Towards **energy of the future**

Report: innovations of the oil, gas and energy sector

PGNiG

Contents

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PREFACE

Polskie Górnictwo Naftowe i Gazownictwo takes full advantage of state of the art solutions. Innovation is the only means of achieving continuous development.

The key solutions for the PGNiG Group relate to prospecting, excavating, storing and distributing carbohydrates, as well as servicing end customers. We are interested in services and products which consolidate our position as a trusted supplier of energy both for individual and business customers, and which improve the effectiveness of our operating processes. There is always one condition – projects of this kind have to translate into an increase in the value of the PGNiG Group.

Currently, we have nearly 150 R&D&I projects in our portfolio. We base on the creativity, experience and expert knowledge of our employees. We are also open to third-party projects, both those performed in cooperation with science and research institutions, such as the INGA program, and with technological companies, including startups. This project stream is the answer to our development requirements, both those we are unable to meet and those on which we would use far too much resources if we had to carry them out using only internal resources. This kind of approach is simply more effective.

For corporations that want to develop and increase their competitive edge, the implementation of new solutions based on an open innovation model has become an indispensable element of the development strategy. This is the path consistently followed by PGNiG. We are active in the government acceleration programs. We readily engage in collaborating with specialized partners, who are searching for prospective projects in which we can engage both in Poland and abroad. At the same time, we operate our own startup centre, InnVento.

The industry in which we do business is now faced with challenges that have never before been encountered. I have no doubts that today development is of strategic importance to the whole sector and for particular enterprises. As far as innovation is concerned, there is no going back.

Łukasz Kroplewski,
Vice-President of the PGNiG SA Management Board for Development

INTRODUCTION

The energy sector is one of the largest and most important industries of the global economy. In most countries it is a strategic sector, of key importance for the local economy.

In recent years actions related to climate factors have gained significance. From time to time, international and national regulations shock the sector, thereby enforcing changes and accelerating transformation. Not only due to the tone set by the European Commission, as well as the growing expectations of the general public, the energy sector – in particular in Europe – is becoming turbulent. In consequence new challenges are being added to old problems.

In this report, experts from Polskie Górnictwo Naftowe i Gazownictwo SA (PGNiG) and the global advisory firm PwC have attempted to identify the key challenges in the energy sector and the role played by innovations in addressing them.

The debate being conducted in public space, similarly to the observations of leading global players in the industry leave us with no illusions. Contemporary challenges can no longer be resolved using traditional methods, which is why innovation is the only way forward.

The report indicates the technologies and key trends inspiring many innovations, which are becoming a tool for energy industries in energy transition. The sector is facing many challenges – the industry has to keep pace with the digital revolution that is leading the changes. The sector must also take care of other areas, in respect of the energy-effectiveness of all processes, look carefully into resources that have so far been unnoticeable and look into raw materials that have been treated as a secondary effect of key processes. The industry is highly motivated to be more effective and environmentally-friendly, to identify new methods of conducting business and seek new sources of value, in which innovations play a major role. The report includes examples of actions, projects and technologies, to raise awareness of the fact that innovation in the sector is not only theory; it is also put into practice.

To enable the development of innovations in their organizations, enterprises must approach the topic systemically. The report mentions the more important planning processes and tools, and management of this area of operations, which enables the successful generation, development and implementation of new innovative solutions.

Innovations may be developed in-house, using available resources. Another way forward is to cooperate within the sector – share experiences and resolve issues together. The authors hope this report will prove to be a pretext for strengthening collaboration among enterprises in the industry in the area of innovations. It is also an excellent occasion for large entities to engage in wider cooperation within the area of innovation with their smaller business partners. Having a competitive edge, many issues and key directions can be developed more effectively and faster based on the common determinations and actions of the sector and its environment.

1

Condition of the energy sector

The energy sector is one of the largest and most important parts of the global economy. It is estimated that the operations related to exploration and production of crude oil and gas will generate a total of USD 3.28 trilliard (10^{21}) in 2019, which is approx. 4% of the global GDP.[1] In the 2025 perspective, this amount is estimated to grow by another USD 240 billion. More importantly, the energy sector also has an impact on other areas of the economy, in particular on the chemical, construction and automotive industries, therefore, the actual impact of the energy sector on the economy as a whole is much larger. Among other things, the fact that from among the Top 500 firms in terms of revenue, 85 are from the broadly-defined energy sector, attests to the strength of this sector.[2] The decisive majority of enterprises operating on the energy market are engaged in global operations. Six corporations can be identified among the top ten in this listing, and whose main area of operations is related to the excavation and processing of crude oil and gas. Two enterprises from among the six mentioned above are based in China, two in Europe and one each in Saudi Arabia and the U.S.A. Nevertheless, all these entities are global firms with many branches and companies located throughout the world. Also more and more Polish companies from the sector that are looking for new sources, suppliers and customers, are entering the international market. This is the direction that has been taken by PGNiG (among others), the Polish leader of natural gas mining. PGNiG has been exploring foreign markets for many years and is the first CEE firm to have obtained a permit to drill in Norway and which currently holds 23 concessions for drilling in the Norwegian Sea.[3]

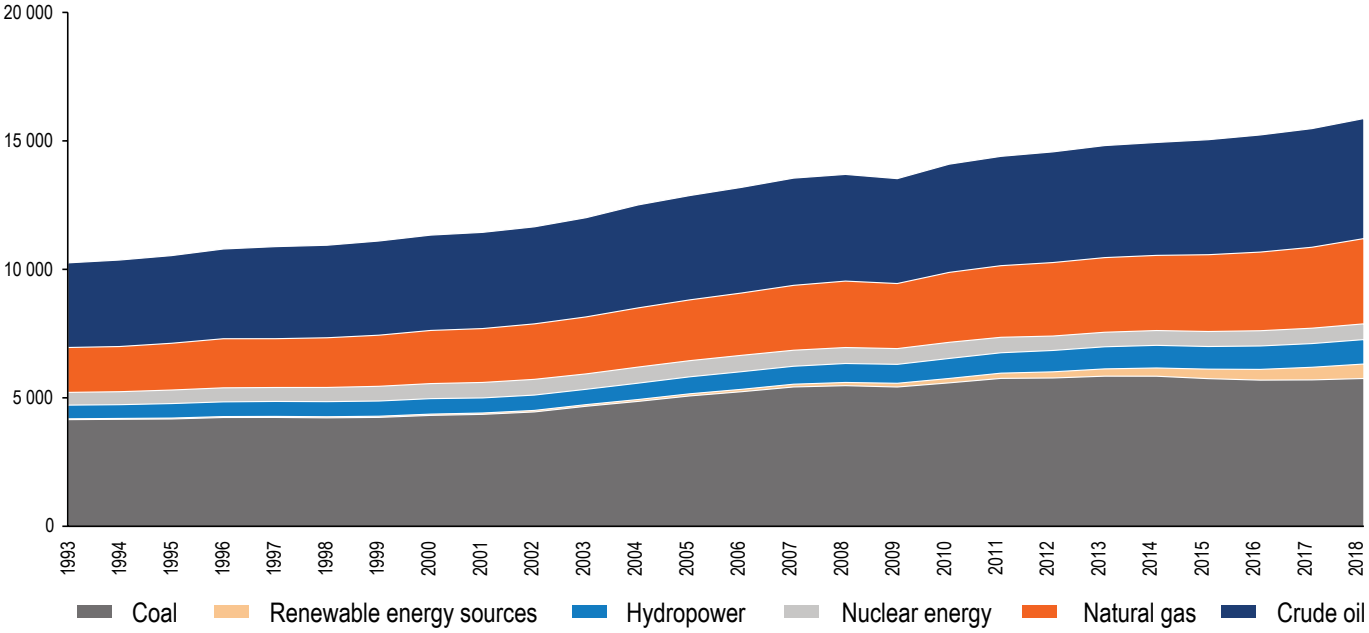
From the perspective of regional segmentation, the key regions that are dealing the cards in the energy sector are those with access to the largest natural gas and oil deposits. Taking into consideration 2019 estimates related to the production of oil and gas, it is possible to isolate three dominant regions: the Middle East, Europe and the U.S.A. Jointly, these regions produce nearly 70% of global gas and oil in terms of value, and in the foreseeable future will remain the most important regions for the energy sector.

Global demand for energy is growing year to year at a stable rate

In 2018, global energy consumption achieved 13.86 billion tonnes of oil equivalent (chart 1). Compared with 2017, this was a 2.9% increase, i.e. the highest y/y increase in the global demand for energy since 2010 (for comparative purposes, the average increase in energy demand over the past ten years was 2%). The stable increase in global demand for energy is due to the ever-increasing population growth and industrial production. In the past 10 years, fast developing economies, in particular China, India and the United States, had the largest impact on the increase in demand for energy.

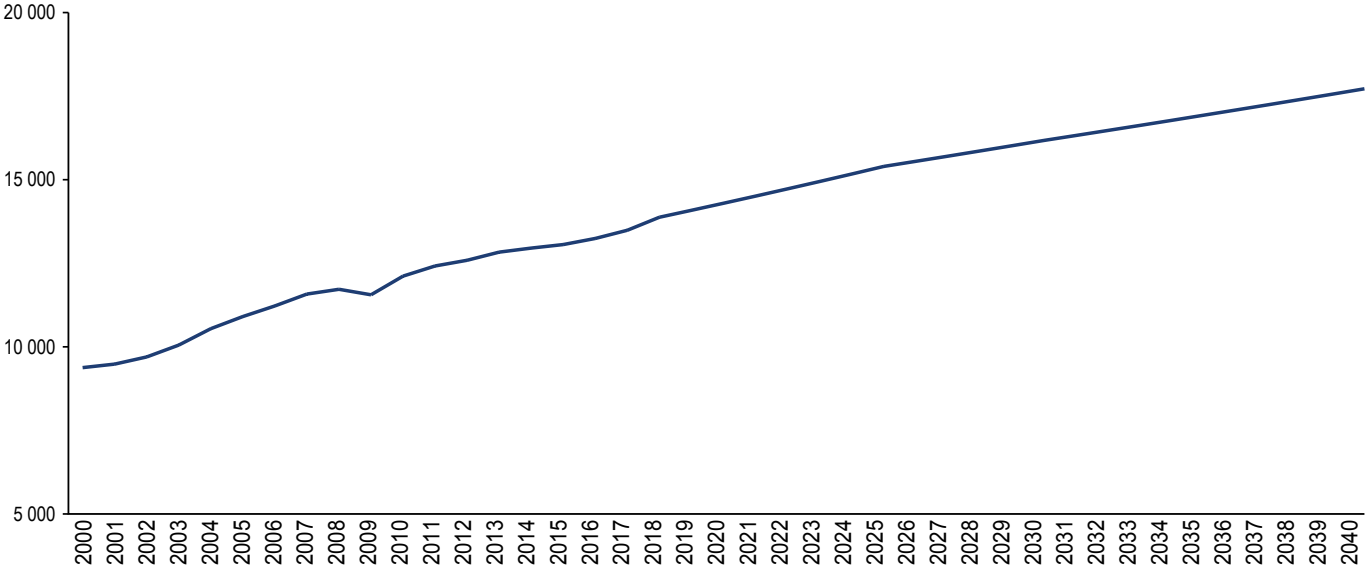
Forecasts showing global energy consumption (chart 2) indicate that up until 2040, the global value of demand for energy will increase steadily and reach an equivalent of nearly 18 billion tonnes of oil – an increase of nearly 28% compared with 2018.

