BRICS
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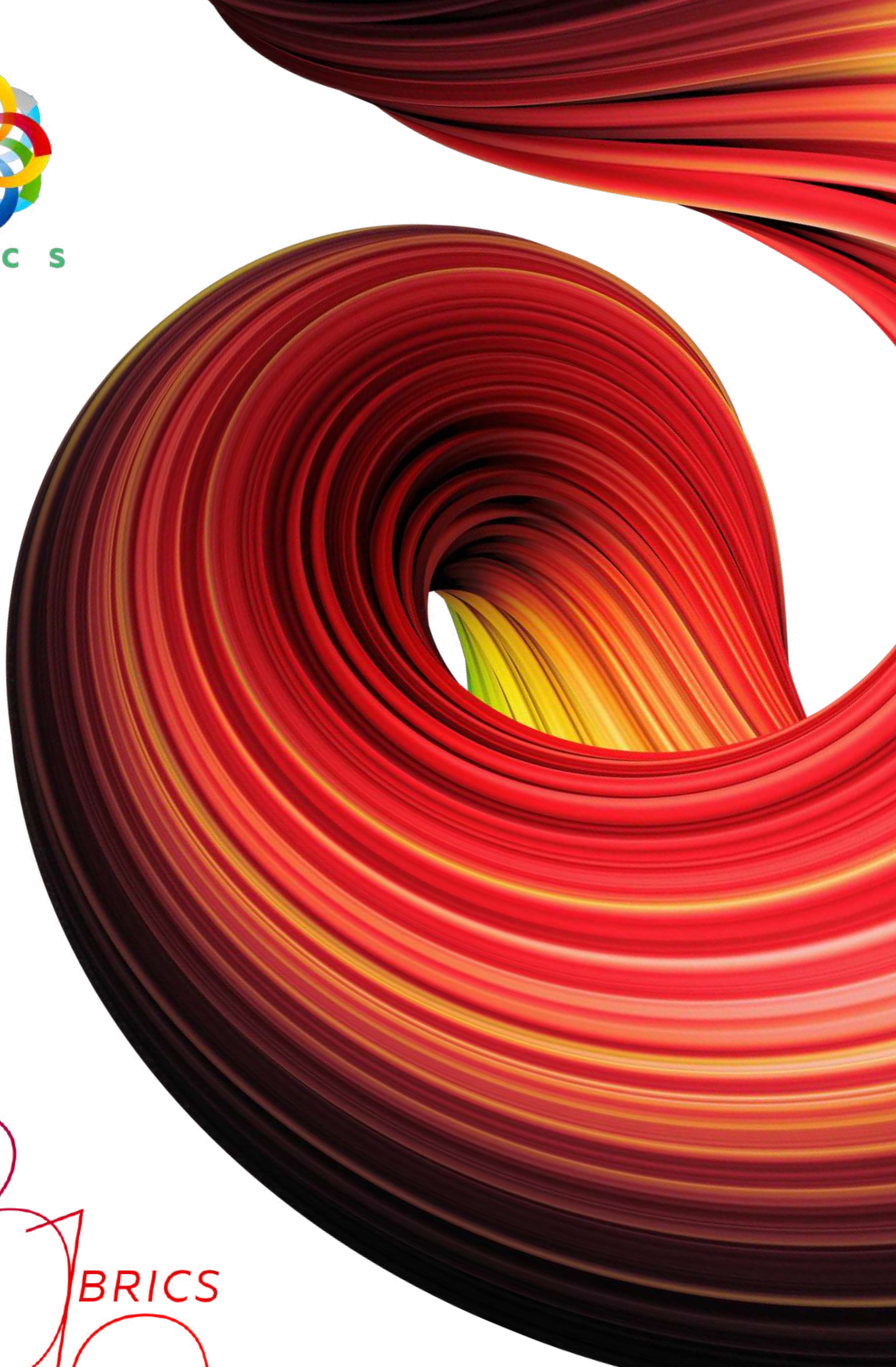

2019 BRICS Youth Energy Outlook

Introducing

BRICS Youth Energy Outlook 2019

The one and only international research on energy development of the BRICS countries prepared by young researchers and scientists

BRICS YOUTH ENERGY AGENCY
ANALYTICAL CENTRE

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FOREWORD

Aleksandr Kormishin

Innovation through experience

Aleksandr Kormishin
Chairman
since 2015

Dear readers,

In the Foreword to the BRICS Youth Energy Outlook 2019, I would like to refer to all the people who supported and accepted a challenge to participate in the development of the first ever outlook, which reflects the views of young researchers and scientists on the future of the BRICS energy industries.

In this day and age youth involvement in the process of energy forecasting and shaping of a common vision is acknowledged important all over the globe. Young professionals play a significant role in promotion of energy efficiency, development of youth energy policy and actively participate in industrial digitalization and other key areas so that they influence the future. Studying the prospects of energy development, adopting the experience and methods of developing solutions, the young generation should replace in the long term the existing expert community and continue the line begun by their predecessors. By studying the industrial experience of the countries and predicting the prospects for their development, the young generation does not only improve their own competencies but also learn more about the BRICS promising areas of cooperation in further research and career. The possible benefits of the project are explained by improving overall knowledge about the challenges and prospects that all five countries face these days and use this information so that common collaboration become once prosperous and fruitful.

The goal of the BRICS Youth Energy Outlook 2019 is to consolidate youth in their efforts to form a common vision for the development of BRICS energy industries, to identify and search for solutions to problems faced by youth, as well as to build effective mechanisms for resolving them, taking into account experience and opportunities of the community countries. This outlook is developed by young people who certainly are not highly experienced analysts but are unbiased and objective instead.

Aleksandr Kormishin
Chairman

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THE POWER OF YOUTH IS THE COMMON WEALTH FOR THE ENTIRE WORLD. THE FACES OF YOUNG PEOPLE ARE THE FACES OF OUR PAST, OUR PRESENT AND OUR FUTURE. NO SEGMENT IN THE SOCIETY CAN MATCH WITH THE POWER, IDEALISM, ENTHUSIASM AND COURAGE OF THE YOUNG PEOPLE. - KAILASH SATYARTHI

About Us

Objectives

Initiation, support and development of collaborative and individual research of the BRICS Youth in the field of energy.

Development of projects aimed at BRICS youth energy cooperation and research.

Our Vision

We believe that empowerment of youth through social participation and community engagement both as state and non-state actors is essential, especially when it comes to energy as a strategically important area of cooperation.

We hope that the BRICS nations will work further to protect youth rights, especially those of minority groups such as religious, caste, linguistic, ethnic, racial, gender, migrants, disabled, displaced and other; we act to realize their full potential and overall development by creating involvement opportunities.

Our Mission

Admiring the efforts of BRICS countries' leaders in transforming the world into a more just and equitable place, we contribute to putting further efforts of BRICS youth into addressing the issues of our common concern.

Our mission is to ensure cooperation of BRICS youth in the field of energy and to promote development of its scientific and analytical potential.

TRY NOT TO BECOME A MAN OF SUCCESS.
RATHER BECOME A MAN OF VALUE.

Development

BRICS Youth Energy Agency acts in accordance with our strategy and corporate values:

Strategy

Our strategy is aimed at expanding multilateral business youth cooperation in order to accelerate social and economic development, increase energy security and competitiveness of BRICS members in the global economy.

Values

1. Respect for the sovereignty of the BRICS nations;
2. Total compliance with BRICS national interests, priorities, growth and development strategies;
3. Transparency, knowledge exchnage and consensus in decision-making;
4. Commitment to supporting sustainable development of the youth involved in BRICS energy cooperation and project-making.

Meet our teams

We are happy to introduce to you the BRICS research teams who participated in development of the Outlook:

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BRAZIL

FEDERAL UNIVERSITY OF RIO DE JANEIRO,
BRAZIL

JIS COLLEGE OF ENGINEERING,
INDIA

KAZAN STATE POWER ENGINEERING UNIVERSITY,
RUSSIA

MGIMO-UNIVERSITY,
RUSSIA

NORTH-WEST UNIVERSITY,
SOUTH AFRICA

THAPAR INSTITUTE OF ENGINEERING & TECHNOLOGY,
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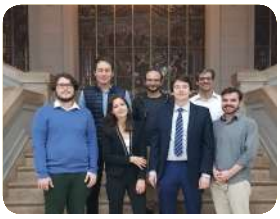
UNIVERSITY OF JOHANNESBURG,
SOUTH AFRICA

UNIVERSITY OF PRETORIA,
SOUTH AFRICA



UNIVERSITY OF SÃO PAULO,
BRAZIL

PJSC «GAZPROM NEFT»,
RUSSIA

BRICS Youth Energy Agency thanks every team and their sending organization for their contribution to the Outlook 2019.

All the teams worked passionately to deliver their best vision on how the challenges for the energy industry will change the way that we think of energy. We believe that we have achieved the goal.

PJSC «NOVOLIPETSK STEEL»,
RUSSIA

PJSC «TRANSNEFT»,
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Yulia Delyukina

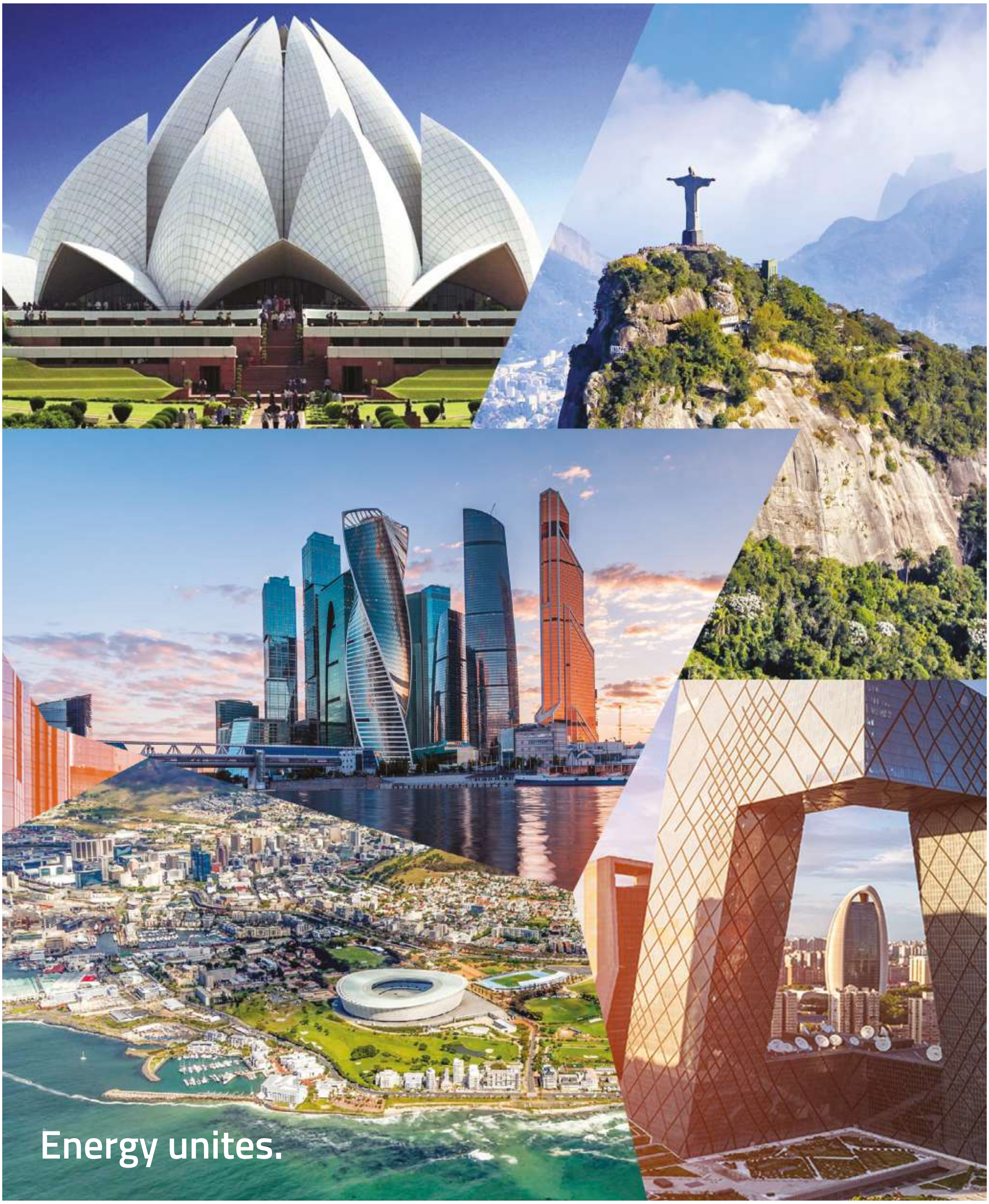
Chief Editor

Welcome to the BRICS Youth Energy Outlook 2019!

I am happy to present you the main work of the Analytical Center of the BRICS Youth Energy Agency. Cooperation of the BRICS Youth is our main priority and this work is the result of a great research of more than 100 developers over the world and the BRICS YEA team. I would like to thank the contribution of the excellent team of the Editors, who has done an excellent job of assembling data, interpreting it, building projections and drawing lessons from them, the Chairman of the Agency and all the rest who supported our great plans.

There's a strong correlation between human development and energy consumption, that is why the topics of our research are very ambitious and challenging to discuss. In this Outlook we tried to unite the vision of our young researchers (BRICS countries' students and young professionals) and the experts' point of view aiming to get the best possible result. Today's youth, we have witnessed strong changes in the beginning of 21th century, the dawn of a new universal technological revolution. Studying the industries' experience of the BRICS countries we prepared Chapter 1, developing the topics related to Energy 4.0, and as gas motor fuel plays an ever-increasing role in energy supply, both today and in the future, we decided to highlight its importance dedicating to its tendencies the whole Chapter 2 - Special Topic. I hope all readers will find the present Outlook a useful contribution to their own discussions and thinking.

LEADERSHIP IS NOT ABOUT YOU; IT'S ABOUT INVESTING IN THE GROWTH OF OTHERS.



CREATIVITY REQUIRES INPUT, AND THAT'S WHAT RESEARCH IS. YOU'RE GATHERING MATERIAL WITH WHICH TO BUILD. - GENE LUEN YANG

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Gratitude

BRICS Youth Energy Agency extends its gratitude to the Ministry of Energy of the Russian Federation, Federal Agency for Youth Affairs of Russia, MGIMO-Univeristy and "Smena" Foundation for continued support of the main projects of the agency.

NO ONE UNDERTAKES RESEARCH IN PHYSICS WITH THE INTENTION OF WINNING A PRIZE. IT IS THE JOY OF DISCOVERING SOMETHING NO ONE KNEW BEFORE.
- STEPHEN HAWKING

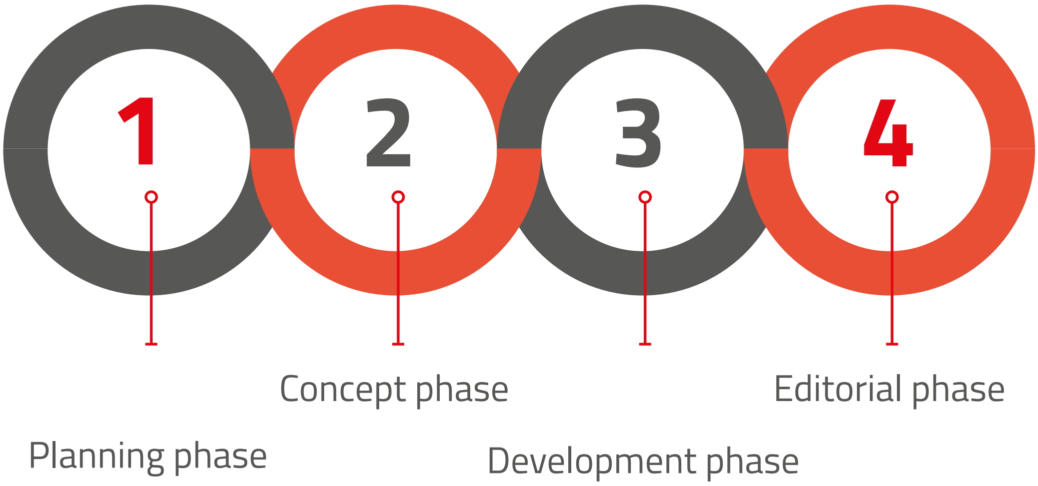
Main Trends

No outlook is perfect if there are not main trends laid into the base of a major research. To define the major trends we have arranged a survey research among industrial and scientific leadership. The results are below.

1. Clean coal technology development;
2. Hydrogen energy: challenges and development prospects;
3. Competition of motor fuels: oil, gas, electricity, hydrogen;
4. Gas motor fuel: market development and technologies;
5. Electric transport and infrastructure of electric filling stations;
6. Improvement of energy efficiency of the national economy;
7. Cyber security issues in the fuel and energy Industry;
8. Digital energy and smart grids' prospects;
9. Gasification: prospects, mechanisms and challenges;
10. Electric power systems: development, survivability and safety;
11. Potential, trends and promising technologies for oil exploration and production;
12. Renewable energy resources: horizon of competition with traditional sources of energy.

Development

There is no development physically or intellectually without effort, and effort means work. We arranged the outlook's developemnt in the phases mentioned below that lead us to the successful research.



First of all, on the Planning phase we did research and analized the most challenging topics of the day relevant to the BRICS countries and chose 12 of them to be a part of the Outlook. Then, on the Concept phase, we designed the structure of the research and the guidelines for participants. We distributed tasks among the teams from BRICS universities and professional communities. As the researchers took up the research, we announced the Development phase. We received the draft papers from the teams and experts, edited them, and thus, they were incorporated into the text of the present Outlook.

RESEARCH HAS SHOWN THAT IT TAKES 31 DAYS OF CONSCIOUS EFFORT TO MAKE OR BREAK A HABIT. THAT MEANS, IF ONE PRACTICES SOMETHING CONSISTENTLY FOR 31 DAYS, ON THE 32ND DAY IT DOES BECOME A HABIT. INFORMATION HAS BEEN INTERNALISED INTO BEHAVIOURAL CHANGE, WHICH IS CALLED TRANSFORMATION. - SHIV KHERA

BRICS Youth Energy Timeline

2015

BRICS Youth Summit 2015 Action Plan: Establishment of the BRICS Youth Energy Association

Upon the initiative of the BRICS Youth after the First BRICS Youth Summit 2015 in Kazan/Moscow, Russia the BRICS YEA was established.

The first meeting of the BRICS YEA was held as part of the Energy Efficiency and Energy Saving (ENES) Forum in Moscow, Russia.

The Initiative group along with the Coordination Council for establishment of the body were found.

It was a great task to consider all possible options in regard to development of an international organisation that was driven solely by the youth on a totally volonteer basis.

The story began...

2016

Contunied negotiations with the partners from BRICS to develop the BRICS youth energy agenda

The Coordination Council continued negotiations with the BRICS authorities on shaping the BRICS YEA into a cross-border informal youth organization to facilitate young reseachers and to make their voices heard.

Within the Presidency of India in BRICS in 2015 the cultural civil cooperation were accentuated, however, the active members worked hard to save succession of the youth energy agenda and to move ahead.

At that time the first idea about a common energy agency for BRICS countries was introduced. It didn't pass unnoticed.

2017

Rebranding of the association into the BRICS Youth Energy Agency (BRICS YEA)

Chinese Presidency in BRICS in 2017 focused on the common issues around energy efficiency and energy saving. That helped the BRICS YEA to revive and to actively proceed on matters of energy between the countries.

At that time BRICS YEA community felt that the focus of the organisation had to switch to energy research and the measures to facilitate energy science and project-making. That led to rebranding of the association into an agency. Having realized that, we moved forward and annouced the first BRICS YEA Summit in 2018.

Supported by numerous partners from BRCS, we couldn't be more excited about our first BRICS youth energy summit.

BRICS YEA was established in 2015. Since then we have put a lot of effort and worked relentlessly to develop youth energy cooperation and research within BRICS. This Outlook is a significant result of our hard-work. That will be our quest from now on.

2018

First BRICS Youth Energy Agency Summit 2018 and the BRICS Youth Energy Cooperation Action Plan

The First BRICS Youth Energy Agency Summit in Moscow was organized within the framework of the "Russian Energy Week-2018" International Forum Youth Day #BrighterTogether. For 3 days young professionals from BRICS countries took part in plenary discussions and round-tables on the future development of the BRICS energy industries as well as meetings with experts on the topic of strategic development of the energy industry.

After various work-shops on development of a common energy agenda and discussions of youth energy cooperation agenda the BRICS Youth Energy Agency presented final documents of the Summit, namely the BRICS Youth Energy Outlook-2018 and the BRICS Youth Energy Cooperation Action Plan.

2019

As part of the BRICS YEA Summit 2019 will be presented the BRICS Youth Energy Outlook 2019 - the first energy research developed by the BRICS Youth

BRICS YEA establishes firmer parterships with the BRICS Youth authorities, especially from Russia, South Africa and Brazil. The first road-show or the agency was held by the National Youth Development Agency of South Africa in Johannesburg, the second road-show has been negotiated to be held as part of the BRICS Youth Summit 2019 in Brasilia.

Along with that, the Agency helds its second Summit as a part of the "Russian Energy Week" International Forum Youth Day #BrighterTogether on 4-5 October, 2019, and presents its key projects: the BRICS Youth Energy Outlook-2019 and the BRICS YEA Network. The Agency presents its plans for the Russian Presidency in BRICS in 2020.

2020*

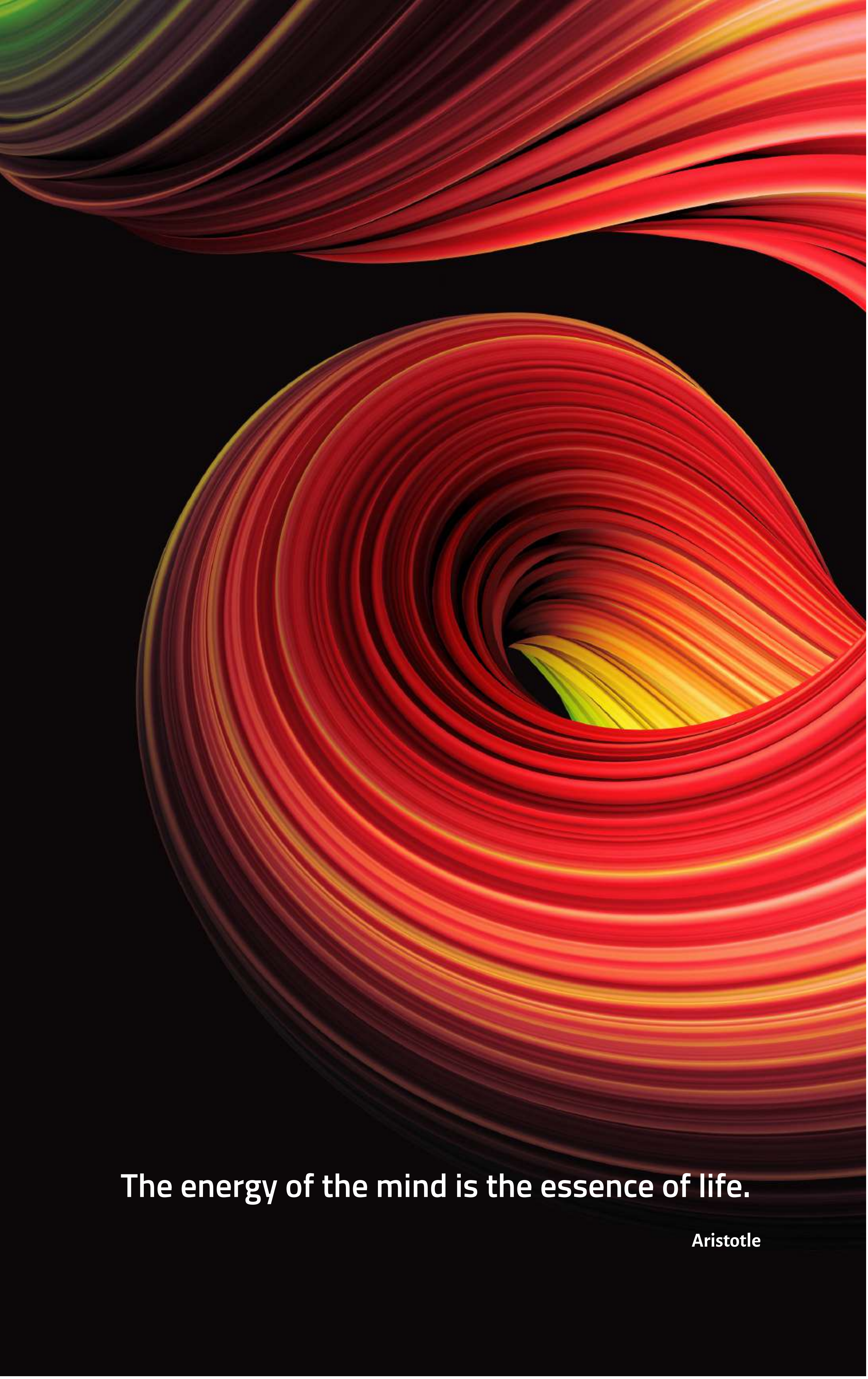
BRICS YEA Summit is an official event of the Russian Presidency in BRICS in 2020

BRICS YEA supported by the Russian Ministry of Energy and the Russian Ministry of Foreign Affairs will hold the 3rd BRICS YEA Summit as part of the official programme of the Russian Presidency in BRICS in 2020.

We have planned to develop the BRICS YEA Network into the environment for young professionals and scientists who will be in collaboration with energy companies and best univeristies develop their potential.

With support of the companies and academia we planned the activties programme for 2020 and eager to move to the next step in regard to BRICS youth energy cooperation.

The next is coming...



The energy of the mind is the essence of life.

Aristotle

Notes

CHAPTER 1

ENERGY 4.0 BRICS COUNTRIES & MAIN CHALLENGES FOR ENERGY INDUSTRY

Energy 4.0 is a notion that is known well in the world. Technology has been increasingly adopted by all major industry sectors over the last several years—and the energy industry is no exception. Although the terms "industry 4.0" and "fourth industrial revolution" are often used interchangeably, "industry 4.0" refers to the concept of factories in which machines are augmented with wireless connectivity and sensors, connected to a system that can visualize the entire production line and make decisions on its own. In essence, industry 4.0 describes the trend towards automation and data exchange in manufacturing technologies and processes which include cyber-physical systems (CPS), the internet of things (IoT), industrial internet of things (IIOT), cloud computing, cognitive computing intelligence. Changes in Energy Industry touched upon many countries and BRICS countries are not the exclusion.

THAPAR INSTITUTE OF ENGINEERING AND TECHNOLOGY PATIALA
REPUBLIC OF INDIA

1.1 RENEWABLE ENERGY RESOURCES: HORIZON OF COMPETITION WITH TRADITIONAL SOURCES OF ENERGY

India has a dedicated ministry to cater for the requirements and developments in the field of renewable energy. The Ministry of New and Renewable Energy (MNRE) is the nodal Ministry of the Government of India for all matters relating to new and renewable energy. The broad aim of the Ministry is to develop and deploy new and renewable energy for supplementing the energy requirements of the country. There are 4 types of renewable energy in India: solar, hydro, geo-thermal and wind power.

1.1.3. GOVERNMENT INITIATIVES

The Indian government identifies power sector as the center of attention in order to create advancement in sustainable industrial growth and development.

An amendment to the Electricity Act, 2003 has been made which highlights the segregation of content and carriage, subsidy's direct benefit transfer, unhampered power supply throughout the day, deploying smart and prepaid metering.
Ujwal Discoms Assurance Yojana (UDAY) encourages outfitted and economic turn of State-owned Power Distribution Companies (DISCOMS), which determines to decrease Aggregate Technical & Commercial (AT&C) losses up to 15%.

National Policy on Bio-fuels – 2018: Provides health workforce remuneration, hygienic surroundings, providing employment, lesser import reliance, advanced infrastructural venture speculation in country sides and supplementary profits to farmers.
The Government of India has targeted to attain 175 GW capacities in renewable energy by 2022, where 100 GW of solar and 60 GW of wind power is included. "Rent a roof policy" under this target embraces the intention to produce 40GW power using solar rooftop projects until 2022. Current coal-based generation is 191.09*GW and it is anticipated to arrive at 330-441 GW until 2040.

India can possibly in the future, be the first ever country to utilize LEDs for every lighting requirement by 2019, and by this means can save Rs 40,000 crore (US$ 6.23 billion) annually.

1.1.4 SOLAR ENERGY IN INDIA

First of all, India has a solar installed capacity determined as 28.18GW currently. Solar-generation capacity in the country has expanded 8 times from 2,650 MW to up to 20 GW as of 31 January 2018. 3.4 GW of solar power at rooftop is reported out of which 70% is consumed in industries or commercially. Moreover, apart from extensive grid-connected solar photovoltaic initiative, India is working on off-grid solar

15000MW GRID CONNECTED SOLAR PROJECT

The national solar mission has proposed a scheme to set up 15,000 MW grid connected solar PV power projects which has been approved by the union cabinet.

Advantages:

- The commencements of such projects will speed up the process of attaining reduced costs of generating solar power. This will also help reduce consumption of kerosene and diesel;
- Better environment to live;
- India's Energy safety measures will be strengthened.

SOLAR POWER STATION IN SPACE (March 2015)

The sunlight from space can be gathered which forms such Space Solar Power that it can be transmitted wirelessly to Earth. This technology can help eradicate our energy problems and greenhouse gas emission troubles.

Advantages of space solar power:

- It does not release any greenhouse gas in contrast to oil, gas, ethanol, and coal-based power plants;
- Different from the solar and wind plants, this power is accessible 24 hours a day, 7 days a week, in large quantities. Also, its mechanism is based not depending anyway on available daylight, speed of wind or cloud cover;
- This power provides energy autonomy in its true sense for countries developing it;
- It can also be easily delivered to almost any position on Earth, and its energy could be transformed for local neighborhood needs like manufacturing of methanol, etc. It could also be utilized for the desalination of seawater.
- India's Energy safety measures will be strengthened.

power to meet general energy requirements. This year, Indian Railways have announced to set up 4 GW capacities all along its tracks. The International Solar Alliance (ISA) has India as a founder member country, and its headquarters is also situated in India.

1.1.5. WIND POWER IN INDIA

Until 31 December 2018 the installed wind power capacity in totality was 35.288 GW, which is the fourth largest in the entire world. Wind power costs are declining swiftly in India. Recently alterations have been made in Tariff Policy of Renewable Purchase Obligation (RPO) in the course of the Electricity Act 2003, which are obligatory entities and are mandatory to acquire a minimum percentage of the entire energy procurement among the renewable sources. But since the wind power potential is largely available in 7–8 windy states of the country, to make the inter-state transmission of power possible, the Tariff Policy requires for waiving of the losses and charges for inter-state transmission and sale of wind power. From the 302 GW wind power potential in India, 297 GW is available in these states.

1.1.5.1 GREEN ENERGY CORRIDORS

The corresponding character of solar and wind power has been brought about by the wind-solar hybrid research. Yet it is unclear how these two technologies will assist in reducing the inconsistency: separately from optimally utilizing the infrastructure or together with land and transmission system. The aim of such venture is to realize wind–solar hybrid power of 10 GW until 2022 in order to persuade innovative technologies, methods, and breakthrough schemes which involve joint operation of wind and solar PV panels.

1.1.5.2 WIND POWER THROUGH KITES (JUNE 2017)

Problems like land availability issue, growing competition from solar energy and lack of investments can be resolved using the latest technology known as scores of kites to create wind power.

Kite-driven power stations:

The kites, which have a light weight and a controllable character like an aerodynamic airborne device, are prearranged in a particular configuration at a height of 750m or higher in order to yield sturdy and constantly available winds in such regions of the atmosphere (wind speed at such altitudes is twice as that at the ground) and thus produce low-priced power.

Solar power in India future targets:

- India is determined to achieve at least 40% of its entire installed capacity from non-fossil fuel sources until 2030.
- The country has the ability to attain 479GW solar power and 410GW wind power by the year 2047.

NATIONAL SOLAR MISSION (June 2016)

Aims:

- To Generate 100 GW of solar power up till 2021-22
- To generate 60 GW ground mounted grid-connected solar power and 40 GW through rooftop grid interactive solar power.
- The current year target is to generate 2,000 MW and the succeeding year target — 12,000 MW.

SOLAR POWER TREE

- This is a ground-breaking technique to produce electricity by using solar power in a limited and restricted space.
- Its structure is similar to a tree that has branches which are made up of steel in order to hold PV panels.

SOLAR GEO-ENGINEERING (April 2018)

Dimming Sunlight is the latest interest of the developing nation's research area by using artificial sun-shade to mitigate the problems related to climate change.

Solar Geo-Engineering / Solar Radiation Management (SRM):

- It is a procedure throughout which the albedo of the Earth's atmosphere or the Earth's plane is augmented, in an endeavor to counterbalance few of the problems caused by GHG-induced climate change.
- This technology resembles large volcanic eruptions which are capable of cooling Earth by covering the Sun with a mask of ash or other related things.

1.1.6. HYDROPOWER IN INDIA

India's hydroelectric power potential is anticipated at 148,700 MW which is ranked 7th amongst other countries in the world. The country's first hydroelectric power plants in Darjeeling and Shivanasamudra rank among the first in Asia.

1.1.6.1 SMALL HYDRO POWER PROGRAMME

The Ministry of New and Renewable Energy is assigned the duty to develop Small Hydro Power (SHP) projects up to 25 MW capacities. The expected potential for power production from these plants is up to 20,000 MW. River-based projects are mainly confined to the Himalayan states and other States rely on irrigation canals to fulfill the potential.

1.1.7 GEO THERMAL ENERGY IN INDIA

Calculations and surveys carried out by GSI, NGRI & CEA have revealed that the potential of around 10000 MW is aspired which could be extended up to 300 hot springs all across the seven geothermal provinces/11 states. According to the international data reports, a 1 MW Geothermal Power Plant produces 8.3 (MU) per MW annually as compared to Solar power production, i.e. 1.6 MU per MW, of Wind it is 1.9 MU per MW and that of Hydro is 3.9 MU per MW. Geothermal provinces are capable to generate 10,600 MW of energy. But still these power projects are not being explored or worked upon at all because of various reasons, mainly the availability of coal at cheap rates.

1.1.8 CHALLENGES AND LIMITATIONS OF INSTALLING RENEWABLE ENERGY SYSTEMS IN INDIA

1.1.8.1 IMPACTS OF SOLAR ENERGY

Economic impacts:

- Large installation costs are one of the major challenges in the development of renewable energy. Therefore, it requires further research and technological innovations in this field.
- Rooftop power-generation systems which are connected via local grids are best suited for the Indian system [15]. This kind of infrastructure requires a lesser operating cost to attract attention of local individuals and households.
- PV's are anticipated to persist their cost cutting, being at par with fossil fuels.

Social impacts:

- Renewable based energy system still lacks social acceptance in the Indian society due to the lack of awareness in rural India and a negligent attitude of urban India.
- In spite of heavily subsidized solar water heater installation and lightning systems, their usage and application are still found to be very low.
- Manpower training is also noted to be the grey area.

Technological impacts:

- The efficiency issue is the major drawback for its widespread usage. The thin-film and crystalline-silicon modules lists of efficiency range from 7% to 10% and from 12% to 18% respectively.
- Another technical issue is of the thermal loss from the heat storage apparatus in these systems [18].
- For each 20–60 (MW) 1 km² land is required for these solar power plants which is a stress to the land resource availability.
- Storage is another serious problem.
- Large capital investments are needed in the grid infrastructure where these intermittent sources are concerned — for smart supply, transmission and managing the demand.

1.1.8.2 IMPACTS OF WIND POWER

Economic impacts:

- 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.

Social impacts:

- Wind energy farms should be set up in rural localities at a particular height in order to ensure sustainable wind energy.
- No pollutants like greenhouse gases are released into the environment during energy production through wind turbines.

Technological impacts:

- 3.00 MW or above is the largest size of machines per unit.
- Many companies in India have manufactured over 50 models of turbines through (i) licensed production under joint ventures, (ii) foreign companies sponsored subsidiaries, and (iii) Indian indigenous technologies.
- Wind turbine components are exported to the US, Australia, Europe, Brazil and some Asian countries. Because of the indigenous manufacturing, 70%–80% indigenization has been achieved.
- Interestingly, the cost of Indian wind turbines is the least expensive in the world.

