Scientific and technological achievements of the oil and gas industry of Vietnam and strategies to address future challenges

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Abstract:

Over more than 40 years of the Vietnam National Oil and Gas Group (PVN) development, Science and Technology has been played a very important role and significantly contribute to the success of PVN in all core business areas. This paper reviews the achievements of Science & Technology activities of PVN so far as well as point outs key strategies to address future challenges of oil & gas industry in Vietnam in order to improve productivity, quality, production, business efficiency, and to achieve sustainable development.

Keywords: ***oil and gas industry, oil exploration and production, refining and petrochemical, science and technology strategy.***

Classification number: ***2.3***

Introduction

Energy security is becoming an enormous global challenge. For the oil and gas sectors, the general context is the increasingly fierce competition from non-renewable resources. While demand for energy is increasing, supply is limited, and regions with large oil and gas potential are getting more and more difficult to access.

As a strategy to develop Vietnam's Oil and Gas industry, scientific and technological solutions are being used to improve productivity, quality, production, business efficiency, and in-depth sustainable development.

Over the years, PVN has achieved remarkable successes in all fields of scientific and technological research and the application of resulting activities, contributing significantly to the sustainable development of PVN [1].

In addition to PVN's average revenue growth of 18.2% per year between 2006 and 2015, Vietnam's oil and gas industry has established synchronized activities for the exploration, production, processing, and distribution of petroleum products and services. This is an opportunity for scientific research activities across all fields to serve the whole chain of production and business activities for PVN. Accompanying each stage of development, research helps to solve problems in science and technology according to the actual requirements of production and business, services, and applied directly to the operating activities and business of PVN. Petroleum scientific and technological advancements have made important contributions to a powerful Petro-Vietnam [2].

To date, PVN has been transferring, applying, and mastering many of the most modern technologies in the world to enhance PVN's operational activities.

In upstream petroleum exploration and production sectors, Vietnam's Oil and Gas industry has been using various modern technologies, including the latest applications of information technology, such as geophysical data interpretation and processing software; reservoir modeling and simulation; production design; and production technology to extract oil from basement rock. A range of the world's most advanced and specialized software solutions have been put to use, including the seismic data processing software [1, 3].

ProMax; the seismic interpretation from Landmark and Geoquest; the reservoir simulation from Geoquest (Eclipse); CMG software (IMEX, GEM, STARS); the drilling software Drilling Office; software for geophysics data interpretation of oil wells, Elan Plus; Finder databases; and others. PVN has studied technologies for drilling into

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deep-sea regions, drilling into geological objects with high temperature and high pressure, horizontal drilling technology, and drilling technology for narrow oil wells. PVN also developed a summative assessment study of the construction of drilling, well completion work, and studies on development of appropriate drilling fluids for different geological conditions of Vietnam. Automatic control technology in drilling and extraction is also widely applied, with a special focus on horizontal drilling technology, drilling technology for narrow oil wells, automatic extraction wells on lightweight rig operation, and sub-sea well operations. Biological and chemical technologies have been applied to enhance the oil recovery efforts in operating oil wells, including at Bach Ho, Rang Dong, Su Tu Den, and Su Tu Vang. Information technology has been used to increase the accuracy of analytical results and to save analysis time for many kinds of samples: paleontology, petrography, geochemical studies, and rock mechanical studies.

In downstream sectors, scientific studies have focused on the analysis of crude oil and gas to establish a database of oil and gas fields in Vietnam. Analytical results are mainly used to build databases, and for reference and guidance plans to select the right processing methods and technologies, and to choose the appropriate type of crude oil [1].

Regarding the gas sector, PVN has implemented research on the gas market, gas pricing, gas price scenarios calculating influence from imported gas from abroad, gas market forecast, and a gas pricing mechanism for Ca Voi Xanh. In-depth studies on electricity have also been deployed, for example on the efficiency of PVN's investment into gas and coal thermal power; and the operation and maintenance of power plants. Furthermore, studies into the feasibility of building power plants from household waste, as well as wind power potential, and on connecting wind power to the independent grid, alongside with studies of coal thermal power, waste handling and processing (ash, fly ash, separation of CO_2 from flue gas) [1, 2].