Chart 1: Global energy consumption in millions of tonnes of oil equivalent in the years 1993–2018, broken down by energy sources



Source: BP Statistical Review of World Energy 2019

Chart 2: Forecasts of global demand for energy until 2040, in millions of tonnes of oil equivalent



Source: World Energy Outlook 2018, IEA

Significance of oil and natural gas in the World energy mix

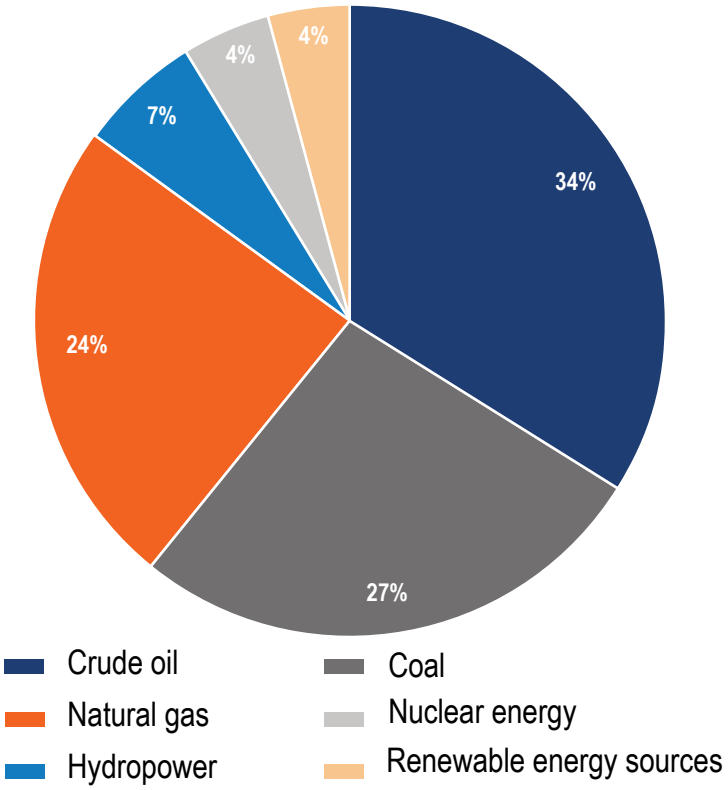
From 2018 data (chart 3), it follows that the share of these raw materials in the World energy mix was 33.6% (oil) and 23.9% (natural gas) respectively. Currently, they correspond to nearly 60% of the globally used energy sources.

Focusing on the two above-named raw materials, there is a constant trend visible on global markets, since 2009, to increase the production of oil and gas despite fluctuations in the prices of those materials.

Analysing the issue of oil, since 2000 the production of this raw material has increased by more than 27% (chart 4), due to many factors such as, among other things, a significant growth in global industrial production, the increasing number of cars used globally year on year, and the aforementioned global increase in demand for energy. In 2018 the highest increase since 2015 was noted in oil production, at 2.4%, due among other things to growing demand for the commodity in rapidly developing countries, such as China and India, which were jointly responsible for approx. 66% of the increase in the global demand for oil. This trend shows that oil is a very important commodity, in particular for countries where high economic growth is noted.

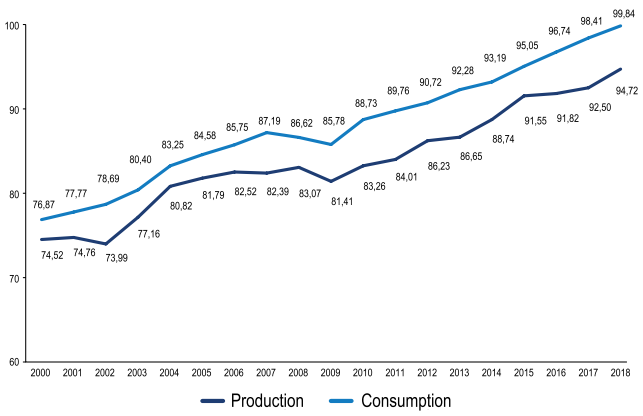
Looking at the production of natural gas, a more than 61% increase in the production of this commodity was noted in the years 2000–2018 (chart 5). This high growth rate is related mainly to the fact that natural gas is a much cleaner commodity in environmental terms than oil or coal. Taking into account the global trend of obtaining energy from increasingly cleaner sources, natural gas is a natural alternative to oil and coal. One of the best years in history,

Chart 3: World energy mix structure in 2018



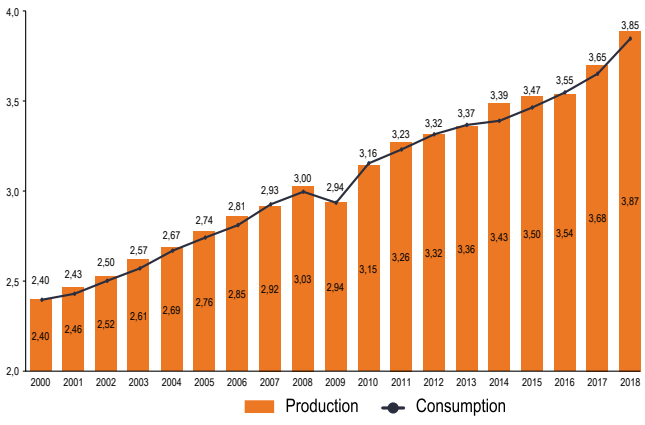
Source: World Energy Outlook 2018, IEA

Chart 4: Global average daily production and consumption of oil in millions of barrels in the years 2000–2018*



Source: BP Statistical Review of World Energy 2019

Chart 5: Global production and consumption in trillions of cubic metres in the years 2000–2018



Source: BP Statistical Review of World Energy 2019

*The differences between the values of global oil consumption and production result from changes in stocks, using additives other than oil and substitute fuels, as well as the unavoidable discrepancies in definitions, measurements or conversions of data relating to oil supply and demand
Source: BP Statistical Review of World Energy 2019

in terms of natural gas mining, was 2018. In 2018 a more than 5% global increase in the production of gas was noted compared with 2017. The key countries jointly responsible for 80% of the global growth in demand include the U.S.A., China, Russia and Iran.

As shown in the forecast prepared by the International Energy Agency (IEA), when taking into account the most probable scenario for the development of the global energy market, the demand for oil will attain 106 million barrels per day in 2040.[4] Therefore, there will be a further increase in demand accompanied, however, by a slower growth in demand for the commodity.

In respect of natural gas, IEA forecasts assume an even higher growth in demand compared with oil, which – among other things – reflects the continued trend for promoting cleaner energy sources. It is estimated that by 2040 the demand for natural gas will exceed 5.3 trillion cubic metres, which is an increase of nearly 40% compared with 2018.[5] In Poland, in accordance with the assumptions of the draft Energy Policy of Poland until 2040, the share of natural gas in the national energy mix will increase from 6 to 16%.[6] PGNiG estimates that the demand for natural gas in Poland until 2030 will grow by more than 30% compared with the demand for 2015.[7]

This trend will, in particular, be related to the increased needs of the energy sector, the fuels market (CNG and LNG) and the distribution and supply infrastructure which follow this lead. Furthermore, an important phenomenon indicating future growth in the demand for gas is the construction of new power units that use gas to produce electricity. At the same time, PGNiG is intensively expanding its natural gas distribution network. It is assumed that the grid will cover 90% of Polish communes by the end of 2022.

Renewable sources of energy as an area for development in the energy sector

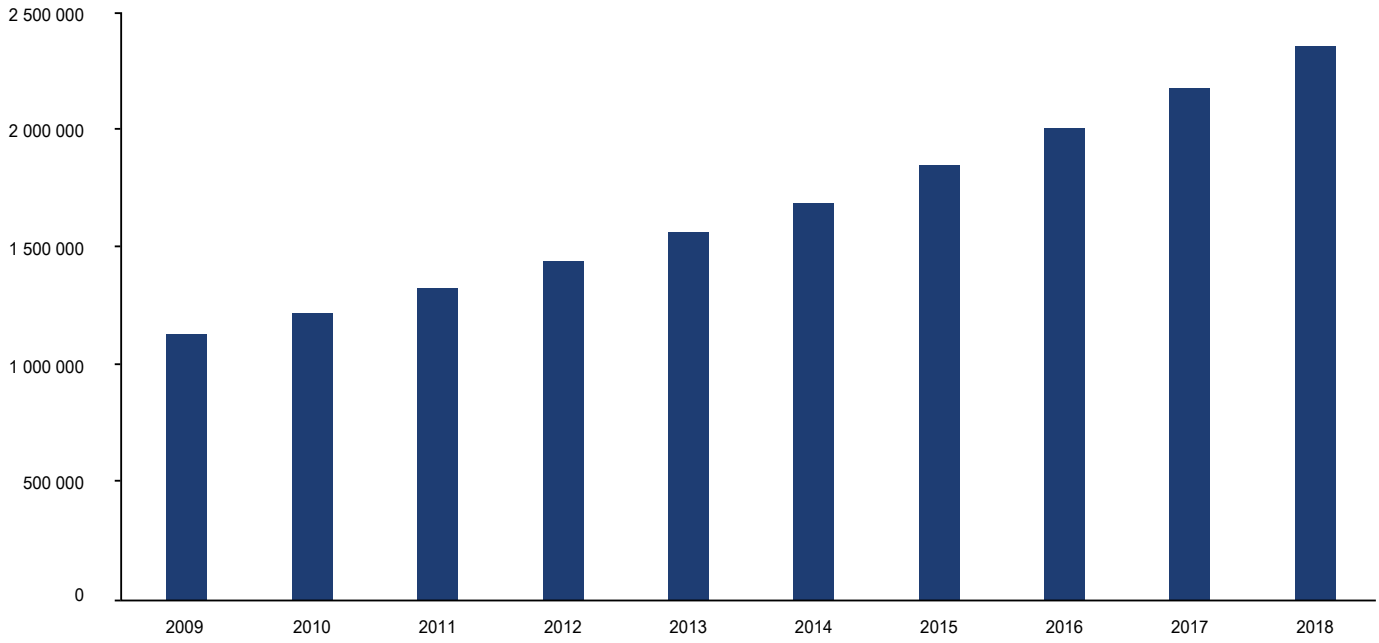
Renewable energy sources (RES) are becoming a very important component of the global energy sector year on year, and are slowly increasing their share in the world energy mix. The RES group includes in particular energy obtained from biomass, water, wind, solar (photovoltaic panels and solar panels) and geothermal energy. In 2018 renewable energy sources provided 11% of the whole production of global energy, whereas in 2010 it was less than 5%. It is forecast that by 2040 RES may constitute almost 30% of the entire energy production.[8] Analysing the absolute values of globally installed power generated from RES in the years 2009 – 2018, in 2018 it amounted to 2.35 million megawatts, which was more than two times higher than in 2009 (chart 6). The said data place RES first in terms of the most rapidly developing energy sources in the world.

The main reason for this is the impact of such types of energy sources on the environment. Taking into account the provisions of the Paris Agreement and other international and national regulations relating to the mitigation of global warming, the key aspect is a reduction in greenhouse gases such as CO2. Data relating to burdening the environment in respect of the production of electricity shows that RES technologies generate far fewer greenhouse gases than conventional fossil fuels. The average emissions for all RES technologies are in the range of 4 to 46 g of CO2 equivalent per 1 kWh, whereas these values for fossil fuels are in the range of 469 to 1001 g of CO2 equivalent per 1 kWh.[9] Taking into consideration all types of sanctions and tariffs imposed on countries or energy producers, related to the emission of greenhouse gases, the increasing share of RES in the World energy mix is an irreversible phenomenon which should help achieve key environmental goals.

Despite significant drops in the production prices of energy from renewable sources, lately they have continued to be higher than the costs of producing energy from conventional sources. Therefore, for RES energy to be competitive in terms of price, it is necessary to subsidize RES energy production. As RES is further promoted, and technological developments encouraged, we can expect the costs of producing energy from RES in this area to attain a level similar to the costs of producing energy from other sources.

In Poland RES do not yet have a significant share in the energy market, but Polish energy companies are undertaking intensive development activities and plan on increasing the production of energy from renewable sources.

Chart 6: Production of energy from renewable sources in MW



Source: "Renewable Energy Statistics 2019" IRENA

2

The sector's strategic challenges

Strategic challenges with an impact on the global energy sector

The optimistic forecasts of a constant increase in the demand for oil and gas do not mean the energy sector is not up against a series of challenges. Market mechanisms will force changes in the manner of doing business, in the portfolio of products offered and in relationships with partners and customers. Enterprises in the energy sector are endeavouring to address market challenges through innovative activities, to reinforce their competitive position and protect their share in this attractive market. This is confirmed by the concrete examples of the actions and the projects they have completed.