1.1.8.3 IMPACTS OF HYDRO POWER PLANT

Economic impacts:

- DISCOMS seemed to hesitate to ratify Power Purchase Agreements (PPAs) because of high tariffs in former years.
- Because of the risks like geological constraints, natural hazards/calamities, forest and environmental issues, this sector is not booming at the pace it should.
- Due to change of river basin and also the commercial risks involved, resettlement and rehabilitation is a worrisome issue.

Social impacts:

- Financing hydropower projects plus evacuation during calamities are the reasons for social non-acceptance.
- The major potential is situated in the reaches of Himalayas and North-East, so it results in socio-economic development by directly providing employment in this sector.
- Indirect employment prospects and entrepreneurial opportunities in transportation, tourism and various other small-scale businesses can be achieved.

Technological impacts:

- Wastage of large amounts of water flowing perennially which could be converted to energy and can hence control the conditions of drought as well as floods.

1.1.8.4 IMPACTS OF GEOTHERMAL ENERGY

Economic impacts:

- Unlike traditional power plants that run on fuel which must be purchased over the life of a plant, geothermal power plants use a renewable resource that is not susceptible to price fluctuations.
- The price of geothermal is within the range of other electricity choices available today when the costs of the lifetime of a plant are considered.
- Most of the costs related to geothermal power plants are related to resource exploration and plant construction.

Social impacts:

- Accessing suitable building location is a challenge.
- Wind, solar and hydro energy sources are well accepted and established; these factors make traders decide not in favor of geothermal.
- Disposing of gas is tricky to be done safely and leaked gases are a concern to surroundings.

Technological impacts:

- Drilling Costs are a major technological constraint, which alone account for one-half of the entire cost of a project.
- Developers may drill too many dry wells before discovering a feasible resource, so locating can be slightly time consuming and difficult.
- Since rocks in geothermal areas consist of rocks that are very hot and harder, drilling equipment needs to be timely replaced.
- Geothermal power plants need to be situated near to a reservoir as it won't be practical to transfer hot water or steam it up to a distance farther than 2 miles.
- It is expensive to install power lines afresh and also site availability is difficult.

1.1.9 ANALYSIS OF TECHNOLOGIES FOR THE FUTURE

Renewable energy sources are not available round-the-clock and therefore are dependent on energy storage systems. For the first time in history electric vehicles (EVs) have outnumbered conventional fuel based cars in Norway. However, EVs are utilizing lithium-based batteries for on-board vehicle energy storage which is not a sustainable solution. Owing to the shortcomings of the currently prevailing technologies, technology of the future will not depend on an individual source of energy but there will be an integrated system comprising of more than one source of energy, for example – solar pv and wind turbine hybrid system, solar pv-fuel cell hybrid system, PV-wind-fuel cell integrated system, etc.

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1.2 CLEAN COAL TECHNOLOGY DEVELOPMENT

1.2.1 JUSTIFICATION OF CLEAN COAL TECHNOLOGY (ECONOMICAL, LEGAL AND TECHNOLOGICAL)

In 1992 Brazil held the first International Conference aimed at combating the ever increasing environmental and socio-economic ills at a global scale. The conference is famously known as the Rio de Janeiro Earth Summit. The conference aimed to achieve this by pursuing sustainable development. Sustainable development could be described as upliftment of socio-economic status without the depletion of natural resources for future generations. The direction of development nowadays is sustainable development which hopes to advance development (socially and environmentally) without the degradation of the environment as emphasized by the Paris Agreement.

TECHNOLOGICAL DEVELOPMENT

Coal plays a very important role as source of energy, accounting for approximately 40% of power around the world. Many countries are more reliant on coal, for instance: South Africa depends on coal 92% and China for 77% (World Coal Institute, 2005). Furthermore four of the five countries that form the BRICS (Russia, India, China and South Africa) are on the top 10 of the countries in the world which depend on coal for energy (Sawe, 2018). Taking into consideration the use of coal predominantly for energy purposes. Modern tendencies dictate the movement of towards cleaner forms of energy. Thus to balance the heavy reliance of coal for energy by many countries (4 countries in the BRICS are in the top 10 countries which rely on coal dominantly for energy purposes). There is a need for technological advance of Clean Coal Technologies (CCTs).

INTERNATIONAL ENVIRONMENTAL LAW

Following the pollution intense 20th century, member states of the United Nations took a step towards the progressive realisation of a carbon emission free society. This step is referred to as the 2005 Kyoto Protocol which was embedded on both the Montreal Protocol (Montreal Protocol on Substances that Deplete the Ozone Layer, adopted in Montreal on 16 September 1987) and the 1992 United Nations Framework Convention on Climate Change (UNFCCC).

Following the Kyoto Protocol was the Paris Climate Agreement of which South Africa is a part off. The above is mentioned because South Africa through section 231 of the Constitution is legally bound to treaties it signs of which in this case shows a commitment to protect the environment in an ecologically sustainable way (Constitution of the Republic of South Africa, 1996). With its obligations to the global community to decrease greenhouse gas emissions, clean coal technology is the point of departure should South Africa want to stay true to its word.

SOUTH AFRICAN ENVIRONMENTAL LAW

In commencing the discussion, it is important to note that South Africa has over the years been at the heart of industrialisation owing to its diverse mineral and energy complex. The industrial activities such as mining, manufacturing and agriculture led to emissions of different greenhouse gases. To the aid of the environment and its inhabitants, the law became central in its protection thus the conception of the very important legislations such as the National Energy Act 34 of 2008, Environmental Conservation Act 73 of 1983 and the National Environmental Management Act 107 of 1998.

The above acts are subsidiary to section 24 of the Constitution of the Republic of South Africa.

Understanding that the production and discovery of energy sources is by implication detrimental to the environment, therefore, it is important to coincide aspirations of clean coal technology with the law at all material times.

The National Energy Act provides a framework for the regulation of energy in South Africa and has in its preamble very bold ambitions which should define the diverse energy sector. From the preamble, an inference can be drawn that the legislator had energy sources such as clean coal technology in mind.

Section 24 of the Constitution sets up a holistic approach to energy which through legislation is given effect. In the event that an energy source is detrimental to the environment, such an energy source needs to be reconsidered of which is not the case with clean coal technology. According to South African law, energy sources need to be cost efficient to the general public, harmless to the environment and enhances the socio economic transformation agenda.

Clean Coal Technology offers this, however, the legislature through regulations has not broadened the base to allow CCTs space. The orthodox coal to electricity mechanism proves to be a dismal failure not only to the environment but also to the South African public. Understanding that the orthodox coal to electricity has its own advantages and disadvantages respectively, there needs to be a new outlook on the energy spectrum of South Africa by providing a more sustainable and ecologically sound energy source.

Therefore, the South African legislation allows space for Clean Coal Technology, the only deadlock is the will of government to abandon orthodox coal to electricity mechanisms for clean coal technology.

1.2.2 KEY TECHNOLOGIES AND PIONEER COMPANIES

CIRCULATING FLUIDISED BED COMBUSTION (CFBC)

The CFBC is a direct rival to the existing Pulverised Fuel /Pulverised coal combustion which is widely used. CFBC technology offers several advantages which are directly better than Pulverised coal combustion. Firstly the CFBC boilers are extremely adaptable, thus except a wide variety of fuel qualities and types, for instance a CFBC boiler can accept poor quality coal and high ash resources. This particularly good news for South Africa because it has abundant low quality coal supply. Secondly the technology emits significantly lower Sox and Nox without the need to use costly gas emissions control systems. The technology is pioneered by Eskom.

FIXED-BED COAL GASIFICATION (SASOL-LURGI)

The Lurgi gasifer is considered the world's best fixed-bed gasifier. It was first created in the 1930s in Germany. The principal business plant operated for the first time in 1936. The plant is widely used in the world but it heavily utilised in China, South Africa and United States of America. The Lurgi gasifier (fixed-bed coal gasification) is advocated by Sasol in its Sasol Synfuels plant in Secunda, South Africa. Sasol-Lurgi uses coal as a fuel source in its fixed bed gasification process. The coal utilized is usually low rank bituminous coarse coal (> 6mm) with low sulfur content. During the gasification process the sulfur is removed. Sasol uses in excess of 30 million tons of coal per year and produces over 150 000 barrels of fuels and chemicals per day.

CAPTURE AND STORAGE (CCS)

Storage (SACCCS) is a division of South African National Energy Development Institute (SANEDI). SACCSS is tasked to aid in research and development of Capture and Storage (CCS) technology in South Africa. So far in the year 2017, the Pilot CO2 Storage Project (PCSP) stored between 10,000 - 50,000t of CO2 . Thus the CCS technology in South Africa are still under study.

UNDERGROUND COAL GASIFICATION (UCG)

It involves injection of a gaseous oxidizing agent, usually oxygen or air, and bringing the resulting product gas to the surface through production wells drilled from the surface. The UCG offer great environmental advantages including low carbon emissions and no addition of chemicals are used during the gasification process. Majuba UCG pilot project in South Africa is in the final stages of the research. Eskom Holdings SOC Limited (Eskom) which is the state owned company pioneering the research in the commercial viability of UCG technology in South Africa is positive about the results so far that the technology may be commercially viable and it is preparing the final report. The technology would be widely accepted in South Africa due to the large coal reserves which are not easy to access via conventional mining process.

SUPERCRITICAL CARBON DIOXIDE (sCO2) CYCLE TECHNOLOGIES

Supercritical carbon dioxide (sCO2) cycle technologies are currently used in Eskom two coal fired power stations, Medupi and Kusile power stations. The technology allows the conversion of thermal energy to electric energy to be highly efficient and may allow a complete Capture and Storage.

1.2.3 DEVELOPMENT PERSPECTIVES OF THIS DIRECTION UNTIL 2030.

Various stakeholders recognise the abundance of coal reserves in South Africa and the need to utilize the resource in a sustainable manner. South Africa will still rely heavily on coal due to the plans detailed in the National Development Plan to mine the coal deposits in the Waterberg and to fix or upgrade existing coal lines. However the country is committed to a greener economy, for instance, the President has marked into law the Carbon Tax Act No 15 of 2019, which became effective from 1st of June 2019. The law is meant to reduce South Africa' s contribution to the Green House Gases (GHG) emissions. The law will be executed in two stages, the first stage will be from the 1st of June 2019 to 31st of December 2022, and the last stage commence in 2023 and end in 2030. The law is preceded by several important policy documents which advocated for a low carbon emission economy, including the National Climate Change Response Policy (NCCRP) of 2011 and the National Development Plan (NDP) of 2012. Furthermore because South Africa signed the Paris Agreement in November 2016 it will support various legislative and technological advancement to ensure that the country caps its contribution to air pollution. Thus due to the government's will to improve the economy, reliance on coal for energy and commitments to protect the environment, it is compelled to support Clean Coal Technology (CCTs).

1.2.4 THE IMPACT OF GLOBAL CHALLENGES IN THE CHOSEN DIRECTION ON SOCIAL AND ECONOMIC AFFAIRS

The survival of the coal industry and the need for a transition to a renewable energy mix has recently been under international scrutiny. Pros and cons for energy industry has been evaluated by both the proponents with vested commercial interests in renewable and environmentalist versus those with vested commercial interests in the survival of the coal industry. Challenges to deploying clean coal technologies vary from country to country, and each CCT has its own challenges from being deployed. To incorporate variability and avoid generalisation, this section presents social and economic challenges imposed by various CCTs and their impact thereof on countries globally, and furthermore provide snippets of information from energy reports particularly from BRICS countries to emphasize the solemnity of these challenges and their interconnection.

ECONOMIC CHALLENGES

Challenges to deploying CCTs includes improvements of existing coal-fired power stations to better their flexibility and availability. Clean coal technologies such as Carbon Capture and Storage (CCS), Coal gasification, and Integrated Gasification Combined Cycle (IGCC) are very expensive and it is viewed that there is a financial restriction for developing countries to deploying such technologies, particularly CCS. In South Africa, Fischer-Tropsch is one of coal conversion processes that result in catalytic hydrocarbon fuel production from synthesis gas. Major challenges associated with this process are high capital costs of equipment, requirement of very large-scale facilities and the complexity of the process. Costs of technologies such as CCS vary with geographical scale, with storage formations widely dispersed such as in South Africa having increased costs because of carbon dioxide transportation. India has not kept pace with global development of CCT advancements because of high cost involved to support the development of CCT to proving stage although CCT development in this country started two decades ago.

Financial barriers in India and numerous developing economies includes the inadequate Research and Development (R&D) infrastructure in academic institutions and national laboratories which also constrains the relationship between the academic institutions and the energy sector. Lack of advanced technologies to countries enriched with coal with high ash content, difficulties in developing coal blocks due to absence of adequate equipment structure and lack of sufficient coal evaluation facilities poses challenges to various developing economies. Deployment of CCTs is not only dependent on the capital available to purchase necessary machinery, the construction of CCTs and advanced power stations, but research prior deployment, appropriate development of academic infrastructure to study the feasibility and potential siting, pros and cons of CCTs of choice is of paramount importance to enable an effective, prolonged operation of CCTs.

SOCIAL CHALLENGES

Deployment of CCTs, depending on their geographical scale and so forth poses a number of different challenges to different countries. Public support is of critical importance to ensure the success of research and commercialisation (Kok and Vural, 2013). It is imperative that communities participate in the social impact assessment for effective planning of CCTs. The countries with numerous official languages and diverse variety of cultures, belief systems and traditional systems poses a challenge to deploying CCTs (Beck et al., 2017). Beck et al., (2017) reviewed the results from the social impact assessment lead by the SRK consulting in South Africa and argued that variety of belief systems have impacts on deploying CCS. Many challenges highlighted by the SRK Consulting are not present on international CCS projects such as high rate of unemployment and underemployment (Beck et al., 2017).

Numerous official languages can be barriers which can forge misunderstanding between the public and the government. Varying belief systems and unemployment can trigger communities do not allow any development of CCS on their soil, and this may be only prevalent in developing economies. The resistance from communities can also stem from knowledge of disadvantages of various CCTs such as coal gasification which uses more water. If the public is aware that CCTs

will somehow affect their social life, health and so forth, they may not allow the development to continue. Public disapproval is very difficult to overcome. Therefore, is it crucial for the relevant government and private entities to engage with the public to explain the technology and address environmental, health and safety concerns. Holistic approach with the public must be conducted where every issue raised by the community is dealt with in an appropriate manner.

A complex governance networks comprised of national, provincial, district and local municipality jurisdiction, with traditional boundaries and authorities is a challenge. With such governance network, comes a meandering relationship among officials, even corruption which may present a challenge to deploying CCTs. Diverse land ownership in the areas of interest for CCTs, including privately owned land and that owned by traditional authorities. This can impact the deployment of CCTs negatively by people not allowing the development in their land. The proximity of protected areas such as national parks in the area of interest for the CCT is a challenge, and in one case in South Africa, the Pilot Carbon Storage Project (PCSP) is in a close proximity with the United Nations Educational, Scientific and Cultural Organisation (UNESCO) World Heritage Site. This can trigger fear to the public by being in close proximity to such machinery in concern of their health and safety.

1.2.4 ANALYSIS THE IMPACT OF GLOBAL CHALLENGES IN THE CHOSEN DIRECTION ON THE TECHNOLOGY

The use of clean coal technologies (CCTs) has been escalating and will continue to do so for at least the upcoming two decades. Whilst developed and developing countries throughout the world are working tirelessly to reduce the environmental, social and economic impact that coal technologies impose on the world, they encounter some global challenges. Henceforth, there is room for improvement as far as the enhancement of the CCTs is concerned once these challenges have been correctly addressed and hopefully eliminated. This will result in more advanced, cleaner and efficient technologies. Therefore, this section will focus on the impact of the global challenges in clean coal technologies with respect to CCTs especially carbon capture and storage. Below is an image of countries involved in the International Energy Agencies (IEA) of clean coal technologies.As far as CCTs are concerned, the main issues lie with the social and economic affairs rather than the technical issues. The main issues are associated with regulation, finance and how the public agrees with the transportation and storage both below and above the ground. The technologies for cleaner coal generation target reducing the consumption of coal, reducing non Green-house gas (GHG) emissions and carbon

capture and storage (CCS). The main challenge experienced with these technologies is the carbon leakages especially those that are large scale from underground reservoirs (Philibert, 2004). This continues to be a challenge as coal power plants will not perpetually exist which raises concerns as to who will monitor these sites when the power plants are out of existence.

Most of the CCS technologies are used on small scale by chemical, gas and oil industries as they are difficult to upscale. This has been a major global challenge as these technologies cannot rectify the problem of coal technologies in terms of pollution as fast as required. Furthermore, these require vast amounts of money and are energy intensive. Hence the amount of energy required to capture the carbon is one of the major global challenges. This creates a loophole in the technology which requires vast attention from researchers around the globe. The development of gauging systems that evaluate and monitor the storage is also a challenge as these have not been optimised as of yet.

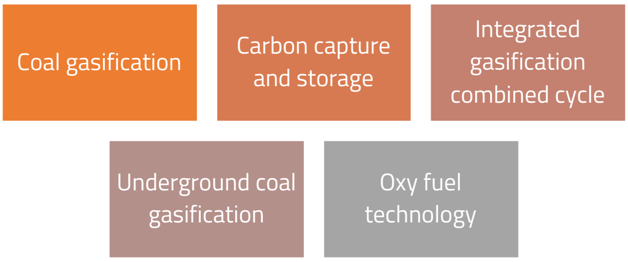

Figure 1.2.1 Technologies for the future (in 2035-2059)

On the other hand, the flow of these gases is multiphase which brings about the challenge of control and regulation). Carbon capture and storage has gotten major attention as compared to other Clean coal technologies however, there are global challenges as to how to transport CO2 without rapture and leakages. Studies have been conducted to reduce the hazards that anthropogenic CO2 poses as different grades of CO2 are produced from the flue gas. Major challenges have been discovered mainly with the engineering design of the pipelines to make them stronger and durable. In addition, overall cycle cost and capacity together with a balance between demand and supply also have been an issue.

The challenges outlined in the previous paragraph are attributed to the fact that anthropogenic CO2 is difficult to transport as the natural gas because it has a severe decomposition curve. This leads to high susceptibility to ductile fracture in the long run hence very hard and wide steel pipes are required or external mechanical devices. In addition, low temperatures due to natural causes or gas leakage will decrease the pressure in the pipes which results in them becoming brittle and hence weak. This is also explained using the Joule Thomson cooling effects. Corrosion of the water pipes could also be an issue when free water phase is present within the CO2 mixture.

Another problem associated with the technologies is that there is increased coal mining with the development of CCTs which means more land exploitation and degradation. This undermines the initiatives to reduce the mining of coal which in turn degrades natural habitats. These technologies require lots of water to use and also lack proven technology maturity which is also a major concern.

1.2.5 TECHNOLOGIES WHICH MAY BE IN GREAT DEMAND IN FUTURE (IN 2035-2059) IN THIS DIRECTION IN TERMS OF GLOBAL CHALLENGES

New coal power plants strive to capture most if not all environmental pollutants of coal combustion such as sulphur and nitrogen oxides (SOx and NOx), traces of mercury (Hg), selenium (Se), arsenic (As) and other fine particulates. Thus, methods are being developed to capture these pollutants, however, the challenge still remain in the cost and efficient way of removing these pollutants. Therefore, only advanced and environmentally clean coal power generating technologies that aim to achieve high efficiency and minimal environmental effect as principal market requirements are expected to remain in stream in the two - three decades coming.

Different methods are applied in clean coal technology including Fischer-Tropsch, Coal gasification, carbon capture and storage, an integrated gasification combined cycle (IGCC) and underground coal gasification (UCG). CO2 can be captured before or after combustion or combusting it in pure oxygen through oxy combustion. Oxy combustion burns coal in pure oxygen instead of air to concentrate the CO2 produced in flue gas, thus it can be easily through amine scrubbing at about 50% less than the cost invested in conventional plants.

Oxy fuel technology show potential to retrofit pulverized coal plants due to the addition of a shift reactor that oxidizes carbon monoxide (CO) with water to form a gas stream of mainly hydrogen and CO2 with some little bit of nitrogen. Impurities of CO2 (at ~85% recovery), Hg and H2S gets separated before combustion to leave free hydrogen which is chanelled to electricity production and disposal of pressurized CO2. However, this is less a viable option in South Africa where we have challenges of water required in the CO to CO2 and water production step, thus less cheaper technologies are still needed.

Coal from South Africa is reported to have high NOx and SOx content which lead to catalyst poisoning. In addition to Fischer-Tropsch, underground coal gasification is also an alternative coal technology option that can be used to exploit value from the low-grade coal currently remaining in some deposits of South Africa. Underground coal gasification involves injection of a gaseous oxidizing agent such as air or oxygen to coal near methane deposit. The resulting product gas in brought to surface through drilled production wells, the major challenge of this technology is the fear of underground water contamination near productions sites from processing pollutants. However, coal gasification seems to be a promising technology with an aim to produce pressurized concentrate CO_2 followed by its geological storage. Coal gasification is not new to South Africa since Sasol operates 72 Lurgi gasifiers at its synfuel plants in Secunda..

From the pollutant and carbon dioxide management viewpoint, coal gasification is a preferred scheme through the Integrated Gasification Combined Cycle (IGCC) route. An IGCC plant produces carbon CO and H_2 from coal at approximately 45% thermal efficiency or higher if without CO_2 capture. The water-gas shift (WGS) reaction further converts the CO syngas to CO2 and H2:

$$CO + H_2O \text{ à } CO_2 + H_2 \ (Eq_1)$$

Several means have been brought forward to capture CO_2 from post combustion gas streams including energy intensive large plant scale hot potassium carbonate, high purity CO_2 producing monoethanolamine process, amine scrubbing and membrane filters, however they have just not yet been optimized to pilot scale of coal power plants. Post combustion capture of CO2 is quite expensive due to hot flue gas with low CO2 concentration at approximately 14%. This cost the plant approximately 20-25% of its output energy reducing efficiency .

In conclusion, a novel concept based on hydrate separation is a promising technology that can be implemented in separating CO2 during before combustion. CO2 is trapped in the lattices of water molecules for an ice like CO2 hydrate substance, the hydrate is much more stable at high pressures and low temperatures. The hydrate is formed from pressurizing synthesis gas containing CO2 to water at high pressure, hence capturing the CO2. Dissociation of the hydrate releases pure CO2. Nexant Inc is still carrying out research funded by the Department of Energy, (DOE) to develop a technology on hydrate-based separation for pre combustion capture of CO2 for an IGCC power plant. The process Nexant Inc calls SIMTECHE CO2 hydrate production is estimated to have a very low energy consumption of ~6 - 8%. This would make hydrate-based separation a near future attractive technology of long-term application in clean coal technology if it's developmental process results in low cost capital investment.

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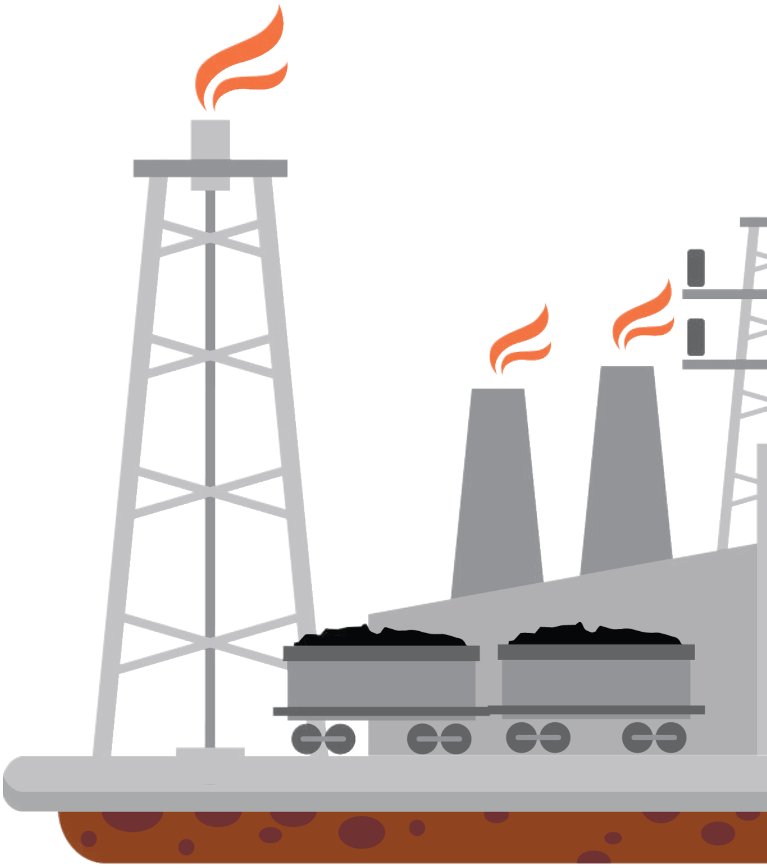

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1.3 HYDROGEN ENERGY: CHALLENGES AND DEVELOPMENT PROSPECTS

1.3.1 REASONS FOR THE DEVELOPMENT OF HYDROGEN ENERGY IN CHINA

Since the discovery of electricity, energy has been the main source of countries' economic growth and development. Overall, the People's Republic of China is rich in energy resources. The exploration of national coal reserves, significantly larger than those of oil and natural gas, has been driving Chinese economy for many decades.

Despite the fact that China has made some large steps towards new more environmentally friendly energy sources old methods of getting energy are not leaning back, almost 60% of energy produced by the country comes from the use of coal. Coal production is mostly concentrated in Shanxi, Inner Mongolia, Guizhou and other inland provinces, while the most energy consuming regions lay in the southeast coast provinces, causing significant transportation costs, alongside with the necessity to import cheaper energy resources, predominantly coal from neighboring countries.

In 2019 Chinese government capped coal imports at the 2018 level in order to secure national producers, and yet the amount of coal imported in the country is still significant (281.23 million tons of coal. Thermal coal, coking coal and anthracite are included). All these facts not only mean that that low-quality energy predominates in China but also serve as an incentive for Chinese government and scientific community to find new energy sources.

In addition, it's extremely important for Chinese government to secure its position as an exporter on a global energy market. Nowadays China is the larger global developer of clean energy technologies and holds a leading position not only in production of renewable energy, but also in its innovation and deployment of new approaches to energy sources.

One of the leading directions in Chinese investments into the search for a new reliable energy source is an investment in hydrogen energy. In this research we will carefully examine the main tendencies in Chinese hydrogen energy use

1.3.3 TECHNOLOGY DEVELOPMENT

The amount of energy that hydrogen carries and its environmental impact depends on the production technology. The main goal for hydrogen producing companies nowadays is to reduce production

1.3.2 CHINESE KEY TECHNOLOGIES

Hydrogen has attracted the attention of scientists from all over the world, in the first place, due to its abundance. Being the first and the simplest element of the periodic table, hydrogen can be found in many combinations with other elements. However, it does not exist naturally as gas but can be separated from other compounds by various techniques:

NATURAL GAS REFORMING

Natural gas reforming is nowadays the most common method to produce hydrogen. It builds upon the existing natural gas pipeline delivery infrastructure and that makes the production of hydrogen significantly cheaper. Natural gas contains methane (CH_4) that can be converted into a mixture of hydrogen, carbon monoxide, and carbon dioxide in small amounts via the steam reforming reaction and the water gas shift (WGS) reaction. Carbon dioxide and other impurities are removed from the gas stream during the final steps of the process, leaving pure hydrogen. Steam reforming can also be used to produce hydrogen from other fuels, such as ethanol, propane, or even gasoline.

RENEWABLE LIQUID REFORMING

Renewable liquid fuels, are liquids derived from biomass (cellulosic ethanol, bio-oils, other liquid biofuels), that are more transportable than actual biomass and can be transformed into hydrogen through a process similar to natural gas reforming. First of all, the liquid fuel is reacted with steam at high temperatures to produce a reformate gas composed mostly of hydrogen, carbon monoxide, and some carbon dioxide. Additional hydrogen and carbon dioxide are produced by reacting the carbon monoxide with high-temperature steam in the "water-gas shift reaction". Finally, the hydrogen is separated out and purified.

costs in order to make hydrogen competitive with more conventional fuels.

The fact that hydrogen can be derived from domestic sources also contributes to its popularity. Natural gas and coal, as well as renewable sources such as water, biomass, and agricultural waste, all can be used to produce hydrogen.

That would make an economy of any hydrogen producing country more independent from export and less vulnerable to volatile prices of the resources.

Despite the fact that NASA has been launching spaceships using liquid hydrogen since 1970s, Chinese entrepreneurs, with the full support of the Chinese government went another way. They are steadily moving towards a large-scale production of hydrogen-powered vehicles.

The predominant technology nowadays used by Chinese car manufacturers is the one of a fuel cell. A fuel cell is a device that converts chemical energy from fuels rich in hydrogen into electrical power and high-quality heat via an electrochemical process that is efficient and emits water vapor rather than pollutants as there is no burning of the fuel. Fuel cell vehicles (FCVs) can help Chinese economy to reduce its oil dependence and lower harmful emissions that contribute to the greenhouse effect. Based on the cutting-edge technology cars powered by hydrogen is an ideal solution for countries that struggle to reduce their carbon dioxide emissions, with China being the world's biggest CO_2 producer, mainly because hydrogen is considered nowadays one of the most promising sources of environmentally friendly energy.

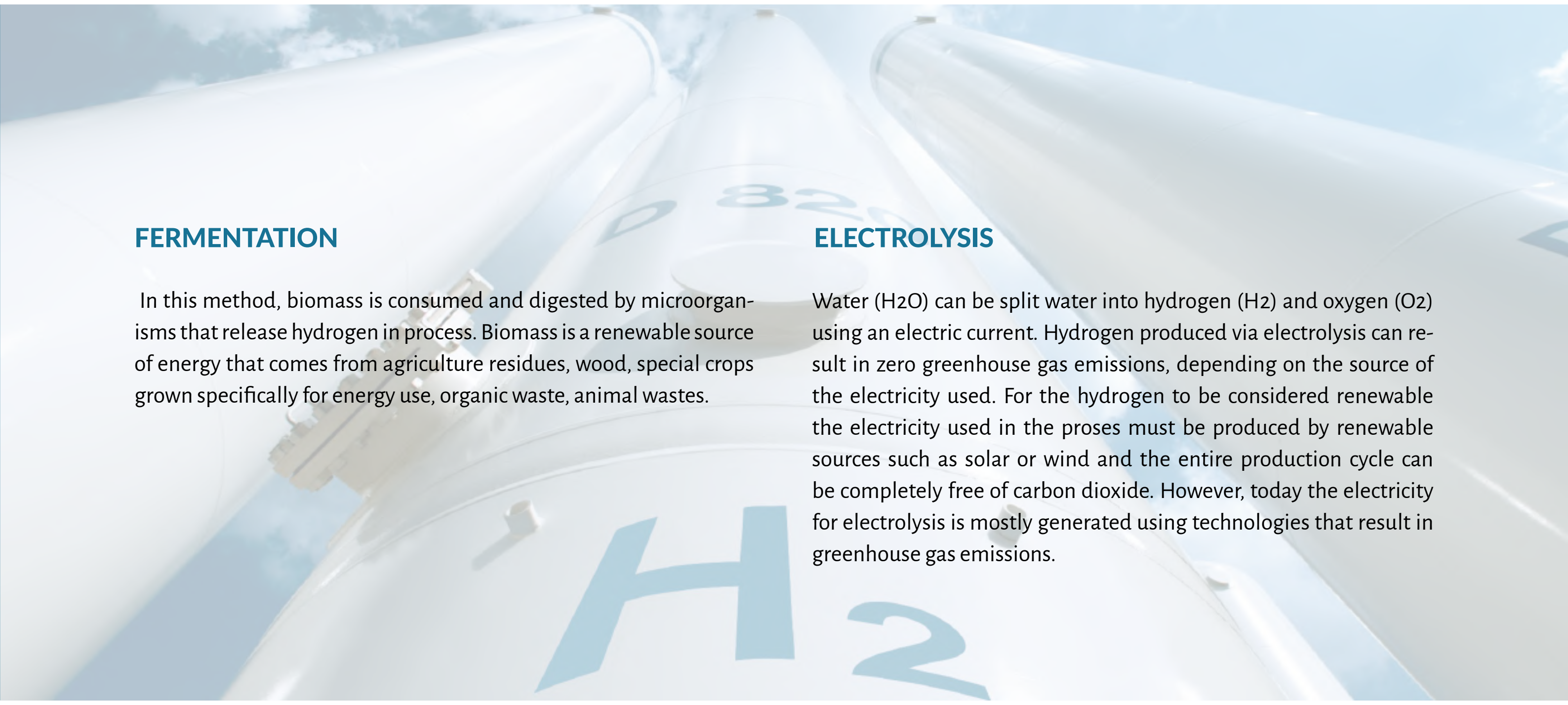
1.3.4 ADVANTAGES OF FUEL CELL VEHICLES

Probably the main advantage of hydrogen powered vehicles, as we have already said, is that they are as fast and powerful as the ones with petrol engines, but do not produce greenhouse gases while operating. Moreover, they are much more efficient in terms of time consuming as they have a shorter fueling time, approximately 5 min, especially compared to electric cars that are also proclaimed one of the environmentally friendly options. It's important to mention that the method for refueling FVCs is similar to that for a petrol or diesel vehicle and basically intuitive for many car users.

1.3.5 PROBLEMS AND DISADVANTAGES OF FUEL CELL VEHICLES

The mass introduction of FVCs involves many problems and it will not be fast and easy. First of all, a proper hydrogen refuelling infrastructure does not currently exist. However, the support from Beijing makes a fast grow of the hydrogen economy over the next decades possible. There are more than 12 hydrogen refuelling station operating in China now and in June of 2019 the wold's biggest station was opened in Shanghai. But some experts remain sceptic, claiming that the new hydrogen stations can't operate properly without sufficient demand. There are only about 1,500 FCVs in use in China today, compared with more than 2 million purely electric vehicles. Nevertheless, according to Xinhua News Agency, the official state-run press agency in China, by 2030 there probably will be 2 million hydrogen fuel vehicles produced in China.

Hydrogen vehicles require very high purity hydrogen to ensure the best performance and avoid technical issues of any kind. There are several documents nowadays that establish the norms for the quali-



FERMENTATION

In this method, biomass is consumed and digested by microorganisms that release hydrogen in process. Biomass is a renewable source of energy that comes from agriculture residues, wood, special crops grown specifically for energy use, organic waste, animal wastes.

ELECTROLYSIS

Water (H_2O) can be split water into hydrogen (H_2) and oxygen (O_2) using an electric current. Hydrogen produced via electrolysis can result in zero greenhouse gas emissions, depending on the source of the electricity used. For the hydrogen to be considered renewable the electricity used in the proses must be produced by renewable sources such as solar or wind and the entire production cycle can be completely free of carbon dioxide. However, today the electricity for electrolysis is mostly generated using technologies that result in greenhouse gas emissions.

ty of hydrogen used in FCVs. The one that in recognised internationally is the SO 14687-2:2012 that specifies the quality characteristics of hydrogen fuel. The complete analyse of hydrogen fuel in order to avoid impurities of any kind requires expensive equipment and takes a significant amount of time. That factors not only make hydrogen fuel more expensive, but also do not benefit the hydrogen refueling stations who need to limit damage to customer vehicles as soon as possible.

The cost of hydrogen fuel makes fuel cell vehicles less affordable. they cannot yet compete economically with more traditional energy technologies, though rapid technical advances are being made.
Although hydrogen is the most abundant element in the universe, it is difficult to store and distribute from the site of manufacture of the hydrogen to the end user. Hydrogen has a high diffusivity, is low dense, and is extremely flammable. Canisters of pure hydrogen are readily available from hydrogen producers, but as of now, you can't just fill up with hydrogen at a local gas station. It's happening not only in China. Hydrogen fuel cells have struggled to gain traction worldwide not just because of high costs but also because of the lack of infrastructure and the complexity of storing hydrogen.

1.3.6 PIONEER COMPANIES IN CHINA

Despite all the problems fuel-cell vehicles face nowadays, Beijing has made it clear that such a promising industry won't be left without a significant material support.

The first Chinese company to take interest in the production and research of hydrogen fuel cell technology is SAIC (Shanghái Automotive Industry Corporation) that has been investing in hydrogen energy research since 2001. In recent month dozens of city governments have made plans to launch hydrogen-vehicle projects partly sponsored by the government. Many cities across China announced plans to set up several projects with leading companies such as Beijing Shouhang IHW Resources Saving Technology Co.. In addition, Beijing Shouhang IHW Resources Saving Technology Co. has recently received government support for a hydrogen fuel cell business when it signed a cooperation agreement with the Datong city government. The company plans to set up three hydrogen production plants and more than 10 hydrogen stations for vehicles in the city. This agreement will help Datong's economy to shift from coal production to more environmentally-friendly options. That is why the government is willing to provide 2 billion yuan alongside with low interest loans and tax exemptions. Local governments' enthusiasm reflects Beijing's signals of continued support for hydrogen fuel cell vehicles despite its decision to slam the brakes on subsidies for electric cars.