Regarding HSE in the oil and gas industry, research projects have achieved excellent results and have been applied to production, including establishing a system of advanced testing methods to control chemicals used in oil and gas harvesting, which assists environmental management agencies to assess the level of danger and manage risk for the use and disposal of toxic chemicals. PVN's research has helped to establish an environmentally sensitive map, oil drift models, and a responsive plan for oil spills. These have been applied to assess the environmental damage caused by oil spills which occurred in the Ganh Rai, Vung Tau Province in 2001; conduct quantitative studies assessing the risk of Vietnam - Russia Ptroleum Joint Venture (VSP) marine works, and gas pipeline system of PVGAS for safety management; do research into working environments to provide management guidelines and improve working conditions; and establish a database of waste and environmental monitoring, and create a VMEGIS system, which helps to manage environmental issues relating to oil and gas operations and the rescue plan for oil spills when incident occurs [1, 2].

Highlights of specific scientific and technological achievements

Until now, four studies of PVN have been awarded the prestigious Ho Chi Minh and State Prizes for Science and Technology. In Series 5 of the Ho Chi Minh and State Prizes for Science and Technology (2017), PVN was honored to be awarded three prizes of total 16 winning works. Earlier, in Series 4 (2012), PVN was awarded the prize for its work relating to oil extraction technology from basement rock. All the award-winning work are of great practical impact and has contributed significantly to the economic and social development of Vietnam [1].

The VSP group of works won the Ho Chi Minh Prize (2012) for the following study: "Effective exploration, discovery, and production of oil successfully conducted in the Pre-Tertiary granitoid basement rock of Cuu Long Basin, on the Vietnam continental shelf"

Before oil was discovered in the basement rock of Bach Ho, many well-known oil and gas companies, including Deminex, Bon Valley, and Agip, carried out exploration of oil and gas within the continental shelf of Vietnam. However, due to the use of traditional oil and gas exploration methods, those exploration missions did not come to any marketable discoveries. In terms of geology, this is an unusual supply of oil, as conventional oil is normally found in terrigenous sediment, but the oil at Cuu Long Basin is contained in the basement rock of Pre-Tertiary granitoid. This unusual existence of oil requires unconventional extraction technologies, and a rethinking of the classic rules of the oil and gas industry. So far there is still a lot of debate about permeability, and porosity, so this technology is progressively improving to determine the ultimate scientific truth. Vietnam is now known all over the world for mastering technology to exploit such a particular type of oil. Many other countries have asked VSP

for co-operation to research in order to help them to develop technology for similar oil supplies, including former CIS countries, Sudan, Venezuela, and Uzbekistan, to name a few.

Vietsovpetro not only has built a methodology for petroleum extraction from fractured basement rock, but has also contributed to research methodologies and reservoir models, technological solutions for fractured basement drilling, production with maintained reservoir pressure, optimized oil recovery factors at a high tempo, created software to calculate reservoir parameters, and mined constructing organization. Based on these developments, foreign oil and gas service companies have made technological improvements in research, drilling and extraction of oil from basement rock, and contributed to an increase in oil production in Vietnam. Currently in the Cuu Long Basin, oil and gas fields have already been discovered in basement rock and operations conducted to extract oil from areas including Bach Ho, Rong from Vietsovpetro, Nam Rong-Doi Moi from joint Vietnam-Russia-Japan; Su Tu Den, Su Tu Vang, Su Tu Nau from Cuu Long JOC; Rang Dong from JVPC; Ruby from Petronas; Ca Ngu Vang from Hoang Long - Hoan Vu JOC, and there are other discoveries including jade, diamonds, and pearls in Hai Su Den, Thang Long, Ho Xam South, which are soon going into operation. Granitoid fractured basement rock becomes objects of interest when conducting exploration into other sedimentary basins. Apart from the Cuu Long Basin, oil and gas have continued to be discovered in basement granitoid in the Nam Con Son Basin including Dai Hung, and Gau Chua Oil Fields. The scientific and technological achievements in Vietnam's oil and gas industry possess practical value, not only for Cuu Long Basin, but also for other oil reservoirs on the continental shelf of Vietnam and the rest of the region. These achievements are the scientific contributions of science and technology for oil and gas industry in Vietnam and the world.

