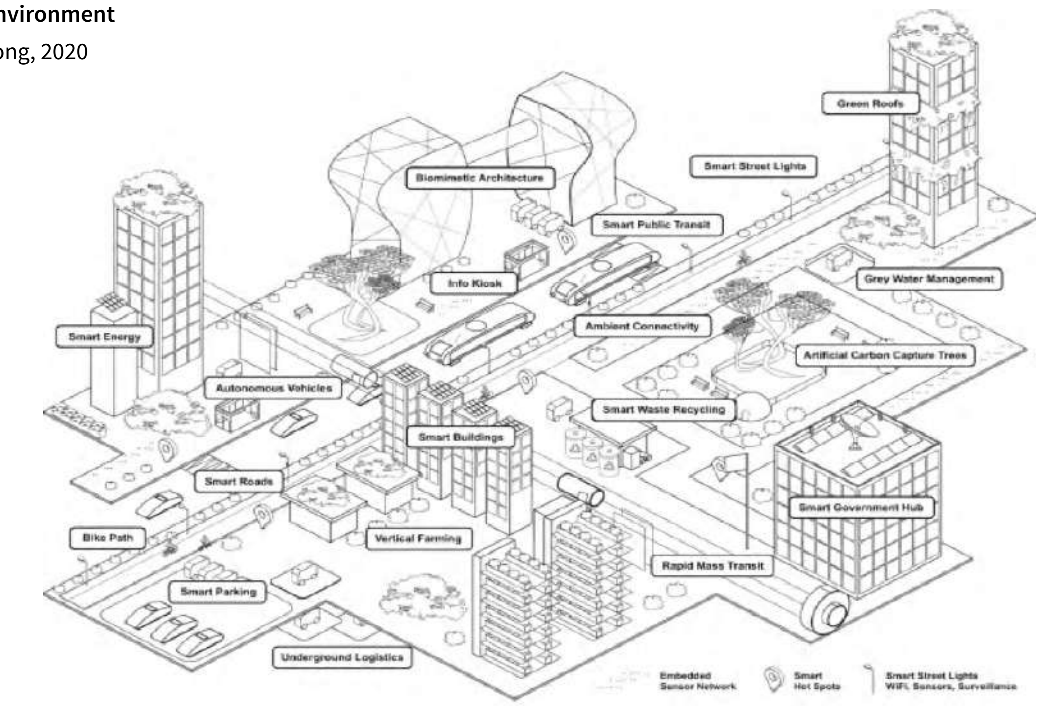
3. Smart City Energy Efficient Municipalities

3.1 Johannesburg

Johannesburg is South Africa's largest city and is an economy hub which is located in the Gauteng province. The smart city initiatives in Johannesburg focus on smart machines, informed organizations and smart mobility. The city has been successful in getting the citizen to be connected to the internet through partnering with corporate entities. In the smart mobility, the city has promoted non-motorized transport and has embarked on a R70 million of build lanes for cycling in the CBD and in Sandton. It also focused on promoting the use of the bus rapid transit system (Arrive alive, 2020). The city has established a bus rapid transit system known as Reya-Vaya project (Reya Vaya, 2020). This bus has improved the quality of life of the city's residence through a public transport system. The approach is people-oriented (through active engagement); it leverages local infrastructure, connectivity and resources; and it provides an interoperable, common underlying smart platform and for the energy efficiency initiative it has started the installation of households with smart meters to reduce electricity losses, increase revenue, and reduce energy consumption (Salga, 2015). However, the state of efficient energy use is at a poor state, due to:

1. Knowledge gap on energy efficiency and low energy conversion efficiency,
2. Non-dispatch ability of generating plant.

Figure 1: Smart City Environment
Source: Kirwan & Zhiyong, 2020



3. Non-availability of efficient utilisation of renewable energy technologies with sufficient transnational energy connectivity of transmission grids with more efficient energy storage technologies
4. According to Lee et al., 2018, energy transition for safe and feasible pathway is the shift from fossil-based to carbon-free economies through solar PV and wind technologies.
5. The sustainability of the application of smart technologies to enable a balanced progress of internet of things (IoT) and smart concepts.

3.2 Cape Town

The initiatives includes:
- Public Wi-Fi hotspots
- Improving Internet access in libraries
- Closed circuit television
- 560 Cameras located in the city
- Open data portal
- The introduction of a smart grid

There is also the Ukitinga enterprise resource planning project (ERP), which is the largest ERP System that offers a comprehensive solution for managing financial, revenue, human resources, operations and other services on a single integrated IT system. These initiatives has enabled the city to win numerous awards and considered a leader in Africa in Smart City initiatives. For its mobility, it has established a bus transit which is known as MyCiti (MyCiti, 2020). It has invested in cycling lanes and walking paths in order to create an accessible and cycling friendly city.

3.3 Ekurhuleni

The city is South Africa's manufacturing hub which is located adjacent to Johannesburg. South Africa's largest airport is found in this city and it has branded itself as an Aerotropolis. Some of the Smart City projects includes installing Wi-Fi facilities for public and its employees to increase economic growth and creating an efficient city. It also enhanced service delivery, they have installed smart electricity metering and other self-help devices.

Methodological approach towards the problems and issues around the smart cities

Efforts should be geared towards addressing challenges and embark on the following research:

1. Introduction of near zero energy building (NZEB) concept (Harkouss et al., 2018) for energy consumption restraint and adoption of new building standards and implementation strategies (Asaee et al., 2019) of a novel technological solutions around air quality, air tightness, effective ventilation, strategies, development of building enveloped performance materials (Huang et al., 2019).
2. The integration of agent technology into manufacturing enterprises (Adeyeri et al., 2015), smart electricity distribution grids coupled with new ambivalent smart metering systems (Shukla et al., 2019).
3. Investigate requires energy demands with respect to energy efficiency improvement of domestic hot water (DHW), through solar geyser in residential, with focus on low-cost methods
4. Efficiency improvement in transport, processes, industry, integrated product-service (Shihundla et al., 2019), waste elimination, optimal resource recovery and technology appropriateness (Adenuga et al., 2020),
5. Circular integration of industries, processes and economies (Walmsley et al., 2019) and a methodology to retrofit effective processes for industrial parks.

2. Opportunities for smart city with energy efficiency

There are greater opportunities to be exploited for the smart cities initiative. Kirwan & Zhiyong, (2020) stated that a smart city urban environment is modelled on convergent human, environmental and technological ecosystems and visualized as a complex blueprint of interconnected and self-regulated systems including all functions of the emerging smart city operating system, represented by Figure 2.

3.Benefit of Smart Cities in South Africa

Smart cities have the potential to deliver multiple benefits, not only to municipalities but to citizens as well. Enhancing the efficiency and management of utilities such as electricity and water could translate into improved service delivery, which means that more citizens will be able to access basic services. However, economic challenges such as the ability of citizens to afford basic services can prove to be a significant barrier to the implementation of smart cities. Prepaid meters, the precursor to smart metering solutions, are an essential technology component which is already available in many areas, but must be implemented and integrated correctly in order to be effective. To establish a common vision for the South African smart cities and establish cities that are inclusive and live-able; more productive, efficient and competitive on a global scale; environmentally, socially, financially and economically sustainable; and resilient to the effects of climate change, other aspects, including but are not limited to, need to be considered:

1. A clear definition of what smart cities are in the South African context.
2. South African smart cities should link to the global market but provide solutions to local problems rather than trying to compete with first world countries.
3. National framework for smart cities in South Africa, which clearly defines roles and responsibilities of the key stakeholders (government, private sector and civil society) need to be integrated

Table 1: State of Johannesburg with regards to Smart cities concept
Source: Rahner 2019

READINESS	RESULTS	POOR	FAIR	GOOD
Smart street lights	In use			x
Smart meters	In use			x
Electricity from renewable resources	5%	x		
POTENTIAL	RESULTS	POOR	FAIR	GOOD
Air quality	25.3µp/m3(annual PM2.5 average)		x	
GHG emission from transport and industry	430 tonnes CO2 per capita		x	
GHG emission from waste	100 tonnes CO2 per capita			x
Drinking water quality and accessibility	69% of consumption		x	

4. Policies need to be flexible and amendable in line with the 4IR.
5. The government needs to first address all the existing challenges faced by South African cities rather than emulating first world smart city models.
6. The building blocks of smart cities, including: STEM education, citizen rights, enablers (such as power, water and internet connectivity), urban versus rural, regulations, and shared goal and vision, need to be taken into consideration.

3.South African Smart City opportunities

The opportunities that exist in the Smart Cities environment are enormous and can be categorised as the following:
1. Waste projects- waste hierarchy adopted by the department of environmental affairs (DEAT, 2005), that focuses on waste prevention, waste for reuse, recycling, waste recovery and disposal as the last resort.
2. Renewable energy – there is a massive opportunity for the implementation of the renewable energy at the small and large scale in all the district municipalities.
3. Opportunities for smart transportation in other municipalities exist , these include the projects ranging from construction, electrification and manufacturing.
4. Street and road lights optimisation is an opportunity for less energy consumption this opportunity may be exploited.

Conclusion

The smart city is a concept under extensive development in South Africa. There are challenges that the country needs to address such as a stable energy supply, a well-connected information technology communication infrastructure coupled with customisation of smart city development to the social context. An opportunity to level the rural, semi-urban and urban city development to reverse the high levels of rural-urban migration will play a key role in ensuring sustainable cities and communities of the future.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2 New technologies of delivering Non-traditional renewable energy and traditional sources to consumers

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Overview

Energy delivery technology is unique to each source of energy. Energy delivery systems are just as vital as energy generation itself. It will be impossible to compensate for the increasing energy demand in South Africa by only developing generation technology and not delivery systems. The International Energy Agency (IEA, 2008), highlights that barriers to the spread of energy efficiency technologies are not always economic and are often related to institutions, governance, information, etc. South Africa has a history of being an energy-intensive country - this is mainly driven by the Mining and Manufacturing industries. Globally, the main policy goal regarding climate change is to reduce global greenhouse gas (GHG) emissions. South African government has outlined its strong commitment to play its part in global efforts to mitigate GHG emissions in South Africa. South Africa is still largely dependent on fossil fuels for energy, which is why the political and environmental discussion on this topic is important. (DEA, 2019a).

1. Political and Environmental

The IEA (2014) report indicates that a key requirement for African countries to realise their development ambitions is the development of effective governance systems. The report suggests that the lack of effective institutions had led to problems such as corruption, lack of transparency and accountability and inadequate regulatory and legal frameworks. One key factor known to reduce these failures is deepening democratic systems. For example, Squalli (2007), argues that aside from poor infrastructure, political influences and mismanagement affect the energy and growth relationship. This is consistent with the view that politics dominate economics as have happened in many reform programs (Banerjee & Munger, 2004). This means democratic environments stimulate effective energy policies which are necessary for promoting growth in the region.

2. Economic and Socio-economic

As indicated South Africa is an energy intensive country which follows the energy growth hypothesis. If the country's economy expands there will be an increase in electricity demand and hence an increased need in improving its energy delivery systems. The South African energy supply market is predominantly dominated by Eskom, a state-owned entity. The entity supplies approximately 91% of generation capacity in South Africa's electricity (World Nuclear Association, 2020). In 2008, Eskom's electricity failed to meet the market demand thereof causing an electricity shortage which cost the economy approximately R50 billion (Blignaut, Inglesi-Lotz, & Weideman, 2014). This prompted the construction of two coal power stations - Medupi and Kusile - to add extra generation capacity to the electricity grid.

Eskom's energy mix is dominated by coal power supply as seen in Figure 1. The supply mix is still largely formed by traditional energy supply and has an electricity supply capacity of 52 140 MW (DoE, 2018). The 2019 IRP indicates the planned energy supply for South Africa up to 2050 (DoE, 2019). The IRP indicates that it has committed to reducing its emissions and aims to decommission 12 GW of coal power plants by 2030, a further 28 GW by 2040 and 35 GW by 2050 (DoE, 2019a). Figure 2 shows the proposed energy supply mix for South Africa by 2030. From this, we can see that there will be a transition from traditional power supply to a non-traditional power supply such as PV and Wind.

The National Energy Regulator of South Africa (NERSA) is the official entity that regulates the price of electricity, piped gas and petroleum pipeline industries in South Africa (NERSA, 2019). Since the 2008 electricity crisis, the price of electricity has seen a significant increase. (Blignaut, Inglesi-Lotz, & Weideman, 2014). According to the DoE (2019a), Independent Power Producers will be responsible for the delivery of over 30% of total energy in South Africa. The main large-scale Independent Power Producers in South Africa are the Industrial Development Corporation, Mondi, RCL Foods Sugar & Milling (Pty) Ltd, Kelvin power. Medium companies are Global Energytion Pty Ltd, UNIQ ENERGY, Marubeni Middle East & Africa Power Ltd (SAIPPA, 2020). Table 1 shows the sectoral breakdown of energy consumption by source. From the totals of the weighted shares, petroleum products are the largest final energy source, with coal at 30.4% taking electricity sources into account. This shows that South Africa is still heavily dependent on fossil fuels, at just over 70% of energy consumption.

A major problem of delivering energy to consumers is the lack of access to electricity. The Department of Energy (2018b) has identified that approximately 2.2 million houses are without electricity. Energy poverty is defined as the lack of access to adequate, reliable and affordable energy to support human and economic development (Ismail & Khembo, 2015). The rural population of South Africa contributed 34.15% of the total population in 2017, in the same year it reported that only 66.88% of the rural population had access to electricity (World Bank, 2020). As previously indicated, the South African electricity transmission network and system operations is operated by a State Owned Enterprise, Eskom, which operates on normal cost minimising principles (Odubiyi and Davidson, 2004). This means that if extending the grid to include rural communities does not make business sense, government intervention is required.