China plans to adapt battery-powered electric vehicles for urban and short-distance passenger travel, while hydrogen fuel cells show themselves more suitable for long-distance and large commercial vehicles. Around 1,500 fuel cell trucks and buses are currently functioning in China, and there are currently 75 distinctive fuel cell vehicle models published on China's MIIT (Ministry of Industry and Information Technology) Promotion Catalogue.

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Expert's opinion

Hydrogen can be produced widely from nature gas, coal, biomass, solar, wind, hydro and nuclear power, etc. If hydrogen is made from renewable energy or nuclear energy, it would be possible to be used on a large scale with low emissions of pollutants. Hydrogen technologies, such as fuel cells and zero-emission hydrogen production systems, are making rapid progress in recent decades. In particular, two types of fuel cells have been paid more attentions, that is, polymer electrolyte membrane (PEM) fuel cells and solid oxide fuel cells (SOFCs).

PEM fuel cells, based on proton conducting electrolytes, are promising for transportation applications with reduced pollutant emissions and dependence on fossil fuels. Fuel cells market has witnessed great progress. Toyota has sold more than 4000 Mirai PEM fuel cell vehicles (FCVs) so far. Primary challenges for the commercialization of PEM fuel cells include durability, cost, and hydrogen infrastructure availability, etc. DOE's target of durability lifetime is greater than 5000 h by 2025 and ultimate goal is 8000 h for FCVs and 25,000 h for fuel cell buses (FCBs). More than 30 hydrogen gas stations are being operated throughout U.S and over 60 in Germany. Water and thermal management, dynamic operation, cold start, channel two-phase flow and low-humidity operation are fundamental issues of PEMFCs, which are important for cell design, operation control, and material development.

Solid oxide fuel cells, based on oxide-ion or proton conducting electrolytes, have several advantages over other types of fuel cells, including relatively inexpensive materials, low sensitivity to impurities in the fuel and high efficiency. Great efforts have been devoted to develop SOFCs operating at low or intermediate temperature (500-8000C) and with hydrocarbon fuels. Slow kinetics of cathode operating at low temperatures and reduced coking with hydrocarbon fuels are fundamental issues of SOFCs. Bloom Energy, founded in 2001 in USA, is a typical SOFC company, which develops and commercializes large reliable SOFC systems with high efficiencies. The reversible operation of SOFCs can be used for electrolysis of $H2O$, $CO2$ or both, called solid oxide electrolysis cells (SOECs), which have several advantages of reduced electricity consumption, fast electrode kinetics and low cost. Since SOFC systems can be built to any scale between several watts up to hundreds of kilowatts, they can serve a large variety of applications. At multi-megawatt scale, traditional power generation technologies can be integrated into SOFCs-based power plants to realize higher electrical efficiency and lower emission of pollutants.

In summary, although great progresses have been made in hydrogen energy in the past decades, technical and cost issues remain. More works are needed to enable fuel cells competitive with the present vehicles, fuel technologies as well as traditional power generation technologies.

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1.4 INFORMATION TECHNOLOGIES IN ENERGY SECTOR

South Africa has one of Africa's biggest value markets for information and technology (ICT) in the energy field. According to the National Development Plan (NDP), by 2030 South African energy sector will enhance country's economic growth and development through substantial investment in energy infrastructure and IT sector. The budget of South African Government within the energy industry focuses on important measures aimed at increasing the use of ICT to promote socio-economic justice and integration, improve competitiveness and prepare for the 4th Industrial Revolution.

1.4.1 STRENGTH AND WEAKNESS OF IT TECHNOLOGIES IN SA

South Africa has several major problems in the energy technology field. The lack of specialists and low availability of clean and affordable energy sources are among the most urgent. Moreover, the country's energy sector is facing major economic turbulences which includes low growth, inequality and infiltration of foreign owned technologies. This could be blamed on low drive of technological innovation. Exactly this is being currently improved. The Council for Scientific and Industrial Research (CSIR) is one of the driving forces behind some of the energy technologies that are being produced in the county. For example, they financially support companies working in the field of renewable energy, producing lithium batteries used in solar or wind power stations and by households. Remarkably, a recent study by the Council found that the wind and solar power capacity operational during 2015 showed an R800 million net benefit to the economy achieved during the year, helping to save more than an additional R4 billion in costs to the economy. In order to prevent technological innovations from sitting on then shelve waiting for commercial partners to take them into the market, the CSIR mediates between science and energy sector creating one of the largest technological hubs on the continent. Another governmental program working for using technologies to improve country's energy sector is the Renewable Energy Independent Power Producers Procurement Bidding Programme (REIPPPP). Established in 2010, REIPPPP has become one of the world's most progressive and successful alternative energy programmes. It seeks to procure energy from small scale IPPs, with projects that generate between one MW and five MW of energy from solar, wind, biomass and landfill gas projects. Through the REIPPPP, the Department of Energy is targeting the procurement of 13225 MW from IPPs by 2025. Finally, the Nuclear Energy Corporation of South Africa, which is responsible for undertaking and promoting research and development in the field of nuclear energy and radiation sciences, works on the implementation of technologies in the field of its specialization, not at least cooperating with BRICS countries, in particular with Russia.

1.4.2 SMART CITIES IN SOUTH AFRICA

South Africa is also known for leading in information communication and technology (ICT) which is big advantage towards building the continent's first smart city. A smart city is briefly defined as a «designation given into a city that incorporate information communication and technologies to enhance the quality and performance of urban services such as energy, transportation and utilities in order to reduce resource consumption, wastage and overall costs». In our case, the smart city concept means rational use of energy resources according to peoples' needs which can settle the issue of clean energy availability for the people. This also complies with the Department of Energy (DoE) goal to ensure that the energy supply is secure and demand is well managed, and that there is an efficient and diverse energy mix for universal access within a transformed energy sector, and implement policies that mitigate the effects of climate change. Goals beyond 2020 include installing more than 20000 megawatts (MW) of renewable energy sources, not at least by increasing the share of regional hydro-electricity. As for smart city initiatives, a number of cities such as Cape Town and Johannesburg introduced smart grid energy systems at some levels in 2016, providing its citizens with the access to clean energy from renewable energy sources. One of the countries resource-planning enterprises «Ukutinga» works on the distribution of energy supply between the industries, services and households in the city. Another example is South Africa's manufacturing hub Ekurhuleni located adjacent to Johannesburg. It is home to South Africa's largest airport, OR Tambo Airport, also called «Aerotropolis». The transportation hub is already using a smart grid energy system which makes it one of the most sustainable airports not only in the country, but also in the whole world.

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As a result, South Africa turns out to be a great example of using information and technological innovations to improve its energy sector, making it more competitive and enhancing the economic growth and population's wellbeing. The initiatives in that sphere could be even more successful if the cooperation between researchers and scientists, energy specialists and industries of the BRICS countries were at a higher level, but the Youth is already working on it.

JIS COLLEGE OF ENGINEERING
REPUBLIC OF INDIA

1.5 ELECTRIC TRANSPORT AND INFRASTRUCTURE OF ELECTRIC FILLING STATIONS

Today India is the fourth largest greenhouse gas (GHG) emitter in the world. With the increase in fossil fuel usage, GSG emission increases day by day, which in turn has an adverse effect on climate. The transport sector accounts for around 15% of India's energy related CO2 emissions (INCCA, 2010). In order to mitigate GHG emissions and make India's transport growth more sustainable, an alternative should be explored for the country's transportation industry. India's National Action Plan on Climate Change recognizes that GHG emissions from transport can be reduced by adopting electric vehicles.

1.5.1 GLOBAL EV TRANSPORTATION SCENARIO

The world today is solely dependent on motorized vehicles most of which use IC engine and petrol/diesel as a fuel. Due to the energy crisis the world price of gasoline has increased by 50% in the last two years. Here comes the potential need for an alternative technology. A few of developed countries have already started taking initiatives towards this change. Cumulative global sales of highway legal plug-in electric passenger cars and light utility vehicles passed the 1.5-million-unit milestone in May 2016, about a third of which were sold in 2015.

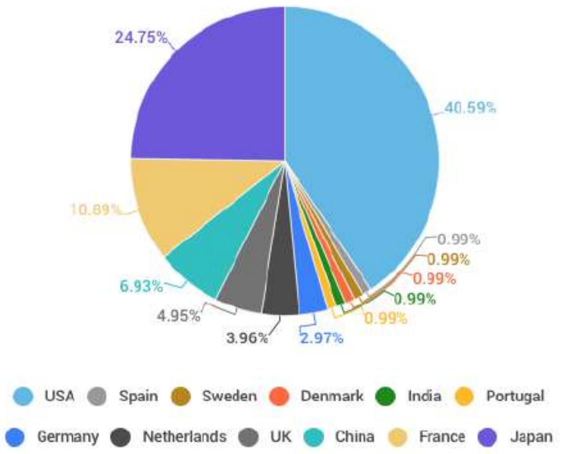

Figure 1.5.1 Worldwide Electric Car cumulative stock by 2016

1.5.2 INDIA EV TRANSPORTATION SCENARIO

Today India is in the top ten automotive markets in the world thanks to its rapidly increasing middle class population with growing buying power and its steady economic growth. The country, however, largely depends on oil countries and imports a huge amount of oil to fulfil its energy requirement. The share of oil imported by India was 57% in 1957, and it is going to be 97% in 2020. This along with the escalating price of oil poses a severe problem on the Indian energy segment in the future. Moreover, emissions from the transport sector is the key source of air pollution next to the country's power sector. For these reasons it is necessary to find a different kind of transportation. Battery Electric Vehicles (EV) and Plug-in Hybrid-Electric Vehicles (PHEV) offer a number of advantages compared to conventional ICE vehicle.

India ranks third in the World's largest auto markets. The motorized traffic volume in India will reach 13000 billion passenger-km in the next decade, out of which 91% will be provided by roads and the rest by railways. According to the In-

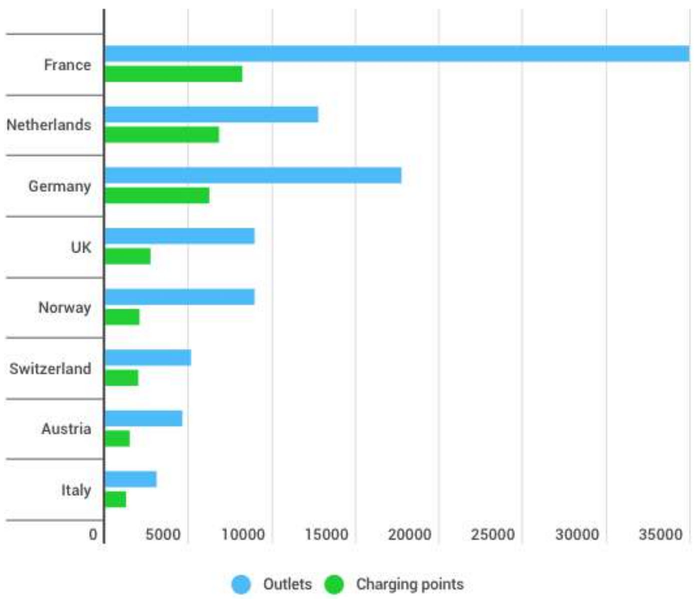

Figure 1.5.2 Current status of charging stations worldwide

ternational Energy Agency (IEA), the transportation sector accounts for 30% of the worldwide energy consumption and is the second largest cause of CO2 emissions. The increase in oil prices as well as environmental issues have made electric vehicles an alternative for IC engine vehicles. In the year 2000, a pair of electric two-wheelers was on hand in the Indian market. Now, the market has expanded to thousands. According to a survey conducted in Ludhiana (Punjab) city, 36% of existing car and two-wheeler owners were interested in shifting from their conventional vehicles to electric vehicles due to the increasing fuel prices and environmental concerns.

1.5.2.1 BENEFITS OF EV TRANSPORTATION

Electric vehicles are the future of automotive industries which can replace IC enginesreducing air pollution to a great extent. The use of electric vehicles will allow using other resources as a fuel including renewable energy. Thus, by introducing electric vehicles to the Indian market, the country's dependence on oil producing countries will be greatly reduced. Moreover, electricity is much cheaper than petrol or diesel, hence electric vehicle users will benefit economically.

1.5.2.2 SPECIFIC OBJECTIVES

1. The main objective of the proposal is to overcome the oil crisis problem.
2. To provide clean transportation.
3. To provide charging facilities to existing electric vehicles in India.
4. To reduce air pollution caused by IC engines.
5. To reduce fuel costs.
6. To provide an opportunity to charge up electric vehicles at home/parking places.

1.5.2.2 SPECIFIC OBJECTIVES

The key-concept is focused on the development of the smart EV charging station which can be used to charge up small electric cars, two- and three-wheelers. This scheme may also control and improve the LV distribution system security and power quality without making expensive investments to improve the existing infrastructure. Charging columns are connected to the network through a front-end active rectifier; their power flow can be managed by means of two bidirectional DC/DC converters in order to use the auxiliary storage systems to shorten recharge times or to improve the number of charging operations that can be accomplished in a certain period. Figure 3 shows the basic schematic diagram of the charging station.

1.5.2.4 THE TARGETED LEVEL OF DEVELOPMENT

The battery is the heart of battery electric vehicles which accounts for half of the total cost and weight of a BEV. So, the battery choice issue is very important. Li–ion battery can be effective for such applications. However, battery life depends on its charging circuit which thereforeshould be efficient. PWM signal fed AC-DC converter and DC-DC converter may serve the purpose. Figure 4 shows a block dia-

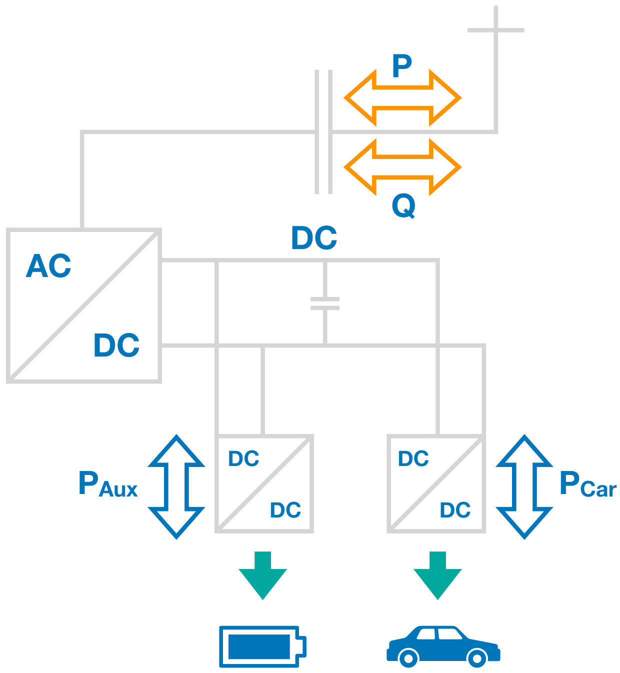

Figure 1.5.3. Schematic Diagram of a charging scheme

gram of a battery electric vehicle.

The proposed charging scheme uses a highly efficient power electronic converter with short charging times. The project proposes LEVEL 2 EV battery charging scheme that charges the battery at a much faster speed in comparison to the level 1 charger.

1.5.2.5 PERFORMANCE STANDARDS

EVs are widely recognized as an instrument to fulfill greenhouse gas emission targets in the transport sector. In contrast to conventional vehicles, EVs produce no pollutant emissions. Therefore, EVs are great for improving air quality.

Additionally, they produce fewer noise emissions. Finally, EVs could help to reduce dependence on fossil fuels. Although some EVs are already on the roads, there are still obstacles for their wide market diffusion. It is a common sense approach to install charging infrastructure in line with the demand for it. But it is difficult to determine the actual demand for different types of charging infrastructure. The proposal is based on a supranational top-down approach to address geographical coverage as well as user demand. User demand is derived from the forecasted number of electric vehicles. However, the general aim of public charging infrastructure is to provide a social infrastructure, i.e. to guarantee a minimum standard of service at a low cost to the widest possible public. A demand-oriented installation of charging infrastructure might not be in line with this task of building up the aforementioned social infrastructure. A comparable conflict of interests can be found in public transport.

Finally, the construction of public charging infrastructure has to be regarded from different levels of perspectives. Approaches range from the discussion of the location criteria to the estimation of the charging infrastructure demand based on complex mathematical models. Therefore, an overview of different options could help stakeholders to decide which approach to apply in each specific case.

1.5.2.6 INNOVATIVE COMPONENTS OF THE PROJECT

Technological roadmap:

Pure electric vehicles will be the main strategic orientation for the development and systemic transformation of the automobile industry. At present, priority will be given to boost the industrialization of battery electric vehicles and plug-in hybrid electric vehicles.

Strategic measures:

The main strategic measures to promote EV industry are:

- to implement the New Energy Automobile Technology Innovation Project.
- to scientifically formulate industry development structure
- to strengthen the power battery cascade utilization and recycle management.

1.5.3 INDIA'S EV POLICY TO THE INDIAN AUTO-INDUSTRY TODAY

There has been a rapid vehicle growth in India: vehicle ownership per 1000 population increased from 53 in 2001 to 167 in 2015. Basing on the last six years of sales data, vehicles on the Indian roads consist of:

1. Two-wheelers: 79% of the total number.
2. Three-wheelers: 4% of the total number.
3. Buses and large goods vehicles: 3% of the total number.
4. Economy four-wheelers (cars costing less than ₹1 million): 12% of the total number.
5. Premium four-wheelers (cars costing more than ₹1 million): 2% of the total number.

In the future, India is going to establish technological and manufacturing leadership in the automobile market. The prevalence of small vehicles in India is unique. These small vehicles need a unique set of technological and industrial infrastructure. Here India has an opportunity to take a leading role in their electrification. India's potential volumes for these vehicles, as the nation grows, lay the foundation for the transformation of its manufacturing and industrial policy.

1.5.3.1 POLICY FOR THE CHARGING INFRASTRUCTURE

EV charging and battery swapping are two different procedures to supply energy to a vehicle and are two equally valid options that industry may choose to use. Businesses that provide charging/swapping will be referred to as Energy Operators. They will deploy slow and fast chargers at suitable locations for EVs. Similarly, they will purchase batteries, set up charging and swapping services and provide charged batteries on lease for EVs. Both charging as well as swapping services will require that EVs have standard charging protocols to connect to a charger of swappable batteries and have a standardized connector.

India may consider providing long-term and short-term tax-incentives and faster depreciation as incentives to Operators for deploying slow/fast chargers and carrying out battery swapping. GST for all these chargers and swappers should be the same as that for vehicles.

1.5.4 IMPACT OF EVS ON ECONOMIC GROWTH AND EMPLOYMENT

The transformation from ICE to EV could provide great opportunity for the economic growth. This transformation could boom in areas like charging and swapping infrastructure, services, etc. In India energy players have entered the mobility industry, while some traditional power companies are exploring possibilities in charging infrastructure and infrastructure companies are seen entering the battery business. An important task that needs attention is transforming and up-scaling small and medium sub-system and auto-component industries. A large number of such mini-micro industries are auto-ancillary companies for diesel/petrol vehicles. They provide a large number of jobs. Many of them will not survive as EV replaces petrol/diesel vehicles. A careful plan to hand-hold such industries and help them during the transition to EV components manufacturing is required. The expansion of transport fleets based on IC engines negatively impact the economy, not to mention their negative health effects. Crude oil price volatility adds uncertainty to an already burgeoning import bill. Moreover, huge investments in oil refineries and related distribution infrastructure are necessary. There are several studies that suggest an overall positive impact on GDP of the introduction of EVs in fuel-importing and service-dominated economies. Coupled with renewable power generation, the battery manufacturing industry in India can become bigger than the total amount spent on import of crude oil.

1.5.4 IMPACT OF EVS ON ECONOMIC GROWTH AND EMPLOYMENT

According to the European Climate Foundation report, thanks to electric cars employment will increase by 500,000 to 850,000 by 2030. Another report estimates that about 2 million additional jobs will be created by EVs by 2050. As imported oil will be replaced by electricity and batteries, more employment opportunities are possible in enhancing power-generation and distribution and in battery manufacturing, including battery-recycling. As far as the automotive sector is concerned, a large part of the supply chain will get transformed in the powertrain segment. Traditional suppliers will move from supplying parts such as exhaust pipes and ICEs to perhaps battery materials, electric motors, and regenerative braking systems. EVs will create opportunities in durable and lightweight thermoplastics, provoke higher demand for electricity, storage and etc.

1.5.4.2 INDIA'S EV INDUSTRY

Indian Automobile industry is fast growing and is set to take over as one of the largest automobile industries by 2030.

GEBRICS, UNIVERSITY OF SÃO PAULO,
FEDERAL REPUBLIC OF BRAZIL

1.6 IMPROVEMENT OF ENERGY EFFICIENCY OF THE NATIONAL ECONOMY

This research aims to present major issues is related to energy investments in Brazil, such as the proclaimed necessity to foster economy by boosting infrastructure or as Brazilian's insertion into a challenger global framework to energetic sector, highlighting the global challenges of the 21st century such as the environmental issues connected with the production of clean energy. Thus, this work will address multifactorial basis, which could make Brazilian energy's market more or less attractive to investments; as well as possible difficulties, arising from internal or external scenarios, that the country faces in such domain.

1.6.1 INVESTMENTS, INFRASTRUCTURE AND THE IMPACT OF GLOBAL CHALLENGES ON SOCIAL AND ECONOMIC AFFAIRS

There is a widespread idea in Brazil that economic growth and development depend on infrastructure improvement, what encompasses energy's efficiency enhanced, mainly by virtue of increasing Foreign Direct Investments (FDI) or public investments. Investments into infrastructure have been presented as the solution to economic recovery, since the country was reached by the crisis.

A report prepared by UNCTAD - the World Investment Report 2018 – points that, in Brazil FDI were increased by 8%, since nine of ten acquisitions in Latin America were in Brazil and seven of the mentioned companies involved Chinese buyers.

By its turn, Brazil Central Bank has produced a report in which it stands that FDI has risen, in 2017 by 9%, whereas foreigners' capital participation has significantly presented an increase up to 93% -, proportionally to intercompany transactions. However, Brazilian FDI's input has declined in 2018, as diagnosed by UNCTAD, by 12%.

In addition, public investments have also fallen in as much as the country has adopted austerity perspective. A study produced by an institution bound to Senate – the Independent Fiscal Institution – gives notice that, from 2015 and 2016, public spending directed to infrastructure has drastically fallen. Currently, Brazilian public spending cannot afford even the existing infrastructure, contrary to recommendations of many concerns circulating in international institutions. Although Brazil showed poor results last year, Brazilian's government is optimistic due to the possibility of expanding infrastructure by means of attracting FDI.

Therefore, the importance of the present research lies, firstly, in Brazilian dilemma of understanding that infrastructure is important to its current economic situation and the difficult it faces to indicate what are the sources of investments to foster its improvement. Furthermore, it is justified in the necessity to discuss possible varying in energetic grid, as well as social and economic impact that Brazilian energy's production may have.

The Brazilian energy sector, marked by water production, has been going through significant changes in recent decades. The environmental issues that until the late 1970s were secondary have become priorities and are currently elementary factors in the design of projects in the Brazilian energy sector.

In the mid-1990s, Brazil experienced a serious energy production crisis, affecting its capacity for growth and forcing the resumption of energy generation projects in the Amazon region, which until then had been paralyzed by environmental and economic issues. However, it was only partially completed in 2016, with the inauguration of the Belo Monte hydroelectric plant in 2016.

Other generation sources are present, but different from BRICS countries where the electric matrix is dominated by non-renewable sources, more than 60% of Brazil's energy production comes from hydroelectric. The impact of the construction of large hydroelectric dams in Brazil, in addition to the changes produced in the local ecosystem, is being protested by populations forced to leave to provide space for water reservoirs and in many cases are not fairly rewarded. The impact of large hydroelectric dams on the ecosystem and local populations is a challenge that the Brazilian energy sector faces and limits its capacity for growth.

The Brazilian energy sector, following a perspective observed all over the world, has been seeking alternative forms of production such as solar and wind energy. Although the high demand for production and the high cost of these alternative forms make this process slow, there is a growing demand for alternative forms.

The Brazilian energy sector continues to expand even in the face of the economic crisis that Brazil has emerged since 2015. Energy demand, in addition to the need promoted by the expansion of the residential consumer network, will need to respond to the high demands of large industries, especially aluminum in next years.

Another major challenge regarding the sector is the access of energy to the entire population. Several isolated regions in the Amazon Basin do not have access to electricity, or when one has access to energy, it is produced by generators powered by diesel oil, more polluting and expensive compared to that which is produced in the hydroelectric power plants.

The new reality of the sector, especially technological ones that have made possible the production of 100% clean energy, such as solar and wind, is a trend in Brazil and also responds to point 7 of the UN's 2030 Agenda, which proposes: "Accessible and Clean Energy Ensure reliable, sustainable, modern and affordable access to energy for all". In this sense, the impact of clean and affordable production for the entire population is one of the greatest challenges of the Brazilian government in the most isolated regions. From another point, the Brazilian economic growth agenda is directly related to the capacity to increase energy production in Brazil. In this sense, the large-scale increase in solar and wind energy will be decisive as well as intensify the productive capacity of the existing hydroelectric plants.

1.6.2 DEVELOPMENT PERSPECTIVES AND THE IMPACT OF GLOBAL CHALLENGES

One of the fundamentals of a country's economic sustainability is its ability to provide logistics and energy for the development of its production, safely and in competitive and environmentally sustainable conditions.

The global demand for energy has been changing in the last decades as the developing countries' share in the world energy use has relatively increased since 1970, when it was about 22%. In 2004, the participation of the emerging countries was already 46% and the projections for 2030 are about 57%. Between 2005 and 2030, the average annual growth of the energy demand from the developing countries is around 1.8%, reaching the amount of 17.7 billion tons of oil equivalent by 2030. During this period, the global energy demand growth is estimated by 55%, and China and India are responsible for 45% of this percentage.

It is possible to affirm that Brazil has done its "homework" in the energy area, so much that it is cited as an international reference in the production of oil in deep waters, in the production of ethanol, in its hydropower generation park, in the exponential use of wind energy, in its extensive and integrated system of transmission of electric energy, and especially in the renewability of its energy matrix and the production of electric energy.

In accordance with the 10-year plan from the Empresa de Pesquisa Energética (EPE), the projected amount of internal energy supply will be around 370 million tons of oil equivalent by 2027, which means an average annual growth of 2.3%.

The Brazilian National Energy Plan 2030 (PNE 2030) includes energy efficiency targets. Increasing the efficiency of energy use would save money for consumers and businesses and reduce the risk of energy shortages, and some of the measures to be used are directly cost saving.

A further global target is to double the share of renewable energy. However, Brazil already has a 40% share and doubling this to 80% would not be cost-effective. A more realistic target is to reduce the share of fossil fuels to 40% by 2035 (from the expected 52-57% for business as usual). This allows for a greater contribution of nuclear energy as well as renewables.

Investing more in renewable electricity generation would reduce both climate impacts and pollution and increase energy security and improve the balance of payments.

A final goal is doubling investment in research and development in energy technologies. Brazil has a well-educated population and experience in high tech industries which should make the country well placed to achieve this. Estimating costs and benefits is really difficult, but it seems clear that this effort could be very beneficial to the Brazilian economy.

Public investment in research is well known to have been instrumental to improving yields in the early stages of the ethanol's development. Research and development in ethanol is currently dominated by private firms thanks to early government-supported investment. Brazilian research and development expenditure per capita are more than ten times smaller than the US per capita expenditure and five times less than South Korea, so there is plenty of scope for improvement.

Moreover, given the wide range of energy sources available in Brazil, there is an ideal ground for testing and demonstration of new technologies. For example, CCS in the pre-salt oil fields, integration of large amounts of renewables, and more basic research in storage and biofuels.

The global trends and new challenges on the energy sector including energy demand growth led by economic and population growth and necessity of investments in energy efficiency and diversification of the energy matrix led to several transformations in Brazil. In the last decades of the 20th Century, the Brazilian government implemented regulatory mechanisms, reforms on the energy system and investments in technology which allowed to a progressively increasing of energy efficiency.

When a sustained economic growth takes place in the country, the energy demand tends to increase considerably. In this scenario, it is expected that the supply expansion strategy considers energy efficient use policies. In the decades of 1970 and 1980 the GNP has increased whereas the relative use of energy decreased in this period due to switch less efficient sources of energy for more efficient ones.

However, due to the its energy sector's relevant dependency from the hydropower, the Brazilian government has taken measures to diversify the energy sources, investing in innovation to create condi-

tions for technological cooperation with potential partners and absorption of technology. The investments in innovation were mainly concentrated on ethanol and agriculture.
The 2001 energy crisis led the Brazilian government to make investments also in hydroelectricity innovation. As Brazil's biggest energy source comes from hydropower, its energy security could not be ensured without investments in this segment, despite the huge costs of this sort of energy source.

Although the technology and innovation in energy sector is expected to be the main mechanisms of improving energy efficiency, it is worth mentioning that some policies were implemented in order to mitigate the energy supply inefficiency.

The National Electrical Energy Conservation Program (PROCEL), implemented in 1985, for instance aimed to improve the energy use efficiency through seminars, training courses and conferences to tackle energy waste and help companies in obtaining lower interest for financing energy efficiency projects. Another example was the Utility Energy Efficiency Obligation launched in 1998 in order to establish electric power distribution companies' obligations and responsibilities.

1.6.3 KEY TECHNOLOGIES AND ITS DEMANDS IN FUTURE IN TERMS OF GLOBAL CHALLENGES

The world human population is already more than 7 billion — a number that could exceed 11 billion by 2100, according to projections from the United Nations. This rising population, combined with environmental challenges, puts even greater pressure on already strained energy resources.

Governments' commitments to COP21 are not substantial enough to stay within the 1000Gt CO_2 carbon budget necessary for keeping the temperature augmentation below 2°C, the upper limit mentioned in the Paris Agreement. In fact, the current country pledges imply a 2.7°C rise. Keeping the temperature increase below the 2°C target will require annual global carbon emissions-reduction rates of a minimum 3% p.a., far beyond any historical experience. The result in 2060 is a shift to a more resilient, lower-carbon energy system. However, although carbon emissions fall to 23 $GtCO_2$ p.a. by 2060, the world does not limit emissions enough to meet the 1000 $GtCO_2$ target for 2°C and faces potential economic losses due to the impact of climate change.

Brazil is the 8th-largest producer of electricity in the world, generating 560 billion kilowatt hours of electricity in 2016, according to the International Energy Agency (IEA). This puts Brazil among the powerful top-10 electricity leaders – together, these 10 countries, led by China and the United States, account for two-thirds of the world's electricity output. Brazil is favored by a vast and diversified territory – 80% of the country's power generation capacity comes from renewable sources, compared to the global average of only 23%. Hydropower alone comprises 65% of Brazil's entire electric power capacity, according to the federal energy planning company EPE. In terms of investment, energy auctions raised tens of billions of BRL in investments last year, as was the case with the new power generation (BRL 14 billion / USD 4 billion) and transmission line (BRL 8.5 billion / USD 2.4 billion) tenders. Alternative renewable sources, such as wind, solar and biomass, still have a relatively small (but growing) share: around 15% in 2015. However, these sources are the target of several government programs, including its main infrastructure programs. EPE's plan forecasts an increase up to 162% in the capacity of alternative energy sources by 2024 and expects their share of the national matrix to reach 53% by 2040. Many of those targets are put into practice by federal concessions determined by public sales, regularly held by the government.

SOURCE	2016	2024 ESTIMATE
Hydro	68,6%	56,7%
Alternative energy (Biofuel, wind)	16,2%	27,3% (including solar)
Thermo	14,7%	14,4%
Nuclear	2,6%	1,6%

Table 1.6.1 Brazil's energy matrix, in percentage (%) of total, Source: Ministry of Mines and Energy (EPE)

The Brazilian electric energy matrix is predominantly hydroelectric and, therefore, renewable. The problem is that the power system operation is very sensitive to droughts that can severely lower water storage levels of reservoirs and lead to a rationing period. One way of producing electric energy in a sustainable way is by creating support incentives to alternative and renewable generation. If we consider as alternative energy those generation enterprises that use foreign technology and display generation marginal costs more than other generation sources (renewable or not), we can include in this category solar photovoltaic plants (PV) and wind farms, besides other methods not present in the national scenario such as geothermal and tidal. In Brazil, these alternative sources of electric energy represent 4.02% of the electric energy matrix, corresponding to a generation of 5.78 GW as of April 2015.

Brazil generates nearly 80.4% of its electricity from renewable resources. While wind and hydropower have been the major sources of Brazil's renewable energy expansion to date, new solar energy developments over the long term could potentially rival investments in wind power. Solar energy already accounts for 1.4 GW in installed capacity in Brazil and should close 2018 at 1.9 GW; projections estimate it will reach 7 GW by 2026. Thus, Brazil has a significant potential for progress in the area of sustainable energy and investments are a key determinant of future energy trends. In terms of global trends, the scenario assumes that: global energy demand will grow by 33% between 2011 and 2035, demand for oil (which maintains its status as the top energy source) will increase by 17%, and demand for renewable energy (starting from significantly lower levels) will grow by 80%. Regarding clean energy, the IEA expects Brazil's total renewables demand to double by 2035, with increases in all main sectors.

By 2050, wind and solar technology will provide almost 50% of total electricity globally – "50 by 50" – with hydro, nuclear and other renewables taking total zero-carbon electricity up to 71%. By 2050, we expect only 29% of the electricity production worldwide to result from burning fossil fuels, down from 63% today. This dramatic shift to "50 by 50" is being driven by cheap solar PV, cheap wind, and falling battery costs. The cost of an average PV plant falls by 71% by 2050.

Solar power is earth's most abundant natural resource. The solar power shining on 135 square miles is greater than the peak capacity of all the electric power plants on earth. Among all the RES present in the Brazilian power system, solar photovoltaic (PV) is the one with the smallest installed capacity, barely showing up in the statistics. This fact seems odd for a tropical country. From a strategic perspective, Brazil has a number of favorable natural features such as high levels of insolation and large reserves of quality quartz, which can generate important competitive advantage for the production of silicon with high purity, solar cells and modules, which are products with high added value. These factors could pave the way for a more important role of the PV technology in the diversification of the electric energy.

Brazil continues to be the most promising onshore market for wind energy in the Latin America region. With almost 8,000 kilometers of coastline, Brazil has a huge potential for generating wind energy, especially on the Northeastern coast, where there is wind all year round and many wind farms have already been built. Solar power is a very young industry in Brazil, starting only after the source was included in the electricity auctions (the first one been held in 2013). The volume contracted since then is almost 4 GW. The installed capacity in photovoltaic plants was only 90 MW in the beginning of 2017, but it already reached 1 GW. This mark positioned Brazil among the top 30 globally. Today, solar parks generate only 0.01% of the national matrix. By 2026, the government plans to increase the solar energy output to 9,660 MW, resulting in 4.5% of the total matrix (considering utility-scale only).

Brazil has the best conditions to implement wind energy technology in its electrical system due to its location and market potential. Nevertheless, the country does not have the necessary capacity to take advantage of it. In this context, the Chinese wind technology and investments could provide this capacity to Brazil by technology transfer.

In relation to key technologies, China plays an important role in Brazilian scenario. In line with the Ministry of Planning, 46% of Chinese investors in Brazil act in electric energy sector and 30% in oil and gas sector. China investments in Brazil in the energy sector were around USD 18.2 billion in 2010.

Chinese investments are concentrated in energy generation and transmission, as smarts electric substation, wind turbines, solar energy converters and inverters and solar panels. The main companies related to these technologies are Goldwind, Sinovel, BYD and Canadian Solar.

One of the main players in this area is the China – Brazil Center for Climate Change and Energy Technology Innovation, cooperation between Coppe/UFRJ and Tsinghua University. The researches include biodiesel and solar energy, which involves Chinese company Tsinghua Solar and Brazilian company Luz e Força Santa Maria. Coppe also holds a patent on tidal power plant technology, registered by n. PI 0402375-7 at INPI (Intellectual Property National Institute).