The work of VSP won the Ho Chi Minh Prize (2017) for the following study: "Technological research, development, and completion used to gather, process, and transport crude oil in the conditions of Vietsovpetro oil fields and their linked oil fields on the continental shelf of Vietnam"

This group of research works is systematic and comprehensive to cover the development of systems used to gather, process, and transport crude oil off the coast of Vietsovpetro, summing up all of the difficulties and challenges with transporting crude oil from Bach Ho and Rong via offshore underground pipe, collecting the length of the project; and is a comprehensive body of research into the rheological properties and processing solutions, transporting crude oil at Vietsovpetro; and works in research and development and innovative treatment technologies and transportation of crude oil offshore in line with the actual conditions of Vietsovpetro oilfields different than traditional technologies. This technology consists of a combination of technological solutions with varying degrees of flexibly, depending on the region and the exploitation period, and has been proven to be highly effective. The use of innovative technologies to transport gas-saturated oil via air preliminary separation and subsequent transportation of oil below its freezing temperature has contributed significantly and made fundamental changes to Vietsovpetro oilfield development guidelines, from the initial fix-rigged model MSP fixed rigs to a simple rig model BK/RC. The application of transportation technology from Vietsovpetro has helped to connect many nearby small fields.

The result of the research conducted is a prerequisite for the development of future overall schemes connecting all oil and gas fields on Vietnam's continental shelf, and create a chance to connect small fields, marginal fields, enhance efficiency in the utilization and maximize resources for the country.

The research works of PV Shipyard won the Ho Chi Minh Prize (2017) for the following study: "A study of the detailed design and application of technology to fabricate assemble and launch self-elevated rig in water depth of 90 m and suitable for the conditions of Vietnam"

During the period of 2009-2012, with support from the Ministry of Science and Technology, PVN ordered PV Shipyard and the National Research Institute of Mechanical Engineering to carry out a national research project to "study the detailed design and application of technology to fabricate, assemble, and launch a jack-up rig in a water depth of 90 m, and suitable for conditions of Vietnam". This project covers 11 scientific research and technological development topics aimed at enhancing self-reliance, increasing local content, training staff in the field of design and manufacture for oil rigs and aimed at self-reliance of design and fabrication of oil and gas drilling rigs; contributing to the construction and development of key mechanical design and fabrication of oil rigs and mechanical equipment gauge serve the cause of rapid and sustainable development of PVN.

Fig. 1. The 90 m water depth Tam Dao 03 rig marked a breakthrough in the science and technology understanding of the PV Shipyard, and laid a foundation for the design and manufacture of drilling rigs for the industry in Vietnam. Source: pvn.vn.

In 2011, a 90 m depth self-elevating rig was set up at Tam Dao 3 (Fig. 1). This was the first domestic rig ever constructed by PetroVietnam, and was successfully launched and put into use two months before schedule. This event marked a maturation and the mastering of high-tech for Vietnam's oil and gas industry. The project added Vietnam to the list of countries capable of designing and manufacturing oil and gas rigs. The 90 m water rig has a weight of nearly 12 thousand tons, is 145 feet in length, and operates in water depths of up to 90 meters, with a capability to drill to depths of 6.1 km. The rig can withstand hurricane winds equivalent to and above level 12, and withstand extreme weather conditions. Tam Dao 03 is the first 90 m depth self-elevating rig built by PV Shipyard, and was completed two months before the deadline, and was registered into the USA Maritime Registry with ABS certification, which shows the rig to meet international standards. The rig is registered to be used by the joint venture Vietnamese - Russia Vietsovpetro, with the stable and effective operation since June 2012.

This scientific research project is a key factor determining the success of the project which is to build the Tam Dao 03 rig and afterwards, have a major role to build the Tam Dao 05 drilling rig across all phases, from design, procurement of materials, and construction equipment manufacturing. For the Tam Dao 05 rig project, PV Shipyard was completely proactive in the implementation of projects, increasing the localization rate, reduce dependence on foreign technologies less than the rig Tam Dao 03 project.

The Tam Dao 03 rig includes the following applications: 1. It applied advanced process design methods for modern drilling rigs; 2. It applied advanced design software; 3. It applied the work rig developed to the highest quality possible. The project increased the rate of localization of the project to build the Tam Dao 05 rig at 39% local engineering compared with the three other projects at Tam Dao at 34.7%. At the same time, there was a reduction in foreign expert work time from around 43,000 hours (Tam Dao 03) to 11,000 hours (Tam Dao 05). Besides, the project construction period for Tam Dao 05 was reduced to 32 months, although the mass fabrication 1.5 times compared with the volume of projects built in Tam Dao 03.

Rig design technology had a key role in the development of the PV Shipyard.

Until now, the PV Shipyard has both basic and advanced technological foundations. The PV Shipyard workforce is also professionally trained on scientific research projects.