2. Technology

Eskom's transmission network spans more than 26 000km, covering South Africa and most of the Southern African Development Community (SADC) countries. It also owns more than 48 000km of distribution lines, almost 300 000km reticulation power lines and about 7 500km underground cables in South Africa. (DoE, 2018) Coal transportation depends on the proximity to the mine/treatment facility. Conveyor belts or trucks are used for short distances, while rail transport is predominantly used for transporting coal to the port of exit for exports. (DoE, 2016) Power stations situated next to mines for use of conveyor belt delivery systems also receive coal via road transport. (DoE, 2016) There are pipelines transporting refined products from KwaZulu-Natal (Durban, at the coast) to Gauteng. More than 65% of all refined products for the inland and 70% of the jet fuel used at OR Tambo International airport is transported via these pipelines, while 100% of the crude oil for the one inland refinery is also transported using the pipelines. (Transnet, 2018). Natural gas is mainly imported from Mozambique and transported via a pipeline in Gauteng, Free State, Mpumalanga and KwaZulu-Natal. (Department of Energy, 2019).

Companies

There are emerging companies that are focusing its investment on renewable energy sources in South Africa. Some companies have focused their attention towards another problem that most countries face; landfills and, more specifically, the utilisation of the landfills. Other entities focus their initiatives on helping all feasible projects come to life by providing technical and/or financial assistance, Green Cape being such a non-profit organisation. Wonderbag, is a company chosen as one of Time Magazine's 'Top 50 Genius Companies 2018' (Climate Neutral Group, 2020), which decided to work on energy efficiency. Recor is a South African company that offers various solutions to different stakeholders. They can convert municipal solid, medical, abattoir, sawmill and agricultural waste to energy (electricity, gas and/or heat). They can also change plastic and waste oil into diesel and offer a waste-to-energy and waste-to-water solution tailored for islands. They mainly utilise pyrolysis in the processes to convert waste to energy. This involves heating up the waste to high temperatures in a controlled atmosphere, without letting the waste combust. (Recor, 2020) The City of Johannesburg has a clean energy project which captures methane from 5 landfills to produce clean energy for the city. (Climate Neutral Group, 2020) Bio2Watt is an example of a successful green energy project in South Africa. The company produces green energy through biogas. (Bio2watt, 2016) Green Cape is a non-profit organisation, which helps push the technological frontier by engaging with businesses, investors, government and academia on ways to promote a greener economy, and help acting as the middleman between ideas and implementation. They provide information for foreign investors to understand the local market, help inventors source funding and aid the government with developing standards, policies and regulations. (Green Cape, 2020) Wonderbag is a company that provides a cooking aid. The 'Wonderbag' is placed around a pot to prevent rapid heat loss after removing it from a heat source. The company states that in one family, in one year's time, the product reduces the fuel needed for cooking by 70%, mitigates 2 tons of carbon emissions reduces. This product is aimed at poor households that cook over open flame fires, usually fuel by wood, charcoal or other dirty fuels. (Wonderbag, 2020) The move towards an energy supply mix that contains a bigger share of non-traditional sources of energy entails risks that might slow down the transition process.

Risk

The main risks associated with moving towards non-traditional sources of energy include technical, financial, social and environmental.

1. Technical Risks

The IRP has now possibly overestimated the demand for electricity over the next few years due to the unexpected decrease of 7.2% in economic growth caused by COVID 19 (National Treasury, 2020). Currently, the uncertainty looms of how fast the economy will recover which impacts the load at which electricity will be used, as discussed in Section 1.2, economic growth and energy consumption are still linked. Also contributing to technical risk is the deteriorating generation plants. A large number of Eskom's power plants are ageing and badly designed therefore face a higher risk of breakdowns which leads to increasing maintenance cost. (Eskom, 2019).

2. Financial Risks

Eskom is facing a debt of R 450 billion, including financial arrears from municipalities (Research and Markets, 2020). By the end of 2019 municipality arrears was R19.9 billion. The entity is facing political risks as credit rating agencies have downgraded the entity's bonds from Baaa3 to Ba1. The main reason why Moody's downgraded Eskom bonds is due to the irrevocable guarantee that the South African government will keep bailing out the entity (Moody's, 2020). Furthermore. Liquidity risk is a significant possibility for Eskom. This risk occurs when revenue shortfalls occur (IRENA, 2016). Eskom had a revenue shortfall of R102 billion in 2019 (Eskom, 2019). Eskom is also struggling with procuring new investments. Earlier this year, South Africa was downgraded to junk status. This has increased the cost of borrowing for the government. A tax revenue shortfall of R304.1 for 2020 is expected (National Treasury, 2020). This leaves very little space to bail out Eskom as other public entities are also in need of government bailouts. Eskom's ability to borrow further is limited by the current global volatility of markets (National Treasury, 2020). This means the entity has insufficient funds to fulfil debt servicing requirements. The entity is also experiencing lower sales due to a decrease in demand for energy, not just because of lower economic growth and COVID 19, but due to consumers using alternative energy sources (Eskom, 2019).

3. Social Risks

For over 3 years, Eskom has been having an ongoing battle with unions over a wage agreement. These industrial relations challenges cause uncertainty in the entity's operations as well. The entity is also facing restructuring of the firm causing uncertainty for its employees' job security, which is what is causing tension with unions. Basic infrastructure such as electricity, water and sanitation are lacking in the rural areas of South Africa, since these settlements may be informal or illegal, or because of the affordability of these amenities (Mimmi & Ecer, 2010). The low access to energy has resulted in 'energy theft' consisting of illegal connections to municipal grids. These connections overload the system resulting in power connection failures such that no-one in the area has access to electricity and causes fires and electrocutions resulting in injury and death (Eskom, 2019). Transport used has a social impact. This also poses a risk when developing additional capacity, as these stakeholders have to be engaged with, which is a timely process.

4. Environmental Risks

Eskom has experienced postponements of applications for minimum admission standards. This postponement causes delays in their station meeting emission requirements (Es-



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kom, 2019). Furthermore, the entity is behind on the modifications on their powerlines to prevent harmful bird collisions. At stations that use water to generate power, the poor management of water usage has occurred causing excessive usage of water (Eskom, 2019).

Scenarios

Quality scenario analysis of energy delivery in South Africa.

Based on the overview of current state of affairs for energy delivery in South Africa, this section will look at three scenarios, firstly a baseline, that considers the current policy directions as outlined in the NDP, REIPPPP and the State of the Nations Address delivered by President Ramaphosa in February 2020. Secondly a positive scenario, which considers technological advancements at a quicker pace than the baseline, and lastly a negative scenario, which is the opposite.

Negative

Attracting new investment from the REIPPPP to refinance power plants might not come to fruition, as Eskom's annual debt has been increasing and municipal arrears increasing, the entity is facing stagnated development in technology as well as with technological transfers. Section 3.2 pointed out that Eskom is finding it hard to attract investors with their current credit rating. This would not change with a new initiative, especially considering; it is expensive to borrow for the entity and the government doesn't have the necessary funds to bail them out completely. With increasing costs and decreasing revenues it is hard to see where the entity will procure the money to move from traditional energy resources to non-traditional energy resources. As Onyeji et al. (2012) mentioned, developing countries often need investment to finance new projects, however, this might not happen. If there is a shortfall in the capacity procured by REIPPPP, then it would force Eskom to postpone decommissioning of old power plants. This will increase their maintenance costs, which would have to be recuperated from another part of the entity, which would either be distribution or transmission. This can lead to the government failing to provide universal electricity access and unmaintained transmission and distribution lines, leading to more breakdowns of equipment, and again higher costs. Economically, this could be devastating to the country, as load shedding would continue, which would force businesses (and municipalities who can afford it) to source their own electricity. This would further compromise Eskom's financial standings, causing the collapse of the entity and potentially a country wide blackout. Even if this worst case scenario does not happen and Eskom simply has a smaller share of renewable energy sources, this would have a detrimental impact on the environment, possibly seeing South Africa reaching the top 5 of countries emitting GHG. This in turn could lead to a large scale disinvestment campaign as companies have increasing pressure to reduce emissions.

Conservative

According to the NDP 2030 (The Presidency, 2012), there is a plan of procuring at least 20 000 MW of renewable electricity by 2030, importing electricity from the region, decommissioning 11 000 MW of ageing coal-fired power stations as mentioned above and increasing investments in energy-efficiency. It is also stated that South Africa will have universal access to electricity by 2030 - the proportion of people with access to the electricity grid is expected to rise to at least 90 percent by 2030. In order to meet these requirements the country would need an additional 29 000 MW of electricity by 2030. About 10 900 MW of existing capacity is expected to be retired, the latter implies that new projects will be built of more than 40 000 MW. From this 40 000 MW capacity at least 20 000 MW of capacity should come from renewable sources. As seen in figure 3 below it will help with the increased demand for electricity and to reach the NDP goal of providing universal access to electricity to the population. The Department of Energy's IRP 2010-2030 (2019a) lays out these options in a policy-adjusted scenario that seeks a trade-off between a least-cost investment, technology risks, water-use implications, localisation and regional imports. The plan calls for 21 500 MW of new renewable energy capacity to be in place by 2030. International bidding rounds have already been held to fast-track renewable energy procurement with positive outcomes in terms of falling prices and substantial new private investment. The NDP previously stated that the country needs 20 000 MW of renewable energy source (RES) produced by REIPPPP by 2030. The REIPPPP was launched out of a need and desire to procure alternative sustainable energy resources, while simultaneously contributing to social and economic development in South Africa. The programme continues to grow, and now, more than ever, needs to play a pivotal role in the provision of power and general growth of the economy.

Positive

South Africa's private sector has been accelerating its development with regards to technological development and installation of infrastructure in renewable energy sources. Currently South Africa has 93 Renewable energy projects in the private sector. Twenty six of these projects are either busy with construction or awaiting construction while the rest is operational. (Energyblog, 2020). Some companies have made some significant progress with RES and are now listed on the JSE for trading. On the African Continent AEP Energy Africa is making leeway in their goal to own and operate clean energy facilities. (AEP Energy Africa, 2017). More companies are now starting to invest in renewable energy projects such as Green cape and Hulisani. Hulisani is committed to socio economic development in areas where they are operating. Furthermore they want to ensure that the project they take on ensures returns in the long run which are also sustainable (Hulisani, 2020). Government made a bid with REIPPPP for refinancing of power plants. REIPPPP can buy existing power plants or buy shares in plants. This may lower the risk profile and decrease the current tariffs. It is also seen to decrease the risk associated with RES for REIPPPP. This gives the REIPPPP a step in the door to influence how energy can be produced in the future and provide them with a bigger share in the market of producing energy (Green Cape, 2020). With private companies developing so fast to install capacity, the IPP goals might be reached long before the 2030 goal.

Strategies to be taken into consideration:

Given that the baseline scenario was based on policies already drafted and accepted, the only recommendation is to ensure that a just transition to cleaner electricity does occur. It is important that workers that would lose their jobs due to the smaller share of coal fired power stations in the electricity mix, be reskilled to be employable in other sectors.

The positive scenario is the "best" scenario from an environmental perspective, however, the problems that could occur are important to address, as they would have economy-wide impacts. The South African government should maintain Eskom's financial sustainability, as any further deterioration would result in devastating ripples through the economy's financial system (Yelland, 2019). The biggest discussion around this would be around how the debt will be split between the three new entities. Another option to ensure the viability of Eskom could be to convert decommissioned power stations to waste incineration plants that can produce electricity and reduce waste. The negative scenario would require the most government intervention, not only to prevent the worst case scenario outlined, but to ensure that the country can move to the baseline scenario. Policies would be required to address the almost certain continued load shedding, which would obstruct economic growth. The most important intervention required would be to ensure the maintenance on the transmission and distribution network. Companies should be allowed to source their own electricity from IPP's to not disincentivise investment in the country due to higher emissions. Prosumers can also be advocated for, as this would help stabilise the energy supply, while encouraging spending from higher income households. The latter would help reduce the negative economic impact.

Table 2: Sectoral energy demand
Source: Author's calculations

ENERGY DEMAND (%)	SECTOR	ENERGY SOURCE				
		ELECTRICITY	COAL	PETROLEUM	GAS	RENEWABLES
47	Industrial	29(14)	23 (11)	7(3)	11 (5)	30(14)
8	Commerce and Public services	57(4.6)	7(0.6)	35(2.8)	0.5(0)	
6	Agriculture	13 (0.8)	1 (0.1)	86(5.2)		
27	Transport	2(0.5)	0.01(0)	98(26.5)		
8	Residential	75(6)	7 (0.6)	5(0.4)		12(1)
96	Total Demand	25.9	12.3	37.9	5	15

3 Traditional hydrocarbon energy within a sustainable development: current consumption patterns, the prospective, the search for new solutions and technologies

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Current state

Historically, energy has been the pivot of economic development of most countries all over the world and this trend persists. It has brought great economic prosperity to South Africa and has been the centre for social and overall human development. It has lent security to the country by harnessing energy to provide heat and power for industry, transportation, and households, despite political problems. Unfortunately, due to the way energy is sourced, produced and used, South Africa currently has a substantial energy deficit, which is a major obstacle to its growth and development.