1. Decarbonization and endeavours to achieve a low-carbon economy

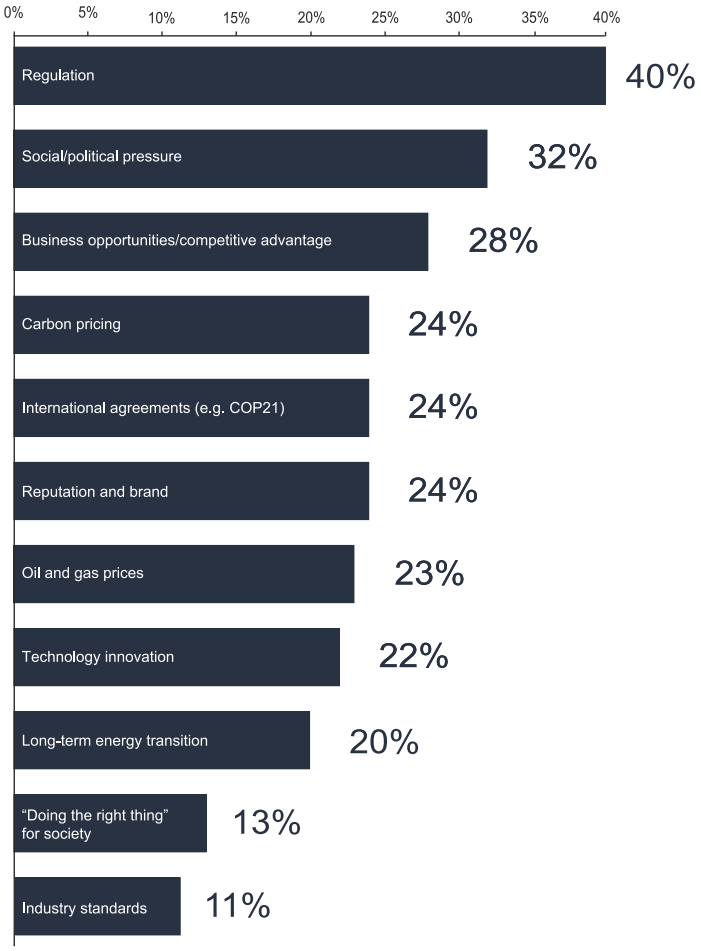
The battle against global warming, and the international community's efforts to reduce the carbon footprint, are some of the most important challenges faced by the energy sector. Sector entities have known about climate changes for many years, however, the stakeholders did not believe the problem would actually require such prompt action. The approach to the energy industry changed with the introduction of environmental regulations that were introduced by particular regions and states (such as the Paris Agreement of 2015 on climate changes, charges for carbon emissions in the European Union). In addition, customers are increasingly imposing ecological pressure on producers, requesting that they find environmentally-friendly solutions. Representatives of the sector are increasingly aware of the impact of environmental problems on their operations.

This translates into the mood of the key stakeholders in the industry. According to a survey by DNV GL (chart 7), carried out each year among nearly 800 energy industry experts, as many as 40% of the respondents believe that the enforced environmental protection regulations will have a decisive impact on the decarbonization process in the sector.[10] Social pressure will also be a material factor (32% of the experts indicated that this is the key factor) as well as new business opportunities resulting from the decarbonization process (28%).

On the other hand, according to the data presented in the report "Energy Technology Perspectives 2017" published by IEA, in order to achieve the aim set in the Paris Agreement, i.e. to maintain global increases in the average temperature until 2050, at a level much lower than 2°C above the level before the Industrial Revolution, requires the introduction of a significant change in the world energy mix. For example, it will be necessary to limit the use of fossil fuels by at least 10% to 2050 compared with 2014. Coal and oil will suffer the most damage, as these fossil fuels leave the largest carbon footprint. Their share in all the energy produced should be reduced by approx. 5 p.p. for oil and approx. 10 p.p. for energy acquired from coal (chart 8). The prospects for 2050 are, however, very promising for gas, which is the only fossil fuel which should increase its share in the world energy mix in the 2050s by 5 p.p. This is the cleanest fossil resource, generating nearly 60% less CO2 and 98% less sulphur oxides than coal[11] in the production of energy, and it will attract even more attention from producers in the energy sector.

Among the international giants operating in the sector, Shell and Total drafted clear strategies assuming both short- and long-term goals related to reducing carbon emissions into the environment, in accordance with the provisions of the Paris Agreement.[12] Other entities, such as BP, Eni and ConocoPhillips, also announced a reduction in carbon emissions in the next ten years. This is discernible in the ambitious approach to climate changes of the largest concerns operating in the sector.

Chart 7: Main decarbonization factors in the energy sector in 2019, and the percentage share attributed to them by respondents that consider them material



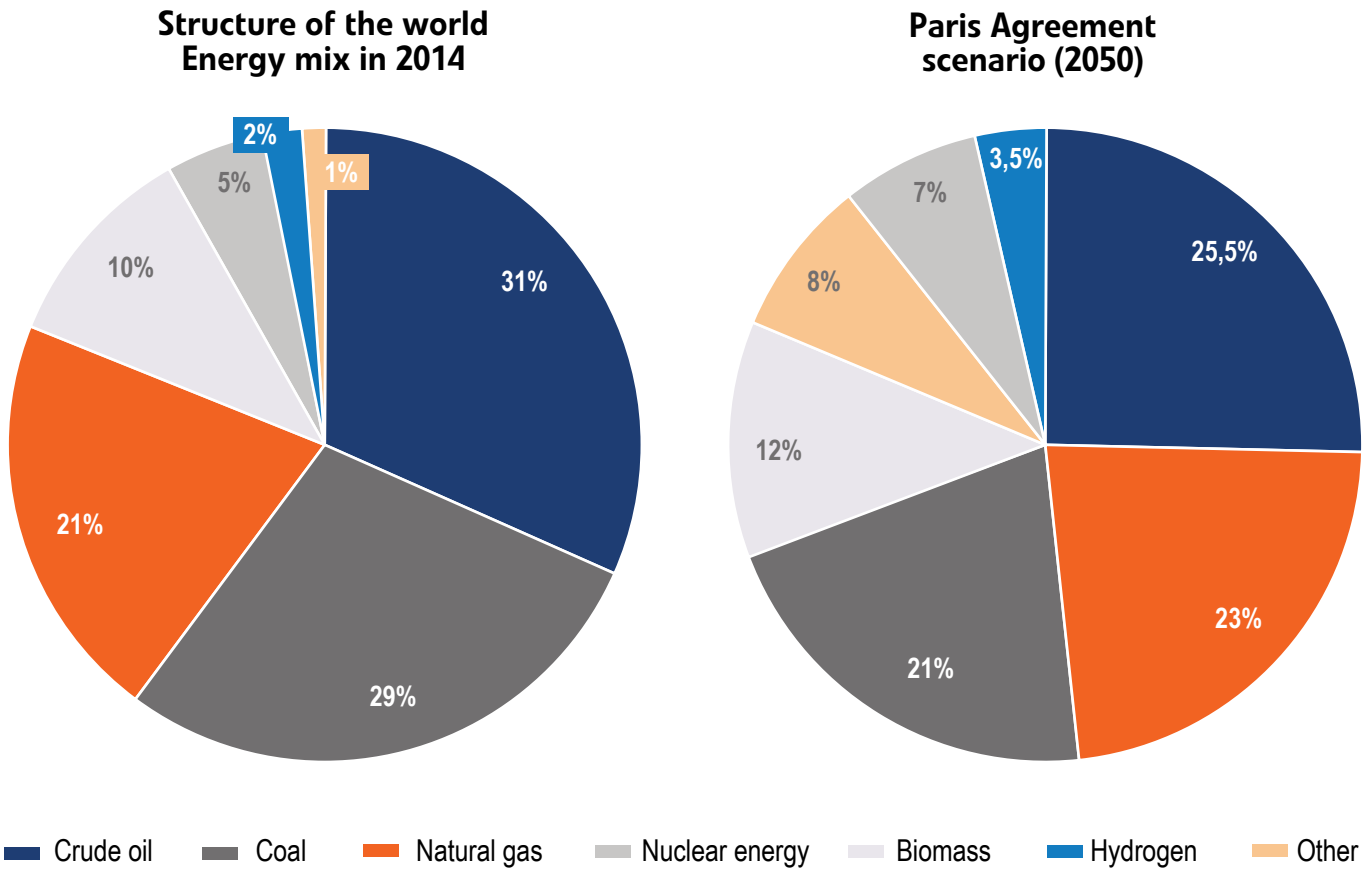
Source: „The outlook for the oil and gas industry in 2019" DNV GL

Entities from the Polish energy sector also engage in many actions aimed at achieving low-emission goals. For example, PGNiG promotes natural gas as a method of achieving clean air. Natural gas is a relatively cheap and safe fuel, which contributes to the development of a sustainable economy in the future and addresses the assumptions of the Paris Agreement. The production of electricity from natural gas leads to virtually no sulphur dioxide or dust emission.

Scanty amounts of nitrogen oxide appear in the combustion process. Therefore, companies in the PGNiG Group pursue a number of programs encouraging customers to use gas. Apart from educational and information programs, subsidizing stakeholders who are interested in replacing their sources of energy from fossil fuels to gas,[13] or performing anti-smog actions, public transport fuelled with gas is also developing (CNG, LNG).

Contemporary environmental challenges are a characteristic driver for innovation. One does not have to look far: the Austrian concern OMV is planning to spend approx. EUR 500 million for innovative energy solutions by 2025, which are to contribute to achieving low-carbon emission goals. A research and development project called ReOil will be completed with these funds, which stipulates the use of plastic waste to produce synthetic oil.[14]

Chart 8: World energy mix in 2014 and forecast for 2050 according to the scenario adopted during the United Nations Conference on climate change in Paris in 2015



Source: „Energy Technology Perspectives 2017" IEA

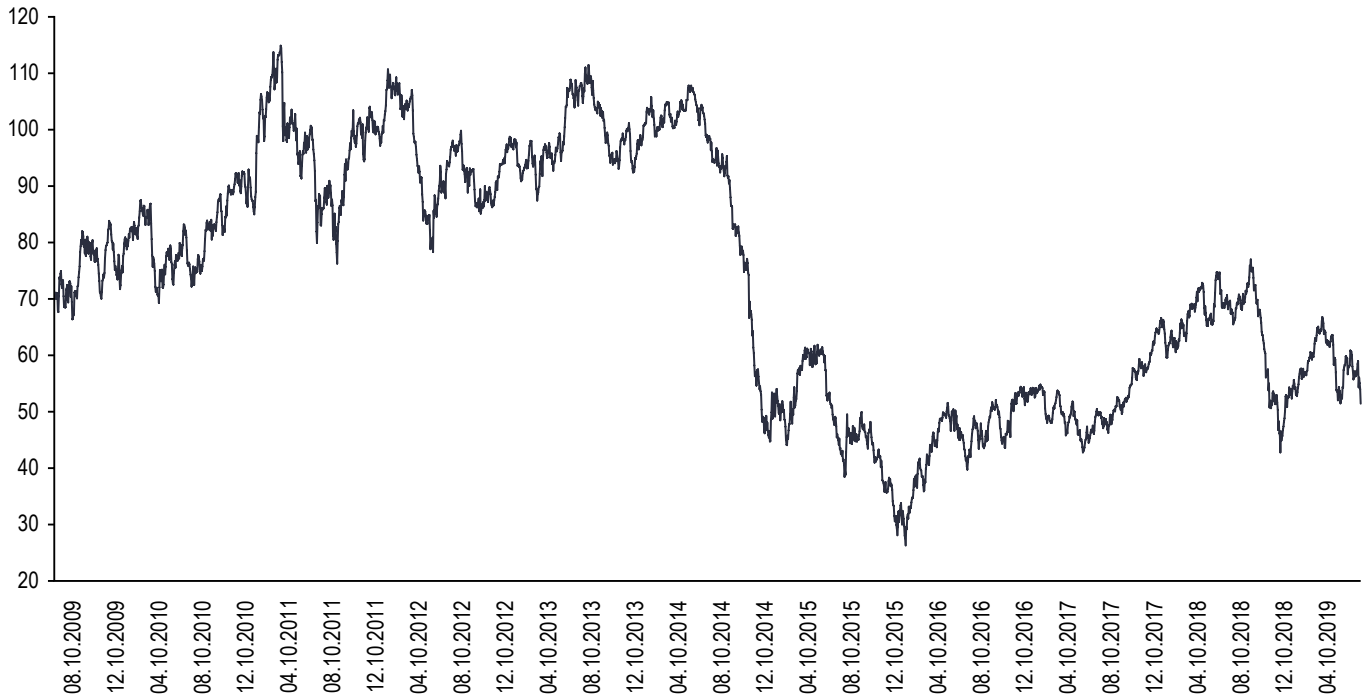
2. Instability of commodity prices

One of the most characteristic features of the energy sector is its very high dependence on the prices of commodities such as gas and oil. A sudden drop in oil prices has more than once led to an imbalance in the entire sector. One example is 2014 (chart 9), when WTI oil prices dropped suddenly over two quarters from approx. USD 105 /bbl to approx. USD 45/bbl. This had a drastic impact on those producers who – in order to maintain their profitability – had to significantly reduce their costs. In particular, this affected research and development activities and the more risky exploration projects for new deposits. Currently, one of the key actions among producers, aimed at diversifying risk related to commodity prices, is searching for and creating new business models. The new business areas developed in the future may become an alternative to the mainstream operations and an additional source of revenue, thereby stabilizing the position of the enterprise. Therefore, among the representatives of the sector, increasing interest in new solutions and innovative technologies outside their core operations is discernible. One of the most attractive areas relating to the diversification of revenue sources are the investments in renewable energy sources. Shell is an example – under its program "Shell New Energies" it purchased a block of 43.83% shares in Silicon Ranch Corporation, which owns and operates solar farms in the U.S.A.[15]

Apart from investing in new sources of energy, as part of diversifying its operations, entities in the sector see their opportunity in the area of ecological transport solutions. This can be confirmed by British BP Ventures investing in an American startup, Freewire, which provides mobile system solutions for quick loading of electric cars.[16]

In the next few years, the development of new competencies beyond the sector's traditional area is expected, and it will play an important role in the strategies of enterprises, and enable them to become partially independent of the problem of commodity price fluctuations. It will also contribute to perceiving traditional fuel companies as modern enterprises that adapt to changes in the economy and to customer expectations.