The work of VSP won the State Prize for Science and Technology (2017) for the following study: "A study of the optimal plan to build, launch, and install super-sized tripods in water depths of over 100 m to be suitable for the conditions of Vietnam"

This study analyzed and selected methods to manufacture tripods using a combination of large blocks. In this project, researchers calculated the base plan by launching a scheme of sliding (Skidding loadouts). This study calculated methods by laying the base for a self-releasing (Launching) rig, and worked on onshore fabrication, and construction works were completed to the calculations, procedures, and plans for combination blocks "panel" so adults can stand up to 20,000 T, which is the length up to 150 meters base. This project also created a panel rotary volume flip code by combining multiple cranes that can be up to 1,000 tons. This innovation is the embodiment of a flip turn lifting large panel blocks using multiple cranes (6 cranes) combined hydraulic lift system and "tie back". Regarding the launch and installation at sea, construction work was completed through a fully standardized process, solving the problem of launching and installing gauge bases by means of self-discharge lines with a condition of equipment in Vietnam. The outstanding creative element here was it was the first time that we were able to perform the stand by a reporter dedicated domestic barge, and was converted and used successfully and safely. The barges used exclusively launched the first base and the only one in Vietnam (VSP-05) and has been optimized to apply barges VSP-05 conversion and marine cranes with lifting capacity is limited (Paracel 1,200 tons).

Science and technology development strategy of PVN during 2016-2025 period and guideline to 2035

In the future, the energy sector in general, and in particular the oil and gas industries, faces a number of problems, such as the depletion of fossil fuel resources, and a high demand for energy, fuel and material requirements for the production to be increasingly strict (Fig. 2). Global climate change, environmental protection requirements lead to increasingly strict standards on waste, improvements to the efficiency of use of resources and energy saving, development of new energy sources to replace traditional ones, the energy demand shifted towards reducing the share of coal and oil, increasing the proportion of electricity and gas.

The trend of scientific and technological applications to improve the efficiency of resource use and energy will contribute to significantly reduce demand for fossil fuels and reducing environmental pollution. Sources of clean and renewable energy will replace fossil energy sources, which are likely the causes of environmental pollution. Research and application of new scientific and technical solutions is a key engine for this energy transformation [4].

In the context of dynamic and unpredictable development in both economic and social aspects, the role of science and technology in production is increasingly appreciated. The issue of innovation, technological application and transfer, operational optimization and energy savings to improve the efficiency of production operations is the core issue throughout the whole industry. The biggest challenge for the development of the science and technology knowledge of PVN now is to rapidly improve the quality of human resources to develop scientific and technological improvements to meet the quality evenly research, not only extensively but also intensively, soon to reach the advanced level for the region across all areas.