Hydrocarbons i.e. crude oil, natural gas, coal and other sources, are naturally occurring compounds which are highly combustible and produce heat, water and carbon dioxide. Coal is the mainstay of the South African energy system, meeting around 72% of primary energy demand. Currently, 33% of the coal mined in South Africa is exported. Of the total domestic supply, 55% is transformed into electricity, 20% is used directly and the remainder is used for synfuels production. South Africa's transport system depends on petroleum fuels for almost all of its energy needs, about 72% liquid fuels derived from crude oil, 23% from coal and 5% from natural gas (Winkler et al. 2005, 2007, Davidson et al. 2006, Krupa et al. 2011) . Most of the crude oil refined to liquid fuels in South Africa is exported. The high import dependency is expected to phase out over the next 40 years due to an increase demand in other chemicals (Overy 2017, Ahuja and Tatsutan 2009). Electricity supplies 28% of the national TFC. Of the total supply, Eskom supplies 95% of the demand, with the remainder coming from small inputs from local authorities. About 60

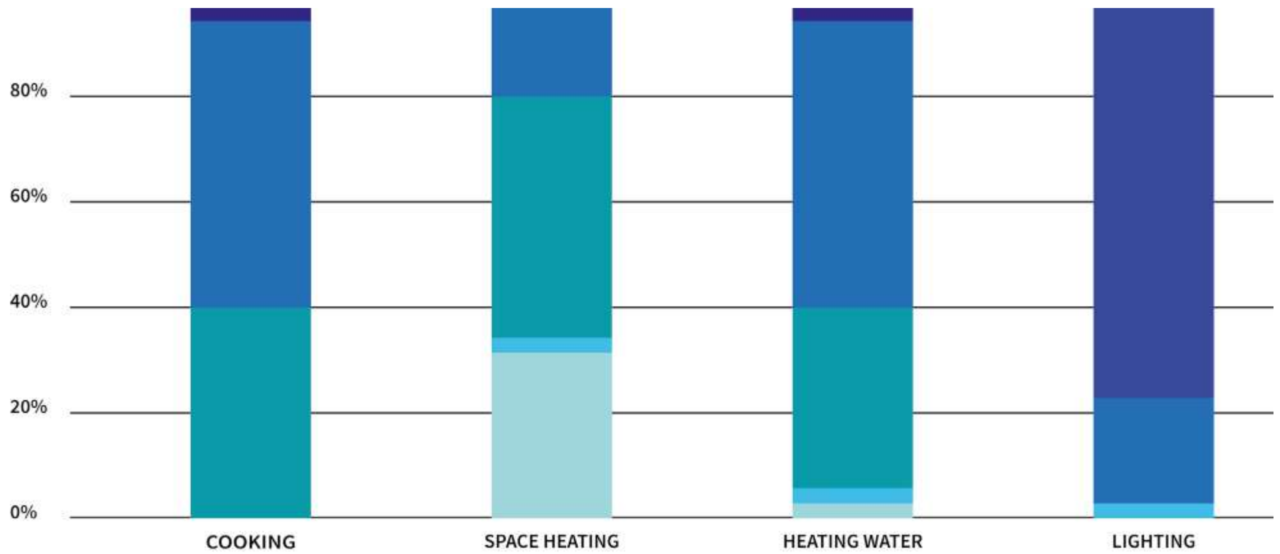

Figure 1: Energy basic needs and sources in these remote areas
Source: Rahner 2019

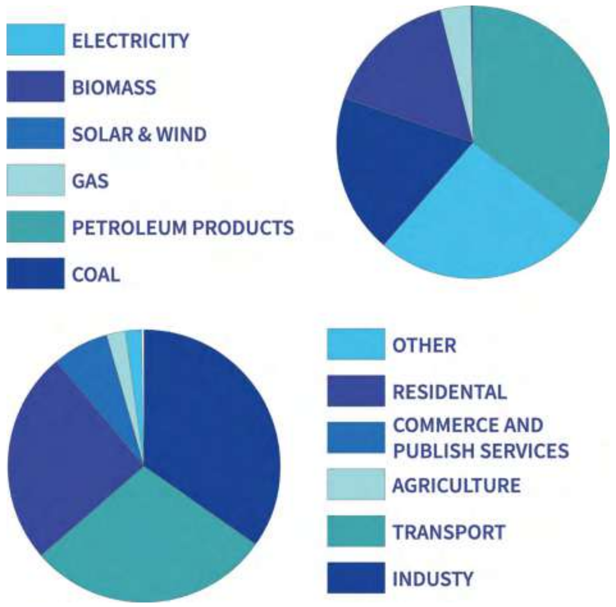

Figure 2: Different energy sources available in South Africa and the sector in which they are used
Source: Self elaboration

percent of South African rural households have no access to electricity (Figure 1), and over 40 percent of the households that are connected are considered energy poor, spending upward of 20 percent of their monthly income on power (Winkler et al. 2005, Davidson et al. 2006). There is a severe lack of access to clean, non-polluting cooking facilities as they continue to rely on traditional biomass, mainly fuelwood and charcoal, for cooking. Currently, there is an imbalance in the generation and supply demand from this energy sector, which results in load shedding and blackouts. The frequent power cuts result in losses estimated at 6 percent of turnover for large firms and as much as 16 percent for informal sector businesses (Overy 2017). Figure 2 shows the different energy sources available in South Africa and the sector in which they are used.

Impact of traditional hydrocarbon energy

Economic Impact

The South African economy is dependent fossil fuel, mainly crude oil for the transportation industry, coal for electricity and other renewable sources such as biomass for electricity and fuels. Crude oil and natural gas are imported by South Africa and are susceptible to price fluctuations and the remaining reserves, as it is a non-renewable resource. Natural gas consumption in South Africa exceed production (See Figure 3) thus reflecting on the huge dependency in imports for energy generation. Oil prices change quickly in response to news cycles, policy changes, and fluctuations in the world's markets. Oil prices have experienced a downward journey, since 2014, falling from highs of around $105 per barrel. In February and March of 2020, crude prices accelerated their decline in reaction to the coronavirus pandemic and an expected sharp drop in demand for oil (Ratshomo and Nembahe 2017). The fuel price in South Africa is composed of several price elements and these can be divided into international and domestic elements. South Africa's fuel prices are heavily influenced by trends in the global oil market, the current petrol price at R15.17/L and diesel at R13.52/L.

The cost of producing electricity increases due to the high SA demand. The eight per cent yearly increase granted by the National Energy Regulator of South Africa means that with current prices at 89.13c/kWh. This could result in the mid to high income households turning to alternative solutions, such as small rooftop solar photovoltaic systems, which in turn will impact negatively on municipal revenue flow. Trollip et al. (2012) suggested that the expected implementation of own-generation photovoltaic could lead to revenue losses of up to 25 per cent. Municipalities generate a significant amount of their overall revenue from electricity sales, which is used to subsidize a range of other important municipal services. In addition, revenue is used to cross subsidize losses from providing electricity to poor households which are not covered by the equitable share grant received from treasury.

Political Impact

The renewable energy transition is fundamentally a political struggle, efforts to shift from fossil fuels and decarbonize societies will not prove effective without confronting and destabilizing dominant systems of energy power. The government face complex choices as it pursues its objectives of diversifying and reducing the environmental impact, incentives for low carbon investment and revenue losses. Provision of modern fuels for the commercial and industrial sectors will promote economic competitiveness and future prosperity.

Socio-cultural impact

South Africa will require a substantial increase in the supply of modern affordable services to every South African, while maintaining the environmental integrity and social cohesiveness of the country. To achieve sustainable development will require replacing firewood and charcoal with more modern energy sources such as the use of solar water heaters for how water and introducing technological innovations to improve the efficiency and environmental problems associated with coal and kerosene. Sustainable development, the public transport system will need to be greatly enhanced in both services and technologies because people now have access to adequate transport.

Environmental impact

Coal-based energy accelerates climate change due to the accrual of greenhouse gases in the atmosphere. A rising concentration of carbon dioxide in the atmosphere is directly linked to the combustion of fossil fuels and related climate change impact, such as natural disasters, which poses a serious threat to humanity and the environment. The effects of climate change on hydroelectric energy generation have already been witnessed with the recent droughts across the region that affected generation capacity in many countries, resulting in blackouts and load shedding. Promoting sustainable development and combating climate change have become integral aspects of energy planning and policy making. The increased temperatures and irradiance resulting from climate change offer opportunities to harness South Africa's abundant renewable energy resources, which includes solar power (CSP), photovoltaics (PV), wind energy, geothermal energy and bioenergy to improve the standard of living. Methane emissions are the second-largest cause of global warming today. Methane emissions come from a range of anthropogenic and natural sources; within the energy sector, from oil, natural gas, coal and bioenergy. While methane tends to receive less attention than CO2, reducing methane emissions will be critical to avoid the worst effects of climate change. Emissions remain high despite initial industry-led initiatives, government policies and regulations, as implementing abatement options quickly and at scale remains a challenge. Policies will be critical to achieve the 75% emissions reduction by 2035 demonstrated in the SDS.

Technology

Massive improvements in the efficiency of technologies and devices have facilitated continuing reductions in the quantity of energy required to produce a unit of goods and services in industrialized economies. Fossil fuel-based technology remains a serious threat to the energy industry and to the global population. Depletion of fossil fuels and stringent environmental regulations has propelled the world into harnessing renewable energy resources. South Africa needs to be demand driven, rather than through supply side interests, drivers and pressures related to the emergence of less carbon intensive. With the potential to produce energy from biomass, wind, solar, small-scale hydro, waste and ocean activity, South Africa is very gifted regarding renewable energy sources, though these resources remain largely unexploited. Renewable energy can be harnessed in bulk or on micro scale, and as stand-alone systems or in combination with traditional power generation. South Africa has particularly high solar power potential, however, it is limited by operational pressures on the environment, which include; the use of land for large solar panel arrays (see Figure 3), which could preclude it from being used for other productive functions and create aesthetically intrusive surfaces; Large solar panel facilities could bring about changes in environmental infrastructure, wetlands, ecosystems and habitats and their supportive infrastructure, are located in marginal or sensitive areas. Nevertheless, photovoltaic systems and solar water heaters has the potential to co-use of land, they can be placed on other structures and thus does not require any additional land. Opportunity costs of the ecological and aesthetic impact of wind turbines limit their use and their manufacturing requires large amounts of energy and raw materials. Commercial applications of biomass as fuel are found in the sugar industry where bagasse is used as feedstock for coal-fired boilers. The sugar refineries where the bagasse is used are considered to have an installed generation capacity of about 245 MW equivalent (Davison et al. 2006). Energy from biomass can also be extracted through processing that converts organic materials into flammable gasses, either through natural decomposition processes or by artificial refining. Natural decomposition that takes place in the absence of oxygen generates methane and other gases, which can be captured and used as fuel. The gases can be cultured in biogas digesters or tapped from larger sources such as waste disposal facilities (landfills). Biomass also holds potential as a liquid fuel. Carbohydrate rich crops such as sugarcane, sunflowers, maize, canola, soya beans or sugar beet, or even waste vegetable oils, can be refined into biodiesel or bioethanol. They are therefore an important consideration as a transitional fuel used to temper the current carbon intense fuel use. Fear that biofuel crops will supplant food crops, or that it merely extends the dependence on fossil fuels without significant change to the amount of energy that we consume raise concerns in the use of biofuels (Wikler et al. 2007).

2035 Development

A projection of the current trends suggests that overall energy use will continue to grow strongly doubling or even tripling by 2035. More troubling from a sustainability perspective is that fossil fuel consumption could grow nearly as strongly as total energy consumption. This would mean that fossil fuels would continue to dominate the overall supply mix, again assuming a continuation of current business-as-usual trends. Renewable energy has the potential to power South Africa's transformation. These renewable energy resources consist of concentrated solar power (CSP), photovoltaics (PV), wind energy, geothermal energy and bioenergy. Development of renewable energy systems for household, farm and industrial use will reduce biomass utilisation for energy, reduce crude oil import dependency, help improve productivity, reduce carbon emissions, and environmental concerns. Figure 5 shows a projection of Sub-Saharan primary electricity generation in 2050 which draws a blueprint for the transition to fossil-free electricity, lower energy costs, better health and environment. Renewable energy can be advantageous for remote areas that not economically feasible for grid electricity supply. The sustainable production and management of solar power and non-grid electrification systems largely targeted at rural communities could benefit South Africa's economy system. At present, South Africa has limited renewable energy sources that can be exploited commercially, but the cost of renewable energy is expected to continue to decline as the technologies mature. The National Development Plan 2030, that was adopted in 2013 as the blueprint for future economic and socio-economic development strategies for the country and it envisages that by 2030 South Africa will have an energy sector that promotes economic growth and development through adequate investment in energy infrastructure. The plan also envisages that by 2030 South Africa will have an adequate supply of electricity and liquid fuels to ensure that economic activity and welfare are not disrupted.

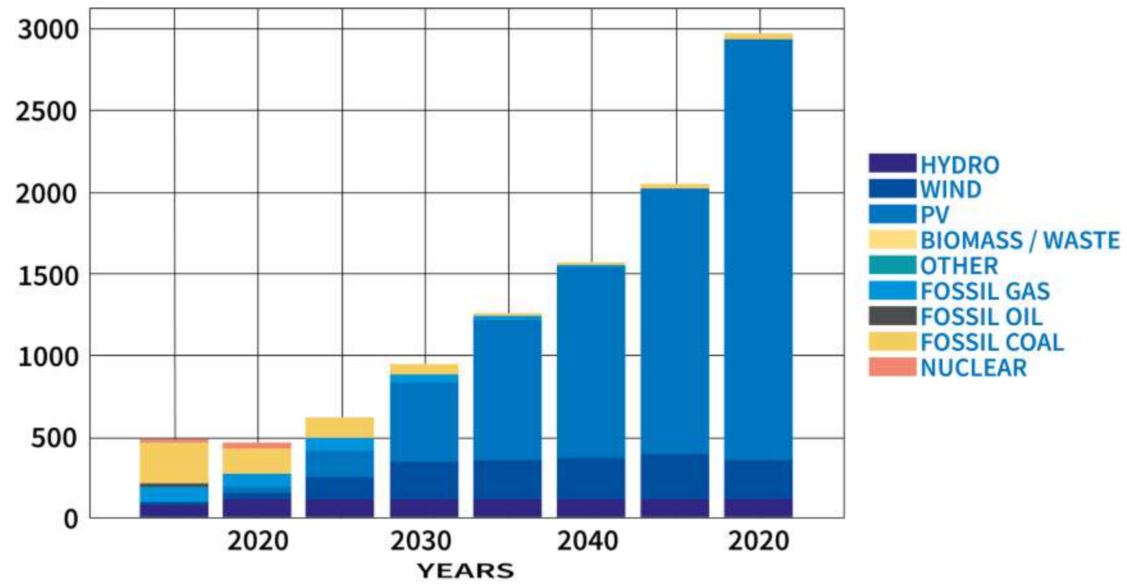

Figure 2: Consumption forecast by the source of energy in South Africa
Source: Self elaboration

4 Nuclear Stations for diversification of energy balance, reduction of the ecology load due to thermal generation in the densely populated countries with sustainable growth of demand on electric power

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Introduction

Scientists have historically made predictions on the inevitable possibilities of rapid population growth due to advancements made in the security of food and energy that would exponentially increase the demand of natural resources (Ehrlich, 1968). The relationship between global increases in population and rising energy demand has therefore been long established (Ehrlich & Ehrlich, 2009).