Chart 9: WTI oil prices in the period: 10 August 2009 – 7 August 2019; in USD/bbl



Source: Macrotrends LLC

3. Reducing costs related to the exploration of new deposits and excavation

Cost reduction in the area of prospecting and mining deposits has invariably been one of the most important issues in the industry over the past few years. Between 1999 and 2013 the average capital expenditure needed to mine for one barrel of oil has been growing dynamically at a CAGR rate of 10.9%.[17] However, after the crisis of 2014, related to significant drops in oil prices, sector companies changed their approach to expending funds on the exploration and excavation of new deposits and focused on cost optimization of the entire process.

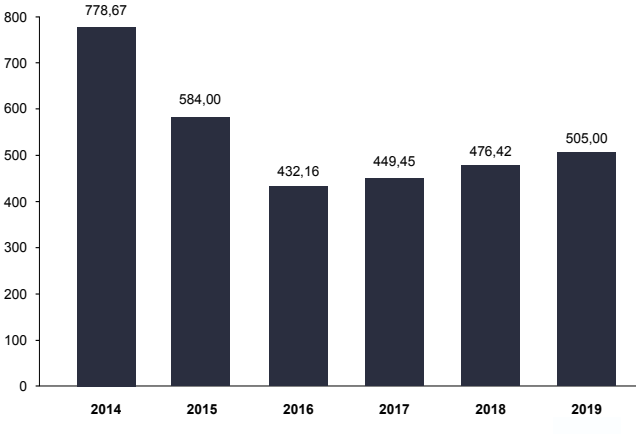
It follows from IEA data dating from 2019 (chart 10) that the forecast global capital expenditure related to the whole upstream industry will exceed USD 505 billion – a 6% increase compared with 2018; however, this result is over USD 200 billion lower than in the record year 2014.[18] Therefore, the sector is at a point where on the one hand a gradual increase in capital expenditure has been observed since 2017 and, on the other hand, the issue of cost optimization remains one of the most important factors in upstream operations.

Such a state of affairs causes the sector to seek solutions, through innovation, which will enable further cost optimization of the most cost-intensive and risky areas of production activities.

The best chance of reducing costs is perceived in the use of state-of-the-art digital technologies. For example, since 2016 Maersk Drilling in collaboration with GE have been working on a project consisting of the implementation of a comprehensive digital solution covering, among other things, a digital twins concept, i.e. creating digital counterparts of key drilling equipment. The optimization of fixed assets management should, according to the program – as a result of an in-depth analysis, lead to a 20% reduction in maintenance costs related to the drilling process.[19]

Other projects are also being developed which will enable faster and more effective completion of the processes related to exploration and excavation. The HyperSciences startup, which developed hypersonic drilling system technology enabling the speeding up of the deposit penetration process even ten-fold compared to conventional methods[20] is an interesting example. The company was noticed and financially supported by Shell and NASA.[21]

Chart 10: Global capital expenditure in the upstream part of the energy industry in the years 2014–2018 and a forecast of the values in USD billions in 2019



Source: "World Energy Investment 2019" IEA 2019

Key challenges related to the European energy market

The energy sector in Europe is facing greater challenges than enterprises from other continents. It seems that two factors will determine the innovation actions of entities operating on the European market.

1. EU regulations

The European Union is a global leader in terms of striving to create a low-carbon economy, and completely climate-neutral by 2050, which has a significant impact on the operations of the energy industry in the region. According to the Energy Union strategy of 2015, the five main pillars comprise, among other things, promoting energy efficiency and energy saving, decarbonization of the EU energy mix, and research and development.[22] In its key strategic documents, the European Union stipulates achieving goals which far exceed international standards in respect of environmental protection. The current approach to the climate and energy policy stipulates the achievement of such goals by 2030 as: limiting greenhouse gas emissions by at least 40% (compared with the 1990 level), increasing the share of energy from renewable sources in the total energy use by at least 32% and increasing energy efficiency by at least 32.5%.[23] Comparing these goals to the assumptions of the 2020 Climate Package,[24] a distinct tightening of the European Union's requirements can be seen with regard to the climate goals set for Member States. For example, until 2020 the goal was to achieve a 20-percent share of renewable energy in the total use of energy in the EU, and by 2030 it is to be 32%, as mentioned above. The goals for 2030 may be further tightened as a result of new, ambitious goals in the area of a further reduction in greenhouse gas emissions adopted by selected EU countries and the European Commission.[25] Moreover, countries such as France and Greece are already announcing that they will adopt tighter aims in respect of using energy from renewable sources to 33 and 35% respectively, which exceeds the Community's aims.[26]

However, these goals may be a significant challenge for some of the Member States, and difficult to achieve without additional support from EU funds, which may help to accelerate the transformation in countries whose RES are less developed. Such ambitious aims also translate directly to the energy industry, which must adapt to the new reality and invest in new technologies.

In the long-term time horizon, the implementation of further, even more restrictive regulations, is planned. In November 2018 the European Commission presented a strategic vision of the European Union as modern, competitive and climate-neutral by 2050. The vision covers almost all aspects of EU policies and is compliant with the aim of the Paris Agreement, i.e. maintaining temperature increase significantly below 2°C and attempting to lower this increase to 1.5°C.[27] In the context of the possibility of achieving this ambitious aim by 2050, the EU indicates eight comprehensive scenarios which assume the use of differentiated, innovative technologies and systemic changes for the purpose of decarbonisation.[28] From the perspective of energy sector companies, selection of the technology lines that will be promoted and supported by the EU will have a huge impact on the business. The scenarios and lead technologies under consideration include electrification, hydrogen, technologies related to energy efficiency and circular economy, or solutions similar to P2X[29] and CCS.[30] Therefore, enterprises which are already developing their operations in the area of hydrogen technologies may gain a significant competitive edge if the EU selects hydrogen as the key fuel of the future. This is one of the reasons why it is important to retain technological neutrality of sorts in the whole of the energy sector. If some selected technologies and energy sources are promoted at the expense of others (on the assumption that they have a comparable effect on the environment), the part of the enterprises that does not manage to adapt to the new market realities may suffer.

It should also be pointed out that energy transition should be carried out in stages, to ensure any further necessary support for low-carbon energy sources, which must continue to be used until e.g. unstable renewable energy sources are in balance, when the transition to new, ecological fuels will be possible (this requires increasing the

energy storage capacity). Sudden cut-off from traditional energy sources could have drastic consequences not only for enterprises in the energy sector, for the economy, but also for the population as a whole due to the cost of access to fuels, power and heat. There is a risk of upsetting energy security and an increase in energy poverty.

Irrespective of the decisions regarding the future, from the perspective of the operations of energy sector enterprises it should be stated that EU regulations are forcing them to adopt at a decidedly faster pace of change. From a short-term perspective this leads to the need to increase expenditure on the reorganization of operations conducted to-date, to improve the effectiveness of operations and adapt to the regulations, which may have an unfavourable impact on margins. Cases are already being reported of enterprises deciding to transfer a part of their business to other regions of the world, where the environmental laws are not as stringent. However, we should emphasize that a faster pace of changes build a better competitive position for European entities on a global scale in the long-term perspective. Restrictive regulations naturally enforce faster and more robust investments in European firms from the sector, in order to create innovative solutions that could help them address the regulatory requirements and meet the expectations of the public.

2. Distribution and transport of commodities

Due to its location and deposits of raw materials, the excavation possibilities of particular European countries are significantly limited. An analysis of the statistical data shows that in 2017, the EU's energy dependency rate was 55%, which means that more than half the EU's demand for energy was satisfied with net imports, which mainly comprised natural gas and oil.[31] This leads to a situation whereby the distribution and transport of commodities play a very important role in the context of energy sector operations, and – more importantly – in the energy security of particular European countries.

Most significant challenges faced by the Polish energy sector

Similarly to other European countries, Poland also has its own, specific strategic challenges related to the energy market. Based on observations of the Polish market we can indicate a few of the most important challenges which will shape the trends and development of the Polish energy sector in the foreseeable future. These challenges are reflected in the Polish government's strategic documents, such as e.g. "Strategy for Responsible Development up until 2020 (with a perspective to 2030)"[32] published by the Ministry of Development or the document "Directions of Energy Innovation Development" published by the Ministry of Energy. One of the most important documents shaping Polish energy strategy will also be the National Energy and Climate Plan for the years 2021–2030, which should reproduce the EU's strategic energy goals up to 2030.

1. Problem of the shape of Polish energy mix

The composition of the energy mix is one of the most important issues that the Polish energy sector will have to handle. From the perspective of the European Union countries, Poland is the sixth largest energy sector, and despite this, it is one of the least energetically diversified European countries.[33] According to data of Polskie Sieci Elektroenergetyczne (Polish Transmission System Operator – PSE) dating from 2018 (chart 11), the current energy structure of Poland is based mainly on coal, which is responsible for nearly 80% of Polish energy production, with an 8.6% share of renewable energy sources, 5.8% share of natural gas and 6.1% of other sources. This shape of the Polish energy mix gives rise to a series of problems and challenges, therefore, in the 2030 perspective, significant changes are planned in the structure of the energy commodities consumption.

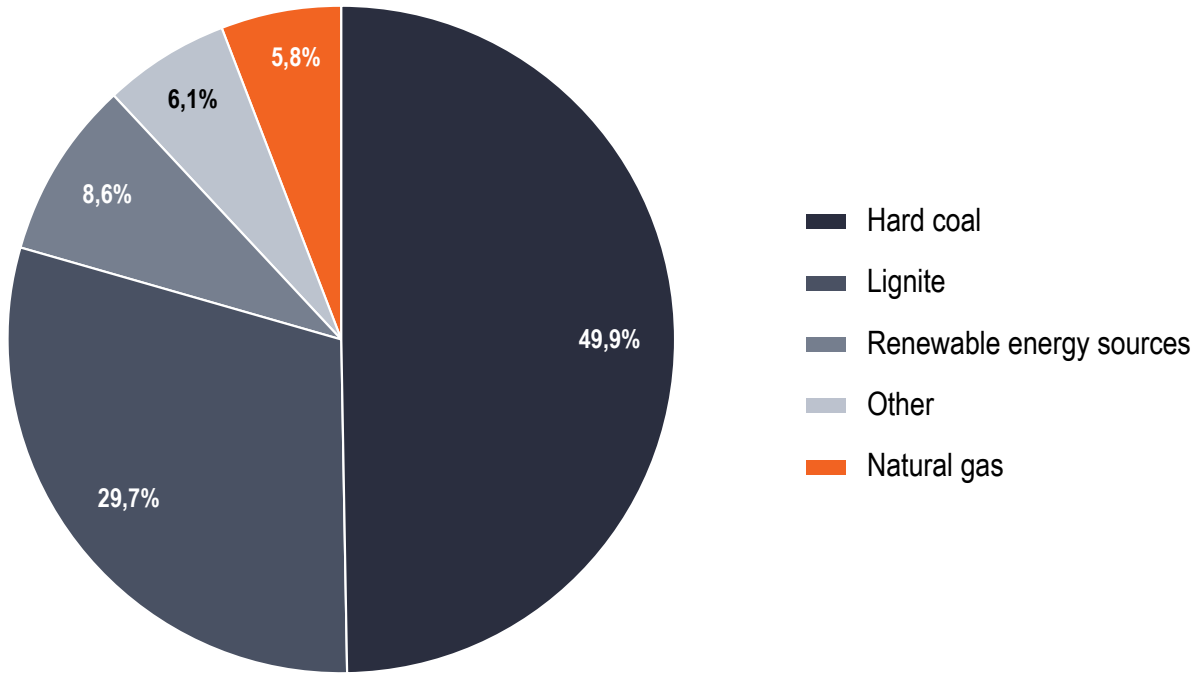
It follows from the publication of the draft document of the Ministry of Energy "Energy Policy of Poland until 2040", that a significant change is planned in the Polish energy mix in the next 10 years. Forecasts show that in 2030 the share of coal in the production of electricity will still dominate over other commodities; however, compared with the current situation its use will drop by nearly 20%. At the same time, the lack in power capacity will be replaced with energy installations using RES and natural gas.