The development of science and

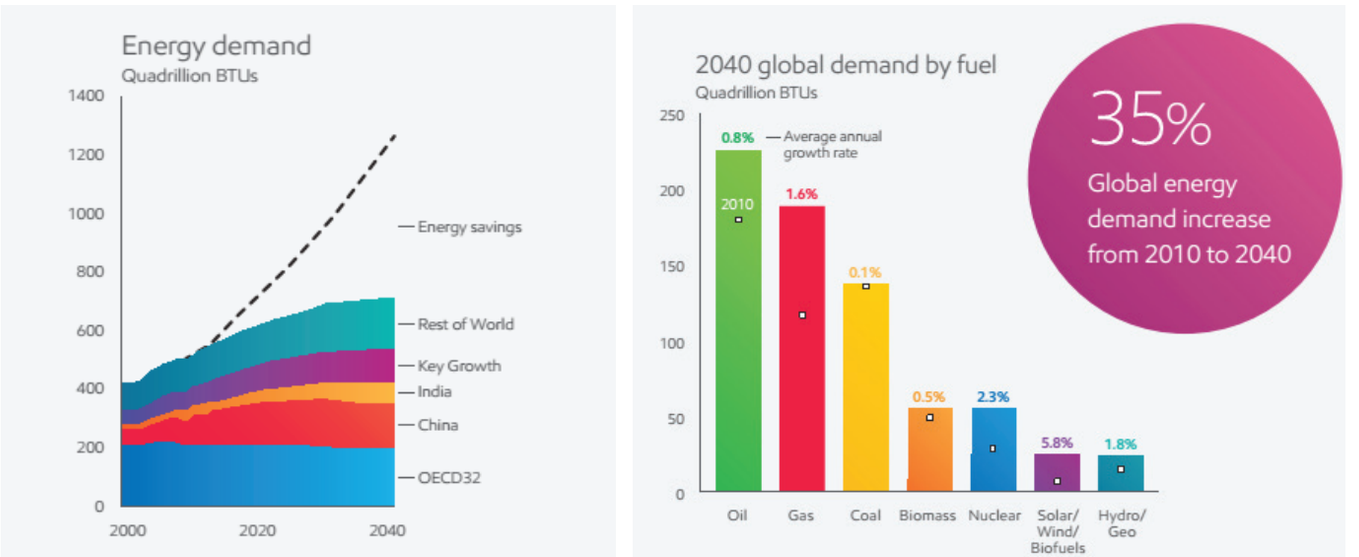

Fig. 2. World's demand of energy and proportions of each type.

technology in Vietnam's oil and gas industry is under the general trend of the world oil and gas industry, in particular by sector is as follows [1, 3]:

Exploration sector

Seismic exploration: Development has been made towards the application of advances in physics and information technology in order to improve reception quality, improve the resolution of objects, improve the exploratory study of small sizes, and at great depths, do better in the complex geological environment. The development of hardware and software that allows direct analysis object images in 3D, 4D is being progressed.

Well-logging: This development is based on the latest progresses in physical science, engineering technology, electronics, and software, and is used to obtain information directly and more reliably, reducing downtime for measuring drill well logging, increasing curve and maximum parameters in one measurement, diverse audience services, and environmental conditions. Intelligent solutions integrate multiple curves, different materials using artificial intelligence network (ANN), and improve reliability prediction calculations physical properties of reservoirs.

Oil and gas production sector

Drilling technology: Aiming at offshore and deep water drilling to expand the scope of exploration using mining and drilling technologies applied to achieve the following objectives: reduce the costs of drilling, drill deep water areas, and integrate with other technologies. The drilling technology trends being developed are as follows:

- Casing drilling technology;

- Single-diameter well drilling technology;

- Slim hole, microphone hole drilling technology;

- Seismic imaging while drilling, real-time drilling technology;

- Drilling fluids suitable for areas with high temperature, high pressure;

- Drilling under balancing pressure;

- Drilling of wells with multi-diameter;

- Horizontal drilling;

- Drilling technology in deep water offshore areas well requires great drilling depths.

Production technology:

- The technology group to enhance water injection efficiency, improving primary oil recovery (IOR);

- Technology for low and ultra-low permeability wells such as tight oil, shale gas, etc., requires exploitation by hydraulic seam cracks;

- Technology object extraction carbonate objects;

- Technology in the area of offshore deep water (groundwater well head, etc.);

- Technology to strengthen the management and supervision of the mining process (automatic measurement systems, management and exploitation online, etc.);

- Technology non-traditional mining: tight oil, gas shale, tar sand, mines permafrost zone, etc;

- Advanced Technologies, including tertiary (or enhanced) oil recovery (EOR) technology mix (such as hydrocarbon, CO_2, N_2); chemical, thermal, physical and chemical micro (MEOR) technologies; water alternating gas (WAG). These methods are most widely developed as chemical methods (surfactant, polymer, alkane, alkali-polymer (AP), alkaline-surfactant-polymer (ASP), alkaline-surfactant-polymer (SAP), and nano-materials). Technological products aimed to match the characteristics of reservoir rock, including fluidity and heat resistance to increase the scope, efficiency, and environmental friendliness, and bio-diversity.

Platform Technology:

- Lightweight construction platform: Lightweight and minimal construction platform is often used to exploit critical oil and gas fields;

- Common platform: The gantry concrete or steel platform is used at less than 200 m deep. Concrete structures are capable of being built with fixed steel structures which are widely used in the North Sea since water depths are less than 300 m. This type of rig is also used for both critical and large fields;

- Elastic platform: SPAR type suitable rigs with a depth of over 1,500 m and for geologically weak foundation;

- Tension Leg Platform-TLP: Theoretically, TLP rigs can work in unlimited water depths;

- Submersible platform is used to exploit deep water fields. The current floating facilities are used for economically-technically critical fields (marginal fields and fields with high depth);

- The floating facilities: Popularly used in deep water areas. Systems of this type have emerged synthesis: Extraction - processing - contains - oil (FSO/FPSO);

- Special rigs used for permafrost conditions: Mainly suitable for northern waters of Russia and Europe.