Efforts to conserve Brazil's biodiversity, policies on land use and water-resource management are also all closely intertwined with the outlook for the energy sector. And changes in those policies, in particular the ones related to transport and infrastructure systems, will have direct implications for future development of the energy policies.

The energy sector in Brazil is facing interesting crossroads, with many challenges and opportunities opening up. Decision-makers seem to be aware of the important measures that need to be taken to promote a more sustainable, affordable and secure energy system, but only time will tell if the rhetoric and implementation walk hand in hand to deliver on the proposed goals.

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1.7 CYBER SECURITY ISSUES IN THE FUEL AND ENERGY INDUSTRY

The technological revolution is the trend of the 21st century, represented on the concept of "digital age". It is characterized by the rapid changes that obligate the society to rethink forms of connections, integration, supply chain management, models, etc. When it comes to the fuel and energy industry, the most outstanding pattern brought by this revolution is the digitization and integration of its systems. The processes realized by both industries are largely digitized and dependent on digital technology, in contrast with previously isolated and proprietary processes. On the other hand, with the digital era new definitions of security and global challenges arise.

1.7.1 THE RELEVANCE OF CYBER SECURITY TO THE FUEL AND ENERGY INDUSTRY

It is undeniable that the Digital Revolution has brought forth many benefits in terms of increased efficiency to the fuel and energy industry. Throughout this process, the gradual deployment of Information and Communications Technologies on the energy infrastructure has caused it to go from a relatively isolated and protected sector to a highly interdependent network. Indeed, data analysis and remote control enable optimization of the supply and distribution chains, however, the resulting transformations have also generated new vulnerabilities to the sector, raising the issue of cyber security.

The World Economic Forum Global Risks Report 2018 clearly reflects this trend, as it ranked cyber security breaches third in the top ten risks in terms of likelihood and sixth in the top ten risks in terms of impact.

Additionally, the 2017-2018 Global Fraud and Risk Report, released by multinational risk consulting firm Kroll, reported that 86% of surveyed executives said that their company had experienced a cyber-incident or information/data theft, loss, or attack in the last 12 months; in some countries and industries, however, the number verges on nearly 100%.

The consequences of a cyber-attack are various, reaching both social and economic level. It highly depends on the malefactors and their aims. Both fuel and energy industry are responsible for ensuring the functioning of the society and economic activities, its unavailability of service 'leads to potential ripple impacts on the economy, civil society risking gross domestic product (GDP), the trade deficit'.

The operational and financial loss can be huge, which makes cyber security so vital for a stable economy. According to UTC Latin America, in an attack simulation in which the energy distribution from the CEB-DIS, Cemig-D, Eletropaulo and Light is shut down for five hours, the loss would be around 642 million reals. Thus, production's shutdown translates as a loss of income for the industry; society will possibly feel the effects of it on the increase of indirect or direct taxes, not to mention that it can result on impossibilities or difficulties on daily activities, as well as leave many unemployed.

However, the risk of a cyber-attack to the energy and fuel industry is not restricted to the interruption of power supply or distribution: it may also be used to gain illegal competitive edge on auction biddings and contract negotiations. A good example of such breach was the PRISM Project: a global surveillance initiative, disclosed in June 2013. The evidence showed that the program had as one of its targets Brazil's oil titan Petrobras, as well as Brazil's President Dilma Rousseff and the Mines and Energy Ministry.

The attack happened on the brink of Brazil's most valuable oil prospect auction yet (the Libra oil field), which would take place on October 21, 2013. On September 19, four Five Eyes oil firms taking part in the auction (Americans Chevron and ExxonMobil, and British BP and BG) would withdraw their offers. Consequently, the auction would proceed to be won by a consortium made up of Petrobras and a French (Total), a Dutch (Shell) and two Chinese companies (CNPC and CNOOC).

Cyber security presents itself as a major issue in the 21st century, given the levels of the energy sector's interconnectivity and automation. The energy sector is particularly targeted due to its social and economic impact. In this context, cyber-attacks may provoke severe damages to energetic infrastructure, what could lead to impairments such as Denial of Service or information theft and cause irreversible material and immaterial damage to corporations and society.

1.7.2 KEY TECHNOLOGIES AND PIONEER BRAZILIAN COMPANIES

With the advent of Intelligent Electrical Networks (Smart grids) and associated disruptive trends such as Distributed Generation, advanced metering, increasing levels of monitoring, network sensing and automation, and increased data flow and information volume in the system, the electrical distribution Industry undergo a significant technological paradigm shift. It enables higher levels of management and security of the electrical system: controls and commands, measurement, monitoring and instantaneous and bi-directional transfer of information between devices make the infrastructure and services provided more efficient, with lower operational and non-operational losses.

The New Cyber Resilience Report by the World Energy Council points out the key and 'innovative' role that technology companies play on this scenario. They are responsible for monitoring the nature of the cyber-attacks and through this analysis, embed security features into the products they are developing and delivering. The insurance sector is also important. It is their task to monitor cyber risks and focus on how to deal with it the right way.

Nevertheless, network automation demands better practices, compliance assessment programs, protection technologies, security attack prevention and detection, trust and privacy, risk analysis, incident handling and attack management. Brazil's insertion of information technology in the electric sector for the development of smart grids is still incipient, and its cyber security technologies are also at an initial stage.

Brazil does not have a regulation regarding cyber security on the fuel and energy sector and that is a huge problem. According to Brazilian law, companies are responsible for generation, transmission and distribution of energy must invest 1% of its income on research and development. Besides the claims of cash problems, many companies find it extremely difficult to do such an investment due to the Electric Energy National Agency (Aneel)'s strict requirements on the research and development projects. UTC Latin America defends that Aneel should authorize the companies to use 1% of its income to invest on cyber security instead. Thus, they would be able to obey the law as well as protect their systems.

Brazil is currently developing methodologies of risk analysis for the specific national context. There are also procedures towards the development and application of corporate security maturity models as well as the development of a set of certifications for components, products and corporate security.

As of 2019, Brazil's local cyber security market is a two-billion-dollars-a-year business, but much of the market share is held by multinational corporations. When it comes to national corporations, one of Brazil's leading cyber security companies, Tempest, recently acquired EZ-Security, and became the country's largest digital security firm. It currently employs 280 workers and serves 250 clients on Latin America, Europe and the United States. Created at Porto Digital, in 2001, Tempest's main clients act in the financial market, which is responsible for two thirds of its 50-million-dollar revenue.

Yet, regarding the Brazilian fuel and energy industry, cyber security solutions are still mainly handled internally instead of hiring specialized companies. One of the main reasons for that is the lack of a legislation that standardizes the policies against cyber threats, as well as obligates the companies to implement cyber security technology on their structure.

Brazil currently has two nuclear power plants (Angra I and II), and, given their strategic importance, both enjoy the support of the Center for Cybernetic Defense (CDCiber), a biministerial autarchy, linked to the Ministries of Defense and of Science and Technology. CDCiber not only executes specific cyber security operations and cybernetic research, but also provides intelligence reports and logistics support, and handles personnel management and staff training (CDCiber, 2013).

The National Operator of the Electric System (ONS) also has its own internal solutions for its cyber security issues. It has 4 datacenters and divides itself into two cyber security teams: a corporate network and an operational network. The first one hosts the team of Datacenter Security Operations, while the second manages the teams of Automation Security Prospection and of Automation Security Operations. It has recently adopted Next Generation Firewall and implemented a corporate Disaster Recovery Plan and protection against Advanced Persistent Threats. Furthermore, it promotes Ethical Hacking initiatives, and sealed a partnership for monitoring and cooperation with CDCiber.

Altogether, Brazil's level of technological maturity, in terms of cyber security, is still at an initial state, proportional to the level of diffusion and implementation of Intelligent Electrical Networks. The Brazilian specialized cyber security market is still relatively small and lead by multinational corporations. There are a few national firms which are thriving, but, within the fuel and energy Industry, most corporations adopt internal cyber security solutions. Naturally, as the countries progress toward the implementation of Intelligent Electrical Network across the National Electric System, so will the emphasis given to developing a mature cyber security environment.

1.7.3 DEVELOPMENT PERSPECTIVES UNTIL 2030

In the wake of the Global Surveillance Disclosures of 2013, cyber security became a top priority for the Rousseff administration. In that context, it was approved the Marco Civil da Internet – Brazil's fundamental law on civil network issues – in April 2014. Supplementary, the Brazilian Congress approved the Lei Geral de Proteção de Dados, which predicts fines up to 50 million reads in case of personal data violation. Also, the government and private companies started building Brazilian-owned domestic and international infrastructure, which includes six new transatlantic fiber-optic cables and the Geostationary Satellite Defense and Strategic Communications - the first fully Brazilian-maintained orbit equipment. Aside from the physical infrastructure, the Rousseff included alternative virtual framework, which included nine new DNS root servers. Brazil has also registered more Top-Level Domains than any other Latin America country, as well as the first city domain, "Rio", in August 2015.

According to the general conditions of the technological prospection in the energy sector in Brazil, it is possible to expect a significant increase in the computerization of the sector towards smart grids. A study corroborated by EPE and MME, indicates that 10% of the electricity consumption in Brazil will be supplied by Distributed Generation by 2030. For the same year, it is expected that 21% of consumers will be served by smart meters, with the associated functionalities and communication system. To maximize the benefits of such changes, there will also be advanced levels of automation, with greater capacity for supervision and support for real-time operation.

With that in mind, at August 28, 2018, Itaipu Binational hydroelectric dam – the world's largest plant in terms of generation capacity – signed a partnership agreement with the Department of Science and Technology of the Brazilian Army and the Itaipu Technological Park Foundation (FTPI) to enable research, development and innovation activities of cyber security institutions. The main purpose of the agreement is to consolidate the Center for Advanced Studies in Protection of Strategic Structures, installed in the FTPI, which will be responsible for the creation of the Laboratory of Cyber Security Studies and Information Technology and Applied Automation in Electrical Systems, that will run simulations intended to increase Itaipu's cyber security.

All these measures reflect a shift towards increased concerns over cyber security issues, but Brazil still has a long way to go in the way of achieving a secure digital environment, especially in the field of fuel and energy. In April 2019, Tempest released the first comprehensive on the Brazilian cyber security market. It indicates that the nearly 35% of its clients dedicate 0 to 1% of its budget to cyber security, but that nearly 70% of them plan to increase the absolute amount by 5% to 20%. Also, 51% are reported to not have Security Operations Centers (Tempest, 2019).

As of 2019, Brazil's detection assets are oriented towards an international problematic, with little alignment to the national problematic. For example: identification of threats is focused on the issues of terrorism and privacy, whereas Brazil's main issue are metrological frauds. In the next decade, Brazil has the challenge of aligning its technologies to the national context and its peculiar issues. In order to achieve full maturity, Brazil needs to decrease the technological dependency in the productive chain of the electric sector for a greater control of security, confidence and privacy. Such measures include a long-term development of national products (hardware and software).

But that goal can only be accomplished in context of a greater evolution of the information technology Industry. Although Brazilians are aware of its importance, that task won't be easily achieved, as it involves an immense quantity of resources (human, material and immaterial), relatively scarce in Brazil's case. Within Latin America, Brazil's information technology market stands out in terms of size but falls behind Uruguay and Costa Rica when it comes to innovation and competitiveness (Deloitte, 2018).

Ultimately, given that Brazil's cyber security and fuel and energy Industry have a relative technological deficit but share a pent-up demand, development perspectives until 2030 are positive. Still, Brazil must overcome some obstacles for its cyber security market to flourish: first, it must foster its information technology and utilities sectors; also, its cyber security market must adapt to its own national needs, so it can improve its technological accessibility and dissemination. These processes are happening, thus there should be a significantly improved outlook by 2030.

1.7.4 FUTURE DEMAND IN CYBER SECURITY TECHNOLOGY (2035-2059)

It is necessary to consider that, due to the striking feature of the Fourth Industrial Revolution, current technologies may no longer be able to solve the cyber security's problems in a long term, which means that the services now available may lose their efficiency to prevent cyber invasions in a couple of years. Thus, an analysis of the technologies that will be highly demanded on the cyber security area from 2035 to 2059 is a hard task to any researcher.

However, there are ranges of cyber security services that are being used by various companies nowadays and that will probably improve in the next decades because of their investment on innovation and research.

1.7.4.1 – ARTIFICIAL INTELLIGENCE (AI) AND MACHINE LEARNING

The use of artificial intelligence has been perceived by many companies as a way to avoid the problem of stealing passwords, e-mails and other personal information due hackers' invasion in both small and large companies, since a group of specialists appoints this tool as a mechanism that guarantees a better protect from cyber-attacks. The AI adoption incorporated the biometric login technique in the market, known for being safer and more reliable. Thus, to have access to the user account, many companies started demanding for digital reading of the account holder as a way to assure a bigger data protection.

Besides that, the artificial intelligence also works as a more efficient tool to combat new threats created every day. In 2018, as an example, more than 800 million of malwares have been created around the world (The Independent IT-Security Institute; 2019), an extremely elevated number for cyber security's traditional systems to be capable of protecting integrity of networks. Artificial intelligence is beneficial, since it is able to conduct an analysis of the software behavior, tracking possible threats. Through the Multi-Factor Authentication, artificial intelligence systems collect information about users and their behavior, ensuring the data's security through the predictability of user's actions.

1.7.4.2 – BLOCKCHAIN

Created initially as a way to storage the virtual currency Bitcoin, the Blockchain technology immediately started to be used as a form to improve the cyber security's policies of many companies. The dissemination of this tool by other sectors of the society may be explained by the fact that blockchain is capable of guaranteeing the data's integrity, as well as preventing from identity's stealing and personal documents. It means that this technology is capable of ensuring privacy and data security stored on this platform. It is possible to point out the following advantages of Blockchain:

- Encryption information progress, which allows the access only to key holder;
- Decentralization of storage information. The strategy found at Blockchain is that the information is divided in more than one encryption, which results on decentralization and decreases the digital vulnerability;
- Complexity capable of minimizing the chances of cyber-attacks and losses. As Blockchain's networks have countless users, to succeed and destroy all the stored data, cyber-attacks must be able to cause damage to millions of computers connected to the network, which a difficult task to be performed by hackers.

1.7.4.3 – BIG DATA

Big Data can be explained as a 'term that describes the large volume of data – both structured and unstructured – that inundates a business on a day-to-day basis'. With this vast amount of information, companies become endowed with the ability to examine and to quickly find irregularities in its network. Thus, because this knowledge allows companies to differentiate the normal pattern from what may be a threat, they are able to prevent themselves from potential cyber-attacks.

While promising and highly demanded, the mentioned technologies have numerous challenges to overcome. In the Brazilian scenario, the big problem is the low spread of these technologies in the companies' activities. As a result, the demand is smaller when compared to developed countries. Brazil needs to pay more attention to cyber security. It is crucial for the country's development, as well as to achieve a strong economy.

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1.8 DIGITAL ENERGY AND SMART GRIDS' PROSPECTS

1.8.1 BRAZILIAN VIEW

Energy consumption and production have a significant participation in the global affairs as it is directly related to the political, social and economic development of nations. Energy, in a strict sense, is one of the most important variables when considering global hierarchies and power distribution in the International Politics. In the case of the BRICS countries, as emerging powers and economies, the development of energy technologies may result in cooperation possibilities among them and elevate their chances to economic growth.

Following the importance of Energy for the global affairs, the Paris Conference (COP 21), of which Brazil is a part, has brought some goals for the energy field. The national policy framework in Brazil is the Federative Republic of Brazil Nationally Determined Contribution (NDC) towards achieving the objectives of the United Nations convention on climate change. This document provides orientation for the Ten Year's Energy Plan, also known as Plan for Energy Expansion (PDE), the main energy planning document of Brazil, elaborated by Energy Research Company (EPE) and published every year by the Ministry of Mines and Energy (MME).
Regarding the Brazilian's National Determined Contributions (NDC) for the Paris Agreement, its main goals are the commitment to reduce carbon emissions by 37% compared to 2005 emissions by 2025, aiming to reduce emissions by 43% by 2030. To reach these goals, Brazil will attempt to reach 45% of renewable energies participation in its energy matrix, expanding the domestic use of non-fossil energy sources, increasing the share of hydropower, wind, biomass and solar energy. Also, Brazil will attempt to increase the share of sustainable bioenergy in its energy matrix to 18%, expanding the consumption of biofuels, the supply of ethanol, the share of advanced biofuels (second generation) and of biodiesel in the diesel blend.

The digitalization of power grids has the potential to develop energy systems and help state economies to achieve better levels of efficiency. Therefore, that is an important technology to improve the levels of social and economic development, once energy is an indispensable element for guaranteeing life quality and industrial production. Also, this technology may help to create an integrated, reliable global energy system. The integration of energy infrastructure is a big step towards largest levels of energy security, which would forever change the scales of industrial production and life quality among populations.

1.8.1.1 BRAZILIAN ENERGY STRATEGY AND INFRASTRUCTURE MODERNIZATION POLICIES

Brazil's energy security strategy is closely linked to the quest of national development, economic growth and employment. Energy self-sufficiency was a central target of Brazilian energy policy at various times over the last 70 years, being sought through the construction of large hydroelectric plants and the increase of national oil production, which will be discussed in the following sections. Second great energy strategy was the search for secure external oil and gas suppliers, especially since the 1960-1970 years. And the third energy strategy was the Brazilian leadership role in regional energetic integration in South America, especially in the South Cone. In the 2000's years, this strategy has left to the exploration of the area now know by "Pré-Sal", that has a huge reserve in the ultra-deep waters of Brazil's territorial waters and Economic Exclusive Zone (EEZ). Also, as a part of the strategy of Self-Sufficiency energy security, Brazil built one of the bigger systems of hydroelectric generation.

The expansion of generation and consumption has stimulated the development of Brazil's transmission line grid, which has been constantly growing since 1960, by Eletrobrás. Eletrobrás is a joint stock company planned in Getúlio Vargas government and effectively created in 1962, under the control of the Brazilian Federal Government that has played a fundamental role in the National Interconnected System (SIN). SIN counts on the participation of companies from all over the country, working in an integrated way, which allows the exchange of electric energy between the different Brazilian regions.

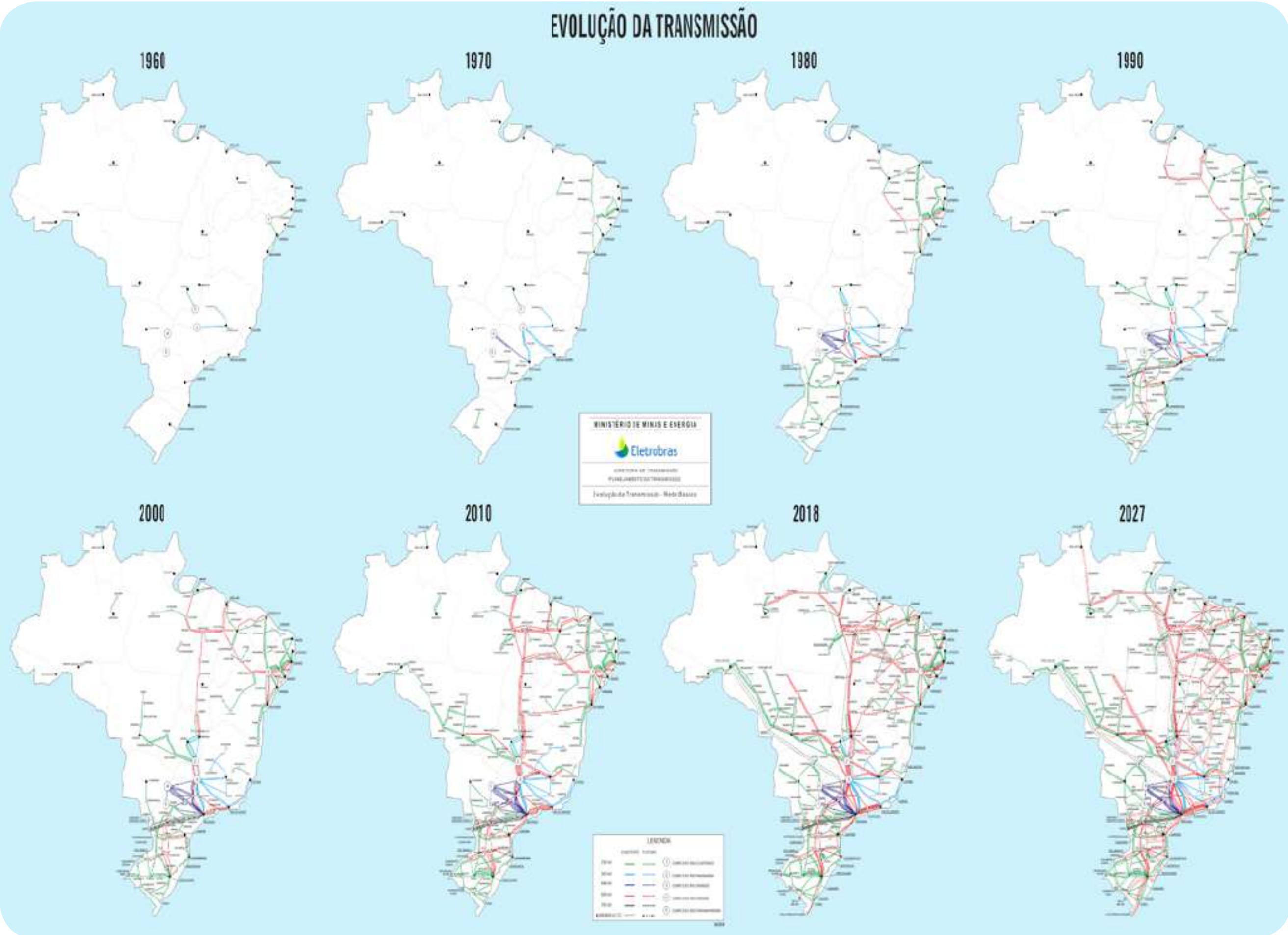


Figure 2.8.1 Historic evolution of Brazil's transmission line grid
Source: Eletrobrás, Brazilian Ministry of Mines and Energy, 2018.

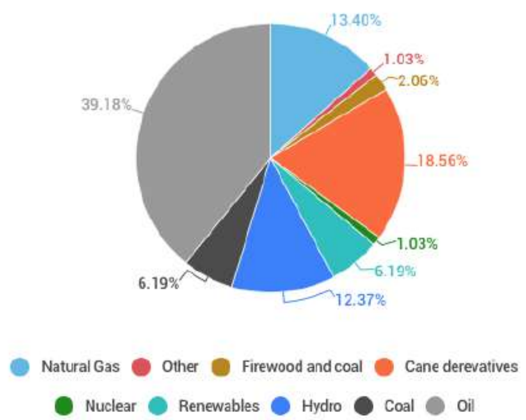
1.8.1.2 HISTORIC EVOLUTION OF BRAZIL'S TRANSMISSION LINE GRID (1960-2018 AND TO 2027)

At the same time, in the 1950-1970 years, innovative projects of biofuels and nuclear power were developed. The greatest project in the biofuels area was the Pro-Alcohol Program, created in 1975. A second energy strategy adopted by Brazil, especially between the 1960s and 1970s, was the securing the external supply of oil. The base of this strategy was operationalized by the diversification of oil suppliers in the 1960-1980 years. This strategy involved the establishment of partnerships through Petrobrás.

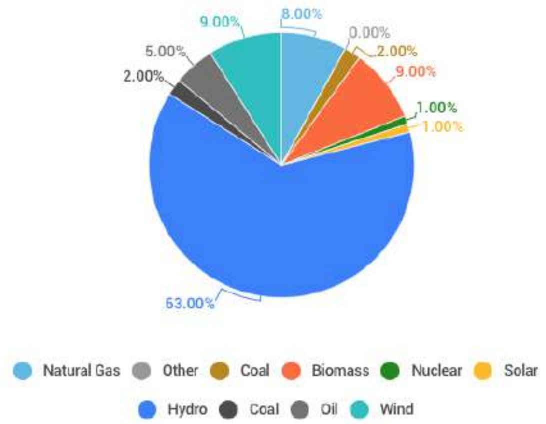
Considering the difficulty of achieving full energy autonomy, the Brazilian government has also adopted the strategy of regional energy integration in the scope of electricity generation. This strategy involved the construction of Itaipu Binational Plant alongside with Paraguay.

1.8.1.3 BRAZIL'S ENERGY PRODUCTION, CONSUMPTION AND DISTRIBUTION

The Brazilian Energy Balance (BEB) contains the accounting relative to energy supply and consumption, as well the conversion processes and foreign trade. It presents in a single document the historical series of these operations and information about reserves, installed capacities and Federal States data. Some of BEB's highlights for 2017, in comparison with the previous year, were: a) In 2017, the amount of B100 produced in Brazil increased 12.9% reaching 4,291,294 m³, against 3,801,339 m³ in the previous year; b) The electricity generation in the Brazilian public service and self-producers power plants reached 588.0 TWh in 2017, an amount 1.6% lower than the result for 2016 as the public service plants remain as the main contributors, with 83.5% of total generation and hydropower, the main source, decreased of 2.6% compared to the previous year; c) The electricity generation from fossil fuels accounted for 20.8% of the national total, compared with 19.6% in 2016; d) The domestic production of oil increased by 4 % in 2017 reaching an average of 2.62 million barrels per day, of which 95.0 % are offshore; e) The natural gas share in the nation-



Brazilian Energy Matrix by Primary Sources - 2017
Source: Brazilian Energy Balance, Energy Research Company (EPE).



Installed Capacity for Electric Power Generation Matrix - Feb / 2019
Source: Brazilian Ministry of Mines and Energy, February 2019.

al energy matrix reached the level of 12.9%, industrial demand for natural gas increased 1.4% in relation to 2016, thermal power generation with natural gas (including self-producers and public service power plants) increased by 13.3% and average consumption in the electricity sector increased in 15.3% compared to 2016.

Regarding the electric energy production, Brazil has an electrical matrix of predominantly renewable origin, with emphasis on the water source. In December 2018 renewable sources represented 90.9% of the Brazilian electricity generation matrix, which is the result of the sum of the amounts referring to domestic production plus imports, which are essentially of renewable origin an what qualifies Brazil as a low carbon economy.

Besides that, solid biomass represents 80% of Brazil's bioenergy, which is mostly of biogases, a form of residue of the sugar-ethanol industry. The other 20% are liquid biofuels, of which 17% is of bioethanol, 3,1% if of biodiesel and only 0,2% is of biogas. Brazil has an electrical matrix of predominantly renewable origin, with emphasis on the water source that accounts for 65.2% of the domestic supply. On the final consumption, in 2017, there was an increase of 0.9%, especially in the agricultural sector, which grew by 1.7% when compared to 2016.

1.8.1.4 SMART GRIDS AND SUPER GRIDS IN BRAZIL: KEY TECHNOLOGIES, PIONEER COMPANIES AND DEVELOPMENT PERSPECTIVES UNTIL 2030

Energy is heavily regulated around the world; thus, each country has its own system operator(s) with specific roles. In Brazil, the system operator is ONS – Operador Nacional do Sistema Elétrico (National Electric System Operator), responsible for electricity planning, scheduling, operating, and analyzing, as well as evaluating grid expansion opportunities and integrating new units into it.

Actually, the BES provides electric service to 98% of the country's population, and it's sustained by the National Interconnected System (SIN) that covers 96% of the national population's demand and 4% of isolated systems, mostly in Amazon region.

Recently a UHVDC 800 kV CC line has been built, from Belo Monte Dam to Brazil's southeast major consumer centers, with 2 lines, with 2.077km and 2.520 km.

Brazil's electricity matrix relies mostly on hydropower, which makes it unique: energy can be stored as water in reservoirs, and generation can be fine-tuned to match consumption by speeding up or down the turbines in hydro plants. The smart grids are going to modify the enhancing quality of service, decreasing technical and non-technical losses, saving operational costs, facilitating the penetration of dispersed generation based on renewable sources and deferring investments on generation and network capacity.

Smart metering and the mandatory rollout of smart meters can contribute to a more efficient and reliable electrical system. However, although the installation of smart meters has the potential to improve quality of service, operational costs and global system operation, their deployment brings new technical, regulatory, economic and social challenges. The advancement of the Internet of Things (IOT) should help this process by increasing the connectivity of various equipment, vehicles and buildings.

But the issue of data privacy is very controversial because there are not yet high levels of digital security that allow its implementation or the use of Big Data.

The telecommunications industry is also important to the development of smart grids. The development of blockchain is important too, since its allows us to know how much a user could contribute in terms of energy production, since in the network there would be information about how much he produced and how much he wants to consume in kWh.

The primarily view of the digitalization concept over Brazilian energy industry is that it consists basically on data management and optimizing processes.

Digitalization strategy in Brazil is mostly focused in the areas of systems control and automation. For instance, online registration systems that can facilitate programme development reduce the costs and resources needed to develop compliance mechanisms.

In 2017, Siemens implemented the MindSphere platform in Brazil, an open operating system on cloud based on Internet of Things, which allows connecting machines to the digital world and, in this way, transforming data into knowledge.

Brazil has successfully implemented these online systems. A good example of that is the Technological Update Plan (or Plano de Atualização Tecnológica, PAT) of Itaipu Power Plant, the greater generator of clean and renewable energy in the world, which includes the implementation of the following technologies on online registration systems: document management system, system of price registration, computerized system. Also, the priority of Itaipu's Information Technology (IT) policy is the adoption of free software.

Besides the trends on energy industry in Brazil, maintaining cyber security is a big challenge. On this matter, many corporations are conducting simulated cyber-attacks to identify unexpected vulnerabilities and develop organizational muscles for managing breaches.

1.8.1.5 NATURAL GAS IN BRAZIL: KEY TECHNOLOGIES, COMPANIES AND DEVELOPMENT PERSPECTIVES UNTIL 2030

Methane gas is the main component of natural gas, generally considered a source of clean energy. Leaking methane in the air before its use is producing pollution, which places it as the second largest contributor to global warming after carbon dioxide (CO_2). Accordingly, to the 64th edition of the BP Statistical Review of World Energy, published in June 2018, Brazil had 0,4 trillions/m³ of natural gas reserves in 2017, approximately 0,2% of the total world reserves. Also, in 2017 Brazilian's production of natural gas was of 27,5 billions/m³ or 23,7 Mtoe, which represented 0,7% of the total world production and a growth of 12,4% when compared to the production in the year of 2016 (BP, 2018). By the other hand, the consumption of natural gas in 2017 was of 38,3 billions/m³ or 33,0 Mtoe, precisely 1,0% of the world's consumption.

1.8.1.5.1 NATURAL GAS PIPELINE, LNG AND THERMAL POWER INFRASTRUCTURE IN BRASIL

Brazilian importation of natural gas through pipelines in 2017 was of 8,6 billions/m³, from Bolivia. As liquefied natural gas (LNG), Brazil imported a total of 1,9 billions/m³ from several countries and/or regions, such as Trinidad and Tobago, Europe, Qatar, Angola and Nigeria.

Currently, the natural gas market in Brazil is condensed in the hands of Petrobras, which is responsible for 70% of the production and owns the entire infrastructure for the treatment of production and regasification of imported liquid natural gas (LNG).

Approximately five years from now, wireless sensor networks connected in the cloud will provide continuous monitoring of the extensive natural gas infrastructure, allowing leaks to be found in minutes instead of weeks, reducing pollution, waste and the likelihood of catastrophic events. The pioneer of this situation is the IBM Company. At the IBM research center, silicon photonics technology in constant evolution transfers data by light, a sensors network, on the ground or within infrastructure.

1.8.1.6 SOCIAL, ECONOMIC AND TECHNOLOGICAL CHALLENGES FOR THE SMART GRIDS AND GAS

Brazil is a developing country with several challenges regarding poverty eradication, education, public health, employment, housing, infrastructure and energy access. In spite of these challenges, Brazil's current actions in the global effort against climate change represent one of the largest undertakings by any single country to date, having reduced its emissions by 43,9% (GWP-100; IPCC SAR) in 2015 in relation to 2005 levels.

Brazil is already a large producer and consumer of bioenergy and it has reduced deforestation rate in the Brazilian Amazonia by 82% between 2004 and 2014. In Brazil, the pursuit of efficiency gains and the improvement of the quality of service offered by the electrical system are the main drivers for the development of smart grids.

The Brazilian Energy Sector (BES), due to the growing and consolidated participation of Utilities with strong and great tradition in the international and national market, will be impacted by technological innovations. But the economic and financial attractiveness of investments in the grid automation and the rollout of smart meters become questionable under most present regulatory frameworks.

Another factor that must be considered is that the digitization will be enable companies of the Electric Sector to concrete productivity gains derived from the use of information and communication technologies. Robots in administrative processes and the processing of big data with meters and smart grids stand out among others. This allows detailed knowledge of consumers' habits and expenses, opening up new business opportunities. Furthermore, there are a lot of challenges for the implementation of the smart grids and the socio-economic context of the country.

1.8.1.7 DEMAND ON TECHNOLOGIES IN FUTURE WITHIN GLOBAL

The great general challenge expected to the period of 2035-2059 will be the challenge of ensuring the expansion of energy supply and the stabilization the energy transition.

The projections indicate that Brazil will continue to use the hydroelectric power and a combination of oil, gas and biofuels. Following its NDC's, some policies have been adopted by the Brazilian State to increase the participation of all kinds of biofuels in its energy matrix. One of these policies is Renovabio, a State policy that aims to develop a joint strategy regarding the strategic role of all types of biofuels in the Brazilian energy matrix, both for energy security and for the reduction of gas emissions.

Harnessing technology is a challenging strategy to improve the development of oil and gas resources, renew the recovery of existing fields, reduce the environmental footprint and find new sources of hydrocarbon energy by entering new operational borders. Moreover, the industrial production of new materials, like superconductors and new semiconductors, the building of a new infrastructures, like super-smart and regional integrated grids, and, besides, a development of a new services to secure the stability of grids, like the needle to advance in cyber security, will be challenges that will be central to the Brazilian energy's sovereignty and security.

1.8.2 RUSSIAN VIEW

The transition to digital energy, the implementation of smart electrical networks and the emergence of new technologies in this direction are due to several reasons:

Technological

Energy transformation was made possible after the emergence of new technologies (BlockChain, Big Data, IoT, artificial intelligence and neural networks), the implementation of smart energy metering, the development of renewable energy. Technologies of the Internet energy provided the implementation of smart power system control based on Machine to machine (M2M), thereby the integration of energy complex in a common digital space – the basis for the digital energy creation;

The replacement of main obsolete fixed assets (degree of depreciation – 43,2%) with more modern equipment using digital technologies;

The distributed generation, the transition to which is due to the need for national security, improving reliability and stability of the energy system, smoothing power peaks and collapses

Economic

Decentralization of energy management and distributed generation form new market relations that require the creation of new business models and services using new digital technologies (Internet energy, electronic trading and smart-contract)

Increasing the economic efficiency of equipment maintenance through the capacity reduction, electric power losses, number of staff etc

Ecological

The use of fossil fuels for electricity generation leads to environmental deterioration;

Due to the situation of anthropogenic air emissions within The United Nations Framework Convention on Climate Change, an agreement regulating measures to reduce the carbon dioxide (CO_2) in the atmosphere since 2020 was signed;

The solution is transition to clean non-carbon energy (increase in the proportion of renewable energy in the energy balance, electric transport and fossil fuel phase-out);

Relevance

The current level of technological development in energy is gradually achieving its maximum efficiency;
This direction is promising.

Legal

In accordance with the annual Presidential address in 2016 digital energy is a key component of the digital economy. This statement served as a starting point for creating a legal framework in the field of energy and in 2017 the Russian Federation Government approved the program "Digital economy of the Russian Federation". In 2018 the President signed Executive Order on National Goals and Strategic Objectives of the Russian Federation through to 2024;

Consolidation of goals and objectives in the field of digital economy at the highest state level served as a legal basis for the emergence of digital energy in Russia and the development of smart electric networks.

Tendency

1. The spread of digital networks, smart control systems, new financial technologies;
2. The development of renewable energy and cheaper technologies for its use;
3. Decentralization of electricity generation;
4. Changing consuming behavior;
5. The liberalization of energy market and the emergence of com-

petition;
6. Growing demand for electricity;
7. Growth in the use of natural gas;
8. Development of efficient energy storage systems;

Key techlonogies

Digital energy is the result of the traditional energy complex transformation based on the use of data collection and processing technologies in order to increase the efficiency of the complex participants, reduce barriers and create prerequisites for the emergence of new business models, implement service for meeting consumer demands. Below we will refer to the technologies that in our opinion will be the key elements of the new country's energy paradigm.