In this context, several actions are planned which should contribute to achieving the energy aims set out above, including, among other things:

- support in acquiring and using energy from new sources (among other things, gas from the Norwegian continental shelf, LNG, stable RES);
- insistence on the promotion of local RES-based projects in the form of energy clusters or energy cooperatives;
- developing the idea of the prosumer as a material RES energy-producing component;
- implementing a smart grid, which will enable integrating all the participants of the energy system.

From the perspective of enterprises operating in the Polish Energy sector, adapting business models to the above energy goals will be a key development factor.

Chart 11: Share of individual energy sources in overall energy production in Poland "Polish energy mix" in 2018 [%]



Source: Polskie Sieci Elektroenergetyczne

2. EcoMobility as a method of improving the energy mix in transport

The development of e-mobility is one of the flagship areas of the Strategy for Responsible Development. In this respect e-mobility should be understood as the whole of the area related to vehicles powered by energy sources such as electricity, gas and hydrogen. The idea relating to the development of e-mobility in Poland is the wish to conform to international trends in respect of the transition of commodities used in the transport sector. An important aspect of the program, related to the development of e-mobility, from the point of view of the energy sector, is that it is a comprehensive program providing for several initiatives, such as the development of the infrastructure, integration of the power grid with various types of vehicles and the creation of the concept of Polish vehicles from the "e" segment. What is important, is that the program covers the development of technology for alternative fuels, such as LNG, CNG, and hydrogen.

For enterprises from the energy sector, the program for developing e-mobility is an excellent chance to create new areas of competence, which in consequence could enable diversifying sources of revenue in the long term.

One example of the projects related to e-mobility by Polish representatives of the energy sector is the one being carried out by the PGE Group. The PGEmobility project has been in progress since 2017 and is aimed at testing and implementing innovative solutions related to electric cars. Currently the project covers both the infrastructure for charging electric cars and a car sharing scheme.[34]

PGNiG, on the other hand, is putting its bets on mobility based on natural gas. More and more public transportation vehicles in Poland are powered with CNG (Compressed Natural Gas). According to PGNiG Obrót Detaliczny, in the foreseeable future 500 ecological CNG-powered buses in total will be operating on Polish roads. By 2023 it is estimated there will be more than one thousand.

3. Energy transmission and storage

Alongside commodity diversification, the storage of energy and its transmission is currently one of the major problems which the Polish energy sector will have to resolve in the foreseeable future. The ancient transmission infrastructure, both in terms of the power grid and the gas and heating grids, leads to large energy losses during distribution to customers, which contributes to a reduction in energy-efficiency throughout the country.[35] In addition, the low degree of gasification in rural areas and the small number of energy storage points have a negative impact on the stability of the Polish energy system.

One of the strategic goals indicated in the most important documents relating to the development of Poland's energy sector is to resolve these problems. They may be addressed via several projects related to the modernization and construction of new grids and energy-storage development projects.

The power system still has no satisfactory solutions in respect of energy storage. On the other hand, due to their specific nature, renewable energy sources cause additional imbalances in the system. Storing energy in the form of hydrogen or synthetic gas, which can be injected into the gas systems, is considered a new and prospective manner of storing energy in the long-term. In both instances, the gas sector is directly involved in implementing the new solutions. PGNiG, among other things, is analysing solutions relating to the production of hydrogen from RES in the periods when energy is relatively cheap, and then injecting it into underground gas storage points or storing it in the form of hydrogen in the gas system. Hydrogen stored in this manner can be transformed into energy at any place and any time. This opens up possibilities of a new and attractive business for PGNiG, related to the storage and distribution of hydrogen.

Another challenge for the Polish energy sector related to storing and transmitting energy is the issue of developing distributed power generation and the related idea of prosumers (i.e. customers who both produce and consume energy). Although the prosumer segment has been developing worldwide for years, Poland is at the very beginning of building an economic environment for such solutions. Distributed supply generated by prosumers has to be properly managed, and this is only possible after adapting the respective infrastructure. This in turn is one of the key challenges faced by the energy sector in respect of the storage and transmission of energy in Poland.

4. Making use of deposits which had previously been by-passed

PGNiG drew attention to the unused potential of methane from coal deposits; methane is a natural gas, a valuable raw material and fuel, but it is also associated with a serious problem in the mining industry. Most of the methane generated in the process of coal mining is released into the atmosphere,[36] and the gas causes serious greenhouse effects, 25 times more severe than carbon dioxide.

Therefore, PGNiG in collaboration with Państwowy Instytut Geologiczny – Państwowy Instytut Badawczy (Polish Geological Institute National Research Institute) is proceeding with a multi-year program Geo-Metan,[37] the aim of which is to develop technology for the prospecting, excavating and commercial use of methane from coal deposits. This is the first project of this type in Europe, and the experience gained from the project is unique on a global scale.

The project focuses on commercializing methane for energy generation, limiting its release into the atmosphere and at the same time improving the safety of miners. PGNiG readily shares the knowledge gained during the Geo-Metan project – it is the co-founder of the Międzynarodowe Centrum Doskonałości w zakresie Metanu z Kopalń Węgla (International Center of Excellence on Coal Mine Methane), acting in cooperation with the United Nations Economic Commission for Europe.

5. A circular economy

The idea of a circular economy (CE) is a concept aimed at the rational use of resources and limiting the negative impact of the goods produced on the environment; those goods, similarly to raw materials and materials, should remain in the economy as long as possible and waste should be minimized. The action plan in this respect was approved both at EU level and by the Polish Ministry of the Environment.

Adapting the operations in the sector to the idea of a CE is challenging, but it also opens up new business possibilities. Enterprises operating in the sector have already noticed the economic potential of recycling and reuse of materials or resources. The idea of a circular economy in the energy sector also enables lowering the intensity of carbon dioxide emissions (which is produced in the utilization of used materials), and contributes to creating new business models and establishing enterprises specializing in recycling for the energy sector.

One of the visible trends in CE in the energy sector is using the idea in the process of liquidating oil rigs. In this context, projects are carried out relating to reuse of the equipment and pipelines used on the defunct rig, e.g. by transferring them to other platforms which are still operating. The processes related to the relocation of whole oil rigs are an example of the implementation of the CE idea in the energy sector its most extended form. The planned relocation of an oil rig from the Ophir oil field to the Jitang field in Malaysian waters is an example of such a process.[38] On the energy market there are specialized entities that offer comprehensive support in the oil rig liquidation process, in accordance with the idea of recycling, such as, Aqualis Braemar or Perenco.

The aspect of waste management, in particular post-production water, is also related to CE. Processes related to gas and oil extraction require the use of hectolitres of water. To meet the requirements of environmental regulations, businesses must engage in processes related to the purification of used water. Therefore, a technology development trend is visible which would enable more effective purification of post-production water, which would enable it to meet environmental standards and be fit for reuse. One example of a project which – on the one hand – enabled meeting the environmental standards – and on the other – contributed to the development of the local community, is the Shell QGC project. Under the project the water that was obtained in the LNG production process is filtered, and then delivered to the local community, and can be used for watering fields or for use in cities.[39]

The production of plastics, which requires oil refining products, is also an important issue. To aspire to achieve the CE goals, businesses are trying to find new plastic recycling possibilities. The ReOil project of the company OMV referred to above may be an example, as well as BP's project conducted together with Vierent and Johnson Matthey, aimed at creating a renewable plastic based on bio-paraxylene.[40]

6. Energy efficiency potential

The EU's ambitious goals regarding energy efficiency referred to above require implementing systemic actions, as a result of which measurable effects will be achieved in the form of savings in all forms of energy (electricity, natural gas, heat, cooling, etc.) through the comprehensive control and optimization of the energy management process in enterprises. Here, innovative technologies may help.

Actions taken by PGNiG Termika Energetyka Przemysłowa S.A. are one of the examples of pursuing energy efficiency premises. For many years, the company is a leader in the use of methane from demethanization mines for the purpose of producing electricity, heat and cold in co-generation for the purposes of the Jastrzębska Spółka Węglowa mines and the citizens of Jastrzębie-Zdrój (registered office of Jastrzębska Spółka Węglowa) and the vicinities. Annually, the company uses over 70 million m^3 of methane from in-mine demethanizing for energy. This results in a significant reduction in the amounts of methane that are released into the atmosphere, and thus a lower emission of carbon dioxide at a level of 900 thousand tonnes per year.

The issue of using heat from waste is related to the issue of cogeneration of power and heat (CHP – Combined Heat and Power). In power producing systems based on the fuels burning processes, heat is nothing other than a by-product in the production of power. In Poland actions related to the production of power in cogeneration are performed, among other things, by PGNiG Termika in Warsaw. The company engages in capital expenditure projects building modern gas and steam units for producing power and heat in cogeneration. The Żerań Heat and Power plant is an example of such activities.

3

Innovative technologies for energy

New technologies in the energy sector

New technologies have always been a driver of the energy sector. The largest enterprises in the industry have outstripped each other in finding new solutions enabling faster and more efficient excavation of raw materials. By the end of the twentieth century entrepreneurs were engaging in new technologies focused mainly on specialist solutions constructed for the purposes of the energy sector. The situation has not changed with the progress of the digitization of the whole economy. Entities from the energy sector saw the potential of using technologies from outside the industry's specialist area, including various types of digital technologies. In the modern world technologies know no boundries, including sectoral ones.

Below is a presentation of the technological areas which, in the foreseeable future, will have a significant impact on the further formation and development of the energy sector, and where key efforts related to widely-understood innovative activities will be focused.

1. Industry 4.0 – the new face of industry

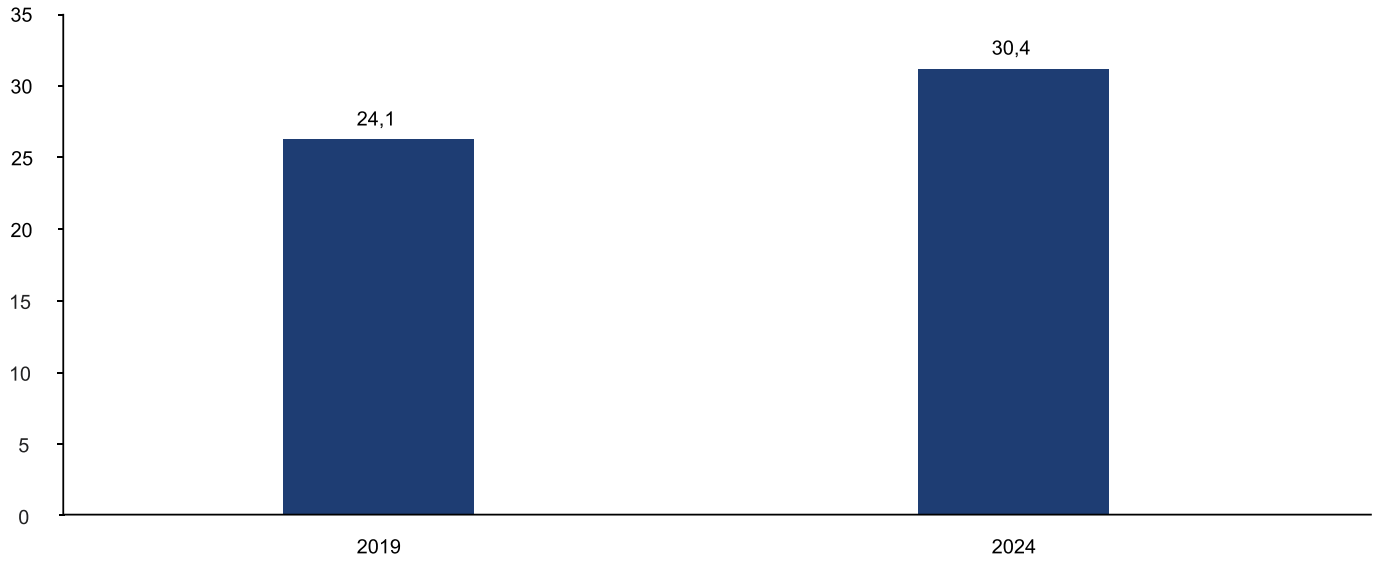
The fourth industrial revolution, the so-called "Industry 4.0" touches upon nearly every sector related to industrial production. The idea is based on the use and integration of various digital techniques, such as: Internet of Things (IoT), Big Data, intelligent sensors or Augmented Reality (AR), to automate production process in a comprehensive manner and transfer part of the decision-making process to the level of Artificial Intelligence (AI).