Gas sector

Development of technologies to effectively collect gas from small and offshore gas fields using pipe-free methods such as FLNG, FCNG, FGTL, and Micro-GTL:

CNG production technology: Onshore CNG production technology has been commercialized and used for years. However, the offshore counterpart, referred to as FCNG (Floating compressed natural gas) has not yet been commercialized. The two CNG manufacturing technologies whether onshore or offshore have the same principles (implementation process).

Among the unconventional technologies for gas collection, FCNG is the simplest. The core of the technology is the process of compressing and storing gas at high pressures, so it is likely to be widely commercialized in the next few years. The gas fields in Vietnam mainly consist of small ones with reserves

<< 1 tcf and scattered and thus FCNG technology is a promising and suitable technology.

Offshore LNG production technology:

The production process of LNG offshore (floating LNG production - FLNG) is not different from the onshore LNG production; however, the FLNG vessel itself integrates with many components, including gas collection equipment, gas treatment equipment for air separation and liquefaction, a storage tank system, and product transfer systems for the LNG tankers.

Floating GTL, micro-GTL technology:

Floating GTL Technology (GTL Floating - FGTL) or Micro-GTL process is not essentially different from GTL - Gas to liquid process. The ultimate aim of both processes is transforming natural gas into liquid products of high economic value. However, the technology aims FGTL transformation toward efficient natural gas resources in the small gas fields, offshore products into a high-value liquid medium capable of transporting both by traditional methods as vessels and pipes.

- The development of advanced technologies to control and improve the efficiency of operation of the air: Technology for risk mitigation;

- Research and development technology for collecting, processing, and using gas and gas products in order to increase processing efficiency, expand markets, and ensure the required product quality and the environment:

+ CO_2, H_2S treatment technology using membrane, sea water, etc.;

+ Technology for transformation of natural gas into high-value products;

+ Fuel conversion technology: LNG, CNG, GTL, etc.;

- The development of advanced technologies to improve gas efficiency: Saving energy, improving the efficiency of combustion.

Petrochemical and refining sector

Refining technology:

Reduced requirements of feedstock and improved product quality: One popular global trend in crude oil exploitation is the movement away from the traditional crude oils (reserves declining) to crude oils with high density, which contain more sulfur and impurities. Moreover, the strict requirement of product quality, especially environmental standards, is becoming increasingly challenging. Therefore, in terms of technology, the current major trends in the field of oil refining is improved, upgraded oil filtration technology to processing sulfur and impurities-contained heavy crude oil is used, and concentrations of chemicals in products which have an adverse effect on the environment (sulfur impurities, olefin, aromatics) are reduced.

Technologies which are expected to grow in the near future to meet the requirements of both hydro-related raw materials and products technologies: Hydro-treating, hydrocracking, and hydrogen production technology.

Improving the processing capacity:

To increase profits, oil refineries, at present and in the future, are likely to increase their processing capacity. Thus the size of a maximum capacity line and equipment in for the oil refining industry will also increase because of the construction of a chain and large equipment, which will reduce overall investment performance and operating costs over two or more lines or small appliances.

Integration with Petrochemistry:

Because conventional petrochemical profits remain stable at higher profiting oil refineries, done to extend the value-added chain, reduce risk, and increase profits, they tend to build refineries to currently and in future maximize integration with petrochemicals from refined petroleum products. The integrated oil refinery can follow the following directions:

- Using naphtha from oil refining (light naphtha, heavy naphtha) for use as raw materials for steam cracking workshops to produce Olefin (ethylene, propylene, and butadiene) from which produces resins, solvents, and chemicals, and is the lead manufacture of ethylene, propylene, and butadiene;

- Using naphtha from oil refining (heavy naphtha, FCC naphtha) for use as raw materials for workshops reforming and BTX extraction to the production of aromatic compounds (benzene, toluene, and xylenes with p-Xylene in particular) which produces all kinds of plastic, solvents, fibers, and chemicals as BTX derivatives;

- Combining the two directions above.

Petrochemical Technology:

Production of platform chemicals from methane is becoming more popular because natural gas reserves in the world are more plentiful than oil, and the main ingredient in natural gas is methane (C1). New technological trends are transforming methane into the middle of petrochemical products, saving valuable time with olefin and aromatic factors and thereby the production of petrochemical products. Converting methane into the intermediate petrochemical products of high value 02 is oriented in the following directions:

- Indirectly through Methanol: MTO technology (methane to olefins), MTP (Methane to Propylene), and MTA (Methane to Aromatics);

- Directly through OCM Technology (oxidative Coupling of Methane) for Ethylene production.