1.8.2.1. DISTRIBUTED GENERATION

In other words – the decentralization of electricity generation.

It will reduce the costs of the network complex and large generation development, restrain the rising electricity prices and expand consumer choice, increase energy efficiency, reduce greenhouse gas emissions, increase investment attractiveness, create new production.

Currently there are more than 34 operating solar power systems in the unified energy system of Russia– only 0,03% of the installed power station capacity of the Russian energy system. The domestic company LLC "Avelar Solar Technology" owns a solar power station with total capacity 344MWt., LLC "Calypso Solar" owns a solar power station Vladislavovka in the Republic of Crimea, LLC "Solar Systems" owns a solar power station with total capacity 80 MWt, PJSC "T Plus" owns Orsk solar power station.

There are several good reasons why consumers will abandon the centralized power grid in favor of independent generation using gas turbine power stations. They have such advantages as efficiency, low cost, fast payback periods, small dimensions, high mobility and acceleration, short construction period, detailed technology of production etc

1.8.2.2 DIGITAL SUBSTATION

"Digital substation" is a substation with a high automation level in which almost all the processes of information exchange among the substation elements as well as management of its operation is carried out digitally.

The feature is the use of primary equipment capable of sending and receiving a digital signal as well as abandoning discrete and analog signals in favor of a digital bus.

The advantages are self-diagnostics of digital devices; in case of any efficiency change data are recorded in real time; reduction of operating costs for maintenance: detailed monitoring of processes in the equipment is an opportunity to predict the maintenance.

There are several disadvantages. Firstly, the need to reserve the lines of data transmission channels and consequently – the danger of virus program penetration. Secondly, high cost of operating in view of using the standard IEC-61850.

The management of distributed energy system implies
Introduction of 'clever network' technologies which are capable of energy distribution, the choice of optimal energy transmission routes and cost minimization, online monitoring.

One of the stages of Smart Grid is artificial neural network technologies such as information technologies that are based on the usage of artificial neural networks. artificial neural networks are program or hardware-realized system built as a biological analogue - a neural human system. As a result of learning this system can increase its capacity and calculation accuracy.

A number of Russian companies such as PAO Rosneft' and PAO Rosseti are already using these technologies. For example, an introduction of clever devices that are able to keep records and create the centers that would control the networks.

1.8.2.3 DEVELOPMENT PROSPECTS UP TO 2030

The following trends are: energy safety, energy effectivity of the economics and energetics, ecology safety.

The development is based on the introduction of innovative technology, transition to the system with renewable sources of energy, ubiquitous introduction of digital energetics and intellectual electronic networks.

Digital solutions let decrease the losses from energy transmissions from the source generation to a customer, increase the safety and reliability of the power supply, distribute energy flows and production processes.

The conception of the intellectual energy is reflected in the definition IEEE «Fully integrated self-regulating, self-recovering energy system that has a network typology and includes all generating sources pf energy (also alternatives ones) that are controlled online by one network of information control devices.

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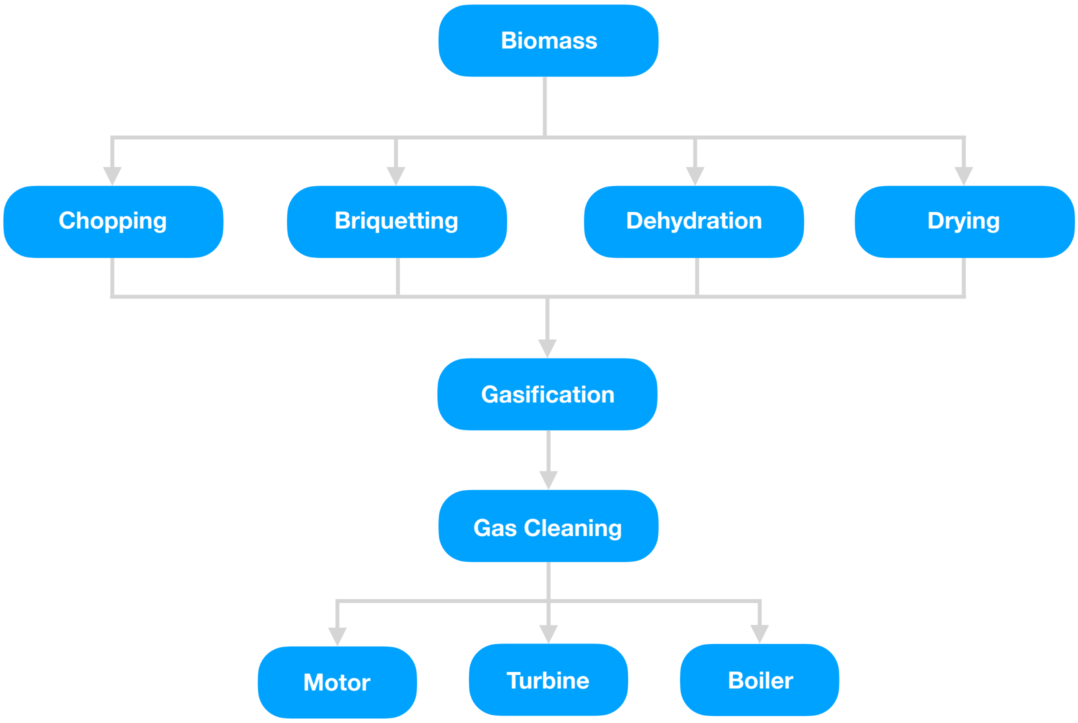
1.9 GASIFICATION: PROSPECTS, MECHANISMS AND CHALLENGES

1.9.1 THE PROCESS AND THE MECHANISM OF GASIFICATION

The thermochemical process which converts solid carbon fuel into carbon monoxide is commonly known as gasification. The process is done inside a closed air-tight chamber under slightly lower pressure than the atmospheric one. The following flowchart shows the process of gasification:



Fugure 1.9.1 Process of Gazification

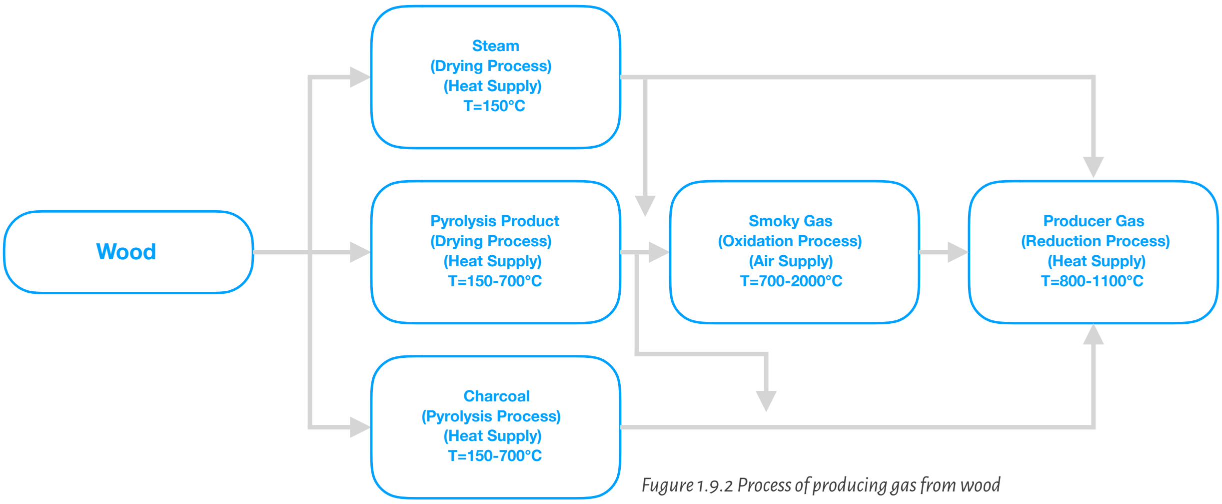
Gasification is a process of incomplete combustion. Solid fuel is burned in insufficient air for incomplete combustion in order to produce gases which will still have combustible matter in it.

These gases have a wide variety of names, e.g. wood gas, syngas, producer gas, town gas, generator gas, etc.

The whole thermochemical process is quite a complex one. It is practically unrealistic to split the gasifier into separate zones but theoretically it is essential. The aforementioned stages of gasification occur simultaneously in different zones of the gasifier.

1.9.2 PROSPECTS AND CHALLENGES OF UNDERGROUND COAL GASIFICATION (UCG)

Even though gasification has bright prospects, yet it is commercially demonstrated in a very basic way. Presently, in a coal fired power station in Angren, Uzbekistan UCG is being used as an auxiliary fuel. But the produced gas is not properly cleaned. Due to minimal cleaning the specific heat of the producer gas is reportedly as low as 5 MJ/scm. At Majuba Power Station, South Africa, UCG is also being used as a secondary fuel. However, in spite of the huge potential of the UCG technology it is hardly being used to produce electricity by firing it into gas turbines or in the chemical and fertilizer industries. The main reason is that there are several problems and challenges that have not been solved yet. The following challenges have to be solved



Fugure 1.9.2 Process of producing gas from wood

in order to commercialize gasification on a large scale:

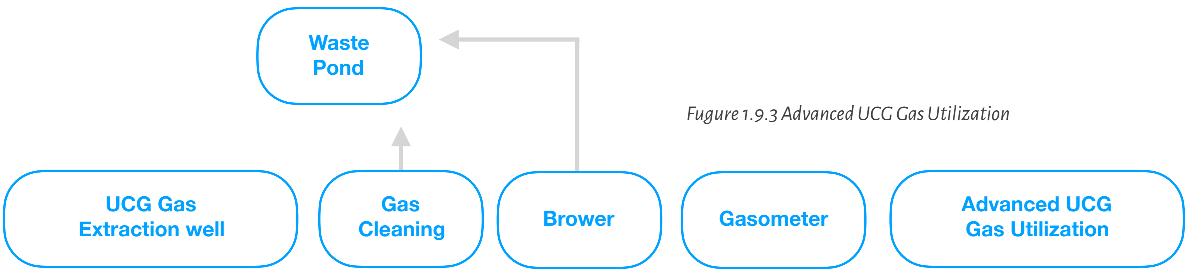
1. The syngas cleaning system has to be developed so that the produced gas can be cleaned properly. Only then the produced gas could achieve acceptability.
2. The quality and quantity of syngas have to be maintained. The production has to be increased to meet the ever-increasing energy demand but this shouldn't be done at the expense of the quality.
3. During the gasification process the whole container undergoes continuous expansion and contraction due to unevenly distribution of heat. As a result, cracks and leaks are found in the walls of vessels. So, vessels have to be manufactured in a better way to overcome this problem.
4. For the success of UCG, multi-cell UCG operation is important.
5. Residues and contaminants have to be removed and disposed with proper measures keeping the pollution in mind.

Although UCG proponents state that fully controlled and developed UCG systems already operate, this needs further validation. Only then UCG can become a big player in the advanced power generation as well as in chemical and fertilizer sectors. The UCG systems need to be developed more to achieve reliability. One of such application can already be seen in the co-firing of UCG and coal in the aforementioned power stations. This ensures the continuous supply of power. Even if the UCG units fail, coal will be there as a backup. Also, the quality of the specific heat of the produced gas can also be increased by thorough cleaning of the gas while coal keeps the system running. In the following figure there is an advanced UCG gas utilization layout:

In the flowchart above a gasometer is shown. This is a very important part of the advanced utilization system and it is a recent development. It has four objectives:

1. It can hold up gas for a designed production. So, it has a function as a temporary storage system.
2. This is where multiple UCG cell outputs can be averaged and mixed for better specific heat.
3. Gasometer can be used for a secondary method of cleaning the produced gas.
4. Samples of the produced gas can be taken from here for the purpose of testing.

The waste pond shown in the flowchart is a place where contaminates, chemicals, particulates and contaminated water are stored. The pond contains highly toxic materials, so in some jurisdictions it is mandatory to be registered as a toxic waste facility. One solution to the problems regarding UCG waste management could be filling up the abandoned or unused gasifiers with waste. But this is not a sustainable process as containers would soon be filled up. Hence, one of the biggest challenges of gasification is to develop a better waste management system.



Fugure 1.9.3 Advanced UCG Gas Utilization

1.9.3 THE CHALLENGES OF CLEANING UCG GAS

Syngas is a mixture of CO and H2. It is a product of UCG. The composition of the produced syngas may vary with the method of gasification used, like air, oxygen or oxygen enriched air as well as the local parameters like the nature (salinity) and the amount of water used.

The downstream processes using syngas are classified into two groups:

1. The ones that use the heat of the syngas to burn it in combustion processes to form CO2 and water.
2. The ones that use chemical processes. These processes require either or both components of the syngas in order to carry out the chemical reactions. These processes require catalysts to make the reactions faster but these catalysts are very sensitive to contaminants.
3. The UCG processes produce a number of pollutants or contaminants along with syngas. Those are:
4. Particulate Matter (PM): As a result of incomplete combustion, soot and mineral dust are produced. They are called particulate matter and they are extremely harmful for the downstream equipment.
5. The UCG processes also produce some heavy hydrocarbons and tar which are harmful for the equipment as well.
6. CO2 is also produced. This gas absorbs a lot of heat, lowering the temperature of the process. It also hinders some catalytic processes.
7. Just like carbon dioxide, nitrogen is also produced and it acts like the former as well. Nitrogen takes away a lot of heat content from the syngas and captivates some of the catalysts.
8. Oxygen is also a matter of concern. Poor combustion control often leaves excess oxygen behind which can cause explosion. It is the reason for some catalyst fouling too.
9. There are certain sulfur compounds which are formed during the UCG processes. They cause hazardous sulfurous emissions which are extremely harmful for the environment. It is also a poison to the catalysts.
10. The processes produce chlorine gas and chlorine compounds as well which are the reason for corrosion in the inner walls of the downstream equipment. It is another catalyst poison.
11. Some heavy metals are often found in coal, e.g. arsenic, mercury etc. They are catalyst poisons which cause harmful emissions.
12. From the above discussion it is evident that these contaminants need to be minimized as much as possible for a better performance, a longer life of the gasifiers and, the last but not the least, due to environmental issues. Fortunately, not all of the contaminants are applicable for every gasifier. The presence of contaminants depends on the location as well. Chemical processes are less tolerant of pollutants than that of the combustion process.

The following chart shows a comparative study between an oxygen blow underground coal gasifier and an entrained bed surface type gasifier. The chart depicts the volume percentage of each constituent in the produced gas.

Moreover, the UCG and surface gasifier yield 356 BTU/scf and 286 BTU/scf, respectively.

The chart illustrates a few points:

1. CO2 content is higher in UCG compared to that of the surface gasifiers. As a result, the most important product or syngas components (H_2 + CO) are much less in amount in case of UCG.
2. CH4 concentration is higher in UCG products than in the surface gasifier products. As a result, the calorific value of the UCG products is higher than that of the surface gasifier products. But as methane acts as an inert gas in most of the reactions it only increases the processing cost without adding much to the output.
3. The N2 content is a little higher in the surface gasifier than that of the UCG one. This is because in the surface gasifier nitrogen is used to transport coal to the gasifier.
4. The tar and C_2+ contents in UCG are significantly higher than that of the surface gasifiers.
5. Both of the processes produce H2S (hydrogen sulphide) and CO (carbonyl sulphide). Also, both processes produce some amount of ammonia and hydrogen cyanide.

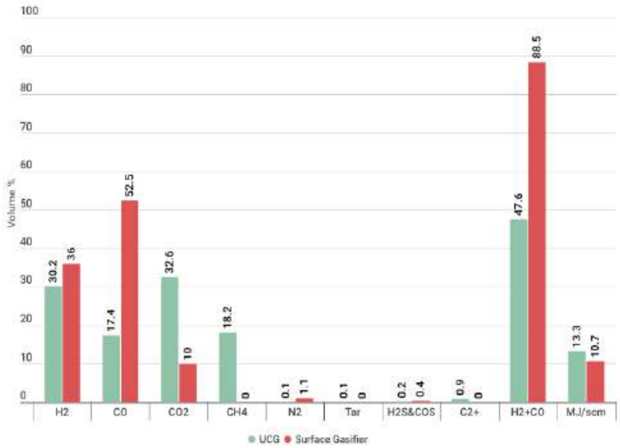


Figure 1.9.4 Syngas composition of UCG and surface gasifier

CLEANING FOR COMBUSTION

For the combustion system the main area of concern is PM (particulate matter) and tar. A scrubber system with water is used to clean this up. This system removes mineral PM and tar condensates. Tar and naphtha obtained from coal sometimes require some solvent like PhenoSolvanTM along with the scrubber water. After the scrubber, the excess water is removed by cooling. This is done before combustion is started. The combustion process will emit a lot of sulfur compounds if they are not removed before the fuel enters the combustion chamber. So, according to the local requirement, the sulfur compounds are removed. Sulfur compounds can partially be cleaned up by some simple processes like iron or zinc oxide adsorption and simple washing. Washing is specifically used for H2S (Stretford process).

CLEANING FOR CHEMICAL PROCESSES

Chemical process does not only require the PM removal but also the adjustment of the syngas stoichiometric ratio, i.e. ratio of concentration of hydrogen to that of the carbon monoxide. This is generally done by removing excess CO_2 and by water-gas shift. After that the excess CO_2 and sulfur compounds are removed in an acid gas removal system. The goal is to reduce the sulfur concentration below 1 ppm. It is often observed that the composition of UCG syngas changes over time making the removal even more challenging. In downstream processes some type of buffering is used to overcome this. A gasometer is one of such solutions to prevent the swift changes in the composition of syngas.

So to summarize, for the sake of simplicity we consider highly purified syngas. At first, the PM and tar are removed using water and scrubber. Then the water-gas shift process is executed to maintain the stoichiometric balance.

$$CO + H_2O = CO_2 + H_2$$

It is necessary to keep the size of the whole plant as small as possible. So, to minimize the size of the plant the whole system is conducted under pressure. Before the water-gas shift process a compressor is introduced. Another challenge with the water-gas shift process is the fact that although it can clean up many contaminants and poisons very well, it requires a significantly high temperature (as high as 350°C).

After that the water-gas shifted syngas is cooled and passed through the carbonyl sulphide converted in order to convert the carbonyl sulphide present in the syngas into H2S.

$$COS + H_2O = CO_2 + H_2S$$

After this step all the sulfur is present in the form of H2S. The gas is then passed through an acid gas plant which essentially removes all the acid gases like CO2 and H2S together or separately. There are multiple ways to do it. The common practice is to treat gases which have hydrocarbons and have been through the water-gas shift system with solvents like RectisolTM . This solvent is often preferred over amine-based systems.

It is required to extract all the sulfurs from the hydrogen sulphide for disposal. Till date, it is a common practice to dispose gases containing carbon dioxide directly into the open air but in future this practice might be changed for the sake of the environment.

After this stage the syngas is almost pure. A few more purification processes are executed such as zinc oxide absorber and carbon absorber polishing operation to extract the remaining sulfur and poisons like mercury and arsenic, respectively. At last, a drier is introduced for drying up remaining moisture, if any.

The main advantage of UCG over other gasifiers is its low-cost production. However, all the aforementioned cleaning processes can almost double the cost but still, compared to the price of natural gas all over the world the cost of the syngas production by UCG will still be low.

In the previous chart we can see that the methane content of the UCG produced syngas is about 18% and that is about half of the syngas energy content. However, methane cannot be directly used in the reactions that produce liquefied fuel. Fischer – Tropsch or methanol is this kind of reaction. So to utilize methane it is necessary to use some sort of a reformer which can produce H_2 and CO. The following flowchart is the process used for methane reformation:

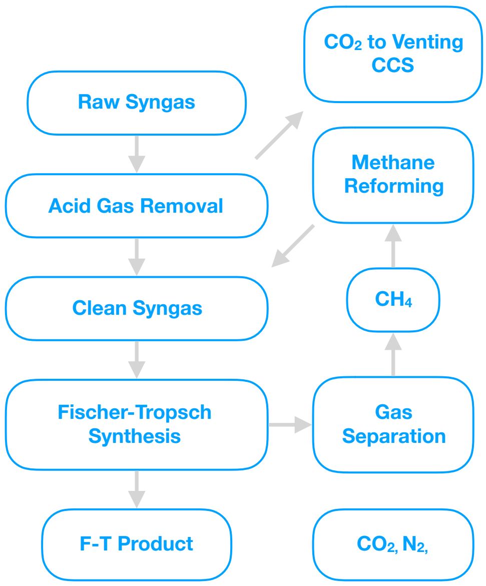


Figure 1.9.5 Methane reformation (1)

There is an alternative way in which methane reformation is not done and syngas is used for power generation. The following flowchart is such a process: There is an alternative way in which methane

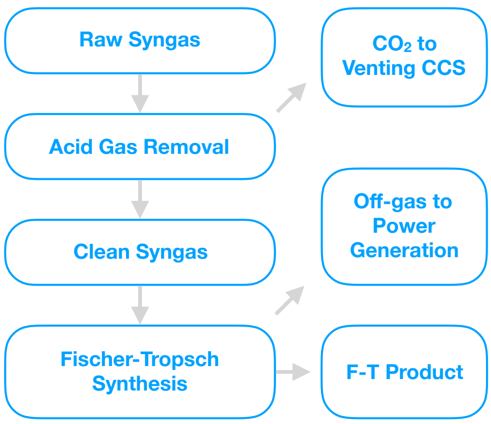


Figure 2.9.7 Methan reformation (2)

reformation is not done and syngas is used for power generation. The following flowchart is such a process:

The choice among these two processes depends upon a few factors such as local circumstances (e.g. demand) and the cost of electricity. We can also see in both of these diagrams that a part of the produced carbon dioxide could be sent to CCS (Carbon Capture and Storage). However, the availability and the feasibility of this facility depends upon the economic hindrances like taxes and the cost of CCS.

UCG DEVELOPMENT: SCALE AND COST

As always, the ultimate decisive factor is the designed output with respect to the installation cost. It is predicted that in future, the developed UCG plants will be able to yield more than 50,000 bbl of raw synthetic crude fuel per day. But plants having output less than 10,000 bbl/day can also be used in the remote area where diesel market is not that popular.

According to Dr. Duncan Seddon and Dr. Mike Clarke, the ground coal-based gasifiers will cost about $11.5 billion to produce 80,000 – 1,00,000 bbl/day. On the contrary, if UCG is used the cost can come down as low as $8 billion, apart from the less operating cost.
Therefore, it is quite obvious that using UCG to produce syngas will be much more cost-efficient than using the conventional ground coal gasifiers.

1.9.4 CONCLUSION

At the end of the discussion it can be said that gasification, more precisely the UCG technology has great potential to support the fossil fuel-based power generation system and fuel demand in general. It is economical, efficient and does not require much space to operate. There are many types of gasifiers present in the market. The choice depends on the requirement, budget and local conditions. Among all the gasifiers, we saw that the underground coal gasifier or the UCG technology is the most promising and cost-efficient one.

There are certain challenges in gasification technology. The main challenge is to make the whole system as less contaminating as possible. The work is going on to develop even better technologies to minimize the contamination and hopefully in the near future such technologies will be there. Whatever we do, we should remember that the process must be efficient and environment-friendly, otherwise it will not last long.

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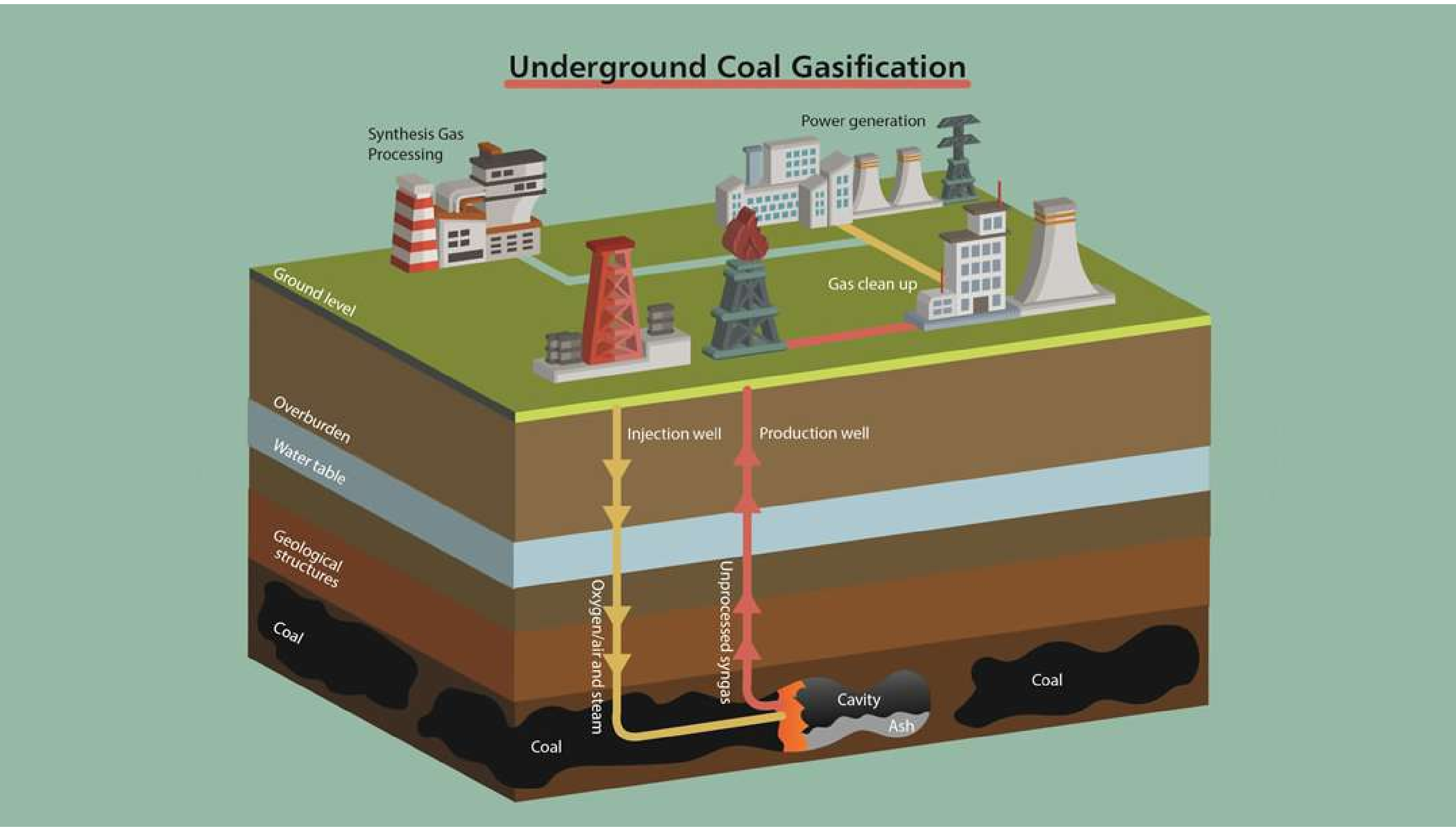

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1.10 ELECTRIC POWER SYSTEMS: DEVELOPMENT, SURVIVABILITY AND SAFETY

The electricity sector is a domestic economy's fundamental and important sector that is strongly linked to economic development. On the one side, electricity is an economic development driving force. The shortage of power supply will have a serious impact on the economy's good growth and can result in major financial losses. On the other side, macroeconomic development level and velocity play a crucial role in determining the demand for electricity.

The process of building electricity will normally take three or even five years, from planning to completion and commissioning. The fluctuation of the economic situation and the delay in investing in electricity will inevitably lead to an imbalance between supply and demand for electricity. Consequently, advance planning for investment in electricity to meet economic demand becomes a crucial problem in the growth of electricity. Shortage in economics implies that the product's effective demand is higher than the real supply. In an efficient economy, the equilibrium price will automatically smooth the imbalance between demand and supply, and in an equilibrium, status there should be no energy shortage.

As smartness can be at different levels. By including distributed generation, this grid decreases dependence on centralized energy plants. Installation and maintenance of Smart Grid needs different branches of engineering. Communication engineers are needed to install, maintain and operate a data network that transfers meter data and sends information to the Independent System Operators in real time. This technology seeks to reduce the reliance on transmission lines while making maximum use of the distributed lines.

That is, the DGs are used to generate local energy and share power among a consumer group. In order to heavily automate energy systems, the ISO utilizes communication equipment to transfer data. In addition, heavy automation helps prevent instability in energy systems and prevent blackouts.

1.10.1 KEY TECHNOLOGIES AND PIONEER COMPANIES IN SOUTH AFRICA

Grid modernization must include the use of smart systems, next-generation components with built-in cybersecurity protections, sophisticated grid modelling and apps, distributed generation, and creative system control architectures. Electrification is critical to long-term carbon reduction goals and will be a growing share of renewable energy. Decentralization makes clients active system components and involves substantial coordination. Digitalization promotes the other two trends by allowing for more control, including automatic, real-time usage and manufacturing optimization and customer interaction.

ELECTRIFICATION

As generation changes to more renewable sources, electrification produces additional environmental advantages by moving many end uses of electricity (e.g. transportation and heating) away from fossil fuels, and electrification in many instances improves energy efficiency (Martin, C. et al 2017). The most promising possibilities for electrification in Organization for Economic Co-operation and Development (OECD) economies are those sectors that are among the biggest polluters: transportation, commercial / industrial apps, and residential heating. Electrification is critical to long-term carbon purposes and a distributed resource of relevance.

DECENTRALIZATION

Makes customers active system elements, but requires substantial coordination. Key technologies: energy efficiency, solar PV, distributed storage, micro grids demand response.

ENERGY EFFICIENCY

Product innovation and energy efficiency programs have combined to dramatically increase the effectiveness of most consumer and industrial power products compared to just a few years ago. In International Energy Agency (IEA) nations, since 1990 investment in effectiveness has helped to prevent annual electrical consumption equivalent to about 5 million households.

DIGITALIZATION

Digital technologies progressively enable grid-wide equipment to interact and provide customer-friendly information, as well as grid management and operation. Smart meters, new smart / Internet of Things (IoT) sensors, remote control and automation network systems, and digital platforms focusing on optimization and aggregation, enable the network and its connected resources to operate in real time and collect network data to enhance situational awareness and utility services. Enables open, real-time, automated system communication and operation.

Key technologies: network technologies (smart metering, remote and automation systems, smart sensors) and beyond the meter (platforms for optimization and aggregation, smart devices and equipment, IoT)

1.10.2 DEVELOPMENT PERSPECTIVES UNTIL 2030

Energy is an engine for growth of the economy and social development. Energy has helped transform societies and has supported human development. Energy is helping human with the needs such as nutrition, warmth, and light. Energy access is reliable, efficient, affordable, and safe energy carriers can affect productivity, income, and health, and can enhance gender equity, education, and access to other infrastructure service (S. Pachauri and A. Brew-Hammond). The major challenge faced by over one-third humanity even today is the lack of access to reliable, affordable, and modern energy carriers particularly in rural areas of developing countries. This presents a major impediment to growth and compromises progress toward sustainable development. Providing access to electricity and modern energy carriers to all populations by improving living conditions and provide economic returns in order exceed the costs involved.

The electric energy sector of South Africa is currently in a state of flux as a result of social, economic and environmental pressures. Water is one of the basic resources in electricity generation in South Africa. South Africa's electricity generation industry is dominated by coal-based electricity generation technology which accounts for approximately 90% of the electricity generated by Eskom. By 2025, South Africa is expected to have about 234 gigalitres as projected within national accounts published by Statistics, South Africa.

Recognizing the improvement access of energy to the poor, the global energy access target has been discussed by the international community. The national targets have set the government and regional bodies to improve access. The United Nations Secretary-General's Advisory Group on Energy and Climate Change recommends ensuring universal energy access by 2030. The provision of affordable is required to meet such target, electricity and modern fuels and improved end-use devices by 2030 to all who currently lack access.
Water use for cooling of thermoelectric power plants is affecting the overall water supply and the ecological health of surface water bodies. In a number of occasions permits for proposed plants have been denied because of water availability concerns and potentially adverse effects on aquatic life in various locations internationally. Similarly, during droughts there have been occasions that generation plants have been shut down because if operated they would not be compliant with water use regulations. Hence, water use for electricity generation affects regional ecology and security of supply of both water and electricity.

There are different technologies used for cooling which possesses advantages and disadvantages which are: once-through (open-loop) cooling, closed-loop (wet) cooling, dry (air) cooling and hybrid cooling.

The needs of the South African's growing demand plan on the government are outlined in the Integrated Resource Plan for Electricity (IRP) of 2010. The average economic growth exceeding 5% per annum and full implementation of the National Development Plan (NDP), there is a gradual ramp-up of renewable energy capacity to 9% of South Africa's total electricity supply capacity by 2030. The WWF, suggesting that the IRP should provide for an 11-19% share of electricity capacity by 2030, depending on the country's growth rate over the next fifteen years.

The National Development Plan (NDP) outlines the 2030 vision for South Africa's energy sector and envisages a sector that will promote economic growth and development through adequate investment in energy infrastructure and the provision of quality energy services that promote environmental sustainability through efforts to reduce pollution and mitigate the effects of climate change'. In particular, it proposes that renewable energy and gas should make up 20 000 MW of the electricity supply by 2030.

1.10.3 THE IMPACT OF GLOBAL CHALLENGES ON SOCIAL AND ECONOMIC AFFAIRS

In today's lives, a quarter of humanity without access to any electricity and in which they depend on unprocessed biomass, coal, or charcoal for its thermal needs. These people suffer to their welfare and most live in rural areas and urban slum in the developing countries. Access to modern energy carriers is an important need to people, but insufficient in alleviating poverty and enabling the expansion of local economies.

The bulk of the South African electricity supply such as generation, transmission and distribution infrastructure were designed ago in different political, societal and technology context.

The ESI stands is to maintain security and quality of supply, to respond to growing supply needs and to new challenges. The biggest challenge will be of finding the right economic and environmental balance between these imperatives:

- Changing and more demanding customer expectations,
- Secure supply of electricity now and in the future,
- Diversified (and distributed) energy mix with a cleaner, more sustainable supply, and
- Affordable infrastructure capable of supporting economic growth and rapid technology advancements

The challenge to changing energy system requirements is not unique to South Africa. South Africa is in a position where this coincides for infrastructure investments to maintain a stable platform for current and growing economic activity.

Smart grids are an essential part of these inevitable industry changes (e.g. replacement of aging infrastructure, clean energy, securing supply, introduction of electric vehicles and distributed generation), in addition to the other many challenges and doing so while managing escalating energy costs.

The South African utility that is responsible for providing the country with electricity, Eskom, has been faced with many challenges recently that has led to worrying interruptions of energy supply called load shedding. In order to match the demand in the country load shedding has to be implemented to balance what is available and to avoid total collapse of the power system. This load shedding is not only bad to Eskom, but to the economy and hence the society of the country.
Load shedding affects the business industry in such a way that companies that utilize electricity tend to not be fully productive due to the limitations of operating hours due to electricity interruptions. This of course reflects badly on the economy of the country.

A statement of warning issued by Agri SA highlighted the negative impacts load shedding would have on the agriculture sector as well as the broader value chain as the expenses of electricity within the sector costs about 5 % (R 7 bill or $ 457 mill equivalent). They emphasized the importance of electricity on energy-intensive and irrigation-reliant industries such as poultry, diary, grains, and horticulture. The cost of food will also rise should there be no electricity supply security and sustainable outages in the long run. According to the Organization Undoing Tax Abuse, load shedding can cost up to R 5 bill or $ 327 mill daily.

The Cape Chamber of Commerce President, Janie Myburg, said that continuous implementation of load shedding will result in scaring investors away and also potential mass job losses leading to household inconveniences.

1.10.4 THE IMPACT OF GLOBAL CHALLENGES

There are two of main systems in the Electric Power System namely the generation system, the transmission system and the distribution system.

GENERATION

The generation system generates electricity in the power plants by converting the primary energy into secondary energy (electricity). Traditional power plants include nuclear, hydro and thermal power plants. About 77% of the electricity in South Africa is produced from the thermal power plant using the coal due to its abundancy within the country.

The usage of coal as a primary energy is already a challenge as it has its share of environmental impacts in such a way that the mining of coal removes the vegetation, destroys wildlife, reduces the quality of air and lead to acid mine drainage among others.

Emalahleni, a city in Mpumalanga, South Africa was declared a High Priority Area in 2007 by the government due to its poor air as a result of excessive coal mining activities.

Also, shortage of low coal stockpiles was one of the reasons the struggling Eskom implemented a process of load shedding due late 2007 to early 2008.