This important trend in industry could not have had no impact on the energy industry. It follows from the research conducted that 45% of all industry experts believe digitization will be the key priority, in terms of capital expenditure and R&D expenses in 2019.[41] From the perspective of firms which operate in the sector, Industry 4.0 is a trend that is visible in all industry segments – from exploration and excavation through the transport of raw materials to the refining process. Therefore, thanks to the transition of current processes with the use of Industry 4.0 technology, entrepreneurs from the sector will have a chance to optimize most areas of their operations to-date.

Capital expenditure projects that have already been completed by the largest international players from the sector can attest to the scale and significance of the trend. In 2017 the Norwegian giant Equinor (previously Statoil) informed it had earmarked almost one billion US dollars for the comprehensive digitization of the organization by 2020, which was to include the digitization of production processes, implementation of advanced techniques for data analyses, and implementation of robotics and remote operation of the company's key operational systems.[42]

Currently, one of the most important areas for using Industry 4.0 in the energy sector are excavation and production, where solutions such as Digital Oilfield have appeared. The Digital Oilfield concept combines the management of business processes with digital technologies to automate processes so as to maximize efficiency, reduce costs and minimalize the overall risks related to gas and oil production. This term can be treated as one that aggregates various technological areas such as: advanced digitization of the production area in the energy sector using specialist software and various techniques for analysing data with the use of, among other things, AI, IoT and Big Data. It is estimated that by 2024 the global market for solutions such as Digital Oilfield will grow to a value of USD 30.4 billion, which is over 26% compared with the forecast value of the market for 2019 (chart 12).

Chart 12: Forecast value of the global market for solutions such as Digital Oilfield in USD billion

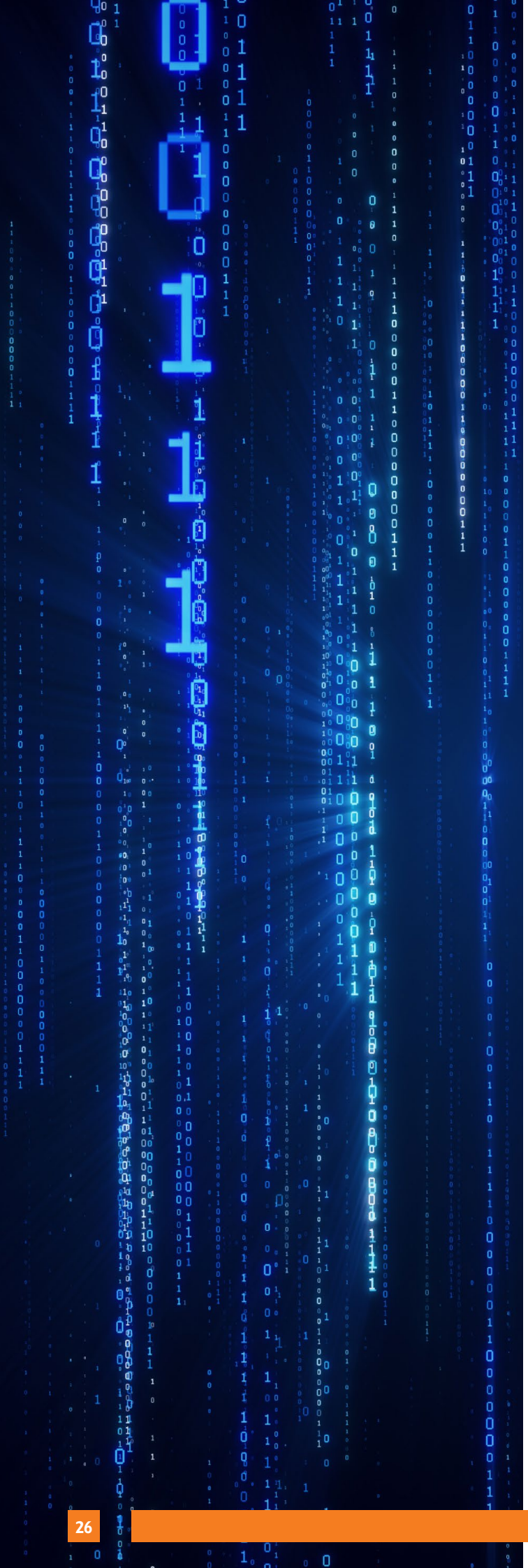


Source: „Digital Oilfield Market" MarketsandMarkets

On the global energy market increasing pressure on developing such comprehensive solutions can be observed. The joint BP and GE project is an example and has resulted in the creation of the Plant Operations Advisor (POA) platform – a digital cloud solution enabling BP to manage four production platforms in the Gulf of Mexico. Ultimately, the system is to include all BP platforms in the world.[43] Furthermore, the fact that the respective services have been implemented in the portfolio of firms engaged in designing and servicing production installations, such as, e.g. Halliburton, Schlumberger or Weatherford, also attests to the importance of Digital Oilfield.

The Integrated System for Managing Oilfields (Zintegrowany System Zarządzania Złożem) project, which supports the optimization of PGNiG's extraction activities, digitizing industrial processes, is an example of a solution of this kind on the Polish market. Specialists such as geologists, oilfield and production engineers, and economists, participate in the process of exploring and excavating deposits. In each of these specializations vast amounts of data are independently developed, collected and used. The "Digital Deposit" ("Cyfrowe złoże") platform integrates the results of the work of specialists from different areas into one deposit model, at the same time facilitating optimal use of the data. This digital model enables, among other things, simulating various excavation scenarios from several deposits at the same time, increasing the accuracy of forecasts, optimizing the drilling program, analysing the effects of planned investments (CAPEX) and optimizing the use of energy (OPEX), as well as supply chains.

The fact that enterprises are beginning to create and accumulate a new type of resource – data – is the inevitable effect of the growing digitization and development of Industry 4.0. If the most current data describing the state of processes has always been the most important for basic use, it is historical data that is now gaining increasing value in more advanced applications. Data which can be used e.g. to create a predictive model regarding the failure of equipment, optimization of excavation processes, virtual prospecting for natural deposits, etc. In traditional industries enterprises still have limited knowledge about the data they possess, how they can use it and what its potential value. This will, of course, change with time, and for the most active and efficient firms in the sector, data and services based on data may even become a new line of business. To think of exploration and the actual use of this newly-built value, firms must face several new challenges and tasks related to awareness in their approach to data, information and knowledge management, implementing e.g. processes and solutions such as Data Governance.



2. Advanced technologies, i.e. IIoT, Big Data and Artificial Intelligence in the energy sector

Insofar as the idea of Industry 4.0 constitutes a type of umbrella covering the effective integration of many advanced digital technologies, a part of those solutions constitute technological trends which in themselves are important for the sector. This covers in particular technologies related to the Industrial Internet of Things (IIOT), Big Data and Artificial Intelligence, which increasingly addresses more problems identified in the energy sector.

The term IIoT relates to networks of interconnected smart sensors and analytical tools, which make production processes more efficient by using current data and steering in real time. The development of the IIoT market is stimulated not only by business requirements but also by the development of innovations in sensors and telecommunication technologies. New communication standards, including 5G, continue to better address the requirements put before IoT by enabling the operation of a larger number of devices, improving the quality of the transmitted data and reducing the demand for energy and in consequence, extending the lifetime of the devices. In 2018 it was estimated that more than 1.3 million devices which used IIoT were operating in the energy sector and that by 2023 this number will be nearly 2 million,[44] thereby confirming the huge significance of this technological area in the industry. IIoT is already bringing about notable results for energy sector entrepreneurs. Chevron, which in collaboration with Microsoft and Emmerson initiated a pilot program for using wireless IIoT sensors on some of the heat exchangers used in production processes is an example of such use. The solution used enables monitoring in real time and predicting the actions of individual exchangers.[45] IIoT is also an interesting area of investment for energy sector entrepreneurs, which is confirmed by the fact that from 2013 to 2017 only 12 corporations in the energy sector completed a total of 35 investments in IoT firms of a total value of USD 575 million.[46]

Big Data is an area related to analysing large sets of data. From the perspective of the energy sector, the Big Data aspect is the basic area of development about which enterprises can make effective decisions regarding their operations based on a wide spectrum of dispersed data. This relates to many aspects of the business – from analyses related to seismic data, through analyses of data collected during the production process, to logistics data. The benefits of using Big Data in the energy sector are discernible in the example of the collaboration between Repsol and Google Cloud in optimizing the operations of the Tarragona refinery. The project assumes digital integration of more than 400 variables, which will be used to manage the operations of the refinery. It is estimated that the completion of the project could translate into savings of up to USD 20 million per year.[47]

In the energy sector the topic of AI is related to several particularly popular areas, which include, among other

things, machine learning. This type of technology is used to simulate the influence of new investment projects on the environment, or to monitor complex production processes. Other uses of AI include: robots equipped with AI used to explore and excavate raw materials, enabling an increase in the efficiency and profitability of the process, while simultaneously reducing the risk of the human factor. It is interesting that in the area of AI, entrepreneurs from the energy sector readily cooperate with startups. At the beginning of 2019 BP Ventures invested GBP 5 million in the Belmont Technology startup which had a cloud geoscience type solution based on AI technology, which enables creating special charts based on historical data, that significantly facilitate the interpretation of various types of data.[48]

3. Hydrogen revolution

Hydrogen technologies constitute an area which, in the foreseeable future, will play an important role in the development of the whole energy sector. Currently approx. 70 million tonnes of hydrogen are used annually worldwide, mainly to refine oil and in chemical production.[49] However, hydrogen is currently produced mainly from fossil fuels, which leads to a large carbon footprint. Therefore, the future must depend on "clean" hydrogen which can be produced e.g. in the electrolysis process – a method that does not lead to negative effects related to CO2 emissions into the atmosphere. This method uses temporary excesses of electricity which usually occur in renewable energy (i.e. wind, solar energy). In such situation the cost of energy is very low, and its collection is often a salvation for the power system, which finds excess energy a huge problem. In this situation the production of hydrogen can be economically profitable even using an energy-intensive method such as electrolysis. In Poland research work aimed at developing a modern technology for producing hydrogen from renewable energy sources using the electrolysis method[50] has been conducted by PGNiG under the ELIZA project, since 2018.

There is also another notable trend related to research on the use of hydrogen as an additive to other energy raw materials, e.g. natural gas. The GRHYD project conducted by the French government and the company Engie, consisting of adding hydrogen to the natural gas distribution grid is an example of such an activity. Currently, the hydrogen added constitutes 6% of the fuel, and according to the project, it is ultimately to constitute 20%.[51]

The modern gas distribution system creates new possibilities for cooperation between the electricity and gas networks to create a specific energy macrosystem. Currently, modern materials are used in gas grids, complex telemetry, monitoring and diagnostic systems. Although the functionalities and operating principles of the system as a whole have not changed significantly, there is no doubt that new challenges are appearing all the time, with which the future system will have to cope, and one of them will be the possibility of distributing through the gas grids gases with a more diversified composition (e.g. natural gas with the addition of hydrogen), or a larger variability in connecting and disconnecting new sources of gas. The new gas grid will have to be more dynamic and able to operate in changing work and environmental conditions.

PGNiG, as a gas company, has the appropriate potential to inject and store hydrogen. The gas systems themselves can be perceived as being powerful energy storage places. The average gas system in a European country has an estimated capacity of several dozen and more TWh. Salt caverns are also an interesting potential place for storing hydrogen. Such storage facilities are characterized by a very high gas injecting and distributing power compared to the working volumes. In addition, these storage facilities require large overground structures, and building such installations is far cheaper and quicker than building classic gas storage facilities, and they are easier to monitor and service. Gas storage in salt caverns can inject and distribute gas many times during a year. They are also relatively safe in terms of leak and seal integrity.