South Africa's increasing energy needs as a result of the expanding population, industry development and escalating climate change demands have given rise to discussions around cleaner sources of energy. With a population of 57 million people, the country has an electricity production capacity of 51 309 MW and demand averages of 29 000 MW. Peak demand is approximately 34.481 MW and is projected to increase to 350 000 GHW by 2030 together with the projected population increase to 67 million people (Eskom, 2016). With 80% of the country's carbon emissions being generated by the energy sector, the transition towards a low carbon future requires key actions to be taken regarding the energy mix to ensure sustainable energy supply as well as achievement of Paris Agreement commitments (DMRE, 2019).

The country's energy mix is primarily reliant on coal as an energy source with a 69% contribution, followed by 14% from crude oil. Renewable energy currently contributes 11%, gas 3%, nuclear 3%, hydro 1% (DOE, 2019). South Africa has embraced the principle of the energy diversification provision in the IRP 2019 (Integrated Resource Plan 2019) in order to ensure security of energy supply from the year 2030 and beyond. As a result, renewable energy was vigorously pursued amidst challenges of consistent energy supply which cost the South African economy up to $6.8 billion. The Renewable Energy Independent Power Producers Procurement Programme (REI4P) was established to include diversity in the energy mix by providing generation capacity of 17.8 giga-watts (GW) from renewable energy sources (DOE, 2019).

Due to the reality of the country's ageing coal-fired power stations that are soon to reach end of operational life, nuclear energy was receiving a lot of attention from policymakers. The controversial energy source was identified as a cleaner energy source in comparison to fossil fuels because significant volumes of energy could be generated from small fuel inputs resulting in negligible greenhouse gas emissions. Unlike renewable energy, nuclear energy was able to provide baseload capacity for consistent energy supply at a fixed frequency to match grid demand that could potentially replace capacity lost from ageing coal power stations (Taebi, 2012). In trying to reduce the country's reliance on fossil fuel (coal), "… the IRP 2019 provides for extension of the design life of Koeberg Nuclear Power Plant as well as additional new nuclear capacity in the future…" (DOE, 2019).

There are many reasons why countries consider adding nuclear energy to national grids or increasing grid share. The reasons range from supporting total socio-economic development, promoting security by expanding reliable and independent sources of supply, to environmental considerations such as reducing energy related greenhouse gases (GHGs) and other pollutants that cause damage at local and regional scales. The significance of these factors differs across countries based on national circumstances such as climate, geography, economic structure, spatial locations, the nature and magnitude of energy intensive sectors, the concentration of population and economic activities determining the energy demand density (IAEA, 2015). The stage of economic development of a country can significantly influence the amounts and types of energy required to stimulate economic growth. At the early stages of development, priority is typically to supply extremely large quantities of cheap energy forms to fuel growth (Kahouli, 2018). South Africa's balanced economic growth that is focused on industrialization, together with the electrification programme to take power into rural areas, has seen a sharp increase in the demand for electricity, which is expected to be twice the current levels by 2030 and beyond (Baruah & Enweremadu, 2019).

According to Ateba, et al. (2019), South Africa's energy supply was deficient in policy implementation and strategic management. In the Medium-Term Budget Policy Statement (October 2019), the country's fiscal deficit was fast approaching 6.5% of gross domestic product (GDP) owing to the effective bankruptcy of Eskom, the country's public electricity utility and other State-Owned Enterprises (SOEs). Without immediate intervention, Eskom's inability to meet the country's baseload requirements could take the country into a recession. The global call for a ''just transition'' was a clarion call for the country to consider the energy sources that were represented in the energy mix and the subsequent contribution to the sustainable development goals and the global climate change agenda.

The purpose of this paper is therefore to consider nuclear stations for diversification of energy balance, reduction of the ecology load due to thermal generation in the densely populated countries with sustainable growth of demand on electric power.

Nuclear Energy Stations for Diversification of Energy Balance

The plight of unreliable power supply caused by under-investment, lack of maintenance, ageing power stations and a general shortage of generating capacity, have had repercussions on the South African economy. This has led to a number of investments in the energy sector through a combination of many sources of energy, including renewables and nuclear power (IEA, 2019).

The National Development Plan 2030 forecasts that adequate investment in energy infrastructure will ultimately promote economic growth and development. It is highlighted that primary energy demand and GDP in a number of stated policies as well as that of the Africa case. The policy aims to achieve the goal of enabling electricity access for 100% of the population and 93% with access to clean cooking by 2040 (IEA, 2019).

The South African government has made a commitment to build 1 GW of new nuclear capacity by 2030 and to extend the operating lifetime of the country's first Nuclear Power Plant (NPP); Koeberg, constructed in the 1980s by 20 years. A roadmap for the procurement of 2500 MWe of new nuclear capacity was therefore being determined in 2020 (WNO, 2020).

Nuclear power can contribute to South Africa's energy security by providing diversity in electricity and primary energy supply. For countries lacking their own domestic energy resources, reliance on nuclear power can reduce import dependence and enhance supply security. Since the inception of Koeberg power plant, South Africa has established a commendable record of safely handling nuclear power devoid of nuclear accidents while harmlessly handling nuclear waste. Nuclear technology is not only a cleaner energy source in comparison to fossil fuels but is suitable for coastal areas in South Africa where cooling water is abundant or in some cases require desalination (Rennkamp & Bhuyan, 2016). The department of Energy has therefore proposed that coal contributes only 46% to the energy mix by 2030, renewable energy 26%, nuclear 13%, open cycle turbines 8%, pumped storage 3% while combined cycle gas turbines contributed 3% (IEA, 2019). This however requires certain considerations to be made.

Koeberg Nuclear Power Station , Source: AFP/Getty Images

2.1 Political considerations of Nuclear Energy

South Africa's role in Africa and growing role in global politics has necessitated the diversification of the energy mix in order to meet the sustainable development goal of providing clean and affordable energy to all through sustainable supply as well as meeting Paris Agreement commitments. The inclusion of nuclear power in the country's energy mix is a political decision that may leapfrog the country to an African trailblazer and one of the global leaders in nuclear capabilities. The decision will also ensure economic growth in the country as a result of sustainable energy supply and will stimulate foreign direct investment (FDI) in the energy sector with investors prowling for opportunities to invest in cleaner energy solutions (Williams, 2015). The country's history has however proven that the execution of the nuclear agenda requires political will as well as transparency and public engagement.

The studies of Rennkamp & Bhuyan (2016), argue that government's proposal to procure an additional 9.6 GW of nuclear energy through the vehicle of the nuclear build programme has nothing to do with the electrification agenda. The study highlights that the main aim of the nuclear build proposal was to satisfy political factors such as the coalition agenda of nuclear energy endorsers that will benefit supporters through financial prospects. Fig (2018) states that government resilience in pursuing nuclear power is linked to status and prestige. South Africa's political administrations have the tall order of ensuring the positive externalities of nuclear power without satisfying the scepticism of opponents.

2.2 Economic and technological considerations of Nuclear Energy

The case for nuclear often seems to lose lustre when the capital costs of new nuclear builds are presented. The installed costs of nuclear power stations were significantly higher than alternative technologies because of the specific safety systems that were part of the build (Fig, 2018). Rothwell (2018) further deliberated that the costs of nuclear are determined by the phenomenal construction costs ($/kw) often represented as overnight costs, cost of capital; which may be high for South Africa in light of credit ratings, the load factor, decommissioning costs, costs of fuel, site costs, high insurance costs, operating costs and costs of externalities. Agar & Locatelli (2020) however claims that the lifecycle costs of nuclear power plants make nuclear power an affordable form of electricity because as soon as the construction costs are amortised, NPPs can provide the lowest cost electricity among all other types of energy sources on the grid. With a plant life that is upwards of 60 years, NPPs total cost ownership seem more economical than the costs of coal fired power stations. At a micro-level, supply of nuclear needs to be able to meet demand without either variables providing an imbalance (James, 2017); (Agar & Locatelli, 2020). The country does however need to consider the state of the economy, immediate energy needs and salient procurement conditions as well total cost of ownership for NPPs.

2.3 Socio-cultural and environmental considerations of Nuclear Energy

Increases in the South African middleclass population and the standard of living, urbanisation and technological advancements are contributors to the country's growing energy needs. Urban populations are projected to increase from 57% to 67% of the total population by 2021. The creation of sustainable economic growth will strengthen the pillars of education, employment and standard of living for all South Africans. (Eskom, 2016).

Nuclear power could provide a sustainable solution to South Africa's energy woes. According to Nuclear Energy institute (NEI), one new nuclear plant creates 400 to 700 permanent jobs and this is comparable to just 90 jobs for a coal plant. (NEI, 2020). Nuclear energy is also capable of generating baseload electricity with insignificant carbon outputs from reactors. This is because, unlike fossil fuels like coal that produce energy through the process of chemical burning, nuclear makes use of a fission process using uranium that is abundantly available in the country (Rhodes, 2018). In South Africa, Koeberg was able to provide 1830 MW of baseload power; operating 24 hours a day to provide minimum electricity requirements (Eskom, 2016). Although coal fired power stations with a total output of 34 952 MW were able to offer baseload power that was reliable and affordable to the South African citizenry, the environmental costs far outweighed the benefits. In addition, nuclear reactors have the capacity to produce energy that is 3.7 million times that of coal equivalent. This is because NPPs perform at more advanced capacity factors when compared to coal and renewable energy sources like solar and wind (Dawson, 2016). Koeberg's capacity factor is around 84%, wind and solar farms, between 20% and 45% while most coal power stations average between 65% and 75%. Eskom's declining energy availability factor (EAF) is as a direct result of ageing coal power stations and lack of maintenance (Wright & Calitz, 2020). The majority of coal fired power stations have already exceeded the mid-life of 25 years and with many fast approaching the plant retirement age of 50 years (DMRE, 2019). As coal plants become decommissioned, baseload capacity will be further compromised, strengthening the case for NPPs.

Renewable energy, although highly recommended for mitigating global warming effects, cannot provide baseload power due to the intermittent nature unless paired with energy storage systems; the costs of which were undesirable. From a futuristic "perspective" the production of nuclear can also be viewed as strategic because nuclear production also produces hydrogen, the subject of many green development studies and future technologies (Hart, 2019).

2.4 Regulatory considerations of Nuclear Energy

South Africa has legislation which, amongst other things is aimed at regulating nuclear activities. The National Nuclear Regulator Act (NNR Act) stipulates objects that include safety standards aimed at the protection of persons, property and the environment against nuclear damage. In addition, to exercise regulatory control related to safety as well as to exercise regulatory control of actions through the granting of authorisation (NNR, 2018). In the Integrated Resource Plan 2019 (IRP 2019), the government recognised the need to increase the role of nuclear energy as part of the process of diversifying the country's primary energy sources to ensure energy security. The increased inclusion of nuclear power stations will assist the country to reduce over reliance on coal, with a long-term vision for South Africa to become globally competitive in the use of innovative technology for the design, manufacture and deployment of state-of-the-art nuclear systems, power reactors, and nuclear fuel-cycle systems (DMRE, 2019).

Prior to installing a nuclear power station, an application for a licence is required. Furthermore, an environmental authorisation in terms of the National Environment Management Act will also be required. These will ensure that hazardous effects of nuclear energy on communities and the ecosystem have been evaluated and that there was legal compliance. In building the case of increasing the share of nuclear energy in South Africa's energy mix, current global trends also need to be observed (Gov, 2019).

3. Current Trends

The likelihood for new nuclear power projects remains highly uncertain in most countries. Some countries have limited investment in new projects and plans are underway to phase out existing capacity, while others forecast a relatively long-term role for nuclear power in the energy mix. The countries that fall within the second category account for most of the global electricity demand and CO2 emissions, which still suggests potential for nuclear power to significantly contribute to the transition to a clean energy future (WNA, 2019).

There is therefore a global drive towards increasing nuclear power capacity and the share of nuclear energy in the energy mix to ensure sustainable energy supply with coal plant retirement. There are 440 nuclear reactors worldwide that provide approximately 10% of global electricity. There are also plans for the construction of over 400 more reactors that are either planned or proposed. Most nuclear capacity is being built in densely populated regions such as Asia and Russia in order to meet escalating energy demand. Several emerging nuclear countries have also made public plans to build nuclear reactors including South Africa and Algeria. These plans come with the signing of intergovernmental agreements that declare nuclear energy development for peaceful purposes. The capabilities required to build new NPPs are usually highly technical and specialised and often sourced from countries that have built these capabilities including technologies (WNA, 2019).

The IEA (2020) also indicates trends in increasing research and development and exploration of new knowledge in nuclear technologies. This trend is seen in both developed and developing countries and spans from basic to applied research including training of local citizens.

Governance is also high on the list of trends in the nuclear sector. Due to the amount of capital and power exchanges that occur during nuclear deals, as well as public scepticism of rent-seeking and corruption, good governance has proven to be the golden thread (Rublee & Cohen, 2018).

Another trend in nuclear energy stations is the upgrading of current nuclear capacity. Countries such as USA and Spain have used this cost effective method to increase generating capacity (WNA, 2019).

Nuclear power plants have an operating lifetime of 25 - 40 years but worldwide engineering assessments are certifying the extension of life to a minimum of 60 years. In South Africa, the lifespan of Koeberg Power station has been extended from 40 years to 60 years (WNA, 2019).

Leading Nuclear Companies

4.1 Lesedi Nuclear Services

Lesedi Nuclear Services, is an engineering, maintenance and project management company that is based in South Africa. This company was partly owned by Areva and boasts several portfolios including power generation that is inclusive of nuclear power. The company offers nuclear services across the globe and has a particular focus on exporting critical skills while providing training and services worldwide (Lesedins, 2020).

Lesedi was involved in Koeberg's plant life extension by providing modifications to equipment. As witnessed in the trends, the company sources capabilities from foreign countries like Korea and China to supplement company efforts (Lesedins, 2020).