TRANSMISSION AND DISTRIBUTION

The transmission system is link between the generation system and the distribution system. It transmits the electricity between these two systems through the transmission lines called the National Grid. These lines are made of copper and aluminum and carries a voltage ranging from 10 to 1100 kV while covering a total distance of 300 000 km.

The distribution system provides electricity to the load. The load is a system that consumes electricity i.e. households and businesses. The distributions system comprises of small voltages between 120 V to 10 kV.

The main challenges in the South African transmission system are identified as bird streamers (38%), lightning (26%) and fires (22%) according to the study on Characterization of power system events on South African transmission power lines, 2012. Eskom website also identifies imports and theft as major challenges.
Large birds are known to cause electric flashovers that excrete long steamers which short circuit the air gap between the structure and the conductor.

The voltage of the line differs the interactions between power lines and birds. Faults due to the electrocution of birds bridging the conductors-to-tower air gap by the wings and body occur primarily at voltages of and below 132 kV where clearances are smaller than on higher voltage lines. Rainfall during summer in South Africa is usually associated with heavy thunderstorms and lighting.

The impacts of these challenges lead to power outages (Load Shedding), damage to appliances, traffic jams, higher prices, slowing production, job creation and economic growth.

1.10.5 TECHNOLOGIES WHICH MAY BE IN GREAT DEMAND IN 2035-2059

The central challenge in South Africa's future path of development is making energy supply and making more use of sustainability. Energy is a critical factor in economic and social development. Any energy system has impacts on the environment. Managing energy-related environmental impacts is a major goal of energy policy (DME 1998) and making energy development more sustainable at a national level (H. Winkler, 2005).

Water consumption factor forecasts of dry cooled power plants (ranging from 0.1 l/kWh to 0.15 l/kWh) are expected to be one order of a magnitude lower than wet cooled power plants (ranging from 2.2 l/kWh to 2.4 l/kWh). Water consumption factor for the RTS fleet is expected to reach 3 l/kWh by the year 2020. Water requirements are expected to increase from roughly 360 gigalitres on current levels to just above 370 gigalitres in 2021.Depending on the retirement of the RTS fleet, total water requirements could be reduced (by 12% to 15%) to 320 gigalitres. RTS power plants are located within water constrained water management areas Olifants and Inkomati. Based on the projection the total base load water consumption will increase from 332 gigalitres in 2013 to roughly 370.5 gigalitres during 2035.

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Expert's opinion

With the increasing development of electricity from renewable energy, it is expected that large-scale renewable power would be transported from the renewable-energy-rich areas (usually also sparsely populated areas) to load centers (also the populated and industrialized area). Besides, in order to take the advantages of the space-time complementary properties of the renewable energies over wide area, it is also necessary to build a wide-area power grid which would be in transnational or even transcontinental. For example, if the power grids of Europe, Russia and East Asia are connected together, when East Asia is in the daytime, Europe is just in the night, and then the solar power can be transported from East Asia to Europe, and vice versa.

But a wide-area and renewable-energy-dominant power grid will be faced by some critical challenges such as long-distance large-capacity power transmission, the stability of the wide-area power grid and large-scale energy storage. In order to deal with those challenges, ultra high voltage DC (UHVDC) power transmission and superconducting power transmission technology would be the possible solution for, and UHVDC can be used as the transnational or transcontinental backbone so that different national or local AC power systems can be decoupled by the UHVDC backbone, leading to a more stable power grid. Because the wide-area power grid can take the advantages of complementary properties of renewable energies, the capacity for large-scale energy storage will be saved, but we still need to establish effective energy storage system through solar fuel, inertia energy storage, batteries, compressed air energy storage or pumped energy storage. Moreover, internet of things (IOT) and big-data and some new equipments such as fault current limiter, fast DC breaker etc., should be well developed for the wide-area power grid too. Then, it is also necessary to develop a safe info system to protect the power grid from Hacker's attack.

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1.11 POTENTIAL, TRENDS AND PROMISING TECHNOLOGIES FOR OIL EXPLORATION AND PRODUCTION

1.11.1 INDIAN VIEW

Enhanced Oil Recovery (EOR) is a process of extracting oil present in the underground reservoir which cannot be done using primary (natural) energy of a reservoir or by doing pressure maintenance via water or gas injection. The main objective of EOR is to alter in-situ properties of oil and/or rock properties in order to make fluid mobile either by decreasing its viscosity or by altering its interaction with a rock surface.

1.11.1.1 EOR: CATEGORIES, TECHNIQUES, METHODS

There are broadly 3 categories of EOR based on a mechanism they use to alter these properties:

1. Thermal Injection: In this method oil present in a reservoir is heated using various methods which results in the reduction of its viscosity and/or in the partial vaporization of oil. It accounts for nearly 40% of U.S. EOR production.
2. Gas Injection: It is the most commonly used approach in EOR. Gas injection or miscible flooding introduces miscible gases into a reservoir which serves dual purposes of pressure maintenance and oil displacement improvement. When the pressure of a reservoir goes below the minimum miscible pressure it is called Immiscible EOR. In this method although gas is not completely miscible with oil yet it interacts with lighter fractions of oil which is considered as an EOR method. It reduces the interfacial tension between oil and water by forming a barrier at the interaction of two fluids. The most commonly used gas is carbon dioxide.
3. Chemical Injection: In this approach various chemicals are injected in the form of dilute solutions to aid mobility and reduce the surface tension. Chemical injection processes are rather expensive.

1.11.1.2 CO_2 FLOODING (GAS INJECTION)

SACROC (Scurry Area Canyon Reef Operators Committee) Unit conducted the first ever CO_2-EOR pilot project in the Permian Basin where CO_2 was transported via a 200-mile-long pipeline from the Delaware-Val Verde Basin. The process, although achieved technical success, some tuning was needed in the CO_2 slug size and in the amount of CO_2 injected to make the process economically feasible. CO_2 is forced to interact with oil forming a miscibility zone which has a higher mobility than normal oil making the solution mobile.

Depth, ft	<9800 & > 2000
Temperature, F	<250, but not critical
Pressure, psia	>1200 to 1500
Permeability, md	>1 & <5 (Not critical)
Oil Gravity, °API	>22
Viscosity, cp	<15
final residual oil saturation	>0.20

Table 1.11.1.1 Screening criteria for CO_2 injection suitability

Interestingly, although some threshold values have been found for the average permeability and temperature, experiments have shown that they are not critical for determining success of an EOR technique. According to the screening criteria based on SPE 12069 and SPE 35385, temperature and permeability are not considered as critical control parameters for miscible injection screening.

1.11.1.2.1 REASONS FOR THE DEVELOPMENT OF CO_2 INJECTION

Economic

The development of EOR techniques is generally pushed by the need of energy independence which leads governments to provide fiscal benefits for operators to go for tertiary recovery. However, the main reason lies in the fact that for starters it is challenging to find a giant reservoir. Moreover, recently discovered reservoirs are difficult to exploit so companies are forced to drain present-day reserves in order to exploit their full economic potential.

Legal

With many countries pulling out of the Paris agreement, we are certainly lagging significantly behind our goals to cut carbon emissions which leaves us with the only option — to use clean coal. CO_2 injection has the ability to be a potential carbon storage unit if the injected CO_2 is captured from a power or an industrial plant. Thus, using techniques like CO_2 injection helps countries to cut their carbon emissions and reach their goals without cutting backbones of their power source.

All in all, carbon capture and storage (CCS) can be used to help currently working plants to meet their emissions goal and at the same time make them a profit by selling captured CO_2.

Technological

When we inject CO_2 into an oil reservoir, it becomes mutually soluble with residual crude oil as light hydrocarbons from the oil dissolve in the CO_2 which in turn dissolves in the oil. This occurs most readily when the CO_2 density is high (when it is compressed) and when oil contains a significant volume of "light" (i.e., lower carbon) hydrocarbons. Below certain minimum pressure, CO_2 and oil will no longer be miscible.

When the injected CO_2 and residual oil are miscible, physical forces holding the two phases apart (interfacial tension) effectively disappear. This enables CO_2 to displace oil from rock pores, pushing it towards a producing well. As CO_2 dissolves in oil, it swells it and reduces its viscosity which also helps to improve the efficiency of the displacement process.

Relevance

The paper raises the idea that CO_2 EOR can add value by maximizing oil recovery while at the same time offering a bridge to a reduced carbon emissions future. CO_2 EOR effectively reduces the cost of sequestering CO_2 by earning revenues for CO_2 emitters from sales of CO_2 to oil producers. EOR operations account for 9 million metric tons of carbon, equivalent to about 80 percent of the industrial use of CO_2 every year. Industrial CCS offers the potential to significantly alter this situation. After years of experience with CO_2 floods, oil and gas operators are confident that when oil production ends and wells are shut down the CO_2 left in the ground will stay permanently stored there given that the wells are properly plugged and abandoned. Carbon Dioxide Enhanced Oil Recovery (EOR) therefore could be an enabling catalyst for large-scale sequestration efforts.

The main differences between the two lie in their goals (minimizing the CO_2 use in EOR vs. maximizing it for sequestration) and regulatory concerns (monitoring, verification, and accounting of the CO_2 over a very long term).

Oil price($/barrel)	$60
Royalties and production taxes	$10
Net revenue	$50
Capital cost	$5-10
CO_2 costs	$15
Well maintenance	$10-15
economic margin, pre tax	$10 to $20

Table 1.11.1.2 The economics of CO_2 injection

1.11.1.3 CARBON CAPTURE

Flue gases that leave a combustion chamber contain CO_2, nitrogen and some unused oxygen from the air. A 1000 MW coal fired unit produces 2500 tons of gas per hour. This is almost 300 tons per hour of CO_2 separation making the task of carbon capture enormous.

1.11.1.3.1 CARBON CAPTURE METHODS

There are three main carbon capture methods:

1. Post Combustion Capture

In this method adsorbents are used to absorb CO_2 present in flue gas that is generated after combustion. This can be done by:

- absorption by using liquid or solid chemicals,
- adsorption by physical or chemical methods,
- filtering using membrane filters.

Most of these chemicals and filters are reused after extracting the absorbed CO_2 by heating it. As the heat capacity of these chemicals rises, the operational cost of the method grows.

2. Pre-Combustion Capture

In this method coal is converted to syngas which then reacts with water to produce CO_2 and H_2 which is then separated and CO_2 pure stream is sent for sequestration while H_2 is used as fuel for a power plant. This method removes carbon from fuel before combustion. An Integrated Gas Combined Cycle (IGCC) where coal is converted to gas and then fired in a combined cycle, which is already in an advanced stage of development, will be the most cost-effective way of power generation.

3. Oxyfuel Combustion

Air contains 23.2% of oxygen by weight with the balance being mainly nitrogen. During combustion, carbon combines with oxygen to form CO_2. In a coal fired unit, typical values of flue gas will be 12% of CO_2, around 3% of O_2 and the balance nitrogen at 85%. In oxy-fuel combustion a pure oxygen gas stream is used as source of oxygen, which results in pure CO_2 flue gas which can be directly sent for storage. The only problem comes with the weight of oxygen which makes the use of a flue gas recirculation boiler necessary. This is the most economic method for a new plant but the cost of retrofitting can be really high.

1.11.1.3.2 ANALYSIS OF TECHNOLOGIES AVAILABLE FOR CARBON CAPTURE

After the analysis it is safe to conclude that Post combustion capture will be suitable for immediate use as it can be retrofitted in old plants and industry but in the long run Oxyfuel combustion will be helpful when new plants are constructed keeping carbon capture in mind.

1.11.1.3 ANALYSIS OF THE POTENTIAL OF INDIA AND PIONEER COMPANY

The country doesn't have a combined CCS and injection plant but has started developing potential locations for CO_2 injection which can be used for carbon sequestration.

India at its disposal has many challenges even for CO_2 injection, but the lack of geological potential limits the search for potential storage sites. In India Oil India Ltd. has been conducting research experiments to find suitable sites for CO_2 injection. These experiments have been conducted in Upper Assam Basin specifically for Tipam, Barail and Lakatham-Thariya sands. The results of the lab experiments are very promising and they are planning to start a pilot project soon.

1.11.1.4 DEVELOPMENT PERSPECTIVES

When we go underneath the earth surface, we encounter reservoirs at a shallow depth or reservoirs that have been depleted and which may go below a pressure level beyond which CO_2 does not become miscible with oil thus creating a gas front that due to the mobility issue does not sweep away oil effectively. This may outcrop as a setback for CO_2 injection but research has shown that in such cases oil properties are not altered so it can't be termed "EOR", yet the injected CO_2 gas does offer a way of pressure maintenance, which increases the secondary recovery while decreasing the levels of CO_2 from the atmosphere.

The first quarter of 2016 saw the signing of the earlier mentioned Paris agreement. However, within just three years many countries have pulled out of this accord. The IPCC (Intergovernmental Panel on Climate Change) in its report has clearly stated that the hope of Paris agreement to be fulfilled lies in the future of CCS.

Many developing countries are suffering from a never-ending acute shortage of employment opportunities. Carbon capture and its injection needs specialized experts to handle and maintain the oper-

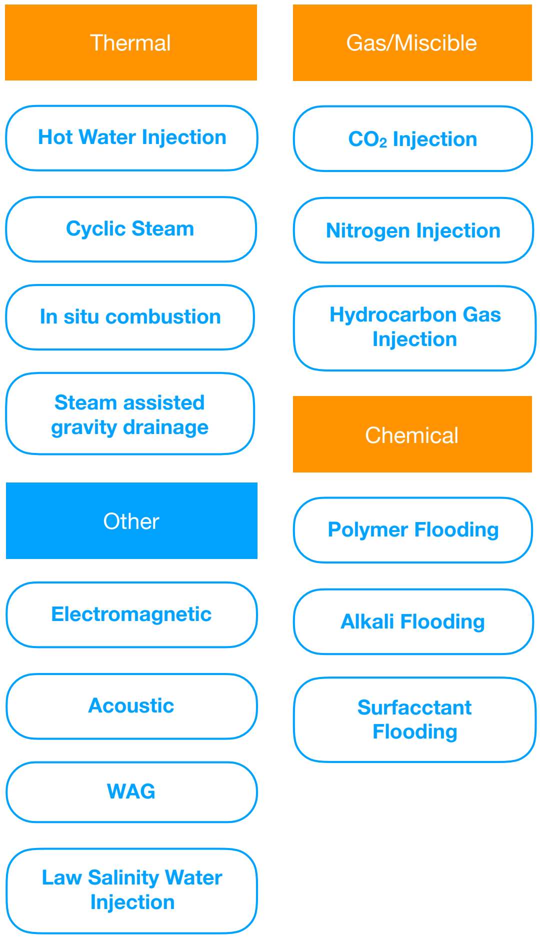

Figure 1.11.1.1 Analysis of all capturing techniques

ations which opens a lot of employment opportunities.
In their attempts to curb such a huge number of emissions many countries have started following stringent environment laws which include heavy taxes and penalties. These requirements often make small factories which can't afford high standard machines shut down their operations. The very idea of carbon capture and its injection can put life into these factories giving more employment opportunities while simultaneously contributing significantly to the GDP growth.

1.11.1.5 BUSINESS MODEL FOR CARBON CAPTURE

Nowadays we do acknowledge that the problem of sustainable development is very important. However, no company will ever apply this system if it doesn't prove to be profitable. Moreover, the concept of incremental oil is hard to prove but it is essential for a business model. Below is given a sample business model which can make this scheme work.

The model shows the interdependence of different parties in a coun-

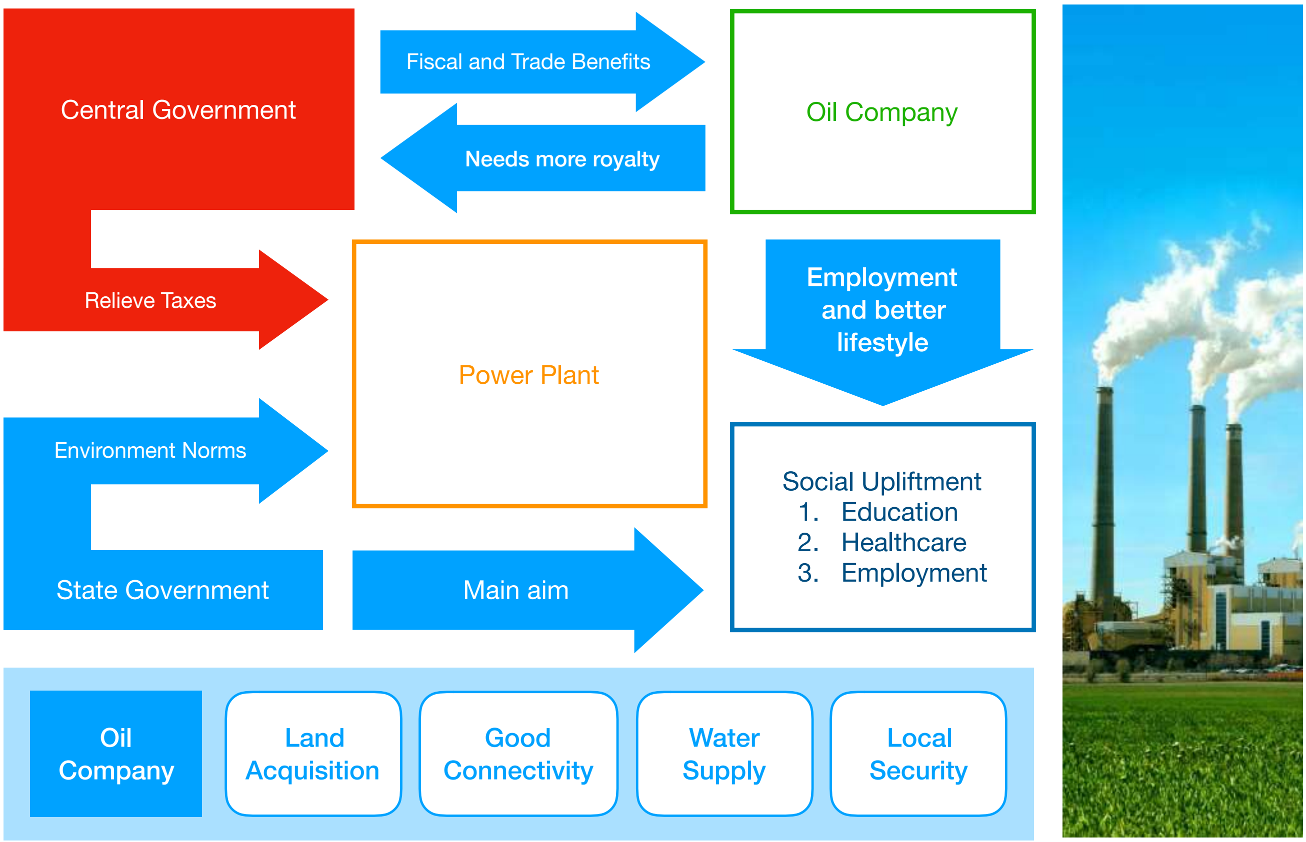

Figure 1.11.1.2 Business Model for Carbon Capture

try. A central government needs extra oil from a company but in turn needs to give it fiscal and trade benefits. Similarly, an oil company needs help from a state government in land acquisition, good infrastructure, water, conducive environment and law & order.

Although essential for functioning, local support can't be attained if social upliftment has not been done which includes providing basic education, clean environment and generating employment opportunities. If companies want to apply this new technology, public support is really crucial because it can be helpful in case a power plant has any compatibility issues and they also need public as a workforce to get local work done.

1.11.1.5.1 THE CONCEPT OF INCREMENTAL

This is an increased number of oil barrels that is produced by applying such techniques as EOR. However, when we merge carbon capture within this concept there arises a controversy that we are extracting CO_2 to pump out more oil which in turn will again release CO_2 which after all is a net intake of CO_2.

The twist in this concept is that even if we don't do CO_2 injection these barrels of oil will be out in one way or another which forces us to think that if this incremental oil is inevitable, then net carbon cut will always be positive because if there is oil there will be a company who will extract it.

1.11.1.5.2 SOCIAL CHALLENGES

In developing countries people in general tend to be technologically illiterate. So if news about the technologies mentioned is released in public it may cause social unrest. It can become a political agenda and some may even use it to misguide the public causing a series of protests.

Many projects are never realized because of land acquisition problems or communal unrest issues.

1.11.1.5.3 TECHNOLOGICAL CHALLENGES

CO_2 EOR requires a reservoir to have a range of value for permeability and fluid viscosity without which CO_2 injection doesn't prove to be profitable or efficient. This is defined by minimum miscibility pressure (MMP).

- Carbon capture requires current power plants and industries which release most emissions to be retrofitted with a capture system which has high costs and a new system may cause compatibility issues with old power plants thus causing power shortage and inadequate run time of the plant.

- However, one may think that instead of converting old plants we should build new ones in compliance with the latest technology but this has its own issues. For instance, a plant will lose 30% of its power to the capture system which leads to the increase of the cost of electricity generation.
- Moreover, right now converting an old plant into a carbon capture unit may cost up to $2 billion and a new plant will need additional funding of around $1 million if we go with oxyfuel combustion. Consequently, although the technology for carbon capture has now been in use for almost 40 years, it will take time before the process become economically feasible and governments start funding such projects.
- A pure stream of CO_2 is impractical to achieve, the stream we use now contains Sulphur and water vapors along with it which when passed through pipelines and wells tends to damage the structure due to the corrosive nature of H_2S which reduces the lifespan of the structures and equipment used in the process. For this reason, certain research is being done to ascertain the effect of impurities on the compression of CO_2.

1.11.1.6 KEY EOR TECHNOLOGIES FOR FUTURE (2035-2059)

CO_2 flooding is a promising enhanced oil recovery method both on technical and environmental bases.

- Stringent environmental laws will enforce the use of clean fuel.
- Skewed demand-supply ratio of energy will make the implementation of EOR techniques imperative which in turn will also result in the aforementioned environmental concerns. Amongst all the available EOR techniques, CO_2 injection is an environment-friendly way to produce hard-to-recover oil. Moreover, as CO_2 injection increases, there will be a simultaneous increase in the number of potential sites for CO_2 storage which will aid in controlling carbon emissions. The viability of any project in the future will be driven by the understanding of a supplier (power plant owner) and a customer (oil company), leaving their individual profits dependent on the market value of incremental oil. While an oil company is directly benefited by the sale of incremental oil, a supplier is benefited due to the relief from environmental taxes and the revenue generated by the sale of the captured CO_2.

1.11.1.7 KEY CARBON CAPTURE TECHNOLOGIES FOR FUTURE (2035-2059)

1.11.1.7.1 OXYFUEL COMBUSTION

This is the most tested and efficient technology that can be easily fitted in a new plant which makes it a suitable candidate for the use in power plants of the future for carbon capture.

- We have vast experience in cryogenic air separators which will help us better integrate the system and increase the efficiency of the process.
- Oxygen is easily available from the atmosphere so its cost will be less than any absorbent we use in post combustion capture and the stream produced will be more purified.
- Rising power costs are a major concern which can lead to unrest, this technology uses only 15% of the produced power keeping inflation in control.

1.11.1.7.2 POST COMBUSTION CAPTURE

This process will be favorable for use in a shorter period of time because it involves retrofitting of old plants and it just adds a separation unit for flue gas.

- It can be fitted to old plants which account for most emissions.
- The solvent used is recycled so there will be fewer expenses on raw materials.
- Upgrading already set-up plants will involve little to no opposition from people residing in that area.

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1.11.2 RUSSIAN VIEW

1.11.2.1 CHALLENGES TO ECONOMY

By 2030, nuclear and alternative energy will cover up to 25% of the world's energy supply. Demand for oil will continue to grow as raw materials for the chemical industry and fuel production. The demand for natural gas will also grow through the use of low-emission raw materials for the production of electricity; the improvement of technologies will lead to increasing alternative energy: wind, solar and bio-energy will cover about 5% of the energy needs. By 2030, oil and natural gas will meet about 55% of energy needs. The share of coal will be reduced due to the desire to reduce emissions.

Oil is currently mainly used as fuel for cars; with the development of the transport fleet, electric power plants will require more electricity, which is an additional incentive for the development of natural gas and coal mining enterprises.

The discrepancy between the reproduction of the mineral resource base and the development of oil and gas production entails economic risks. The low level of oil and gas recovery can have an impact on the social sphere as jobs are lost. Ensuring the expanded reproduction of oil and gas reserves through geological exploration, as well as through the preparation of fields, both in new and traditional areas of oil production is a possible solution to these problems.
This challenge is very significant, and to overcome it; so, technological solutions are required. The low rate of oil and gas recovery is more usually due to complex geological conditions, so in this case it is necessary to work towards the creation, modernization of technologies and methods.

1.11.2.2 KEY TECHNOLOGIES AND TRACK

Currently, the main means of exploration are seismic work and drilling, but traditional reserves are reducing. In this regard, there is a need to search for and exploration of unconventional, hard-to-recover reserves, such as shale oil (Bazhenov formation), production from low-permeability reservoirs, involvement in the production of reserves from oil-saturated thicknesses of less than two meters. In view of these difficulties, oil production is becoming less profitable, and this limitation creates a challenge to find technologies to increase the speed of work, increase the accuracy of the data obtained, reduce the cost.

The main directions of development in seismic exploration are high-density seismic survey, "green seismic". High-density seismic survey implies a large number of sources and receivers for excitation and registration of elastic waves.

There is also the development of non-seismic methods of exploration. Main directions: obtaining information on the basis of registration of gravitational, electric, magnetic fields, field geochemistry, basin modeling.

Areal geochemical survey is an upgraded method of searching for hydrocarbons at the molecular level. This approach allows without large initial financial investments to determine the composition of hydrocarbon gases on the surface of the potential promising areas for further study and exploration drilling.

Based on the information of electromagnetic fields, it is possible to obtain information in different horizons of the geological section, such as electrical resistivity. Its size can be judged on the composition of the underlying rocks, including determine and fluid-saturated reservoirs. Experience with the CSB method showed that the high sensitivity of the recorded signals to changes in the geo-electric parameters of rocks makes it possible to predict the nature of fluids, accurately predict when the reservoir contains water, and when — hydrocarbons. When combining data with seismic, it is possible to obtain a detailed structure of the geological section, and to predict the filtration-intensive properties and the nature of saturation.

Basin modeling is the process of constructing a model of a huge oil and gas basin, which is located on a huge area. These models allow us to understand what layers make up a particular field, thus more accurately interpret seismic, make effective design exploration.

The next stage, after exploration, is the development of the oil Deposit/field, i.e. oil production. It is possible to distinguish the main stages of oil production: drilling, method of field development, selection of necessary equipment, collection system, oil preparation.
At the first stage of drilling, which includes a set of choice of materials and technologies, it is necessary to choose the optimal number and location of wells, the optimal design of wells, determining the method of drilling rocks.

At the stage of field development method determine a set of measures to ensure the flow of oil from the deposit to the well. These activities are divided into the method of drilling (punching, holding GRP, open the trunk, filter), determination of the mode of operation of the wells (due to some force, some energy will be installed and maintained for optimal operation), definition of method of stimulation (depletion, reservoir pressure maintenance, injection of heat or chemical agents).

At the stage of equipment selection, the main task is to deliver fluid from the bottom of the well to the surface. And here it is important to understand the features of the first two stages and also subsequent. First, the boundary conditions for the equipment such as well design, properties and composition of the fluid to be lifted, the required downhole pressure, the required wellhead pressure are determined. At all stages of production implies a huge metal content, manufacturability and the presence of uncertainties. Accordingly, the replacement of metal leads to a decrease in the cost of produced tons of oil. The collection systems are applied FRP pipes are replaced, tanks are manufactured from polymeric materials.
Manufacturability contributes to the efficiency of opening productive layers, the speed of achieving design goals, obtaining the target product. Drilling technologies enable us to drill long horizontal wells (over 1500 meters), multilateral wells (number of cuts from the parent horizontal shaft of more than 10, each over 400 meters). This is all made possible thanks to modern telemetry technologies, precise definitions of geological coordinates, the possibility of registering more rock parameters, data transmission from the bottom of the well in real time, operational interpretation of geophysical parameters, rapid decision-making. Robotization of the drill tool makes it possible to make drilling more accurate, allows you to quickly and accurately change the direction of drilling, depending on the geological situation, and follow a given trajectory.

At the stage of the development method, various high-tech solutions are also used. To maximize the connectivity between the well and layer optimized technology method of drilling. The main goal is to cover the largest area of the reservoir, creating as few barriers as possible to the movement of fluid from the reservoir to the bottom of the well. To do this, there are different technologies for fixing the walls of wells, such as different types of filters that create minimal resistance to fluids, but do not allow destruction. There is a direction of fixing the walls with "adhesive" solutions, which are pumped to the bottom of the well in the liquid state and after exposure to the reagent are polarized, as if the walls of the trunk are glued together. In rocks with poor reservoir properties with high dissociation/dismemberment typical solution is the use of fracture technology. The basis of this technology, the creation of highly conductive cracks spread as much as possible from the bottom of the well vertically and horizontally. The crack is fixed by a granular agent (propane), which allows you to attach to the work of the entire thickness of the formation and create a high communicability.

The next track in oil production is the search for the optimal method of impact on the reservoir. The simplest and most common way is to maintain reservoir pressure with water. No high-tech equipment is required to create a high injection pressure, as the weight of the water column itself is large. And with the correct/optimal placement of injection wells, the water front helps to increase the amount of reserves involved, by displacing them to the producing wells. So, collectors may have cracks auto-hydraulic fracturing, which will be in rapid water breakthrough to production wells, which all the advantages of PPD water eroded. At present, the direction of injection of surfactants or polymers has become widespread. These substances help to change the physic-chemical properties of the oil, the ratio of oil mobility and the injected fluid, which allows you to align the displacement front and avoid premature breakthroughs of the injected agent.

In that sense, mixed displacement can be identified as a separate category. The basic idea is that similar thing dissolves into similar thing. This approach is aimed at solving several problems at once: utilization of associated produced gas, maintenance of reservoir pressure, increase of oil recovery coefficient. There are also environmental requirements for the use and disposal of fluids produced along the way. These restrictions create the preconditions for the organization of the reverse gas injection. This decision makes it possible to abandon the construction of an external gas pipeline a large UCP. But it requires a fine calculation of the composition and quantity of injected gas. Compressors are also required to create the necessary injection pressure.

1.11.2.3 MEASURES TO STIMULATE THE DEVELOPMENT OF TECHNOLOGY IN RUSSIA

In Russia, the engineering and technological development of the fuel and energy sector is a com-plex and multifactorial process. In order to secure the sustainable development of the country's economy, it is imperative to analyze the existing measures contributing to the implementation of State policy concerning technological development and ensuring its orientation on innovation. In the interests of technological development, the advanced integration of new technologies into the existing strategies of oil companies is indicated. On the basis of generalization and grouping of mechanisms of innovative technological development, conclusions were drawn about the prospects for the development of certain mechanisms that allow to effectively integrate, test and operate innovative technologies in the oil and gas sector. Among government incentives to foster the technological development in Russia it is necessary to note mainly economic mechanisms. Besides tax preferences, technoparks, innovative nanocentres, testing laboratories and other platforms, which stimulate innovation in the development of new, competitive technologies comparable to those of the West, are being created in Russia.

Until 2009, in the Russian Federation, state support for the development of computer technologies was confined to creating a supercomputer. The state financed the purchase of American-made super-computers "on a turn-key basis" or the purchase of components from large American companies, which laid the foundation for the domestic production of super-computers. As a result, experimental samples of application software of systems and technologies of their use were created, which cannot exist without their developers and do not have the necessary productive properties. In order to construct hydrodynamic deposit models, the Russian oil and gas industry uses the hydrodynamic simulator Schlumberger, Landmark (USA), the Norwegian Tempest More produced by ROXAR and STAR produced by the Canadian firm Compute Modeling Group Ltd. In a con-text of the current technological gap of the Russian oil and gas companies the project "The basic directions of policy of the Russian Federation in the field of the development of innovation system for the period till 2020" has been formulated. The government has set a goal to create economic conditions and a favorable economic and legal environment for innovation activities of enterprises.

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CHAPTER 2: SPECIAL TOPIC

GAS MOTOR FUEL: MARKET DEVELOPMENT & TECHNOLOGIES

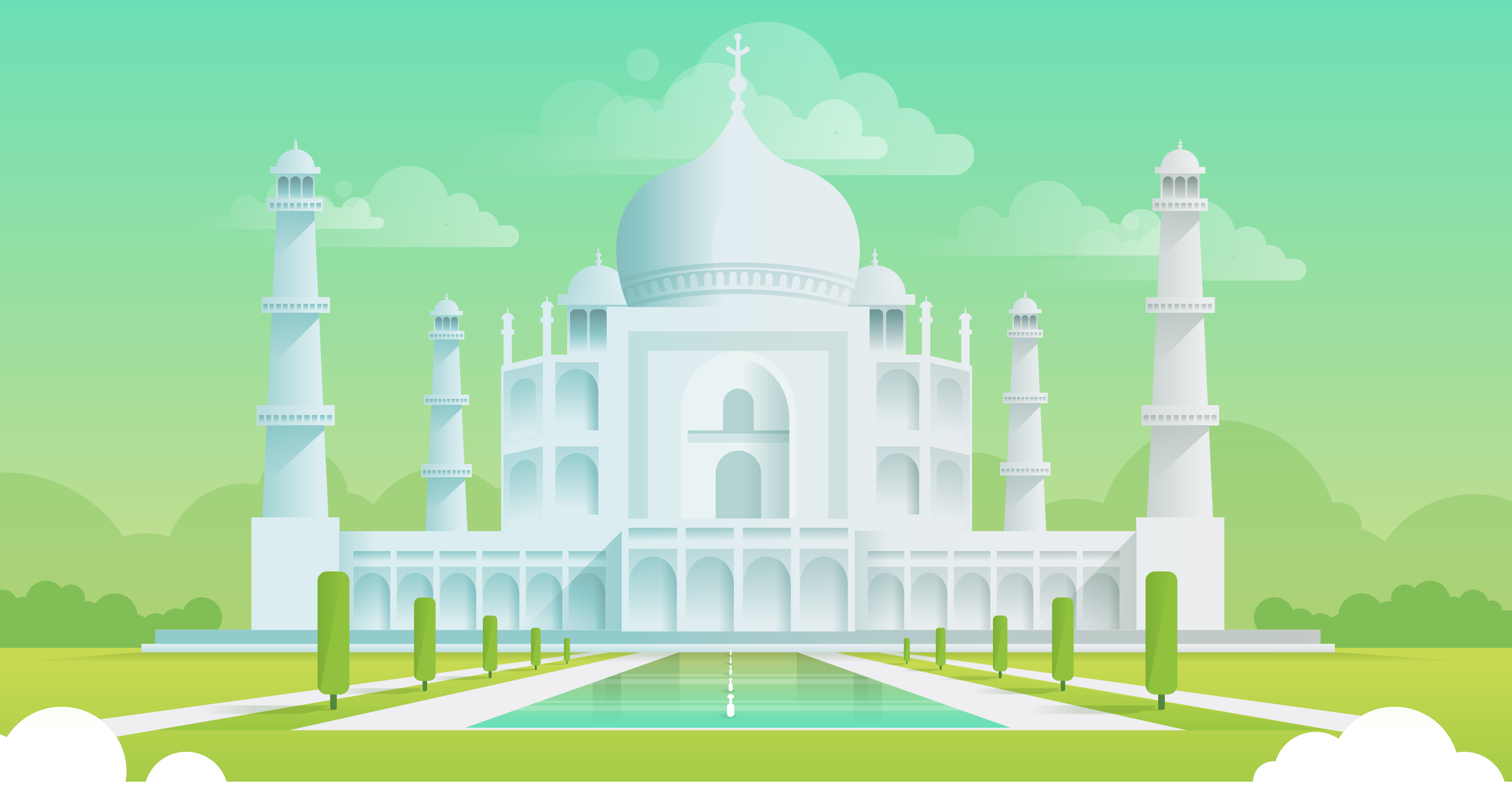
In the Special Topic 2019 we are approaching the Gas Motor fuel. The world's top energy brands are encouraging global transport industry to adopt natural gas instead of diesel and gasoline. Many have their own programs for developing CNG and LNG filling infrastructure, natural gas liquefaction plants, and sea or river bunkering facilities.

Emissions of a car powered by the 'blue fuel' are five times less harmful than those of a car equipped with a gasoline engine. This is a solid advantage of natural gas, because cars are the main air pollutant, especially in big cities. The conversion of cars and buses to natural gas can make the air cleaner and improve the environmental situation in cities.