Developing work on fuel cells and widely understood transport is an important technological area. In the longer term, vehicles based on hydrogen solutions are expected to drive vehicles with batteries out of business, in particular this refers to heavy transport, where vehicles are expected to cover long distances and have short loading/fuelling periods.

The map of the development of hydrogen technologies created by South Korea – one of the largest car manufacturers in the world – assuming that by 2040 hydrogen-powered Fuel Cell Electric Vehicles (FCEV) will reach 6.2 million – attests to the significance of those technologies for the future of world transport.[52]

In the context of the further development of hydrogen technologies, building a whole value chain, including in particular the parts responsible for hydrogen consumption, to balance supply and demand will be crucial for the sector.

4. Development of technology around LNG

Liquefied Natural Gas (LNG) is a type of fuel that is becoming more and more important in the global and national energy mix, which is drawing particular attention in innovation development. This follows from the material advantage of LNG over other fossil fuels, and in particular:

- low environmental impact – LNG is a fuel which does not generate harmful dust or smoke when burning, and CO2 emissions are 30% lower than when burning heating oil or coal;
- many possibilities for use – LNG can be a traditional fuel for producing energy in large-scale power plants, it can fuel small energy installations of local entrepreneurs, it can also be used as a fuel for combustion engines in road, rail and water transport.

These merits had resulted in increased interest in LNG. This trend is confirmed by forecasts which indicate that LNG production will reach 630 million tonnes a year by 2050, almost three times more than in 2016.[53] Technological areas related to LNG, on which development work will focus in the foreseeable future, include in particular:

- FLNG (Floating Liquefied Natural Gas) technologies, which enable producing LNG at sea, directly over an offshore gas field, enabling a reduction in the costs of LNG production by as much as 50%;[54]
- technologies related to transport, covering both fuelling infrastructure, and creating more efficient LNG vehicles.

The development of LNG technology is an impetus for developing gas mobility, which could be an alternative for electric vehicles, in particular in heavy transport. This trend allows firms in the sector to develop new business models, addressed both to individual and institutional customers.

Since liquefied natural gas enables meeting the restrictive requirements of the International Maritime Organization (IMO), both ports and ship producers are looking at technologies that enable the use of LNG to propel ships. It is worth noting that in the spring of 2019 in the port of Gdynia one of the first commercial ship bunkering operations in Poland took place with LNG provided by PGNiG.

In Poland in particular the development of the LNG gas segment, similarly to the case of hydrogen technologies, requires – among other things – a wise operating strategy, integrating the efforts of key players and consistently building the whole value chain.

Energy transition is naturally related to other branches – the transport, machine, electronic and IT industries. The lack of action of even one industry or non-performance of a whole group of projects in the area of infrastructure, facilities and installations, or vehicles, or sluggishness in implementing state-of-the-art technological solutions could effectively slow down strategic changes in the energy sector.

5. RES technologies as a response to increased demand for energy

Currently, renewable energy sources are one of the key areas of the technological challenges in the energy sector. An analysis of renewable energy market trends shows that photovoltaic solar panels are the most rapidly developing technology, in 2018 they were responsible for 55% of total newly-installed power in terms of world renewable energy. The high attractiveness of this technological area, from the perspective of enterprises operating in the sector, is confirmed by BP's investment in Lightsource – one of the largest European producers of energy from photovoltaic panels,[55] or the initiative of the joint-venture of Total, ISE Group and SunPower aimed at creating one of the largest photovoltaic farms in Japan.[56]

A joint venture by the Australian renewable energy agency (ARENA) and Santos, aimed at powering pumps used in oil wells with energy acquired from solar panels, which in consequence will contribute to reducing emissions and production losses, giving savings of approx. 140 oil barrels a day, is another interesting example.[57]

However, solar energy is not everything. Technologies related to wind energy are important and intensely developing RES technologies. It is forecast that by 2023 the whole wind energy power used worldwide will increase by over 60% compared with 2018.[58] In this respect, projects aimed at creating wind farms at sea are particularly interesting; such farms allow building wind installations that are larger, more efficient and less onerous for society. The United Kingdom is one of the leaders in developing wind energy technologies at sea; in 2019 it established a special fund to support commercial offshore wind farm projects.[59] Wind energy is also a noticeable trend among Polish entrepreneurs, as shown by such examples as the PGE Group, which – according to statements of its representatives during the Economic Forum in Krynica, in 2019 – is to reach a level of energy produced by wind farms of 1.6 GW by 2025, and 2.5 GW by 2030.[60]

Apart from the above most popular RES technologies related to wind and solar energy, the development of other technologies for generating energy from renewable sources is visible in the energy sector. The technology for generating ocean tidal energy is one worth mentioning. This type of technology based on underwater offshore turbines allows predictability and independence from external factors due to the constant repeatability of tides; also it does not have any negative impact on the environment. [61]

In the future, geothermal energy may play an important role; currently it amounts to approx. 2% of globally generated RES energy.[62] One example of the technology developed in this area is a solution developed by Eavor Technologies, based on the concept of a closed system that uses the effect of the natural geothermal gradient of the Earth.[63] Shell is one of the partners in this project.[64]

The market activation of small energy producers, prosumers and firms that develop innovative solutions in the area of generation, distribution and storage of energy from RES is an additional RES development factor.

6. Unmanned vehicles in the sector's service

More and more often the energy sector uses unmanned aerial vehicles and autonomous land and water vehicles. This type of technology is an important and prospective area that will have an impact both on actions related to widely understood safety and supervision over various installations, and will allow optimizing and automating parts of processes which until now required engaging specialists and costly resources (such as optimization using transport drones).

Currently, the most dynamic development is observed in the Unmanned Aircraft Systems(UAS) technology, which is based mainly on drones. It is estimated that in the period from 2018 to 2025 this market will grow at a rate of 14.15% per year.[65] This trend will also leave a footprint on the energy sector, mainly due to the autonomic monitoring of infrastructural assets, monitoring of environmental aspects and the automation of audit processes. Currently many firms on the market are offering specialist drone services dedicated exclusively to the needs of the energy sector. Firms such as, e.g. PrecisionHawk, SkySpecs or My Drone Services are examples of enterprises that provide services using unmanned aerial vehicles to perform various works on installations typical of the energy sector, including e.g. monitoring chimneys, pipelines and gas flares.

In future years drone technologies are expected to support other areas related to the energy industry, including the area related to the exploration of new deposits by providing images of potential excavation sites, as well as collecting earth samples and creating 3D maps. Many projects performed by industry leaders, including e.g. a joint project by ExxonMobil and Trumbull, which has conducted drone inspections of 25 service points of ExxonMobil installations since 2014, attest to the important role of drone services in the energy sector. In 2019 ExxonMobil decided to rescale the said project to all the company's installations in the United States.[66]

Offshore excavations are becoming increasingly important for the energy sector. They necessitate developing equipment to make research and production processes in the aquatic environment possible. Therefore, apart from unmanned aerial systems, unmanned underwater devices and vehicles are being developed. This type of equipment enables performing such tasks as e.g. collecting geological samples, performing construction and repair works, monitoring the progress of projects, and subsequent monitoring of underwater installations. Previously, such actions required the use of specialist exploration ships or were impossible to perform. One of the projects conducted in this area is the Saudi Aramco project related to developing an unmanned underwater vehicle to survey the surface of the seabed and to monitor pipelines located under water to find potential leaks. According to the firm, the vehicle whose construction cost approx. USD 2.5 million, will be capable of taking over the duties of exploration ships whose value is estimated at USD 50 million.[67]

7. Smart monitoring and leak prediction systems

The transmission and transport of commodities is a very important area in the energy sector's activities. Interruptions in deliveries of gas or oil caused by leaks from the transmission pipelines are not only an operational problem, but also an environmental one. Therefore, technologies that enable more effective monitoring of transmission and potential leaks will be an extremely important element of the sector's development. On the global energy market more and more projects to address this problem are being conducted, developed both internally and externally. For example the Toku startup developed a technology based on IoT, which enables monitoring potential leaks both in pipelines and in places such as pumping stations and tanks.[68]

In the foreseeable future, the systems monitoring leaks in the sector's installations are expected to be gradually transformed into systems that not only cover monitoring, but also predict damage or potential leaks. This will enable taking failure preventive actions which will significantly reduce the costs of all types of repairs or actions aimed at removing the consequences of such failures.

8. Space technologies also supports the sector

Advanced satellite technologies are addressing the requirements of the energy sector better and better, and this does not mean just satellite communication, which has for many years been the basis for the operations of the energy sector. Satellite technologies, which are becoming increasingly important, include both technologies enabling geological analyses in terms of searching for oil and gas, monitoring positions and the condition of all movable assets based on satellite photographs, but also the prediction of failures and monitoring leaks based on on-going analyses. The modern-day possibilities of using radar satellites allow the observation of even the smallest land movements. Such solutions are already being intensely developed by specialist firms. One example is Airbus, which offers a wide range of satellite solutions dedicated to the requirements of the energy sector.[69] At the same time, nanosatellites are entering the scene. They comprise constellations of several dozen (and in the future – hundreds or even thousands) of pieces and use the technology of automatic data analysis to provide images of a quality comparable to those from large satellites.

4

Models of innovative actions undertaken by enterprises in the energy sector

In enterprises, in particular large ones, innovations are increasingly becoming a key tool that supports constant development and the achievement of strategic goals. Technological and organizational innovations are of key importance, although other types of innovations (such as process or marketing innovations) are not without significance. The scale of innovative activities depends, among other things, on the size of the enterprise, because such activities require significant R&D expenditure, access to specialist infrastructure and expert knowledge.

R&D work requires expenditure which is at risk of not giving any returns, and this is something only large players can afford. Innovative actions require a coordinated approach to managing the area, including providing a clear operating strategy, preparing the necessary tools (processes, organizational structure) and dedicating the appropriate resources. Both the literature on the subject of innovation management and practitioners indicate another significant element of this important puzzle. Without reinforcing the organization's innovation culture and without reviving employees' creativity potential, enterprises will not manage to generate and absorb innovations.

It is no wonder that enterprises from the energy sector also venture outside their previous functional models and make intensive use of innovation to ensure their stable development in the future. New digital technologies, restrictive regulations, changes in the value chain and cooperation models are forcing some to follow the path of energy transition and facilitating it for others.

Actions directed at generating and developing innovations

The simplest classification of actions dedicated to the area of innovation is the classification into the internal actions of enterprises and those performed as so-called open innovation. In the first case, only internal resources are used for innovation purposes, in the second, the enterprise opens up to external partners such as e.g. scientific entities, startups, business partners and even customers. Selecting the form of action to be taken depends mainly on the aims an enterprise wishes to achieve. Measuring strength by intentions is also important – the degree of advancement of the tools used and their forms must be adapted to the maturity of the organization's innovation culture and to the competencies of the team which is to be responsible for managing particular initiatives.

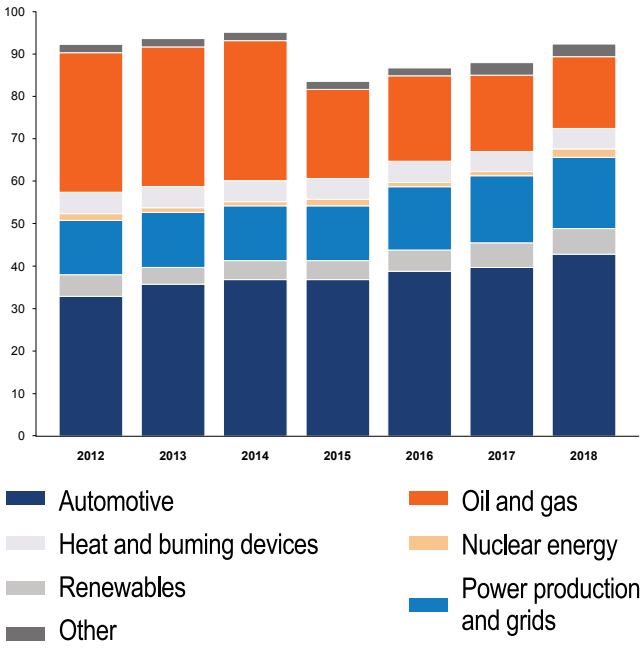
Internal R&D activities remain important for innovations in the sector

Global data shows that conducting internal R&D work is the basic trend for most enterprises in the sector. Chart 13 shows the changes in the expenses of private firm on R&D in the last seven years, broken down by energy sources. According to data from 2018, the total value of private funds spent on research and development in the widely-understood energy industry reached USD 94 billion.[70] Since 2015 a gradual increase in private expenditure on R&D has been noted. However, it is still lower than in 2014, when the prices of oil on global markets suddenly slumped and R&D expenditure related to this source of energy fell drastically. An interesting fact is that as much as 45% of private expenses on R&D in the sector comes from the automotive industry, which is investing increasing amounts on e-mobility technologies.