4.2 Rosatom State Nuclear Energy Corporation

Rosatom is a specialist in clean energy solutions in nuclear energy value chains. The company that has headquarters in Moscow, has specialities in nuclear designs, uranium mining, decommissioning of NPPs, transportation and disposal of nuclear waste and operation of NPPs (Rosatom, 2020).

In Africa, the company provides uranium products to Koeberg nuclear power plant, uranium exploration and mining and facilitation of nuclear industry development for countries that plan to include nuclear in the energy mix as in the case of Nigeria. The company also plays a key role in education, research and development in the field of nuclear science while providing training to various African countries like South Africa on nuclear energy. The company also bears witness to several intergovernmental agreements between Russia and other African countries to commit to the use of nuclear energy for peaceful purposes. Rosatom is also instrumental in promoting Russian nuclear technologies across Africa and ensuring strict governance in all nuclear dealings (Rosatom, 2020).

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4.3 NTP Radioisotopes SOC Ltd (NTP)

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4.4 EDF

EDF energy is a global nuclear operator that has strengths in engineering, off-grid electricity, thermal energy, gas, renewable energies, transmission and distribution (EDF, 2020).

In South Africa, this global company has been instrumental in the commissioning of coal fired power plants after shutdowns. The company has also played a major role in establishing the Eskom Power Plant Engineering Institute (EPPI) that is mandated with training engineers to develop skills to enable operation and maintenance of power plants. The company was also instrumental in the construction of Koeberg and are providing maintenance, training, operational know-how and engineering at the nuclear power plant (EDF, 2020).

4.5 Tractebel Engie

Tractebel Engie is a global company that helps players in the nuclear field to build nuclear power plants, decommission existing plants and assist in the operations of the plants (Tractabel-Engie, 2020).

Risks of Nuclear Energy Stations

Nuclear energy has over the years been the subject of many contentious debates centred on positive externalities of competitive energy pricing, sustainable supply and reduced emissions; mitigating global warming impacts. Critics however, have highlighted negative externalities such as the impact of nuclear waste, political tensions, radiation impacts, nuclear accidents and the dangers of nuclear weapon inventions (Ho & Kristiansen, 2019). A PESTEL analysis is therefore required to outline the risks of nuclear energy or nuclear power plants in the South African context.

5.1 Political Risks

South Africa's roadmap for incorporating Nuclear Energy into the country's energy mix has been marred with several abandonments and accusations of non-transparency and lack of accountability. The lack of consistency in the resolve to implement the nuclear agenda across successive political administrations has highlighted the political divide in endorsing the new build of NPPs, causing implementation delays. The nuclear deal was also concealed and inter-governmental agreements with the United States of America, Korea and Russia, unconstitutionally concluded without public consultation; curtailing democracy (Fig, 2018). The secrecy in conducting nuclear deals raised public concerns of suspected governance breaches, unethical conduct, corruption and rent-seeking (Warmback, 2019). Changes in the office of the Energy Minister have also indicated a level of uncertainty and deeper political agendas relating to the nuclear deal with three (3) changes of energy ministers in a single fiscal year (2017). The draft 2018 IRP also did not have nuclear build considerations and yet in the finalised 2019 IRP, nuclear build was part of the proposed capital projects. The general lack of public trust as a result of how the nuclear agenda was actioned and the building of a NPP could lack public support and constrain development (Agyekum, Ansah & Afornu, 2020).

The risk of intergovernmental agreements with other countries translating into South Africa depending on those countries, specifically Russia for energy supply and nuclear safety raise concerns on South Africa's independence and sovereignty against being a captured state. The relationship with Russia could also implicate the country in trade restrictions and sanctions by association with Russia's oil price wars with Saudi Arabia escalating. The oil price wars may also affect Russia's insolvency in future; a risk South Africa needs to evaluate and mitigate (Warmback, 2019); (Agyekum, Ansah & Afornu, 2020).

5.2 Economic

Although Nuclear Power Plants (NPP) have been argued to have lower operating costs than coal fired power stations, the initial Capex costs are significantly higher than traditional energy sources and as a result higher interest rate sensitivity (Akyuz, 2017). Nuclear power may be unable to significantly compete with other generating technologies on cost, especially in countries that have introduced competitive wholesale markets. This is much worse in power sectors where nuclear low-carbon nature is not recognised, either through policies such as carbon pricing or wholesale market designs and mechanisms supporting investments in low-carbon technologies in general (IAEA, 2019).

The costs of a newly built NPP are increased by the end of life costs of decommissioning radioactive plants, maintenance of aged facilities as well as waste storage. The costs of the nuclear reactors that were to be supplied to the country by Russia were projected at R1 trillion, marking the nuclear build programme in South Africa as the largest in the history of the country (Warmback, 2019).

This is a grave concern for an already ailing South African economy that is riddled with high levels of debt and debt servicing costs. Due to the country's downgraded credit ratings to junk status, possible investors in the nuclear deal may require guarantees in the form of long-term power purchase agreements or loans from the government (Treasury), a request that was previously declined. This may be further exacerbated by the historical knowledge of the failed PBMR that resulted in $1.8 billion losses. The current cost overruns and time delays in the construction of Kusile and Medupi may also result in potential investors inflating costs in order to cater for projected delays (Lovins & Eberhard, 2018).

The most favourable Russian model considered for the nuclear deal could lead to economic turmoil, as the model requires increasing electricity costs to be fixed for extended periods. This may result in consumers switching from nuclear to cheaper renewable energy sources and as a result affecting Eskom revenues. The impact may result in Eskom's inconsistency or inability to repay Russia, culminating into electricity disruption that would further cripple the South African economy (Lovins & Eberhard, 2018).

The risk of constructing an NPP to the country's fiscus presents a possible increase in public debt and electricity disruption risk paired with significant economic risk.

5.3 Social

The human health aspects that are synonymous with the nuclear energy discussion because of the impacts of nuclear waste and radiation have prompted debates on the social impact of the energy resource. Civil organisations have indicated that the negative externalities of nuclear energy have detrimental effects on the mortality rate and other health aspects of communities. The presence of a NPP has also raised concerns on noise and visual disturbances on nearby communities (WNA, 2015).

The construction of a Nuclear Power Plant may not be entirely beneficial to the localisation strategy of employing local skills for the construction and subsequent management of the NPP. This is because NPPs require specialised technical capabilities and skills, which are scarce in South Africa. This poses a risk of industrial action by local communities that may not fit the employment or procurement criteria for the construction and operation of the NPP (Alam, Sarkar & Chowdhury, 2019).

South Africa has had a nuclear power station for approximately 36 years with no nuclear accidents recorded. This then assumes that public outcry on the safety of an increased nuclear share may be from lack of education and understanding on the potential benefits as well as risk mitigation strategies of nuclear energy generation; a risk that the country needs to mitigate in order to win public approval of the new nuclear build (Chung & Kim, 2018).

5.4 Technological

South Africa does not have local technological capabilities to facilitate the nuclear build and will be heavily reliant on foreign capabilities i.e. from Russia as well as foreign support for the maintenance of the technology. This is a risk to the country's public procurement policies that support local content requirements to promote local production of materials required in a capital-intensive project such as a NPP and the national drive to significantly reduce technology imports in favour of local technologies. In the Request for Information (RFI) issued for the nuclear build programme, pressurised water reactors and small modular reactors that have the capacity to deliver up to 2500 MW were required to be at experimental design stage and ready for commercialisation by 2030. The drive to localise technology development may also increase technology costs and contribute to project delays because of technological upskilling (Rennkamp & Bhuyan, 2016).

Fig (2018) also notes that the procurement of nuclear technology would put the country at a disadvantage in future when other opportunities arise in the energy sector that require capital investment.

5.5 Environmental Risks

The studies of Akyuz (2017) indicate that the impact of nuclear on future generations could have far more reaching effects with arguments that the resource may have a certain level of vulnerability towards natural disasters such as cyclones and earthquakes. Nuclear energy is also shadowed by a history of global nuclear accidents that wiped out densely populated communities in Chernobyl and Fukushima; a consideration for South African policymakers. Sarkodie & Adams (2018) cite environmental risks such as improper management of nuclear, radioactive waste disposal and outdated technologies used in plant decommissioning as risks that need to be considered when deliberating over the decision to build new nuclear capacity in a country. The impact of warm water may also increase the migrating of fish and significantly alter the ecosystem.

The arguments presented about nuclear energy been a cleaner source of energy are also challenged by Fig (2018) that claims that nuclear energy is not carbon neutral as the process of producing nuclear energy, from uranium mining, to milling, gasification and enrichment uses coal based electricity with notable emissions. Plant retirement also results in considerable amounts of nuclear waste. The risk of adding an energy source that is not carbon neutral to the energy mix is that the country may be unable to meet climate change commitments.

Agyekum, Ansah & Afornu (2020) argue that many developing countries like South Africa have a poor culture of maintaining commercial assets and infrastructure. In South Africa, this culture is evidenced in the poor maintenance of ageing coal fleet and subsequent breakdowns. The culture of poor infrastructural maintenance raises concerns of the countries readiness to integrate nuclear capacity in the energy mix because the lack of maintenance in this regard may compromise the safety of the plant resulting in catastrophic environmental outcomes.

5.6 Legal

The increase in the share of nuclear in South Africa's energy future until 2035 advocates for effective regulation of the resource to ensure public safety and governance. In integrating Nuclear Power into the countries energy mix, legal and regulatory considerations relating to pricing, externalities, contract management and transparency, governance and safety need to be made. If safety risks are not considered, the negative externalities of nuclear could result in class action lawsuits against the state and related companies (Sarkodie & Adams, 2018).

5.7 Commercial

The cost of nuclear is relatively competitive and stable. The Levelised Cost of Electricity (LCOE), which consists of the costs incurred in building, and operating a NPP divided by the plant's electricity output provide an indication of the cost per megawatt hour. In the case of NPPs, the costs over the lifetime of the assets are economic due to high plant predictability and reliability. The operating costs are much lower than the operating costs of coal and with an extended lifespan of up to 80 years, seem to be more viable. The commercial risks for Nuclear energy in South Africa is the fact that 60% of the LCOE is made up of capital costs and due to the absence of constructed reactors in the country, it may be difficult to contain these costs (WNO, 2019).

The proposed nuclear projects are closer to major infrastructure projects than most other power generation technologies. It will therefore be prudent of the government in increasing the share of nuclear energy in the energy mix, to be cognisant of additional risks such as project management risks, policy risks, project lead-times, economic lifetimes and complexity of stakeholder management issues.

6. Policy Recommendations

To retain the option of nuclear and possibly increase the nuclear portfolio, the below policy recommendations should be considered:

- The National Nuclear Regulatory Authority (NNRA) should work vigilantly and proactively enforce current regulations and encourage a strong safety culture to reduce the risk of significant operating events that can lead to extensive plant shutdowns.
- The Energy Department, in collaboration with the NNRA, should also create a new research and development program in nuclear engineering to provide the advanced tools needed to analyse the safety of reactor designs and fuels. This would allow the NNRA to analyse new reactor designs with the expectation that such an approach can lead to transparently safer and less costly projects.
- The South Africa Energy Department should fund projects that find creative solutions via regional partnerships to the nuclear waste created from reactor operation.
- South Africa should increase their funding of the IAEA and enable the agency to strengthen its existing role. The IAEA should also work with the regulatory agencies of those member countries that have extensive nuclear power programs and experience to develop global safety standards.
- Develop standards for the physical protection of fissile materials to assure the physical security of civilian nuclear fuel-cycle facilities and power reactors.
- A variety of interest groups, including regulators, the nuclear industry, experts, and nongovernmental organizations, should be consulted as part of this process.

6.1 General Recommendations

Finish outstanding Medupi and Kusile projects to regain credibility with the public and address immediate capacity needs

Institute governance reforms including transparency that will enable accountability and be enforced to avoid rent seeking and corruption

Review IRP with capacity for solar, wind and storage

Open up the market for self-generation by intensive users to relieve current pressure off the grid. These users can absorb operations and maintenance costs. State can also build under concession from this group with the aim of owning assets after 20 years

Then consider building on PBMR learnings and technology instead of new nuclear build (to reduce public debt)

Consider building internal capabilities within the country for nuclear technology, instead of looking at foreign technology to come into the domestic nuclear market (implications of importing nuclear technology on the localisation agenda)

Ensure local skills and knowledge transfer from all internationally procured services from Koeberg

Capacitate the South African citizenry through nuclear education to make informed decisions on the benefits and impacts of Nuclear power

Conclusion

The integration of nuclear power in the energy mix is a bold and somewhat controversial move for the South African government. Although, the benefits of nuclear power far outweigh the current coal resource, in efficiency, emission contribution and total cost of ownership, the retirement of coal plants requires action to be taken in order to ensure sustainable energy supply that will translate into economic growth. On the balance of probabilities, nuclear power will be a sterling addition to the country's energy mix and will be recommended for development until 2035 but housekeeping needs to be done to ensure success.

5 Desalination complexes integrated with Nuclear Energy Stations as a mean to provide drinkable water in conditions of expected global shortage of this resource

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Background

Seventy percent of the planet is covered with water, but only 2.5% of that is fresh water (Heat Transfer Engineering, 2002). Nearly 70% of this fresh water is frozen in the icecaps of Antarctica and Greenland. Most of the rest is in the form of soil moisture or in deep inaccessible aquifers or comes in the form of heavy rains and floods that are difficult to contain and exploit. Consequently, only less than 0.008% (about 70 000 km3) of the world's water is readily accessible for direct human use, and even that is very unevenly distributed, this water is found in lakes, rivers, dams. The sources of this fresh water are rain and snowfall. According to the International Atomic Energy Agency (IAEA), there are currently 2.3 billion people who live in the water-stressed areas and among them, only 1.7 billion of them have access to not more than 1000 m 3 of potable water per year (International Atomic Energy Agency, 2020). The United Nations has speculated that 25% of the Earth's population will have shortage of fresh water by year 2025, this means that the number of people suffering from water stress or scarcity could swell to 3.5 billion. Water scarcity is a global issue and should be treated as a global crises.