Nowadays, almost all major car makers produce methane-powered cars. The world leaders of the car industry – Volvo, Audi, Chevrolet, Daimler-Benz, Iveco, MAN, Opel, Peugeot, Citroen, Scania, Fiat, Volkswagen, Ford, Honda, Toyota – they all offer today series cars with engines running on CNG. These vehicles are in no way inferior to conventional gasoline counterparts and are very popular among car owners. There are more than 17 million methane-powered cars worldwide today and their number continues to grow.

Motor fuel presents a unique combination of environmental, economical and technological advantages that distinguish it from other types of propellants.

Gazprom Export LLC



JIS COLLEGE OF ENGINEERING
REPUBLIC OF INDIA

Republic of India

2.1.1 REASONS FOR THE DEVELOPMENT OF GAS MOTOR FUEL MARKET IN INDIA

There are several reasons behind the urge to shift to gas motor fuel from gasoline. Although high carbon emission is the most alarming threat to the environment, there are certain economical, legal and technological issues which are discussed below.

India's dependency on foreign crude oil is at its peak. Honorable Prime Minister Mr. Narendra Modi has set a goal to decrease India's foreign crude oil dependency. However, the government data shows that the dependency has increased to 84% to meet the energy demand of the country. In March 2015, the Prime Minister stated at the 'Urja Sangam' conference that when India would celebrate its 75th anniversary of independence in 2022, the foreign oil import dependence should be cut down to 67% from 77% in 2013 – 2014. He added the dependence could be cut down to 50% by the year 2030.

However, the present situation is quite different. The Petroleum Planning and Analysis Cell (PPAC) of oil ministry claimed that the dependence had jumped up to 83.7% in 2018 – 2019 from 82.9% in 2017 – 2018 mainly due to the mismatch between the growth in demand and domestic production. PPAC added that the dependence had jumped to 81-87% in 2016 – 2017 from 80.6% in 2015 – 2016.

The demand for foreign crude oil has increased to 194.6 million tons in 2016 – 2017 from 184.7 million tons in 2015 – 2016. The following year it became 206.2 million tons and in 2018 – 2019 it grew by 2.6% to 211.6 million tons.

On the contrary, PPAC indicated that the domestic output kept falling during that time. The output reduced to 36 million tons in 2016 – 2017 from 36.9 million tons in 2015 – 2016. This trend kept on going as the output fell further to 35.7 and 34.2 million tons in 2017 – 2018 and 2018 – 2019 respectively.

The main focus of the government now is to increase domestic production as well as promote the use of natural gas and conservation of energy in order to cut down the dependency on foreign crude oil import.

The exploration rules had to be changed many times in the last five years to achieve the cagey private and foreign investment. The policy known as New Exploration Licensing Policy (NELP) became Hydrocarbon Exploration and Licensing Policy (HELP) to promise freedom in marketing and pricing.

Companies needed freedom to explore areas of their choice. HELP came up with the idea of open acreage licensing policy to provide that freedom. However, the idea of auctioning the discovered oil and gas fields after taking them away from state owned firms did not turn out to be fruitful, just like the open acreage policy. Both failed to gain attention of big companies to invest in oil and gas exploration and production.

According to PPAC, India spent USD 111.9 billion on oil imports in 2018 –2019, up from USD 87.8 billion in the previous fiscal year. The import bill was USD 64 billion in 2015-2016. PPAC also stated that India had spent a significantly large amount of $64 billion in 2015 – 2016 and $87.8 billion in 2017 – 2018 to import oil which got only worse as in the next financial year it jumped up to $111.9 billion. The crude oil import is estimated to increase to 233 million tons and $112.7 billion during the current financial year.

The production output of the state owned ONGC's (Oil and Natural Gas Corp's) also kept on decreasing. It was 21.1 million tons in 2015 – 2016, 20.9 million tons in 2016 – 2017, 20.8 million tons in 2017 – 2018 and it fell as low as 19.6 million tons in the last fiscal year.

Not only the government firms' but also the private firms' output has dropped. It went down to 9.6 million tons in 2018 – 2019 from 11.2 million tons in 2015 – 2016. If the government-proposed infrastructure plan is to be matched with the demand over the next ten years, half of the vehicles in the country have to be fueled by natural gas by 2030. This may benefit the leading natural gas car manufacturers like Maruti Suzuki India Limited (MSIL) and Hyundai Motor India Limited (HMIL).

Recently the government has come up with another Natural Gas Infrastructure Development Plan with an aim to establish 10,000 compressed natural gas (CNG) stations across the country over the next decade. The Petroleum and Natural Gas Regulatory Board (PNGRB) is going to launch the 10th round of bidding for CGD (city gas distribution) very soon for the betterment of CNG infrastructure to 124 districts more.

As mentioned earlier, the leading CNG vehicle manufacturers in India, Maruti Suzuki and Hyundai Motors, have got a very high demand for CNG vehicles over the past few months. Within the first six months of the running fiscal year these companies have seen a 50% rise in more than 55,000 CNG vehicle sales. It can be assumed that this is due to the inflation of petrol and diesel over the last few months.

The dominance of CNG vehicles can be profoundly seen in Delhi NCR and in a few selected cities in the states like Gujarat, Maharashtra, Andhra Pradesh, Telangana, Odisha, Uttar Pradesh and Punjab. In April 2018, the number of CNG stations in India was 1424.

This approach towards natural gas-powered vehicles has two economic prospects. Firstly, by reducing the foreign crude oil import dependence a lot of money could be saved. Secondly, according to Nomura's report, there could be 400,000 new jobs if the natural gas development plan becomes successful. If people who drive three wheelers and light vehicles shift to CNG to fuel up their vehicles they could save up to ₹5000 - ₹8000 every month. Nomura's report added that since particulate matter emissions (PM 2.5 and PM 10) were negligible in CNG vehicles, higher penetration of CNG vehicles would also help curb air pollution in Indian cities. Nomura's report also stated that the PM emissions (PM 2.5 and PM 10) are significantly fewer in CNG vehicles compared to that of gasoline vehicles. So6 the rise in the usage of CNG vehicles could also help to reduce air pollution.

LNG is used in heavy commercial vehicles as it can be stored in larger quantities and it occupies less space which would reduce payload penalty and increase the range.

Therefore, the government should emphasize the CNG and LNG adoption in the country by promoting investments to create CNG infrastructure. A governance mechanism should be included so that the CGD infrastructure projects can gain momentum. More participation is also required to set up new pipelines and CNG and LNG fueling stations.

2.1.2 PIONEER GAS FUELED VEHICLE COMPANIES IN INDIA

Private car buyers have not shown much interest in CNG powered vehicles for a long time. But as the price of petrol and diesel is increasing by leaps and bounds it is affecting household budgets. At this point CNG is turning out to be both one of the cheapest and efficient alternatives. Even though it is not widespread yet, CNG infrastructure is gathering pace drastically and it is safe to say that it will leapfrog gasoline-powered vehicles in the coming years. In the last 7 – 8 years the usage of CNG-powered vehicles has boomed. Many taxi and private car owners have shifted to CNG due to its cheaper cost, e.g. the price for 1 kg of CNG is about ₹ 40.51 in Delhi which is almost half of that of the petrol. As mentioned earlier, the leading companies in this field have released several of such cars in recent years which are gathering attention in no time.

2.1.3 DEVELOPMENT PERSPECTIVES OF THIS DIRECTION UNTIL 2030. WILL NATURAL GAS BE THE FUEL OF THE FUTURE?

As there are several options it is hard to predict the fuel that will eventually dethrone gasoline in the future. But thanks to being less expensive, more available and less polluting natural gas will be a strong contender in the race, as per the federally funded Argonne National Laboratory. It is all possible due to the growing demand of hassle-free fuel which could replace gasoline in terms of fewer carbon emissions.

Mike Duoba, an engineer in the auto research center in Argonne National Laboratory near Chicago, said to the Talking Points Memo news blog: "Our conclusion is that natural gas as a transportation fuel has both adequate abundance and cost advantages that make a strong case to focus interest in the technology as a real game changer in U.S. energy security. In terms of consumer ownership and use costs, the case to make a switch from current fuels to compressed natural gas (CNG) is much more compelling than for other alternative fuels like ethanol and electricity."

Duoba and his colleagues are working on the analysis of the vehicle system as well as on research on the engine and testing around CNG in order to end India's dependency on foreign fuel resources. In February 2012 the Department of Energy announced a competition worth $30 million "to harness our abundant supplies of domestic natural gas for vehicles".

They are trying to increase the efficiency of the combustion of CNG so that it can be incorporated with a new type of engine which can run on gasoline as well as on natural gas. That could give the freedom of choice to users. As the response towards the latest trend of sales of electric vehicle from the leading companies is not so good, Duoba thinks the foretold engine may have a greater appeal.

CNG storage system can be refueled or recharged faster, it has greater energy storage as well as a lower cost and weight compared to electric-vehicle batteries. Besides, electric vehicles are recharged by drawing power from grids which get it from the combustion of fossil fuels. So, the Argonne team also believes that carbon emissions from CNG engine would be much fewer than that of electric vehicles.

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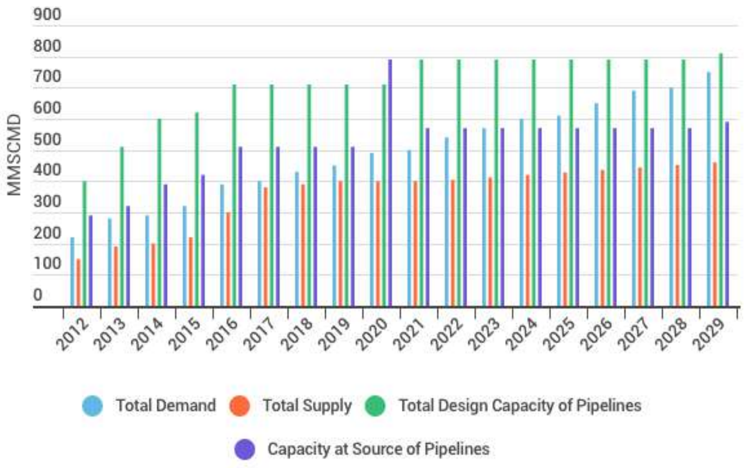
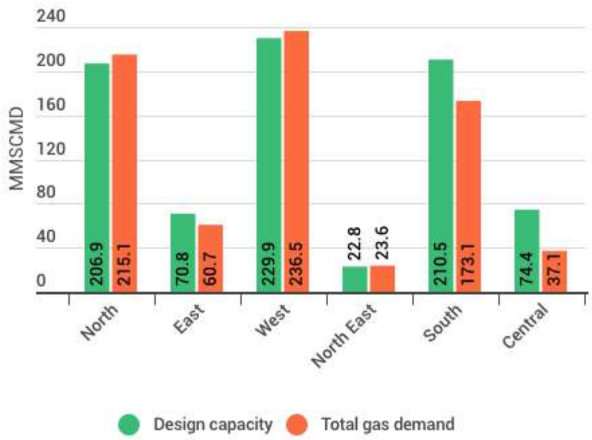


Demand Supply Capacity from 2012 to 2029
Source: Vision-NGPV-2030



Regional Infrastructure in 2030
Source: Vision-NGPV-2030

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2.1.4 FROM INDIA'S PERSPECTIVE:

According to the vision-NGPV-2030 report, about 32,727 km of natural gas pipeline would be there in India with a designed capacity of 815 million metric standard cubic meters per day (MMSCMD) by 2030. But the capacity of connecting supply point and market is expected to be 582 MMSCMD only. Thus, it is clear that natural gas has the potential to meet the energy demand of India.

However, from the data it is also evident that more pipelines are needed to be incorporated in order to meet the designed capacity. The regional markets with the largest gaps between these two parameters need to develop their infrastructure so that they can match the ever-growing demand. India is expected to have 815 MMSCMD and 746 MMSCMD of the design capacity and the total gas demand by 2030 respectively.

From the above chart it is clear that the shared pipeline capacities of all the regions are expected to meet the total demand by 2030. Still, as the pipelines need to have higher capacity than the one they were designed with, more pipelines are needed to be added to keep pace with the growing demand. The chart also shows that the share of the design capacity and demand are significantly low in the north east and east region. So, there is as scope for further development to achieve balance in the availability of natural gas throughout the country. These regions will also need to have more pipelines to match the increasing demand.

2.1.5 IMPACT OF GLOBAL CHALLENGES IN THE DEVELOPMENT OF THE GAS MOTOR FUEL MARKET ON SOCIAL AND ECONOMIC AFFAIRS

Although policymakers have emphasized the importance of the usage of natural gas-based fuel, the progress of natural gas fuel industries has been hampered due to various reasons. For example, 1999's Hydrocarbon Vision 2025 claimed that India would have 20% of the total fuel in the form of natural gas by 2025, but in reality, the current vision is to meet only 15% by 2030. The good news is that India's climate change pledge at the COP21 (United Nations Conference of Parties 21) is expected to reverse these hindrances by promoting gas industries in transportation as well as an alternative renewable source of energy.
The main reasons behind these impediments can be enlisted as followings:

1. In spite of all the proposals and measures, it is the government, not market forces, that controls prices of the greater part of the country which results in the difficulty in affordability. This is probably the biggest challenge for gas industries to boom in India.
2. The domestic production is not enough to meet the demand of the whole country. So, some types of gas, especially LNG, have to be imported. And there rises another problem in the form of included taxes. This makes the challenge even harder in terms of costs.
3. Because of the insufficient resources, the energy developed using natural gas is expected to have an imbalanced and unaffordable price. This could result in the fact that industries, transportation and households might avoid it.
4. There have been multiple jurisdictional conflicts between different regulatory boards and that has hindered the progress. This problem can be solved by giving more power to the Petroleum and Natural Gas Regulatory Board to operate the markets in the midstream and the downstream parts. The same problem for the upstream can be solved by strengthening the regulating power of the Directorate General of Hydrocarbons.
5. Gas pipelines are confined within the areas where the resources, production and import terminals are located. In order to achieve greater balance in the gas industry across the country more pipelines have to be constructed. This requires a clear roadmap and proper planning.

2.1.6 GLOBAL CHALLENGES IN 2035 – 59 AND THEIR PANACEA: GAS MOTOR TECHNOLOGY

Economic Condition: In truth, one of the major issues India has been facing for a few decades is unemployment. Many graduate students are unemployed because of the lack of job opportunities. So, this new era of vehicles and fuel may appear as a boon to the nation. The gas fuel technology and engine manufacturing industries could surely create a lot of job opportunities across India. This way unemployment could be a driving factor to force the country to shift to gas fuel. The other aspect is very straightforward. India spends a huge amount of its wealth to import fuel from other countries. So, if India could produce its own fuel at a cheaper rate it would save a lot of money which could be used for further development of the country.

Environmental Impact: It has already been discussed how much pollution could be reduced by using CNG vehicles instead of gasoline vehicles. Therefore, it is not only a cheaper way to power up vehicles but also an environment-friendly approach to reduce carbon emissions. The main resources we use till date to generate power are coal, petroleum and water which are limited. Moreover, India has had an alarming water crisis recently. So, it is not advisable to use water to generate electricity. CNG in its turn does not require any of these.

The primary objective is to reduce harmful emissions and save the environment. For example, the air of Delhi becomes highly unhygienic and suffocating due to a high pollution rate. Dense, harmful smog captures the whole city for almost the entire day. This results in the increase in lung, eye and respiratory diseases.

The upcoming natural gas fueled industries have a great potential to overcome all the aforementioned problems and challenges.

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2.2.1 REASONS FOR THE DEVELOPMENT OF GAS MOTOR FUEL MARKET IN BRAZIL

Brazil is one of the largest fuel users in the world and, in the last decade, the pace of growth in fuels consumption was higher than its GDP (Gross Domestic Product) evolution. To fulfill this demand, the country has an important infrastructure in refining, imports, production, specification, movement and supply to population of oil products, natural gas and biofuels.

Natural gas turned from a relatively undervalued resource to one of the main sources in the world energy matrix. Interest in natural gas is directly related to the search for alternatives to oil and less aggressive sources to the environment.

Motor fuel gas has many qualities that make it an efficient, relatively clean burning, and economical energy source. It generates significantly less carbon monoxide, carbon dioxide, particulate matter, and nitrous oxide compared to similar fossil fuel vehicles. Natural gas vehicles (NGVs) offer an array of economic and environmental benefits, including the economic benefits of a low-cost, developing a market for green jobs, improving regional air quality, reducing greenhouse gas emissions, reducing our dependence on petroleum and providing a pathway to a hydrogen economy.

By 2020, it is estimated that Brazil will have more than 3.2 million natural gas customers, an increase of 62.5%. Building on this work, a number of companies have since implemented this technology.
In Brazil, the majority part of natural gas research and development resources come from Scientific and Technological Development National Fund. In the same time, there were 137 research institutions, organized in several research units, that were able to develop research projects. They were mostly situated in São Paulo and Rio de Janeiro states. Among them, we must highlight the Federal University of Rio de Janeiro (142 research units), PUC-Rio (53 research units). In São Paulo state, highlights are University of São Paulo (46 research units), University of Campinas (14 research units).

Among 3433 lines of research, only 133, or 4%, refer to natural gas researches. The majority of them are related to exploration and production and biofuels. In this framework, the RCGI – Research Centre for Gas Innovation, based at the University of São Paulo, – appears as a world center for advanced studies of the sustainable use of natural gas, biogas, hydrogen and management, transport, storage and usage of CO_2.

2.2.2 KEY TECHNOLOGIES AND PIONEER BRAZILIAN COMPANIES THAT APPLY GAS MOTOR FUEL TECHNOLOGY

Among the technologies currently available in the Brazilian gas motor fuel market, three stand out: the use of dedicated gas engines, otto cycle, and bi-fuel conversion. A fourth one, gas and fuel cell microturbines.

CNG began to be used in the Brazilian transport sector in the late 1990s with incentive policies from federal and state governments. Brazil still has no dedicated gas or bi-fuel engine production lines: engine conversion is the only option currently available in the country. There are two distinct types of conversion from diesel to gas engines. The most common is the ottonization, that is, the transformation of the diesel cycle engine to the otto cycle – the same one of gasoline and ethanol engines. After the ottonization, the engine runs solely on gas and no longer uses diesel.

The other type is bi-fuel conversion. In this transformation, the diesel engine undergoes fewer adaptations than in the ottonization and works simultaneously with both fuels, in a mixture that can reach 50% gas and 50% diesel. It is not possible to use only natural gas. The choice between ottonization and bi-fuel conversion basically depends on gas availability.

Some studies carried in Brazil indicate that the next decade's heavy vehicles could be powered by LNG. The fuel used today in cars and trucks (CNG), arrives through the pipelines and undergoes intense pressurization at the filling station, equivalent to 200 times ambient pressure (200 atm), and is injected into the vehicle's cylinders. The high pressure of CNG aims to reduce the volume of fuel to facilitate its transport. Even so, cylinders for storing gas under pressure are heavy and occupy significant space in vehicles. LNG, on the other hand, occupies a much smaller volume than GNC. For this, natural gas is cooled to -160° Celsius, turning into a liquid fuel. LNG-powered trucks use stainless steel tanks with a special cooling system to store fuel.

Although operating at a very low temperature, LNG is easier to fill and transport because it is in liquid form. In addition to needing smaller tanks, LNG-powered vehicles have greater autonomy than the GNC ones. With the same volume of LNG, a truck runs almost twice the mileage it could get with CNG, because LNG has higher energy power than CNG. A research carried by the Research Center for Gas Innovation of the University of São Paulo assesses the economic viability of distributing LNG throughout the state of São Paulo through the creation of "blue corridors" - road routes that allow the circulation and supply of trucks using LNG. The results indicate a cost reduction of 40% as opposed to diesel, a CO^2 emission reduction of up to 5.2%, a particular matter (PM) emission reduction of 88%, a nitrogen oxides (NOx) reduction of 75% and the elimination of hydrocarbon emissions. Volvo has already tested an LNG truck in Brazil, in partnership with White Martins, which has a gas liquefaction unit associated with Petrobras.

2.2.3 IMPACT OF GLOBAL CHALLENGES IN THE DEVELOPMENT OF THE GAS MOTOR FUEL MARKET ON SOCIAL AND ECONOMIC AFFAIRS

In the last 4 years, Brazilian economy has gone through serious political and economic problems. The energy sector has also been undergoing major transformations. Although the Brazilian energy matrix is hydro and considered relatively clean, the environmental impacts generated in the construction of reservoirs are currently questioned by several environmental institutions. In this sense, the use of actually clean and efficient energy has become the agenda of the moment. Brazilian gas sector, along with wind and solar energy, are the institutional bets on the production of alternative energies in this sense of new energy forms.

Gas sector in Brazil is still very small and underused. Until 2017, the monopoly of the Brazilian company Petrobras prevented the participation of other companies and groups interested in developing the sector and, in turn, Petrobras intended its investments in the fuel oil market, relegating the marginalization the gas market.
According to the Ministry of Mines and Energy, the end of the gas monopoly by Petrobras will generate investments up to R$ 32.8 billion and reduction in the price to the final consumer. The development of the gas market in Brazil, especially vehicles and even thermal energy production, could directly lead to lower prices and give more access to low-income populations.

Although the natural gas sector constitutes a cleaner source of energy in comparison with other ones, its development in terms of technology is also needed in building a more competitive energy sector. However, the technological sphere doesn't seem to be the main problem in the development of this sector in Brazil.

As already exposed, the Brazilian gas market is still incipient. After the promulgation of the Gas Law in 2009, the concession model was adopted to attract new investors to develop the natural gas sector by opening its market. Given that, the main challenge is to develop transport and distribution infrastructure in order to expand the demand for natural gas. In this context, it is necessary to identify potential big costumers so that the investments can be justified.

Half of the Brazilian demand has been supplied by the natural gas produced internally, as the other 50% is supplied by the imports from Bolivia (through the Gas-Bol gasodute) and imports of Liquid Natural Gas (LNG). Considering that it is a big importer of natural gas, the development of internal supply may constitute a strategic asset for Brazil.

Given that, the gas sector has regionalized aspects. It means that the global market trends don't have a significant impact in the Brazilian natural gas market, even in its technological development. Nevertheless, the expansion of natural gas supply and development of the sector rely on its economic viability, considering that the costs of transport demand the highest investments. Technically, there are no significant technological barriers for it, but the infrastructure needed to guarantee the flows of natural gas.

2.2.4 DEVELOPMENT PERSPECTIVES OF THE BRAZILIAN GAS MOTOR FUEL MARKET UNTIL 2030

Since the oil crises of the 1970s, Brazilian energy policy revisions have been based on energy saving and reducing dependence on oil products. Since then, the evolution of natural gas in the total consumption of primary energy sources in Brazil is notable. Brazil's gas production has been growing steadily and in the last nine years gas output accelerated, with an average yearly growth rate of 11%. According to the government's projections, the share of gas in the primary energy mix will increase by 2% until 2026, when it will account for 12% of the primary energy supply of the country. Brazil aims to double its natural gas output by 2030 and to increase the number of producing states from 8 to 16 (IEA, 2018b).

As gas demand grows rapidly in Asia, the Western Hemisphere is increasingly becoming a gas exporter. Still, the Brazilian production is only expected to surpass demand by 2030. Natural gas demand in Brazil was around 37 billion cubic meters (bcm) in 2016, representing approximately 10% of Brazil's energy mix (IEA, 2018b), but consumption is expected to grow at an average annual rate of 1.6% to 2024. By then, gas consumption is forecast to exceed 4.3 trillion cubic metres (tcm) – compared with 3.9 tcm in 2018 (IEA, 2019).
Currently, most Brazilian gas production comes from associated gas from offshore oil fields - especially from the Santos basin. In this sense, the state-controlled company Petrobras plays a major role in the sector and is responsible for the gross of the domestic output (IEA, 2018a). The program(«the Gas to Grow») aims to break Petrobras' de facto monopoly by decreasing its participation in the sector and giving away its spare capacity to other companies, through a partnership and divestment program (Programa de Parcerias para Investimentos - PPI). It also seeks to introduce market-oriented measures such as new tax rules for natural gas downstream and more flexible licensing procedures for the construction and operation of gas pipelines and integration of the gas and power markets (IEA, 2018b):

Brazil is currently witnessing an increasing number of foreign investments in the sector, including in the transmission infrastructure. The country is also offering new opportunities for oil and gas exploration investments

The crisis caused by the truckers strike is leading some automakers to reevaluate the potential of the Brazilian market for large-scale production of buses and trucks powered by natural gas. Starting production of gas heavy vehicles in Brazil would be relatively simple. Gas vehicles could use the same structure (chassis and body) as national diesel models.

Demand stimulus could come from the public transportation fleet. Another new source of demand could be the railway fleet. Brazil currently has about 2,100 diesel-electric locomotives in operation. Fuel costs are the largest expense item of any Brazilian railroad. The diesel/gas conversions, by providing a lower cost energy for this sector, represent a real opportunity to gain competitiveness of railways within the logistics chain.

Another source of demand could be gas motor fuel for ships. The main fuel for these ships is heavy fuel oil, a waste from crude oil distillation, which emits sulfur oxides as a byproduct of their combustion in the engine. IMO 2020 states that from 1 January 2020 all vessels shall use propulsion means within the new limits for sulfur oxides. In Brazilian ports, such as Guanabara Bay, areas should be chosen to measure sulfur emissions from ships near the ports' entry. To avoid problems, there is a race in the industry to match the deadline. In Brazil, there is a need to adapt the existing fleet considering commercially available options, and LNG is the solution being taken in more developed countries as fuel for new vessels. Natural gas, and consequently LNG, is by nature low in sulfur and cheaper than diesel oil and engine maintenance is also cheaper. Therefore, the cost of adapting the fleet would be paid in the long run. The availability of natural gas to be produced in Brazil from the massive pre-salt reservoirs and the installation of LNG terminals along the Brazilian coast will contribute to ensuring supply without interruption.
In sum, development perspectives of the Brazilian gas motor fuel market until 2030 are very favorable. Brazil's Executive has taken the promotion of the gas market as a priority and has promoted several changes in terms of a legal framework capable of making it more competitive, in order to reduce prices. Still given the particularities for the gas motor fuel market, investments in infrastructure must follow. Demand could be supported by several sources such as road freight transportation, maritime transportation, public urban transportation and railway transportation. All of these activities could benefit greatly from the implementation gas motor fuel to its engines.

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Natural gas is one of the world's most widespread and demanded primary energy resources. According to the International Energy Agency's baseline forecast scenario, global natural gas consumption may grow to 3,797 billion tons of oil equivalent by 2030 (over 4 trillion cubic meters). This energy carrier, unique in its environmental and economic properties, is used efficiently as a fuel for vehicles and stationary engines.

The basic component of natural gas (up to 98%) is methane (CH4). This is a colorless and odorless gas, lighter than air; it is chemically inert and readily soluble in gaseous and liquid states such as air, water, or oil. Natural gas is mostly of organic origin.

The widespread availability of natural gas, along with its environmental and economic properties make it a valuable fuel. On-board a transportation vehicle natural gas can be stored either in gaseous form as compressed natural gas (CNG), or in liquid form as liquefied natural gas (LNG).

CNG and LNG are "blood brothers". All the same, as is common in families, they each have different personalities or, technically speaking, physical and chemical properties. These variations determine the design of fuel management and storage systems for NGVs, as well as that of filling stations.

Liquefied petroleum gas (LPG) is also a very popular fuel around the world. LPG is a mixture of propane and butane, while natural gas is mostly methane. For simplicity's sake, therefore, LPG is often called "propane" while CNG and LNG are called "methane." In some countries, propane is also called "autogas."
Methane is lighter than air, and if released it rapidly dissipates in atmosphere. Propane is heavier than air and tends to sink to the ground. It can fill garage service pits or drain trenches and form explosive mixtures with air. A single spark is enough to trigger an explosion.

In terms of fueling speed, there are two types of CNG filling stations: fast-fill stations, generally equipped with cascading gas storage tanks; and slow-fill stations which can refuel one or more vehicles over a period of several hours, such as a night's stopover. Slow-fill systems can be economical in some cases and are used effectively by, for example, bus fleets.

In terms of gas sources, CNG filling stations can be divided into "mother stations", where gas is piped in, and "daughter stations", where vehicles are refueled with compressed gas delivered by tank trucks from a "mother" station. In some countries, these gas tank trucks are called virtual pipelines. All LNG and LCNG station are basically "daughter" stations.

Vehicles can be refueled at CNG filling stations by specially trained and certified personnel. Some countries permit self-service, with drivers performing the filling process themselves.
The main current trend is to build small automated CNG filling stations: one or two dispensers with a telemetric monitoring system, no staff at all, serviced on schedule by offsite technicians. Such stations

require very little construction time (under a month, including all engineering work) and reasonable investments (€250,000-300,000).

One of the main problems with CNG filling station network development is a lack of suitable sites and unjustifiably complicated bureaucratic procedures in acquiring them.

Mobile CNG filling stations have various capacities, from 50 m3 to 5,000 m3. They can refuel vehicles independently by using booster compressors or pressure differences. From a commercial point of view, it is better to use CNG tankers with boosters. In this case 95% of transported gas may be filled into the NGVs. Otherwise, when mobile unit has no compressor, only 65% of gas in the container is commercially available, and the rest of gas is just staying inside.

LCNG filling stations are a special class of refueling stations, with natural gas being delivered and stored in liquefied form. It can be dispensed into vehicles in liquefied form, or regasified and compressed to a filling pressure of 240-250 atmospheres, to be used as CNG. Liquefied/compressed natural gas stations (LCNG) make it possible to have a wider range of customers, since such stations can fill both LNG and CNG vehicles. Mobile LNG units can also fuel locomotives and ships.

The development of the global gas motor fuel (GMF) market is one of the strategic priorities of the Russian energy state policy. The gradual transition of all modes of transport to the consumption of natural gas as a fuel will reduce the cost of transportation, improve the energy efficiency of the country's transport system, reduce the negative impact of transport on the environment, and form production capacities in the use of natural gas as a motor fuel.

Transport is one of the main sources of harmful emissions into the environment, it accounts for about 40% of total emissions of pollutants into the atmosphere and about 10% of greenhouse gas emissions. The use of natural gas as a motor fuel can reduce emissions of harmful substances into the environment, increase the life of engines and the life of vehicles. At the same time, the development of this segment will have a multiplier effect associated with an increase in the volume of natural gas sales within the country and the loading of existing gas distribution systems.

2.3.1 INTERNATIONAL PRACTICE AND SYSTEMS OF GMF MARKET MANAGEMENT

Currently many countries are implementing programs with government support of introducing alternative fuel vehicles (electric vehicles, hydrogen-fueled vehicles, liquefied petroleum gases, and liquefied and compressed natural gas).

Today, the involvement of energy companies is essential to the development of the global transportation fuel NGV market and its European segment. The world's top energy brands are encouraging global transport industry to adopt natural gas instead of diesel and gasoline. Many have their own programs for developing CNG and LNG filling infrastructure, natural gas liquefaction plants, and sea or river bunkering facilities.

Gazprom is no exception. Gazprom's production, research, and engineering subsidiaries have been not only building and operating CNG filling stations. They have also been directly involved in creating Russia's NGV industry: developing new gas-consuming and gas-filling technologies for CNG and LNG, building up regional filling networks, improving national regulatory environment, proposing tempting federal and regional incentives for NGV market stakeholders.
Gazprom has been directly involved in launching the NGV programs in aviation (creating the world's first LNG airplane), railway industry (creating the world's most powerful LNG locomotive), water transport (converting tourist boats to use CNG), and agriculture (testing and certifying prototype CNG- and LNG-fueled wheel tractors and caterpillars). Domestically-produced compressors and cylinders for CNG, as well as cryogenic hardware for LNG, valves and other components, locally built CNG trucks and buses - all these equipment have been in Gazprom's focus.

Gazprom Export is one of the Gazprom Group subsidiaries enthusiastically operating in the global transportation fuel NGV market. Its task is to expand number of customers and export Russian gas that can be used as a transportation fuel. To achieve this goal, Gazprom Export is coordinating activities of Gazprom's outlets worldwide, marketing natural gas transportation fuel for vehicles.
The Blue Corridor NGV Rally has become a brand-name event associated with the use of natural gas for transportation.
The rallies in this series - nine of them took place since 2008 - are part of the eponymous project linking theory (UNECE study), public relations (holding the actual NGV races), and practice (the European Union's pilot program for creating a network of LNG/LCNG filling stations and a fleet of LNG-fueled vehicles).

The Blue Corridor project was initiated by the V.I. Vernadsky Non-governmental Ecological Foundation and supported by Gazprom in 1999. It approached Gazprom in 1999, proposing conceptual development for international cargo and passenger road transportation using CNG- and LNG-powered vehicles.

For the first time, the issue of using natural gas as a transportation fuel was considered from the standpoint of transnational, trans-sector (gas industry + automotive + logistics), and trans-institutional (political entities + business + consumers) cooperation.

An international experts group supported by Gazprom, the Russian and European NGV Associations, and the UN Economic Commission for Europe, was established. It developed a theoretical concept for using CNG and LNG in vehicles transporting passengers and freights along European major transport corridors. In 2003 UNECE made public the final report on The Blue Corridor Project.

The concept was based on international transport corridors (Crete corridors). Over time, this notion matured into the European Union's key transport corridors (TEN-T Core Corridors). These corridors link Europe's main cargo and passenger traffic hubs across all transportation modes.

The Blue Corridor Project's public stage started from 2008 when Gazprom organized the first NGV rally from St. Petersburg to Moscow. This and subsequent rallies were aimed at demonstrating the environmental and economic advantages of natural gas and the diversity of OEM NGVs. The rallies became an annual event.

Since 2010, Germany's E.ON joined Gazprom in organizing the Blue Corridor NGV Rally. The Rally routes cover the territory of European countries as well as Russia. In 2014, Russian Gazprom's NGV outlet 'Gazprom Gas-Engine Fuel' teamed in to drive the NGV rally "Baltia-Adria" from Saint-Petersburg to Belgrade.

Over the years, Blue Corridor rally crews have driven across all of Europe (and even a bit of Asia): from Yekaterinburg to Brussels, from St. Petersburg to Sochi, and from Gothenburg to Belgrade. In one of the tours - the Hansa rally in 2013 - NGVs traveled from Turku to Stockholm on the LNG ferry Viking Grace.

The rallies are accompanied by public displays of natural gas vehicles and roundtables including gas and automotive industry representatives, leaders of national and municipal authorities, transportation companies, the European Commission and the European Parliament.

Over 150 originally-equipped (OEM) NGVs, running on compressed and liquefied natural gas (CNG and LNG), have taken part in the project over its lifetime: from the smallest Volkswagen Eco Up to Iveco Stralis and Volvo FM heavy duty trucks, Solbus LNG buses, and KAMAZ racing truck. They have driven over 34,000 kilometers, passing through 90 cities in 22 European countries.

In May 2013, the NGVA Europe launched the project called LNG Blue Corridors. The goal is to build an EU pilot network of LNG filling stations (14 fixed and mobile stations) and a limited fleet of 100 vehicles running on this type of fuel. The project is co-funded by the European Commission, which is providing €7.96 million for refueling infrastructure, or 56% of the total cost.

LIQUEFIED NATURAL GAS

Liquefied natural gas (LNG) is a colorless, odorless cryogenic liquid with a density half that of water. LNG is nontoxic. Its boiling point is -158 to -163°C. LNG as transportation fuel contains at least 95% of methane; the remaining 5% include ethane, propane, butane, and nitrogen. LNG production process includes removing impurities from natural gas - primarily, from carbon dioxide.

Compression and liquefaction of natural gas both intend to minimize storage container volumes. Under normal conditions (at 1 bar pressure, 0°C temperature), a container with water capacity of 1,000 liters can hold one cubic meter of natural gas (Nm^3); the same container can hold around 220 Nm^3 at 200 bar, and 600 Nm^3 at -162°C. In other words, if fuel reservoir capacities are equal, an LNG-fueled vehicle can travel almost 3 times further than a CNG-fueled vehicle. For long-distance vehicles, this is a critical factor.

LNG is now an established independent segment of the gas market, with its own regulations, technologies, industry, resources, and infrastructure. One in three cubic meters of gas traded in the global marketplace is sold in liquefied form.

The greatest economic effect from using liquefied natural gas can be obtained in heavy-duty transport: sea and river vessels, railway locomotives, freight trucks, mining trucks, and airplanes.
All of them damage the environment, with the major adverse impacts being dumped water ballast and solid or liquid waste, greenhouse gas emissions, oil spills, and noise.