Production of petrochemical products from petrochemical raw materials of biological origin:

With the need to reduce the effects of total emissions on the environment, the use of biological materials, such as ethanol, to produce the intermediate petrochemical products (ethylene) and other petrochemical products, such as PE biological chain; and the use of bio-PET is also developing as a trend. Also, the demand for biodegradable plastic products after being discharged

to the environment is also on the rise. Consequently, technology must be able to process raw petrochemical materials of biological origin, which are usually not as pure as petrochemical raw materials from petroleum. More specifically, the following petrochemical technologies will be able to use all kinds of biological materials with biodegradable materials derived from petroleum hardly decomposed from which to form the plastic medium whose properties facilitate the manufacture and use of such petroleum derivative plastics that are likely to decompose when discharged into the environment.

Safety, health, environment sectors

Cleaner production technologies: To meet the increasingly strict environmental protection requirements and use of resources in a most efficient, clean trend in production in the oil industry, which includes an optimization of the operation and application of new technologies of energy savings, oil and gas resources must be efficiently used to reduce emissions.

CO_2 storage and sequestration technologies: Aimed at reducing the greenhouse gas emissions causing climate change, the current separation technologies of stored CO_2 (CO_2 capture and storage) are being developed and applied in the petroleum sector in which CO_2 is separated from emissions of power plants, refineries, petrochemical processing or from natural gas. CO_2 is separated after being buried in exploited gas fields or aquifers which have suitable geological structures.

Power sector

- Continue to develop and improve technology configuration for the power plant in order to improve capacity, reduce emissions, and diversify resources. Over time the following technologies have been developed:

+ For gas-powered plants, gas turbines combine the cycle generation F last life (F4, F5) or Generation H;

+ For coal-fired power plants, boiler parameters supercritical and ultra-supercritical;

- Development, clean energy and technology improvements, renewable energy such as hydro, wind, and solar, in order to improve performance, the capacity and the share of renewable energy in the energy structure measure;

- O_2.

Conclusions

Through 55 years of operation, PVN has evolved from an "apprentice" and "employee" for foreign oil companies to the one who can master difficult tasks in the exploration, exploitation, storage, transportation, and processing of oil and gas. Success has been enjoyed via the construction of Tam Dao 03 and Tam Dao 05 platforms; construction and operation of the project such as the Bien Dong 01; operating and ensuring safety for the Dung Quat Refinery; and the construction and safe operation of gas-fired power plants, and fertilizer production plants. It is a testament to the determination and continuous efforts of several generations of PVN leaders and employees towards scientific and technological research and application activities, and has contributed significantly to the sustainable development of the organization. Technological solutions and scientific content have contributed more and more to production and business activities. To date, PVN has managed five basic areas: exploration and exploitation, gas industry, power industry, processing industry, and high-tech services. Scientific and technological activities have been continuing to bring high economic efficiency and contribute greatly to the success of PVN.

To implement the "Strategy for development of PVN by 2025 and guidelines to 2035" with an aim of making PVN the core unit of the oil and gas industry; to have dynamic, strong financial resources, and science and technology backing with high competitiveness in domestic and international markets, an important contribution in the process of building, developing, and protecting the country. On the basis of an assessment of the status and level of scientific and technological capacity, the Group's scientific and technological development perspective is: "Science and Technology are the essential tools to improve competitiveness and to ensure the successful implementation of the development strategy of PVN. The scientific and technological development aims to raise the level of science and technology for the petroleum industry and contribute to the development of world's science and technology, in which the focus is the applied research and basic research in service-oriented applications for operating business activities and petroleum science. The petroleum scientific and technological activities should be implemented on the basis of internal resources, incorporated with the cooperation at both domestic and international scales, and accompanied by research - training - production to create synergy strength and enhance competitiveness".

In the future, to overcome the challenges of domestic and global oil and gas industry changes, the PVN will determine scientific and technological developmental strategies for the organization based on an overall objective to raise scientific and technological resources; improve research capacity, mastery, innovation, creativity, and consulting; and to develop technological options to reach the advanced levels of the area in 2025. This will reach an advancement level with the rest of the world in a number of core areas for after 2035; contributing to improving the competitiveness and the successful implementation of the development strategy of PVN.

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