Solution

"Nuclear desalination has been demonstrated and eyed as a viable option to meet the growing demand for potable water and provide hope to areas with acute water shortages in many arid and semi-arid zones" (International Atomic Energy Agency, 2020). Al-Othmana, et al alluded that Installation of seawater desalination plants is one of the practical solutions to meet the demand of fresh water around the world. In a country where 77% of electrical energy comes from coal, a cleaner energy is needed for desalination plants to reduce emissions into the atmosphere as South Africa is ranked 14th at emitting greenhouse gases in the world (Brand South Africa, 2012).

1. Nuclear Energy

(International Atomic Energy Agency, 2020) states that by the 31st of December 2019, there were 450 nuclear power reactors operating around the world and producing a total of 398,9 GWe (gigawatt of electricity), this translate to 10% of world's electricity in 2019. This number is expected to increase over the coming years according to IAEA data and this can be coupled with the construction of the nuclear desalination plants as a solution to portable water crisis.

2. Nuclear Desalination

Nuclear desalination is defined to be the production of potable water from seawater in a facility in which a nuclear reactor is used as the source of energy for the desalination process (Avrin, He, & Kammen, 2018). It is no argument that desalination of seawater requires tremendous energy than other conversional fresh water plants. To ensure that the desalination plants have adequate energy supply, energy stations are usually erected and integrated with these plants. Al-Othmana stated that nuclear energy offers higher energy density compared to other conventional and renewable energy sources, thus making it a feasible option to power a desalination plant. The design approaches for a nuclear desalination plant are essentially derived from those of the nuclear reactor alone, with some additional aspects to be considered in the design of a desalination plant and its integration with the nuclear system. All nuclear reactor types can provide the energy required by the various desalination processes. In this regard, it has been shown that Small and Medium Reactors (SMRs) offer the largest potential as coupling options to nuclear desalination systems in developing countries. The development of innovative reactor concepts and fuel cycles with enhanced safety features as well as their attractive economics are expected to improve the public acceptance and further the prospects of nuclear desalination. The coupling with nuclear system is not difficult technically but needs some consideration in (a) avoiding cross-contamination by radioactivity, (b) providing backup heat or power sources in case the nuclear system is not in operation (e.g. for refuelling and maintenance), (c) incorporation of certain design features, minimising the impact of the thermal desalination systems' coupling to the nuclear reactors. For nuclear desalination to be attractive in any given country, two conditions have to be satisfied simultaneously: a lack of water and the ability to use nuclear energy for desalination. In most regions, only one of the two is present. Both are present for example in China, the Republic of Korea, India and Pakistan. These regions already account for almost half the world's population, and thus represent a potential long term market for nuclear desalination.

3. Nuclear Desalination Demand

In recent years, the option of combining nuclear power with seawater desalination has been explored to tackle water shortage problems. Desalination can play a major role for big coastal cities in South Africa such as Cape Town, Durban and Port Elizabeth. South Africa has been experiencing water crises over the past few years, with Cape Town, the only African city with a nuclear power plant been affected the most. The desalination of seawater using nuclear energy in the South African's coastal cities is a feasible option to meet the growing demand for potable water. Over 175 reactor-years of operating experience on nuclear desalination have been accumulated worldwide. Several demonstration programs of nuclear desalination are also in progress to confirm its technical and economic viability under country specific conditions, with technical coordination or support of IAEA. There are many reasons that favour a possible revival of nuclear power production in the years to come: the development of innovative reactor concepts and fuel cycles with enhanced safety features that are expected to improve public acceptance, the production of less expensive energy as compared to other options, the need for prudent use of fossil energy sources, and increasing requirements to curtail the production of greenhouse gases (GHGs). It is estimated that for producing fresh water with the present desalination capacity, but by using nuclear energy, the needed nuclear capacity would be about 40 1000 MWe (megawatt of electricity) nuclear reactors. Using nuclear energy for the production of freshwater from seawater and brackish aquifers (nuclear desalination) has been of interest as a result of acute water shortage issues in many arid and semi-arid zones worldwide. This stems from their expectation of not only its possible contribution to the freshwater issue, but has also been motivated by a variety of reasons that include: likely competitiveness of nuclear desalination in areas lacking cheap hydropower or fossil resources, energy supply diversification, conservation of fossil fuel resources, and spin-off effects of nuclear technology for industrial development.

- Rosatom: one of the leading companies that provide support to the South African nuclear technology and fuel supplier to Koeberg nuclear power station.
- EDF: local independent renewable energy power producer
- Tractabel Engie: one of the leading companies that provide support to the South African nuclear technology.
- Framatome: designed and built the only Nuclear Power Plant in the continent, the Koeberg Nuclear power station.
- Westinghouse: not so prominent in South African nuclear space but they tried to penetrate the this market
- Veoliao: a leading company in seawater desalination in South Africa, with services spanning from large scale to small scale desalination plants for municipal use and industrial processes. All these plants are not using nuclear reactor as source of power.

4. Economic

Over the years, the cost of water produced in seawater desalination plants has dropped considerably, but the cost of water produced in conventional treatment plants has risen. The rise is due to over-exploitation of aquifers, intrusion of saline water in coastal areas, and generally increasing contamination of ground water. Economic comparisons indicate that water costs (and associated electricity generation costs) from nuclear seawater desalination are generally in the same range as costs associated with fossil-fuelled desalination at their present costs. Given the conclusion that nuclear and fossil-fuelled desalination are broadly competitive with each other, any particular future investment decision will depend on site specific cost factors and on the values of key parameters (capital cost, fuel price, interest rate, construction time, etc.) at the time of investment. Higher fossil fuel prices would, of course, favour nuclear desalination; higher interest rates would favour less capital-intensive fossil-fuelled options. The financial risks associated with the dual-purpose nuclear energy comprises of several elements (Michael, Cipollinaa, Commarea, Micalea, Zaragozac, and Kosmadakisb, "Assessment of methodologies and data used to calculate desalination costs" 2017 419 Desalination 8 14). These elements include, the required skills to implement and manage the operations. Notwithstanding Koeberg Nuclear Power Station's good performance record, dual-purpose or single purpose nuclear desalination technology is new to South Africa and this may results in cost overruns during the implementation phase.

5. Political

Section 27(1) (c) of the Bill of Rights states that everyone has the right to have access to sufficient water (Gov, 1996). The current desalination plants are relatively small, able to provide water only for household use that are in the vicinity due to high costs required in building larger desalination plants. The responsibility is placed to the state or government to provide such resources. Projects associated with high costs usually increase the risk of corruption not only in the nuclear industry but everywhere in the society. Transparency is crucial to avoid the misuse of funds and it is a challenge that is rather political and economic. Currently there are attempts to remove corrupt government officials but human nature is improving impossible to deal with as there are societies where individualism is high.

6. Public perception

Public is generally is aware of the contribution of nuclear power but they are more concerned about the nuclear waste, proliferation and high cost than safety of the operations, although public opinion on nuclear energy seems to be changing slowly.

7. Socio-cultural

The sea is a constant water source and it is seemingly wise to utilise it as the demand for water keeps on increasing. There is more rural-to-urban migration, high unemployment rate especially amongst youths resulting in the increase of materialism in societies. The country lacks skilled professionals in this field due to lack of positive career attitude in the nuclear field. It can be solved by public awareness of nuclear technology and desalination helping the country to be independent of foreign skilled manpower when major problems occur at the plants. Also people will be more obedient to measures set in place in improving the current socio-economic status.

8. Socio-environmental aspects

South Africa is a state that is politically, cultural and socially divided. The division thus requires leaders or drivers of the project to create cohesion from the hugely diversified nation. An article on South Africa's literacy by Professor Mary Metcalfe of the University of Cape Town states that about 60% of the cohort of pupils who starts grade 1, actually finish grade 12. This then means that 40% of pupils become illegible to embark on tertiary studies. Introducing Nuclear Energy Desalination concept to this group of people will undoubtedly prove to be a toll order. Furthermore, those who are in the rural arears and mostly affected by the water shortage will also be unable to contribute and intellectually comprehend the nature of this project.

There have been developments in the past of small nuclear reactors such as Pebble Bed Modular Reactor (PBMR). It showed the country's interest in innovation and the changes brought by research and development to the society. Such technological development is crucial but risky and uncertain as it does not guarantee immediate profit yields though it is necessary in future development intended for economic growth (Gosling, 2010). The government is working on reviving the PBMR project as a solution to the current energy and water crisis though there are many factors that can contribute to the stagnation of technology (Gosling, 2010).

9. Factors Affecting the Rate of Development and Technology Transfer

Designing, constructing and operating of a nuclear desalination facility will require highly skilled individuals to execute the works and government support in terms of funding the project, with that said, South Africa have a relatively low number of engineers, technicians and scientist with nuclear desalination experience. Another issue is, any project that is undertaken by government must get approval from different government departments. The absence of highly skilled people in this space puts the country in a position where there is no organisation that is advocating for unknown technologies. A successful implementation of this kind of initiative primarily depends on the government support and if there the government is not aware of such technology then it will not be persuaded. Also, desalination plants are more suitable in coastal towns and infrastructure for water transportation to drought-affected and low lying areas must be readily available. These plants must be ideally situated in areas like ports and harbours where there is large space for exceptionally compact plant designs (Patel, 2018).

Implementation Factors

1. Regulation of nuclear desolination power station

In 2010, the United Nations adopted a resolution whereby it acknowledged the importance of having access to equitable safe and clean drinking water. The resolution stipulates that safe and clean drinking water is a human right that is essential for the full enjoyment of life and all human rights. Therefore, States are called upon to "…provide financial resources, capacity-building and technology transfer, through international assistance and cooperation, in particular to developing countries, in order to scale up efforts to provide safe, clean, accessible and affordable drinking water and sanitation for all…" (SAHRC, 2010). Section 26 of the Constitution provides that everyone has the right to have access to sufficient food and water. The State has an obligation to take reasonable legislative and other measures within its available resources to achieve the progressive realization of this right. The right to have access to sufficient water is understood to mean that the State has an obligation to create mechanisms that enable people to have access to sufficient water (Gov, 1996). In terms of the National Nuclear Regulator Act (NNRA), a facility, installation, plant or structure designed or adapted for or which may involve the carrying out of any process (NNR, 2018). Therefore, the nuclear installation, while used to provide energy, may also be used to desalinate water to provide drinkable water. In order for a person to site or construct a nuclear installation, such person needs a license (Gov, 2014). The legal policy in respect of desalination complexes integrated with nuclear energy stations as a means to provide drinkable water, is whether the law in South Africa allows for the nuclear installation in the marine environment (the only consideration in this discussion is up to the territorial sea) and the rights and obligation attached to the development. Currently, in South Africa there are no nuclear energy stations in the marine environment with the dual-purpose to desalinate water in order to make it drinkable. The NNAR does not mention favourable or preferred sites for the construction and installation of nuclear power station. The Maritime Zones Act (MZA) stipulates that an installation is "any installation, including a pipeline, which is used for the transfer of any substance to or from" the coast of South Africa (Gov, 1994). Therefore, "any installation" may include nuclear energy station with dual-purpose aimed at desalinating water. Water is defined as "Water, a substance composed of the chemical elements hydrogen and oxygen and existing in gaseous, liquid, and solid states" (Britannica, 2019). It is therefore submitted that, in terms of the MZA, nuclear energy stations may be installed in the marine environment of South Africa in order to desalinate water while producing electricity.Since the nuclear energy stations is without its own disadvantages, in terms of the Conservation, the nuclear energy station is a listed activity that require an authorization prior to an undertaking. Such authorization is on condition that an environmental impact assessment is made by the persons wishing to construct and install this energy station (Environment, 1989). In light of the above, the policy strategies aimed at dual-purpose nuclear energy will have to mention the existing legislation and how they advance or do not advance this installation. Furthermore, the benefits of this dual-purpose nuclear energy station has been described, the risks associated with it as well as the means to

prevent or reduce the risks will have to be discussed in the policy strategy.

Strategies for policy implementation

Use of energy from nuclear reactors for seawater desalination is a demonstrated option; it is environmentally friendly and can be a sustainable energy source. Feasibility studies indicate that current costs of water produced from nuclear desalination plants are similar to those of fossil fuel based desalination plants. Thus nuclear desalination is an important option for safe, economic and sustainable supply of large amounts of fresh water to meet the ever-increasing worldwide water demand. With regard to the market size, it is expected that freshwater requirements will grow in the future, which will increase the attractiveness of nuclear desalination.int.

1. Strategy for Slow Rate of Development and Technology Transfer

- Provide educational events to the society about nuclear and desalination.
- Use affordable small scale nuclear reactors.
- Invest more in nuclear research.
- Provide engineering skills required for such an industry.

2. Strategy for Conservative Development and Technology Transfer

- Organize research and design engineering competitions to high schools and universities.
- Provide funding to research chairs around the country in nuclear.
- Provide quicker process for licencing without compromising safety.

3. Strategy for Acceleration of Development and Technology Transfer

- Consider using both the output heat for electric generation and desalination.
- Explore other possible benefits of using this type of technology.
- Inform the society about changes and developments within the industry.
- Partner with international technology providers
- Partner with international research institutions
- Partner with countries that are already operating nuclear desalination plant for training skill transfer purposes.

6 Low capacity nuclear stations with a long fuel cycle to supply energy to remote areas and the areas with a low level of grid development

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Introduction

There're several challenges (economic, social, environmental and technological challenges) that the nuclear industry currently faces. To be more precise, affordability, safety and security are the major factors hindering growth of the nuclear energy industry. In terms of Safety & Security, major issues are around the long-term management (disposal) of radiotoxic nuclear waste and the risk of proliferation.

Together with the current research trends in nuclear fuel design and optimization, small reactors with long fuel cycle can improve the economy of nuclear plants and in the long run energy security. The incentives of the long fuel cycle of small reactors will be reduced for spent fuel and waste management obligations with greater assurance of non-proliferation to the international community.