The International Maritime Organization has calculated that unless urgent measures are taken, maritime transport's share of global industrial CO_2 emissions could rise from 2.7% in 2007 to 8.1% in 2050. Natural gas makes it possible not only to comply with set requirements, but also to reduce fuel costs, thus covering the additional costs of converting vessels to this type of fuel. The promising LNG market for bunkering seagoing vessels in Europe through to 2030 is estimated at around 8 - 10 bcm per year.

Historically, outside of Russia, the use of LNG as a natural gas motor fuel has become more widespread, due to the peculiarities of transportation. In the absence of an extensive gas transmission network, the only effective way to transport gas is its liquefaction, in which the gas density increases by 600 times. For this reason, in Russia, where the gas transportation network is developed, CNG is a significant competitor to LNG.

At the same time, the high density of LNG makes it possible to transport it and use it in powerful engines with high specific fuel consumption. Thus, LNG has great prospects as a fuel for large-capacity trucks, water, rail transport, agricultural and quarry equipment. At the same time, CNG in the conditions of a developed gas transportation network is preferred for the sectors of passenger vehicles, small and medium - tonnage freight and passenger transportation.

EFFECTIVE DIRECTIONS OF STATE POLICY IMPLEMENTATION

The legislation and strategic documents set goals for the transition to natural gas fuel in the form of indicators on the consumption of GMF, the number of units of transport, branching CNG filling stations network.

The relevant objectives at the legislative level are allocated to the regions of the countries. At this level, legislation and programs aimed at the development of transport in the GMF are being created.
Creation of planning tools for the development of transport corridors, acting as a guide for the analysis of the demand for co-financing of projects aimed at expanding the infrastructure for transport operating on the GMF.

CREATING FINANCIAL INCENTIVES

Ensuring sufficient price differences between natural gas and conventional fuels by introducing zero or reduced excise duties on natural gas.

State financing and co-financing of infrastructure provision and construction of CNG stations on the main transport corridors and in densely populated agglomerations. Project financing under global transport initiatives is generally used, rather than a subsidy program linked directly to natural gas.

Introduction of cost recovery programs for equipping autogas vehicles. However, the availability of such programs is more effective as a means of informing consumers about the financial benefits of using GMF as a fuel than as a financial incentive for conversion. At the same time, financial incentives directly to the acquisition of vehicles on the GMF does not lead to significant demand.

Implementation of tax benefit programs for owners of vehicles using GMF, such as, for example, tax deductions for owners and users of such vehicles, applicable in the United States.

TECHNOLOGICAL AND ENVIRONMENTAL REGULATION

The most frequently applied measure of technological regulation is the introduction of restrictions on the purchase of transport equipment by state and municipal transport companies and housing and communal services organizations. At the same time, both increased emission requirements, which are easily met by gas-fueled vehicles, and direct indication of the mandatory share of purchased equipment on gas-fueled vehicles are applied.

Directly environmental requirements for NOx and SOx emissions for manufactured and operated vehicles. In an environment where GMF provides virtually zero emissions of sulfur and nitrogen oxides, high-quality automotive fuel requires additional purification, which, among other things, creates an indirect effect of financial incentives by increasing the difference in the price of fuel. Allowable emissions are gradually reduced.

Much attention is paid to the unification of technical requirements for the filling infrastructure, as well as to the gas engine fuel and autogas, which makes it possible to create a single market and ensure safety requirements.

2.3.2 NATURAL GAS FUEL AND TYPES OF VEHICLES

ROAD TRANSPORT

Among all modes of transport, the highest rates of transition to the use of natural gas fuel can be achieved in road transport. Currently, the number of vehicles powered by natural gas is estimated at 95 thousand vehicles. Given that over 28 million vehicles registered in the Russian Federation have been in operation for more than 10 years and need to be replaced, the natural gas fleet can be significantly increased with the implementation of a set of incentive measures.

In the segment of road transport using compressed natural gas (hereinafter – CNG), the greatest potential for demand have transport companies that perform passenger and cargo transportation, using light commercial transport, as well as utilities that serve the territory of large cities and zones of gravity. The greatest demand for CNG is projected in the largest cities with a population of over 1 million people, as well as in the regions of the Russian Federation with the largest fleet of vehicles.

According to the relevance of advanced construction of CNG stations, the subjects of the Russian Federation are divided into two groups:

- regions where there is a high potential for the conversion of vehicles to natural gas and a network of CNG stations has already been established, but for a more complete coverage of the market requires the construction of new CNG sales facilities located in the areas of localization of large consumers and in places with convenient transport accessibility to the main highways;
- the largest cities and regions in which there is a significant potential for the transfer of vehicles to gas motor fuel and CNG stations are located in close proximity to a number of large consumers of gas motor fuel, but there is no available network of gas filling facilities that provides refueling of CNG vehicles in the main directions of regular route transportation, as well as priority development regions.

In the segment of road transport using liquefied natural gas, the greatest potential for demand has enterprises engaged in freight and passenger transportation over long distances in interregional and international traffic and operating heavy trucks, tractors, intercity and tourist buses. The greatest demand for LNG is projected on the network of public roads of Federal importance, which have a high traffic density of vehicles.

When placing objects of gas infrastructure in the network of Federal roads the distance between cryogenic car filling stations should not exceed 400 km, to ensure the reliability of the refueling of motor vehicles on major routes included in the Federal motorways and the major international corridors.

The main Russian manufacturers of equipment using natural gas as a motor fuel include KAMAZ PJSC, GAZ group, Volgabus group of companies, etc.to increase the production of equipment using compressed and liquefied natural gas as a motor fuel, Russian automakers are allocated subsidies from the Federal budget provided that buyers are provided with a set number of discounts on gas-powered equipment.

For the dynamic development of the market of vehicles using natural gas as a motor fuel by 40-50 thousand units per year, it is necessary to increase production and expand the range of equipment using compressed natural gas, as well as to organize serial production of vehicles using liquefied natural gas. To increase production and expand the range of gas-engine equipment, foreign manufacturers may be involved provided that the production of equipment meets the requirements of the decree of the Government of the Russian Federation of July 17, 2015 No. 719 "on confirmation of production of industrial products in the territory of the Russian Federation.

RAILWAY TRANSPORT

In the rail transport segment, the highest demand potential is for freight-intensive non-electrified railway lines, where there is a need for the formation of heavy trains weighing more than 6,000 tons.
The purchase of new LNG-powered mainline and shunting locomotives is considered as the most preferable option for replenishing the fleet of traction rolling stock with gas-powered equipment. Conversion of operated locomotives to use natural gas as fuel is considered economically inefficient.

The transition of traction rolling stock to liquefied natural gas allows reducing the life cycle cost of locomotives due to lower fuel, maintenance and repair costs, improving their traction properties and increasing the service life, increasing the capacity of the railway network by forming trains of increased weight and length, reducing the volume of harmful emissions.

Currently, there are no developments in Russia to convert medium-capacity mainline locomotives and passenger locomotives to LNG, although these two segments of traction equipment can also use natural gas. A more capacious and attractive segment for gasification is the fleet of medium-capacity mainline locomotives, which has a significant potential LNG consumption capacity and is characterized by high profitability of transportation. To cover additional segments, the development of a domestic gas engine of medium power will be required.

RAILWAY TRANSPORT

Currently, there are about 130 LNG-powered vessels in operation worldwide, and about 120 vessels are under design and construction for shipping companies. It is predicted that by 2020 the world fleet of LNG vessels can reach 300 units.

Currently, about half of the vessels of the sea transport fleet and most of the vessels of the river fleet of the Russian Federation need to be replaced by new vessels due to the excessive service life. In order to order new ships using LNG, it is necessary to develop incentives for shipowners and create a bunkering infrastructure in major sea and river ports of the Russian Federation. At Russian shipyards, it is advisable to organize the construction of the following types of LNG-powered vessels.

In the Maritime transport segment, shipping companies operating in marine basins with the most stringent environmental regulations have the greatest potential for LNG demand. According to MARPOL 73/78, emission control zones currently include the Baltic sea area, the North Sea area, the North American area and the Caribbean Sea area of the United States.

The Baltic sea is part of the emission control areas for nitrogen oxides (NECA) and sulfur (SECA), so the Baltic basin can be considered as a pilot region for the creation of LNG bunkering infrastructure in the seaports of the Russian Federation. Also, a high demand for LNG as a bunker fuel is projected in the seaports of the far Eastern and Azov-black sea basins, which have a large number of ship calls and a significant cargo turnover.

LNG bunkering infrastructure in seaports of the Russian Federation shall include:
- high-capacity bunker stations for refueling large cargo vessels that can be built near LNG import terminals;
- bunker stations with lower capacity, designed for refueling medium and small cargo ships and ships of the port fleet, which can be built in all major ports of the Russian Federation.

Bunkering of LNG vessels is expected to be carried out in two main ways:
- in the roadstead with the help of special bunkering vessels;
- with berths of sea ports using fixed bunkering stations, or mobile stations (Cryopegs).

In river transport, the bulk of cargo transportation is carried out under the Unified deep-water system of the European part of the Russian Federation (USS), which, thanks to the availability of navigable inland waterways, connects the White, Baltic, Caspian, Azov and Black seas.

The largest freight-forming points of the USS include the area of lake Onega, Samara and Saratov regions, the Republic of Tatarstan (cargo flows with a capacity of over 300 thousand tons per year on the inland waterways of the USS).

On the inland waterways of the USS, the LNG bunkering infrastructure should first of all provide routes for regular transportation of large consignments of export-oriented cargo in order to optimize the placement of bunkering bases in sea and river ports of the Russian Federation. The priority sections of the EGS for the creation of LNG bunkering infrastructure include the Volga-Baltic and Volga-don canals, through which large consignments are transported during navigation in the direction of the Big port of St. Petersburg and the port of Kavkaz for further export.

To encourage the use of LNG as a bunker fuel, a coefficient of 0.9 is applied to the calculation of port charges levied in the Russian seaports of Primorsk and Ust-Luga for bulk vessels using liquefied natural gas as the main fuel.

AGRICULTURAL MACHINERY

In the segment of agricultural machinery, the most promising target segment for the use of natural gas is the fleet of tractors. The main potential consumers of LNG in the segment of agricultural machinery are located in the regions with the largest volumes of crop production – in the Krasnodar, Stavropol and Altai territories, the Republic of Bashkortostan, Astrakhan, Volgograd, Voronezh, Orenburg, Rostov and Saratov regions. Provision of agricultural equipment CNG is expected to be performed using mobile stations (Cryo MAGRT).

QUARRY EQUIPMENT

In the segment of quarry equipment, the most promising for the use of gas motor fuel is the fleet of dump trucks. The main potential consumers of LNG in the segment of quarry equipment are mining enterprises located in the regions with large deposits and significant volumes of mineral extraction - in the Republic of Karelia, the Republic of Bashkortostan, the Republic of Sakha (Yakutia), the TRANS-Baikal territory, Kursk, Belgorod, Chelyabinsk, Kemerovo, Chita and Murmansk regions. Providing mining equipment for LNG is expected to be performed using mobile stations (Cryo MAGRT).

2.3.3 IMPLEMENTATION OF THE STATE ENERGY POLICY IN THE FIELD OF GMF MARKET DEVELOPMENT

Implementation of the conceptual program can be planned in several stages:

1. planning and preparation (2018-2019) – building management system at Federal and regional level, identifying the feasibility of using natural gas in various sectors of activity, definition of the potential demand for NGV fuel in the subjects, the formation of promising Federal and regional schemes of the host gas infrastructure, identify areas of research and development work and production plans, preparation of draft normative legal acts, updating security requirements to objects of gas infrastructure, formation and testing of mechanisms to stimulate demand for natural gas fuel;
2. development and implementation (2020-2024) - ensuring the construction of the main volume of gas filling infrastructure, the implementation of measures to stimulate the serial production of a wide range of gas engine equipment and its acquisition by enterprises and entrepreneurs engaged in transport and utilities, agricultural production, mining, etc.;

3. increase in demand (2021-2024) - improvement of the procurement process, implementation of measures to increase the number of fleet of gas-powered vehicles and equipment to ensure a commercially efficient level of loading of existing and new gas-filling infrastructure facilities, strengthening of environmental requirements to stimulate demand for natural gas equipment.

The main directions of implementation of the state policy in the scenario of advanced development:

- ensuring the price balance between natural gas and liquid motor fuel on a long-term basis (benchmark-the cost of 1 kg of gas motor fuel is not more than ½ the cost of 1 kg of diesel fuel);
- financial support in the form of compensation for part of the costs of enterprises investing in the construction of gas filling infrastructure facilities, taking into account their prospective capacity;
- advanced construction of gas filling infrastructure:

In the road transport segment:

- the creation of a network cryogenic car filling station on the roads of General use of Federal value, characterized by high intensity of movement of motor vehicles. To ensure reliability fuel motor vehicles LNG all over Federal highways and the main international corridors, the distance between cryogenic car filling stations should not exceed 400 km, and the capacity of NGV filling stations shall be not less than 4 million cubic meters per year. The construction zone cryogenic car filling stations must be defined in a Federal scheme of placing of objects of gas infrastructure CNG on the roads of General use of Federal value. Required amount of subsidies for the construction of cryogenic car filling stations defined as 40% of the average cost of 150 million rubles, which, according to expert forecasts, allows to compensate for negative financial flows in the first three years after construction cryogenic car filling stations and reduce the payback period of 2 years to 7-8 years;
- according to the cluster principle, the CNG network is planned to be developed in the regions with the largest number of vehicles and significant volumes of road transport. The construction of CNG stations is envisaged in cities with a population of over 100 thousand people and large motor transport enterprises, or on the approaches to them in order to ensure convenient transport accessibility for filling vehicles with compressed natural gas. Within the cities, it is advisable to place CNG stations in areas adjacent to main roads, main streets of citywide value of regulated traffic, transport and pedestrian main streets of district importance. Within rural settlements of CNG stations - in the territories adjacent to settlement roads. Outside settlements - in the territories adjacent to the highways of II-III categories. The capacity of CNG stations should be at least 1 million cubic meters per year. CNG filling station construction zones should be defined in the regional schemes of CNG gas filling infrastructure facilities location developed by the subjects of the Russian Federation.

The required amounts of subsidies are defined as 25% of the average cost of 160 million rubles. (for CNG with a capacity of less than 10 million m3/g), which, with the price of natural gas in ½ of the cost of diesel fuel, allows to compensate for negative financial flows in the first three years after the construction of the CNG and reduce the payback period of the project to 7 years.

In the segment of railway transport – on the most heavily loaded non-electrified railway lines, allowing to provide commercially efficient mode of operation of gas-powered main traction rolling stock.

- in the segment of water transport – in major seaports and in the busiest areas of inland waterways;
- in the segment of quarry equipment – in regions with large deposits and significant volumes of mining;
- In the segment of agricultural machinery – in the regions with the largest volumes of crop production;
- improvement of the procurement process in order to provide the advantage of natural gas equipment at the state and municipal orders, the implementation of regular passenger traffic;
- improvement of technical regulation in order to update the safety requirements of equipment and filling infrastructure in accordance with the current level of technology and optimization of registration and control procedures;
- financial support for the production of equipment using natural gas in order to develop technologies and expand the range of gas engine equipment, as well as the acquisition of vehicles using natural gas as a motor fuel;
- financing of research and development activities aimed at the

development and development of modern technologies in the field of gas piston engines, mobile and small filling infrastructure, composite gas cylinders, efficient gas cylinder equipment (HBO), technologies for the entire cycle of CNG and LNG as a motor fuel;

- financial support for the conversion of the existing fleet to CNG and LNG as motor fuel to compensate for part of the costs of individuals and legal entities engaged in the conversion of vehicles to the use of natural gas;
- financial support for regional programs to inform and promote the GMT.

The main co-executors of the program can be: the Ministry of transport of Russia, the Ministry of industry and trade of Russia. In the field of improvement of technical regulation – EMERCOM of Russia, Rostekhnadzor, Ministry of industry and trade of Russia, Rosstandart. In the field of stimulating industrial consumption-the Ministry of agriculture of Russia, the Ministry of industry and trade of Russia.
in the field of improving the procurement process and the tax environment – FAS Russia, Ministry of economic development of Russia, Ministry of Finance of Russia.

Implementation of the advanced development scenario is possible only in case of allocation of additional appropriations of the Federal budget according to the list of the put main actions.

As a result of the implementation of the scenario, a significant growth of the gas engine fuel market can be expected by 2030. The target consumption of natural gas as a motor fuel is 10.7 billion cubic meters (against 2.6 billion cubic meters in the inertial scenario), the number of gas filling infrastructure facilities is 2.3 thousand (against 554), the number of vehicles that can use natural gas as a motor fuel is more than 0.7 million units (against 270 thousand).

Under the advanced development scenario, the annual economic effect of reducing fuel costs for all modes of transport will be more than 300 billion rubles by 2030, and the accumulated total will be more than 1.7 trillion rubles.

The total environmental impact of reducing emissions from all modes of transport could reach 2030:

- greenhouse gases - more than 4 million tons, and the accumulated total of more than 23 million tons of CO2 equivalent;
- certain types of emissions (sulfur dioxide, soot, benzopyrene) - 5% of the total emissions of vehicles.
- In order to ensure the necessary involvement of public authorities of the Russian Federation in the work on the development of the gas engine fuel market, it is advisable to ensure the individual responsibility of the heads of the subjects of the Russian Federation implementing measures in their part. This responsibility can be ensured by:
- inclusion of indicators of development of the market of gas motor fuel coordinated with indicators of implementation of the corresponding state program in strategy of social and economic development of subjects of the Russian Federation;
- monitoring of achievement of the established indicators and implementation of actions within work of bodies of the State Council of the Russian Federation on an annual basis.

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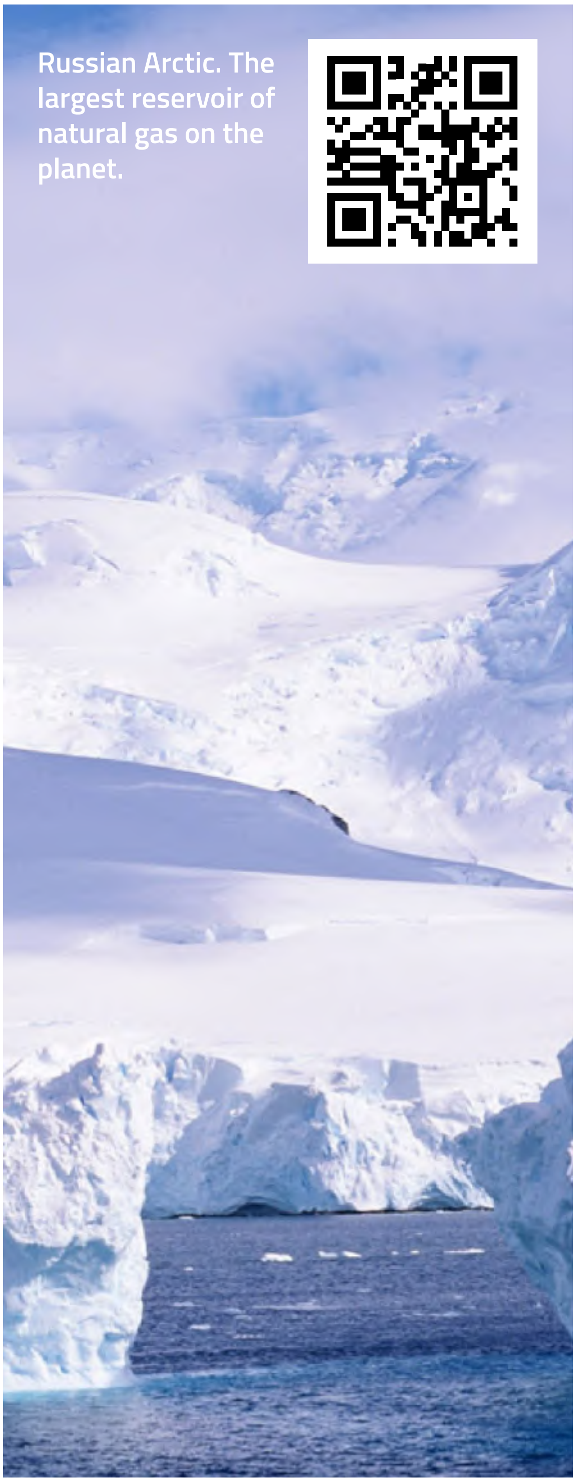

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Republic of South Africa

2.4.1 REASONS FOR THE DEVELOPMENT OF GAS MOTOR FUEL MARKET IN SOUTH AFRICA

Transport is South Africa's leading consumer of liquid fuels. Energy demand in the industry is projected to expand to 24–37 percent of complete power demand by 2050, potentially representing South Africa's biggest industry power demand.

Natural gas is the power source that is most effective and abundant. It is one of the market's cleanest burning business fuels. There is enormous demand for a natural gas vehicle that meets fleet operators, customers and manufacturers' emission objectives. The demand in the manufacturing of natural gas is increasing due to technological advances in techniques of extraction of natural gas. The industry is on an upward growth curve and is yet to penetrate into different areas and customer segments, this reality offers strong market development possibilities in the years to come.

The transport sector's power usage in South Africa is high, accounting for about 28% of total final production (TFC) in the domestic power balances. The majority of this demand for electricity (97%) is in the form of fluid fuels, which is the bulk of domestic demand for liquid fuel (84%). Transport demands evolution, both in terms of size and shape (carriage).

The liquid fuel sector's future relies on four variables, namely growth in demand, sustainable resources and limitations on the environment. The rise in demand for petroleum products will be mainly determined by the country's GDP development, per capita GDP, urbanization rate, and population growth. Fossil fuels, whose development is restricted by the finite nature of these resources, currently meet around 80 percent of worldwide primary energy demand. Growth in the petroleum sector will rely on the sustainability of these assets as well as on non-conventional sources such as shale oil and gas being introduced. Because of South Africa's low oil assets, the safety of supply will rely on financial and political stability in the nations of the Organization of Petroleum Exporting Countries (OPEC) as well as on the significant investment required in the refinery capability of South Africa.

Energy demand from the transport industry is anticipated to stay dominated by oil, according to the US Energy Information Administration (EIA). However, it is expected that the growth in transport demand for liquid fuels will slow down after 2025, as efficiency improves and gas ramps up displacement. Natural gas is the fastest increasing option at 6.8 percent per year and is anticipated to overtake biofuels before reaching nearly 7 percent of the transport market by 2035.

The Department of Energy supervises the creation and execution of energy policy. Energy policy and its later legislative and regulatory frameworks are the basis on which regulators and investors make decisions and customers choose which power alternative to use. As the economy of South Africa opened up after the democratic election of 1994, the new government assessed, and established policies driven by global developments in the energy industry. As a consequence, the White Paper on Energy Policy was created in 1998 and used as the first policy document to guide all later power industry policies, strategies and laws. The White Paper aims at enhancing access to accessible power services, improving energy governance, stimulating financial growth, managing energy-related environmental and health impacts, and ensuring diversity and availability.

South Africa has tiny quantities of proven crude oil reserves and there is very little crude oil production in the country. As a consequence, crude oil and refined fuels are imported by the nation to satisfy its requirements for liquid fuels. Crude petroleum exports were mainly imported from OPEC nations in 2016, with 38.1% imported from Saudi Arabia, followed by Nigeria (29.4%), Angola (19.2%), Qatar (3.3%), United Arab Emirates (29.4%).

The economy of hydrogen is undergoing serious consideration in South Africa, to develop safe, clean and reliable alternative energy sources. Hydrogen is an energy carrier that can be combined with fuel cell technologies to produce electricity. Fuel cells were invented about 150 years ago and directly convert chemical energy into electrical energy in a clean, environmentally friendly way, with no harmful carbon dioxide (CO_2) emissions. Hydrogen and fuel cell technology falls under the energy security grand challenge, with implications for global-change science with the potential to help mitigate the effects of climate change by the reduced emissions and the improved use of cleaner energy technologies. Hydrogen can be produced from any hydrocarbon compounds, including fossil fuels, but the emphasis in South Africa is upon developing hydrogen from renewable energy sources in the long term. Fuel cell technology is more efficient, reliable, quieter and compact, and if the hydrogen used is from a renewable source, this technology is also cleaner and better for the environment.

Economic contribution: value chain impact in SA

Refinery operations contributed R213 billion to the most extra financial activity, with R80 billion contributed to retail operations (excluding convenience stores). Refinery operations have had 484 478 employments, while retail operations have contributed 221 580 employments.

Distribution operations have the largest multiplier with each produced R1 contributing an extra R1.68 that could be added to the South African economy. Revenue produced in headquarters, storage, wholesale and retail elements means that an extra 4 jobs could be maintained per R1 million expenditure in each element.

We are assisting with cleaner-burning natural gas to satisfy increasing worldwide demand for energy and restrict CO_2 emissions. Its power, heat and cool sectors, households and companies, and renewable energy sources such as wind and solar can be a nice partner. Natural gas can also be used for boats, trucks, buses and trains as a lower-carbon fuel.

Advantages of natural gas

Natural gas is the cleanest-burning hydrocarbon that produces about half of carbon dioxide (CO_2) and only one fifth of coal's air pollutants when burned for electricity generation. It's plenty, if consumption continued at today's rates, sufficient recoverable gas resources would be available for about 230 years. It's polyvalent. It requires much less time to begin and stop a gas-fired power station than a coal-fired power plant. This flexibility makes natural gas a useful partner for renewable sources of energy such as solar and wind, which are accessible only when the sun shines and the wind blows.

2.4.2 KEY TECHNOLOGIES AND THEIR APPLICATION

How will the filling station be evolving in a high-tech future?
Over the previous three centuries, the petroleum retail industry has developed in terms of structure, design, ownership and technology. Processes are streamlined by means of the embedded processes and systems, ranging from mechanical DU, tank gages to electronic, automated desktop underwriter (DU)/automatic tank gauge (ATG) and liquid catalytic cracking (FCC) and integrated point of sale (POS), back office system (BOS) and service hours (HOS).

Oil stations are under pressure from a number of distributors to adapt to changing demographics (digital natives, millennials) and new techniques such as e-commerce, robotics, mobility, and Internet of Things (IoT). All of these developments are ongoing operations at the site and customer service

2.4.3 DEVELOPMENT PERSPECTIVES OF THIS DIRECTION UNTIL 2030

Natural Gas in South Africa

Natural gas provides the world with over 20 percent of its energy across applications in power generations, industry and transport. It is one of the cleanest, safest, and useful forms of energy. In South Africa, about 3 percent of natural gas is added to the country’s energy.
The additions of the natural gas to the country’s energy mix will provide, more effective methods such as the out-dated energy infrastructure and a steady reduction in cyclical energy shortfalls. This will stimulate the economy by allowing business and industry to lower their energy and operational costs.

The creation of new jobs and skills development opportunities, by growing of the new market in the country, the construction of conversion workshops, gas filling stations and satellite gas distribution infrastructure will provide a permanent stream of direct employment opportunities. Manufacturing of trailers, cylinders and other gas equipment will also create significant employment avenues.

Petroleum in South Africa

The major petroleum products in South Africa are petrol, diesel, jet fuel, illuminating paraffin, fuel oil, bitumen and liquefied petroleum gas (LPG). In South Africa, petrol and diesel are the major liquid fuels that are commonly used.

In 2016, Crude oil was one of the world's leading fuels. Oil supplies about 95% of the energy for global transport system in the form of petroleum fuels. South Africa's transport system depends on petroleum fuels for almost all of its energy needs, with more than 80% of the petroleum fuels consumption made up of petrol and diesel . The National Development Plan (NDP) 2030 provides South Africa's vision for socio-economic growth and development. The plan recognises that the country should have adequate supply security in electricity and in liquid fuels such that economic activity, transport, and welfare are not disrupted. The plan envisages that, by 2030, South Africa will have an energy sector that promotes:

- Economic growth and development through adequate investment in energy infrastructure;
- The sector should provide a reliable and efficient energy service at competitive rates, while supporting economic growth through job creation;
- Social equity through expanded access to energy at affordable tariffs and through targeted, sustainable subsidies for needy households;
- Environmental sustainability through efforts to reduce pollution and mitigate the effects of climate change.

The liquid fuel sector depends on four factors such as the demand growth, sustainable resources and environmental constraints. The increase in demand for petroleum products will be determined primarily by the growth in the country's GDP, GDP per capita, the rate of urbanisation and population growth. Currently, around 80% of global primary energy demand is met by fossil fuels, whose growth is constrained by the finite nature of these resources. The growth in the petroleum sector will depend on the sustainability of these resources as well as the introduction of non-conventional sources, such as shale oil and gas. Due to low oil resources in South Africa, the security of supply will depend on the economic and political stability in the Organization of the Petroleum Exporting Countries (OPEC) countries, as well as the substantial investment needed in South Africa's refinery capacity.

The Department of Energy of South Africa oversees the development of energy policy and implementation thereof. Energy policy and its subsequent legislative and regulatory frameworks are the foundation upon which the regulator and investors make decisions and consumers make choices about which energy solution to use.

In South Africa, the White Paper on Energy Policy was developed in 1998. The White Paper Energy Policy was used as the premier policy document which guides all subsequent policies, strategies and legislation within the energy sector. The objectives of the White Paper are to increase access to affordable energy services, improve energy governance, stimulate economic development, manage energy-related environmental and health effects and secure supply through diversity.

This was reiterated in the National Development Plan 2030, that was adopted in 2013 as the blueprint for future economic and socio-economic development strategies for the country. The plan 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.

In fuel production and supply of the country, a high level of oil product supply in 2045 results if electric vehicle lower crude oil prices of vehicles during the planning period. The scenarios that realize a high level of EVs in the vehicle fleet would reduce oil product supply from about 90 to 75% of total supply in 2030. Electricity ranges from 1-7% as transport fuel supply in 2030 to 1-30% of supply in 2045.

2.4.4 IMPACT OF GLOBAL CHALLENGES IN THE DEVELOPMENT OF GAS MOTOR FUEL MARKET ON SOCIAL AND ECONOMIC AFFAIRS

Firstly, to develop a fully productive gas-field takes years and a lot of things can change during that time.

In South Africa, a potential gas rich sight was spotted by Total (Ltd Pty) in Brulpadda deep under the floor and the surface of the sea. This means that it will be of great difficulty to construct on a sight that is known for heavy seas and strong winds. It will be very costly to compress the natural gas for long distances exports. This requires state of the art structures and facilities and which South Africa lacks currently. There are currently no vehicles that use gas as a fuel in South Africa. Natural gas has traces of carbon dioxide emission which is bad for the environment although it is cleaner than fossil fuels. If this technology is to be implemented, then it would be wise to take note that natural gas is toxic and flammable.

The challenge of the electric vehicle will be the use of the battery and the costs. The long charging time is another technical challenge and commercial barrier for electric vehicles. The charging system come to the additional costs and weight as they require cooling system. Battery technology is expensive because the electric cars batteries must be able to hold massive amounts of charge for a longer time and building these batteries needs expensive materials. Since building these electric cars cost a lot, they cost more than comparable gasoline cars to buy. Electric cars could be less expensive if electric car makers could ramp up production volume and use economies of scale. But, the price must come down for that to happen so that lots of consumers need to buy electric cars.

The people who are making electric car get some complains on people about whether the battery is stable of full enough to travel for a longer distance before the battery dies.

The charging stations are another challenge because they can alleviate a number of concerns consumers have about electric cars. Electric cars change the infrastructure of the country. While some charging stations are out in trial phases, and most of the charging stations needs to be at home in the garage. Which means that people who are sharing houses or use parking in the streets, it will be the hardest time for them to charge.

2.4.5 FUTURE DEMAND IN GAS MOTOR FUEL MARKET (2035-2059)

According to the US Energy Information Administration (EIA), energy demand from the transport sector is expected to remain dominated by oil. However, the growth in transport demand for liquid fuels is anticipated to slow down post 2025, as efficiency improves and displacement by gas ramp up. Natural gas is the fastest growing alternative at 6.8% per annum and is expected to overtake biofuels in 2022 before reaching almost 7% of the transport market by 2035. The market share of biofuels in the energy sector is forecasted to grow from 2.5% currently to 4% by 2035. Transport is the primary consumer of liquid fuels in South Africa (Merven et al., 2012). Demand for energy in the sector is forecasted to grow to 24–37% of total energy demand by 2050, possibly representing the largest growth.

The Integrated Energy Plan (IEP) is the key integrated energy planning strategy in the energy sector' that resulted in underinvestment in domestic electricity and petroleum product supply capacity. The electric vehicle (EV) penetration rates, a CO_2 emission constraint and refinery investments are uncertainties key in determining the future energy supply requirements for the transport sector. The National Transport Master Plan 2050's (NATMAP 2050) assertion is that transport in South Africa will offer transport alternatives in order to promote a low-carbon economy. The IEP and NATMAP emphasis the three main sectors of road transport such as freight, private, and public transport in 2050.

The South Africa TIMES model was used to examine how to make the transition of the transport sector to a low-carbon economy; to examine the use of new emerging technologies, like electric vehicles, and sources that would supply transport fuels for long-term and in future. Oil product vehicles including the hybrid and E85 vehicles will remain until at least 2030. The transport sectors such as freight, private and public, would encourage petroleum product consumption by increasing of the internal combustion engine (ICE) vehicles share during the interim horizon in 2030.

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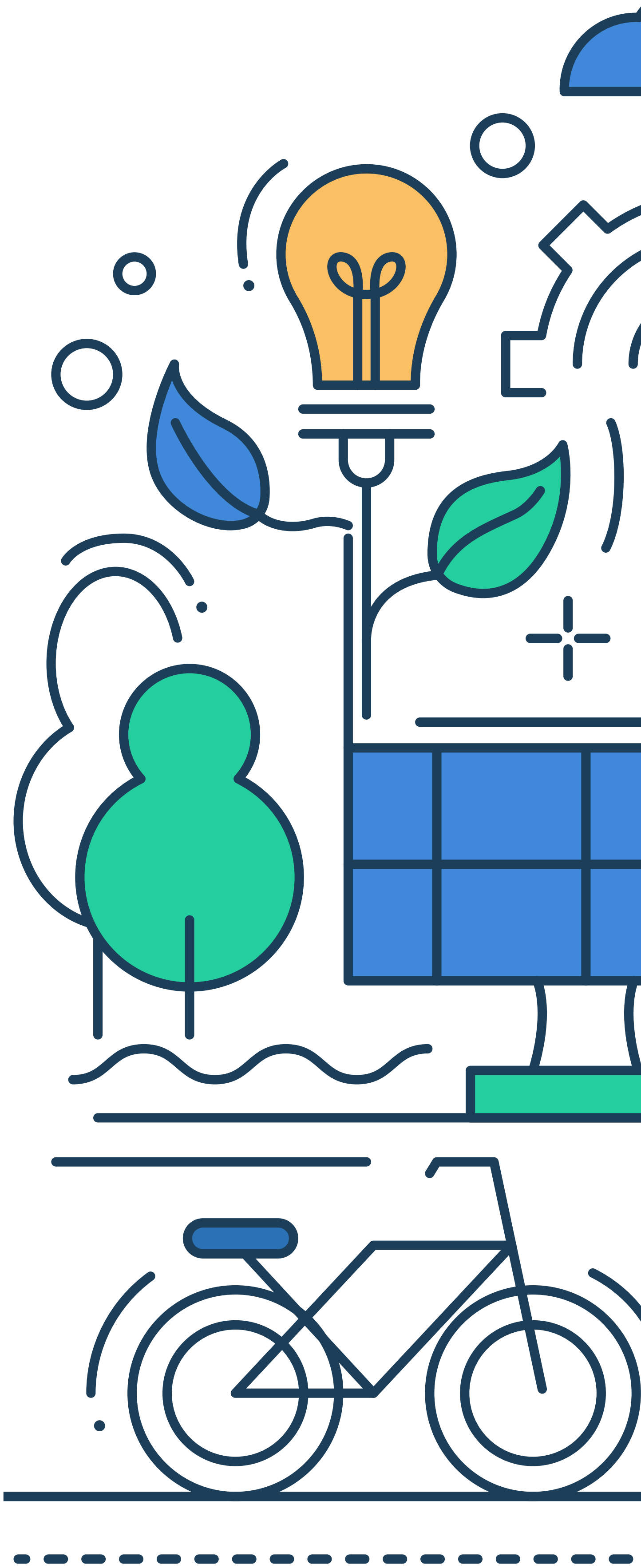

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