According to the IAEA, Small Modulator Reactors (SMRs) are the reactors which are designed to generate electric power up to 300 MW and/or the components and system of the reactor can be fabricated and transported as modules for installation to the sites (IAEA, 2016). Small refers to the reactor power rating and modular refers to the unit assembly of the nuclear steam supply system (NSSS) which can be grouped with others to form a large nuclear plant (Locatelli and Mignacca, 2020). This means other equipment such as turbine-generator, condenser, the cooling system etc. can be produced as modules (SMR, 2020). SMRs can be manufactured and transported using roads, railways or barges to the power plant site for deployment (Bowen, 2017). SMR technology involves scaled down versions of existing reactors as well as Generation 4 (Gen-IV) reactor designs. SMRs should be able to use various fuel compositions and configurations and are therefore designed to be more efficient in fuel utilization than conventional LWRs (Nordhaus et al., 2013).

Low Capacity Nuclear Stations for remote areas

SMR technology aims to be part of the network of reactor technology striving for sustainable development in the nuclear energy industry. It aims to overcome challenges currently faced by existing nuclear plant designs, to optimize them in the design stage in areas such as sustainability; safety & reliability; economics and proliferation resistance & physical protection. The world's biggest economies namely USA, China, UK and Canada are in support of SMRs as future nuclear plants and have invested in the development of this technology.

Technological and economic benefits of SMR

Small modular reactors (SMRs) are of interest as they can move into a brownfield sites in place of decommissioned coal-fired plants. Small modulator reactors reduce the total capital costs of nuclear power plants and provide power to small grid systems (SMR, 2020).

Small modulator reactors enhance nuclear safety. The transmission infrastructure requirements are smaller because of low electricity output and can be suitable to be deployed in larger locations.

Challenges facing SMR development:

The Licensing for low costs power stations are challenging as the design certificate, construction and operation license costs are still as high as those of large reactors (SNPR, 2020).

One of the important challenges is the regulatory barriers. For nuclear regulatory development, the features could reduce the staffing requirements for operation and reduces the size of emergency planning zone of small modulator reactors according to vendors (SMR, 2020).

SMRs adopting various types of reactor technology:

The difference between SMRs and conventional light-water reactors (LWRs) is their modularity. The full factory units according to the SMRs designers, will allow large savings in the manufacturing costs. Most of the SMRs require the designs of five to seven plants to get the most of supply chain establish-

Table 1: Small reactors operating

NAME	CAPACITY	TYPE	DEVELOPER
CNP-300	300 MWe	PWR	SNERDI/CNNC, Pakistan & China
PHWR-220	220 MWe	PHWR	NPCIL, India
EGP-6	11 MWe	LWGR	at Bilibino, Siberia (cogen, soon to retire)
KLT-40S	35 MWe	PWR	OKBM, Russia
RITM-200	50 MWe	Integral PWR, civil marine	OKBM, Russia

Table 2: Small reactor designs under construction

NAME	CAPACITY	TYPE	DEVELOPER
CAREM-25	27 MWe	Integral PWR	CNEA & INVAP, Argentina
HTR-PM	210 MWe	Twin HTR	INET, CNEC & Huaneng, China
ACPR50S	60 MWe	PWR	CGN, China

Table 3: Small reactors for near-term deployment – development well advanced

NAME	CAPACITY	TYPE	DEVELOPER
VBER-300	300 MWe	PWR	OKBM, Russia
NuScale	60 MWe	Integral PWR	NuScale Power + Fluor, USA
SMR-160	160 MWe	PWR	Holtec, USA + SNC-Lavalin, Canada
ACP100/Linglong One	125 MWe	Integral PWR	NPIC/CNPE/CNNC, China
SMART	100 MWe	Integral PWR	KAERI, South Korea
BWRX-300	300 MWe	BWR	GE Hitachi, USA
PRISM	311 MWe	Sodium FNR	GE Hitachi, USA
ARC-100	100 MWe	Sodium FNR	ARC with GE Hitachi, USA
Integral MSR	192 MWe	MSR	Terrestrial Energy, Canada
BREST	300 MWe	Lead FNR	RDIPE, Russia
RITM-200M	50 MWe	Integral PWR	OKBM, Russia

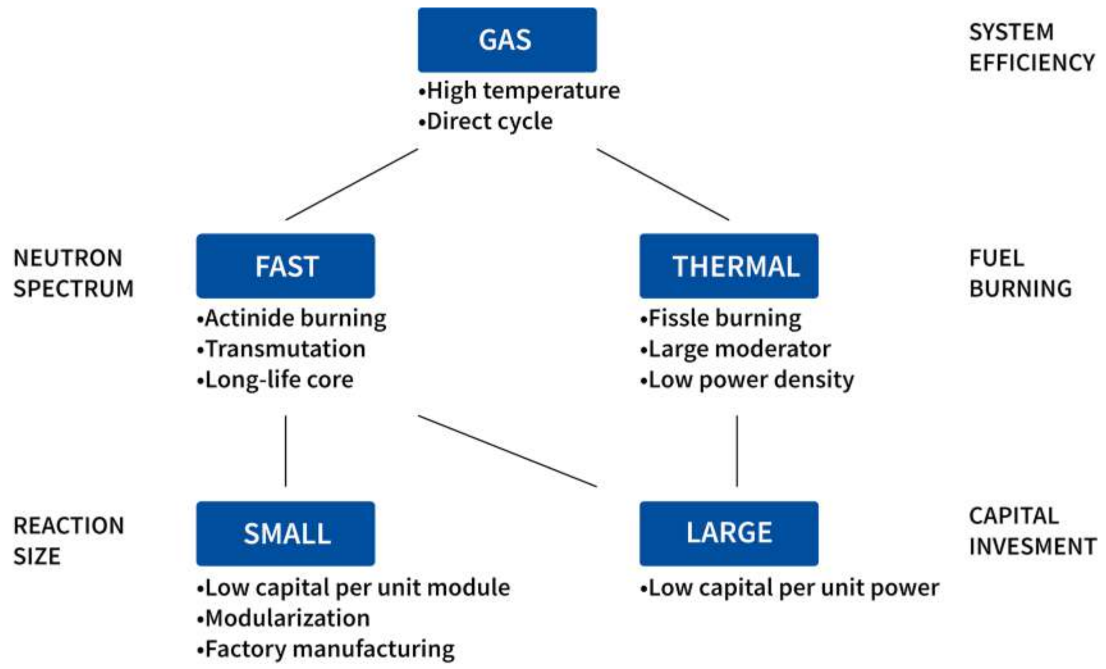

Figure 1: Design choices and economic factors of fast and thermal gas cooled reactors
Source: WNA, 2020

ment. The benefits of having several units of SMR instead of having one large unit is the refueling and the maintenance team could be fully employed (SMR, 2020).

There are other advanced nuclear technologies which can mitigate some of the challenges to nuclear deployment especially in developing countries. These technologies include High-Temperature Gas Reactors (HTGR), and Fast Reactors[1]. The greatest advantage in African countries is that they can supply electricity in a suitable or in sizeable grid infrastructure. African countries have a grid capacity in which a single power plant's capacity should not exceed 10% of a country's total grip capacity. The SMRs use any nuclear fuel, coolants or fuel cycle and moderator. It uses either low enriched uranium-oxide or mixed-oxide plutonium and uranium fuel.

RSA nuclear development plans

South African power utility Eskom supplies 95% of the country's electrical energy and approximately 45% of Africa's energy. South Africa is the only African country which has operating nuclear power plant with capacity of 1800 MW made of two units of pressurized water reactors since 1984. Koeberg Power Station is about 30 km the northwest of Cape Town and has two units of 900 MW capacity of PWR reactors each. Eskom owned the power station which supply 5% of South Africa's electricity annually (Jewell, 2011). Nuclear waste facility, Vaalputs (administered by Necsa) is the country's low and intermediate waste disposal site, and the high-level wastes

Table 4: Power Reactors operating in South Africa

REACTOR NAME	MODEL	RECTOR TYPE	NET CAPACITY (MWE)	CONSTRUCTION START	FIRST GRID CONNECTION
Koeberg 1	CP1	PWR	930	1976-07	1984-04
Koeberg 2	CP1	PWR	930	1976-07	1985-07

(1) - The floating reactor is unique that it is built with an island so that it floats on water, but however it is a LWR. Other reactor technology types are Fast (neutron) Reactors which use no moderator and use metals (i.e Sodium) as coolants! And another type is the Canadian Heavy Water Reactor which are currently being phased out due to the expensive process of producing heavy water.

are stored in the pool of the power station. South Africa is planning to expand the nuclear capacity by 2500 MW by 2030 to increase the energy supply to the country.South Africa's nuclear energy policy of 2008 provides policy principles of nuclear programme such as nuclear energy shall contribute to economic growth and technology development in south Africa through infrastructure investments, job creations and skills development for workers. Nuclear energy should be use for peaceful purposes with national and international legal obligations. South Africa should know how to acquire skills for design, development, construction and marketing of its own systems of nuclear reactor and fuel cycle. The policy recognized that many countries have resulted in pressure of greenhouse gas emission and climate change, and many countries were considering nuclear energy development for electricity generations because greenhouse gases in nuclear energy is negligible. South Africa has a shortage of fresh water, the design of new nuclear technology will be an option for sea-water desalination (DMRE, 2020).

Please note that there aren't many companies involved in the development of nuclear in South Africa, Necsa and Eskom are potentially the only two corporations who've been very instrumental in that regard. Bodies such as the South African regulator NNR (National Nuclear Regulator), NGO's such as SAYNP (South African Young Nuclear Youth Professionals) and NIASA (Nuclear Industry Association of South Africa) have been very instrumental in educating the general public about nuclear energy and also in influencing the government to consider nuclear as an option in the country's energy mix.

Risk of development (Socio-cultural, Political and economic)

Both Eskom and Necsa are state owned enterprises and lately these corporations have been rather dysfunctional due to political uncertainty, corruption and board incompetence. The aforementioned factors at the forefront of potential risk of development of new nuclear technology in South Africa.

In most cases nuclear is competitive with other energy sources except where there's access to cheaper fossil fuels. South Africa's has an abundance of coal which is also the driver of the country's economy. Due to the instability of power utility Eskom, investors are not at ease with the country's support for nuclear because of the country's resent fiscal constraints which have endangered its credit rating. For this reason, energy experts foresee the addition of nuclear as a burden for the country's economy. adding new nuclear is more expensive than other power options (EWN, 2019).

Advanced fuels for long fuel cycles

Current research in fuel involves the implementation of Th and MOX (Pu(PWR)) fuel in the existing fleet of reactors particularly Gen3+ PWR's and future plants to increase their fuel life cycle and to reduce their production of radiotoxic waste and their risk of proliferation. Though there's sufficient published research which shows Th and MOX as alternative fuel options which can make nuclear power more economic and low on radiotoxic waste, there's a need for extensive R&D in, in core designs to accelerate the viability and commercial implementation of these fuels (NEA-OECD, 2003) (Du Toit, 2017). For the R&D two main technical teams are required, one team is to work on Th and MOX fuel implementation by doing in core designs for different reactors and the other to optimize spent fuel reprocessing and make it more economic to fabricate MOX.

Sustainability:

Thorium is greatly abundant in nature than uranium (NF-T, 2012). As long natural uranium is used as fuel in thermal reactors, piles of plutonium will always be produced. It has been estimated that from 1000 MWe thermal reactor that has been running for a year we can expect to recover 25 tons of spent fuel with 290 kilograms being plutonium for MOX (WNA, 2018).

Economics competitiveness

The fissile concentration of fuel can be increased by adding a bit of plutonium. Studies show that 5-10% of fissile 239Pu or 241Pu mixed with depleted uranium is equivalent to 4-5% enrichment for fissile 235U. Therefore, incorporating fissile plutonium in fuel eliminates the need to build expensive enrichment plants. And as uranium prices increase, it becomes much cheaper to reprocess spent fuel to recover fissile plutonium to be used as fuel (WNA, 2018).

Due to its fertile nature, Thorium has a weaker starting reactivity in a reactor but breeds fissile fuel overtime (NF-T, 2012). This is a huge advantage as this alone can increase the fuel lifetime therefore increasing fuel cycle length of a reactor for higher availability. Availability increases by as much as 33% which amounts to approximately 33% more profit for the Utility. Furthermore, the Thorium fuel cycle cost is more economically viable than other fuel types. It is inexpensive to fabricate, it increases and produces less intense radioactive waste (Du Toit, 2017).

Radiotoxic waste reduction, recycling and proliferation resistance:

One way of to produce nuclear energy with low radio-toxic nuclear waste and most importantly proliferation resistant nuclear waste is through the thorium fuel cycle (Du Toit, 2017). MOX fuel reduces the volume of spent fuel waste and reduces the potential risk of proliferation by using up the fissile plutonium arising from spent fuel (WNA, 2018).

Generation 3+ PWR plants such as the VVER-1200 and EPR have been specifically designed to accommodate various fuel options such as Th-UO2, MOX and Th-MOX. The added advantage of these is their ability to achieve high burnups thus utilizing fuel more effectively and therefore reducing the production of radio-toxic nuclear waste (Dwiddar et al., 2015).

Modelled results of Th and MOX in PWRs:

Three different fuel models of different isotopic compositions (Mainly of UO2, ThO2 and Pu-MOX) were modelled in MCNP (Monte Carlo N Particle) using an infinite unit cell fuel pin model adopted from the Koeberg reactor (The South African Generation 3 PWR built by Framatome (now Areva) in the 80's). The purpose of the simulation is to show how alternative fuel compositions of thorium and MOX can be used to prolong the fuel cycle in existing PWRs which could also be adopted and adapted in SMRs. The table shows the simulated fuel compositions and their respective cycle lengths and refueling periods. The plot depicts the change in the effective multiplication factor (keff, considering the neutron non-leakage probability) with time.

A safety-feasibility analysis study of this fuel composition in term of reactivity coefficients was also performed and it was found that the thorium and Pu-MOX fuel yield more desirable reactivity coefficients compared to the conventional UO2 fuel. These means as alternative fuels, these not only prolong the fuel life cycle but can also give added inherent safety to PWRs.

It is important to note the above fuel composition were modelled only in a fuel pin model and there's a need for further extensive R&D involving more sophisticated models, in core designs and optimized fuel cycles of alternative fuels (Th and MOX) to accelerate the viability and commercial implementation of these fuels (Du Toit, 2017).

Potential for thorium and Pu-MOX fuel fabrication in South Africa:

South Africa has two 960 MWe nuclear reactor units at the Koeberg NPP which have been running reliably for more than 30 years. Again, the SAFARI-1 research reactor in Pelindaba (NECSA) was commissioned in 1965. It is without a doubt that volumes of nuclear waste have been produced in the country for over 40 years. Furthermore, the country already has hot cell facilities (NECSA, NTP) which means that most of the resources needed to process spent nuclear fuel and produce MOX are in place.

Benefits and Potential Risks of development:

According to many studies, spent fuel processing which includes the use of hot cells is of proliferation concern (MIT, 2011). South Africa signed a nuclear treaty in the early 90's

Table 5: Shows different fuel compositions and their respective cycle lengths
Source: Erlank, 2016

	FUEL/ ISOTOPIC COMPOSITION	CYCLE LENGTH: (MONTHS)	REFUELLING PERIOD (DAYS):
Fuel model A	4.5% enriched UO2 (Koeberg fuel composition)	≈16	37
Fuel model B	(5% 235U, 93% 238U and 2% 232Th) O2	≈17.6-18	37
Fuel model C	(0.8% Pu (PWR), 4.5276 % 235U and 94.6724% 238U) O2	≈18.5- 19.5	37

for the Non-proliferation of nuclear weapons and it has ever since kept to that oath. The country has the capacity or at least the potential to produce its own Th and Pu-MOX fuel to minimize the production of radiotoxic waste and proliferation material to ease the burden on the Vaalputs geological repository.

Projected development of nuclear technology globally and in South Africa

According to the figures of NEA/IAEA, 2014, the nuclear capacity will be 700 GWe in the highest case scenario and 400 GWe in the lowest case scenario in 2035. About 300 GWe of new nuclear capacity in the high-case scenario will be added in the next 20 years in the period of 2020-2035 (SMR, 2020). To estimate the size of the global market in 2035, it was assumed that SMRs will be silenced this year 2020, the supply chain will be established and the trained labor for construction and operation of SMRs (SMR, 2020). It is assumed that SMRs are more expensive to build and to operate compared to other power sources. In the high-case scenario, SMRs will be cheaper to build than advanced light-water reactors (ALWRs) but will be higher valuable in costs of operation, maintenance and fuel costs. In the period of 2020-2035 according to the analysis, about 9% of new nuclear build could be done with SMRs in the high-case scenario and 2.3% of low-case scenario. SMRs will count for 3% of the nuclear capacity installed in the year 2035.

The risks also come with the decommissioning of the nuclear plants and safety concern of Russian nuclear industry. It was found that the nuclear generated electricity will be more expensive than coal plants and solar photovoltaic panels and wind (Environment and energy, 2015).

Since the Integrated Resource Plan 2010 has forced 9.6GW of nuclear power into the final build plan (DoE, 2011). There are some potential effects on the economy of South African government to invest in 9.6GW of nuclear power (DoE, 2011). Based on the scenarios proposed on the socioeconomic risks, South Africa has the higher levels of growth between 2015 and 2040 with the average of 3.6 5 per year. The costs of the nuclear power are lower. The economy of South Africa growth rate is lower with 2.7% per year and electricity demand is therefore lower; nuclear power costs are higher (ERC, 2015).

5.5 Environmental Risks

The studies of Akyuz (2017) indicate that the impact of nuclear on future generations could have far more reaching effects with arguments that the resource may have a certain level of vulnerability towards natural disasters such as cyclones and earthquakes. Nuclear energy is also shadowed by a history of global nuclear accidents that wiped out densely populated communities in Chernobyl and Fukushima; a consideration for South African policymakers. Sarkodie & Adams (2018) cite environmental risks such as improper management of nuclear, radioactive waste disposal and outdated technologies used in plant decommissioning as risks that need to be considered when deliberating over the decision to build new nuclear capacity in a country. The impact of warm water may also increase the migrating of fish and significantly alter the ecosystem.

The arguments presented about nuclear energy been a cleaner source of energy are also challenged by Fig (2018) that claims that nuclear energy is not carbon neutral as the process of producing nuclear energy, from uranium mining, to milling, gasification and enrichment uses coal based electricity with notable emissions. Plant retirement also results in considerable amounts of nuclear waste. The risk of adding an energy source that is not carbon neutral to the energy mix is that the country may be unable to meet climate change commitments.

Table 6: Projected share of SMRs in nuclear new build in 2020-2035
Source: SMR, 2020

COUNTRY	NEW BUILD IN 220-2035 (LOW CASE)	NEW BUILD IN 2020-2035 (HIGH CASE)	SHARE OF SMRS IN NEW BUILD IN 2020-2035 (LOW CASE)	SHARE OF SMRS IN NEW BUILD IN 2020-2035 (HIGH CASE)
South Africa	0	18 160	0%	15%

Agyekum, Ansah & Afornu (2020) argue that many developing countries like South Africa have a poor culture of maintaining commercial assets and infrastructure. In South Africa, this culture is evidenced in the poor maintenance of ageing coal fleet and subsequent breakdowns. The culture of poor infrastructural maintenance raises concerns of the countries readiness to integrate nuclear capacity in the energy mix because the lack of maintenance in this regard may compromise the safety of the plant resulting in catastrophic environmental outcomes.

5.6 Legal

The increase in the share of nuclear in South Africa's energy future until 2035 advocates for effective regulation of the resource to ensure public safety and governance. In integrating Nuclear Power into the countries energy mix, legal and regulatory considerations relating to pricing, externalities, contract management and transparency, governance and safety need to be made. If safety risks are not considered, the negative externalities of nuclear could result in class action lawsuits against the state and related companies (Sarkodie & Adams, 2018).

5.7 Commercial

The cost of nuclear is relatively competitive and stable. The Levelised Cost of Electricity (LCOE), which consists of the costs incurred in building, and operating a NPP divided by the plant's electricity output provide an indication of the cost per megawatt hour. In the case of NPPs, the costs over the lifetime of the assets are economic due to high plant predictability and reliability. The operating costs are much lower than the operating costs of coal and with an extended lifespan of up to 80 years, seem to be more viable. The commercial risks for Nuclear energy in South Africa is the fact that 60% of the LCOE is made up of capital costs and due to the absence of constructed reactors in the country, it may be difficult to contain these costs (WNO, 2019).

The proposed nuclear projects are closer to major infrastructure projects than most other power generation technologies. It will therefore be prudent of the government in increasing the share of nuclear energy in the energy mix, to be cognisant of additional risks such as project management risks, policy risks, project lead-times, economic lifetimes and complexity of stakeholder management issues.

6. Policy Recommendations

To retain the option of nuclear and possibly increase the nuclear portfolio, the below policy recommendations should be considered:

- The National Nuclear Regulatory Authority (NNRA) should work vigilantly and proactively enforce current regulations and encourage a strong safety culture to reduce the risk of significant operating events that can lead to extensive plant shutdowns.
- The Energy Department, in collaboration with the NNRA, should also create a new research and development program in nuclear engineering to provide the advanced tools needed to analyse the safety of reactor designs and fuels. This would allow the NNRA to analyse new reactor designs with the expectation that such an approach can lead to transparently safer and less costly projects.
- The South Africa Energy Department should fund projects that find creative solutions via regional partnerships to the nuclear waste created from reactor operation.
- South Africa should increase their funding of the IAEA and enable the agency to strengthen its existing role. The IAEA should also work with the regulatory agencies of those member countries that have extensive nuclear power programs and experience to develop global safety standards.
- Develop standards for the physical protection of fissile materials to assure the physical security of civilian nuclear fuel-cycle facilities and power reactors.
- A variety of interest groups, including regulators, the nuclear industry, experts, and nongovernmental organizations, should be consulted as part of this process.

6.1 General Recommendations

1. Finish outstanding Medupi and Kusile projects to regain credibility with the public and address immediate capacity needs
2. Institute governance reforms including transparency that will enable accountability and be enforced to avoid rent seeking and corruption

3. Review IRP with capacity for solar, wind and storage
4. Open up the market for self-generation by intensive users to relieve current pressure off the grid. These users can absorb operations and maintenance costs. State can also build under concession from this group with the aim of owning assets after 20 years
5. Then consider building on PBMR learnings and technology instead of new nuclear build (to reduce public debt)
6. Consider building internal capabilities within the country for nuclear technology, instead of looking at foreign technology to come into the domestic nuclear market (implications of importing nuclear technology on the localisation agenda)
7. Ensure local skills and knowledge transfer from all internationally procured services from Koeberg
8. Capacitate the South African citizenry through nuclear education to make informed decisions on the benefits and impacts of Nuclear power

Conclusion

The integration of nuclear power in the energy mix is a bold and somewhat controversial move for the South African government. Although, the benefits of nuclear power far outweigh the current coal resource, in efficiency, emission contribution and total cost of ownership, the retirement of coal plants requires action to be taken in order to ensure sustainable energy supply that will translate into economic growth. On the balance of probabilities, nuclear power will be a sterling addition to the country's energy mix and will be recommended for development until 2035 but housekeeping needs to be done to ensure success.

TheEnd

Links & resources _

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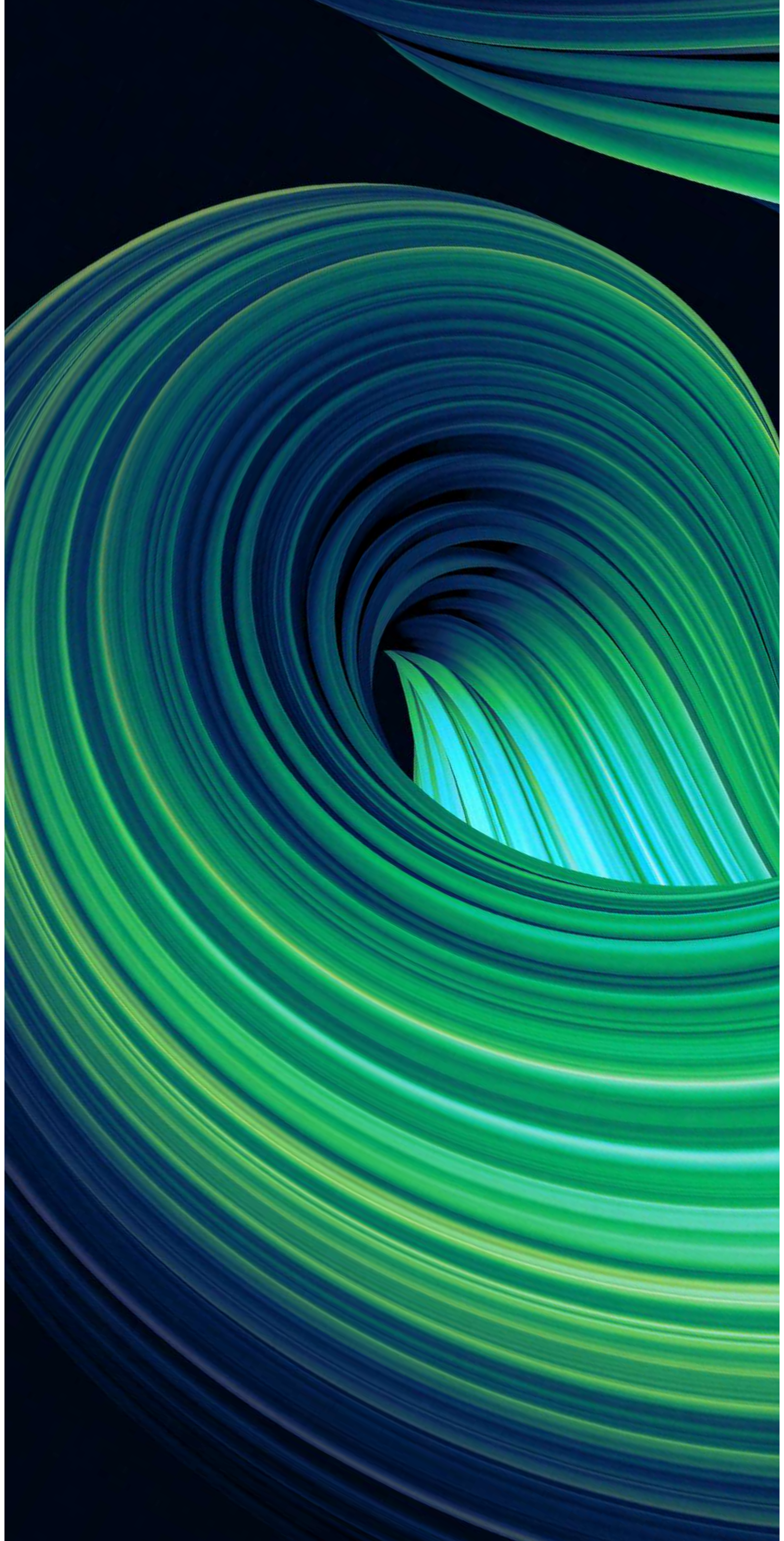
As long as we cannot refuse to print this annual edition of the BRICS Youth Energy Outlook 2020, we decided to allocate all the sources of informations, i.e. lists of references, figures and tables, which follow the main content at our web server. You can access the data by scanning the QR code below.



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BRICS Youth Energy Outlook 2020
by BRICS Youth Energy Agency

Report citation:

BRICS Youth Energy Agency (BRICS YEA). BRICS Youth Energy Outlook 2020. October 2020. Available from: www.yeabrics.org

BRICS Youth Energy Outlook 2020 is an international annual project by the BRICS Youth Energy Agency aimed at delivering a view of young people on the energy challenges that BRICS countries will be facing in the nearest future. The Outlook is developed by teams of researchers, who are students, assistant researchers or young professionals representing leading universities and energy-related organizations from BRICS countries. The Outlook has gained much authority and recognition by the BRICS Energy Ministries as it reflects the view of the new generation of the industries' leaders and professionals.

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