Global leaders on the market often own several R&D centres where work on topically diversified projects is carried out. Shell is a good example, which has its key R&D facilities in the Netherlands, the U.S.A. and India.[71] Another interesting example of R&D activities is the model implemented by Total, of so-called Prospective Labs. Contrary to the company's key R&D centres, in Prospective Labs research is conducted on future technologies which have not been the subject of the company's core operations to-date (such as nanotechnology and robotics).[72]

Projects carried out independently may be especially important when they relate to the most recent technologies related to core activities, which the enterprise wants to protect at all cost and keep secret from external entities for as long as possible.

Chart 13: Global expenditure on R&D in the energy sector among private entities in USD billion in the years 2012-2018, broken down by investment area



Source: „World Energy Investment 2019" IEA

Innovators not only from R&D departments

People employed in the R&D departments of enterprises are mainly responsible for generating and developing innovations in core operational areas. However, this is often no longer sufficient, and new value is generated by innovations from outside the area of core business activities. For energy sector companies, the activation and stimulation of entrepreneurial thinking among employees in departments such as e.g. marketing, IT or sales, may be particularly important. This is due to the fact that entities in this sector have conducted R&D work related to their core operations e.g. excavating or processing raw materials. They were not knowledgeable about the growing digitization of processes or searching for new business models. Developing new areas and the need to use modern technologies requires firms to employ specialists with competencies other than those employed before – competencies that had not yet been used by the enterprise or which none of the employees has.

There are various tools dedicated to generating and developing ideas put forward by employees, which have already been proven to work. Most often the least advanced tools are used, such as competitions for employees. In such competitions an enterprise announces for example three topics /issues which are currently faced by the organization, and employees are encouraged to put forward their ideas for resolving such issues.

However, more advanced tools are frequently used which enable the internal generation of innovations. The latter can be compared to internally incubated programs, under which an employee not only puts forward his/her idea, but is also responsible for its further development and participates in its implementation. A good example of employee innovation is Total's Best Innovators initiative. Each year the company rewards the employees who were responsible for the most innovative projects which generated value for the company. The enterprise publicly praises its innovators, announcing the best projects and the people responsible for them on the corporate website.[73]

Table 1: Key benefits and challenges for an enterprise related to the stimulation of employee innovation

Key benefits and challenges for an enterprise related to the stimulation of employee innovation

Benefits

01
Stable inflow of new ideas, translating into achieving or maintaining a competitive position

02
Stimulating the creativity and involvement of employees

03
Image of the employer as supporting innovation and the development of employees

04
Building an innovative culture in the organization

Challenges

01
Selection of appropriate incentives for the employees

02
Explaining why "as of now" the employees should be innovative

03
Developing evaluation criteria and selection criteria for the reported initiatives

04
Ensuring resources that will allow the development and implementation of the suggested innovations

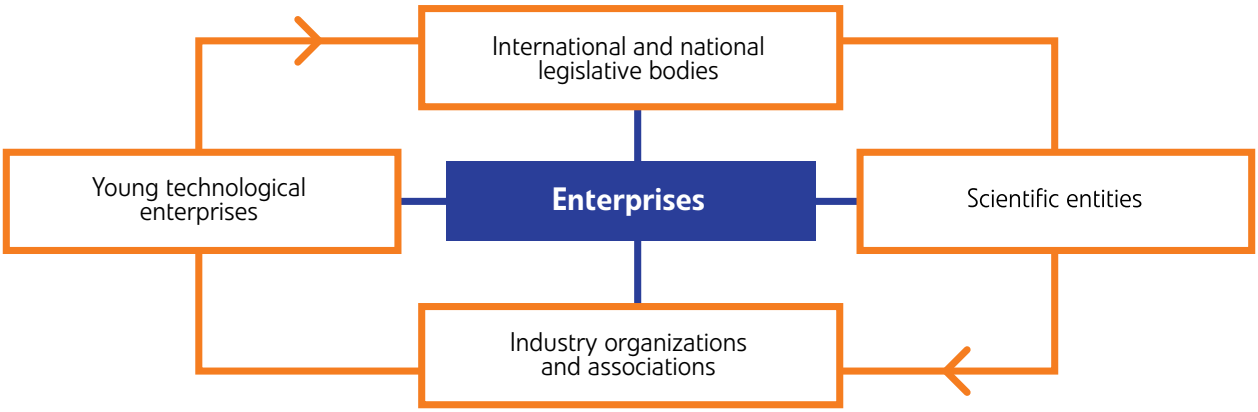
Source: PwC

Open innovation – cooperation within the ecosystem on behalf of innovations in the sector

Entities from the energy sector are increasingly open to collaboration with external partners to engage in R&D&I projects. Such cooperation with – for example – academic entities, is inherent to the DNA of organizations, and therefore, usually does not cause many problems. In respect of cooperation with other entities e.g. startups, where the rules of collaboration are not that obvious, and are not described in corporate guidelines, the situation is different. It transpires that a problem is suddenly identified in an enterprise and an innovative, agile solution of a startup is urgently sought.

Thanks to opening up to external innovations, the sharing of knowledge, skills and ideas is possible among entities which had hitherto been closed to cooperation, and which jointly form the sector's innovation ecosystem. Apart from the above-mentioned groups of stakeholders who actually engage in R&D&I projects, it is worth mentioning two other types of entities that are important for innovation. The first are international and national legislative authorities. These entities indicate the new directions that have to be followed by other stakeholders. Through international and national regulations state authorities may facilitate or accelerate the development of selected technologies on a given market, creating an appropriate formal and legal base and/or supporting the financing of R&D&I initiatives in selected areas. Another significant group of entities includes industry organizations and associations which – by engaging practically all the stakeholders of the ecosystem – create a specific platform for cooperation and knowledge diffusion.

Drawing 1: Key stakeholders of the innovation ecosystem in the energy sector



Source: PwC

R&D partnerships

Most frequently, scientific entities are engaged by enterprises as partners in R&D projects, in the areas of their core activities. For example, only in 2018, Shell launched 260 R&D projects in cooperation with universities throughout the world.[74]

Cooperation can be initiated not only by enterprises – academic entities with ideas for a project which requires access to infrastructure possessed only through key players in the energy sector – can also initiate joint ventures of a R&D nature.

Any entity in the value chain, of which the enterprise is a part, may be a partner in R&D&I activities. Therefore, projects can be conducted e.g. with suppliers of specialist equipment who – in order to test and give the final touches to a new product at a relatively early stage of its technological readiness – can ask a market leader for access to its infrastructure.

For projects requiring the highest capital expenditure and engaging a large number of interdisciplinary R&D&I staff, sector leaders may decide to set up a joint venture. An example of such initiative is Infineum, an entity dedicated to additives for oil used in lubricants and fuels, which is the effect of the joint venture project between ExxonMobil and Shell.[75] Another initiative of two giants – Shell and DuPont – in the form of Butamax Advanced Biofuels – is being carried out for the purpose of the commercialization of bio-isobutanol as a transport fuel using patented technology developed due to the joint efforts of the two corporations.[76]

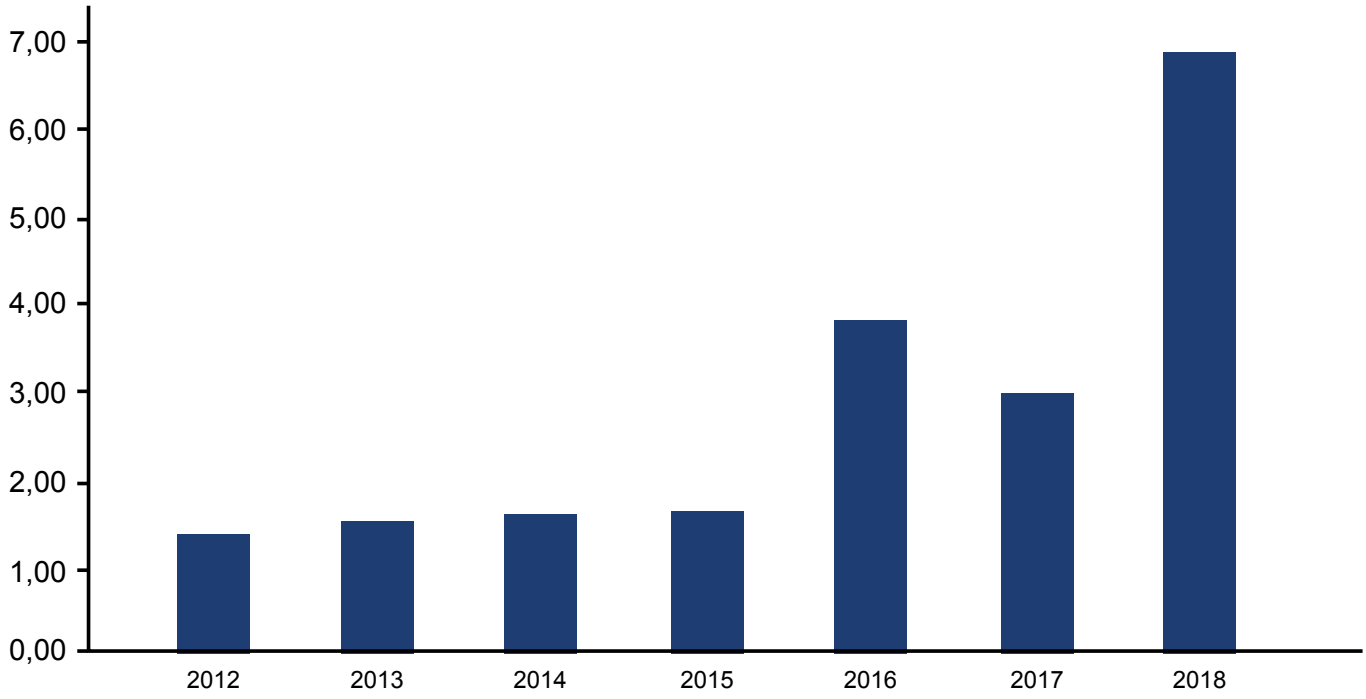
However, new challenges related to the development of technology lead to very unusual partnerships arising. The announced intended partnership between Saudi Aramco and the technological company Raytheon is an interesting joint venture in an area new to the industry. The entity created based on this collaboration is to ensure the highest class cybersecurity solutions to protect the Saudi firm's resources from a potential cyberattack. The established company is to ensure protection not only for Saudi Aramco itself, but also for the suppliers, customers, and partners of the enterprise. [77]

Corporate venturing

Corporate venturing[78] comprises various forms of involvement by a large enterprise in the startup ecosystem. Most of the leaders in the energy sector undertake initiatives aimed at using the potential of startups. Below we present selected corporate venturing tools, from those requiring the least involvement to the most advanced that require a mature innovation culture within the organization, a large risk appetite and significant capital expenditure. The forms of involvement used by the representatives of the energy sector in the startup ecosystem do not differ, as a rule, from those used by corporations in other sectors, however, the emphasis on concrete, selected activities, is visible, as seen from the popularity of SPVs. The fact that practically all sector leaders engage in investments in new innovative enterprises attests to the importance of such a form of innovative activities, and companies such as Shell and Chevron have already been engaging in such activities for two decades.

In the context of corporate venturing it is also worth noticing an increasing venture capital (VC) investments made in the energy sector. On chart 14 we observe how dynamically, over the past several years, the value of global venture capital investments in energy sector enterprises has increased. In 2018 the value amounted to USD 6.9 billion, while in 2012 it was only approx. USD 1.5 billion. This data shows how the importance of startups in the energy sector has increased for private investors who decide to invest in the most promising technological areas. This has an impact on the sector leaders who are taking a close look at startups, as they do not want to overlook new technologies that may revolutionize their business and the whole industry.

Chart 14: Global venture capital investments in energy sector enterprises in USD billions



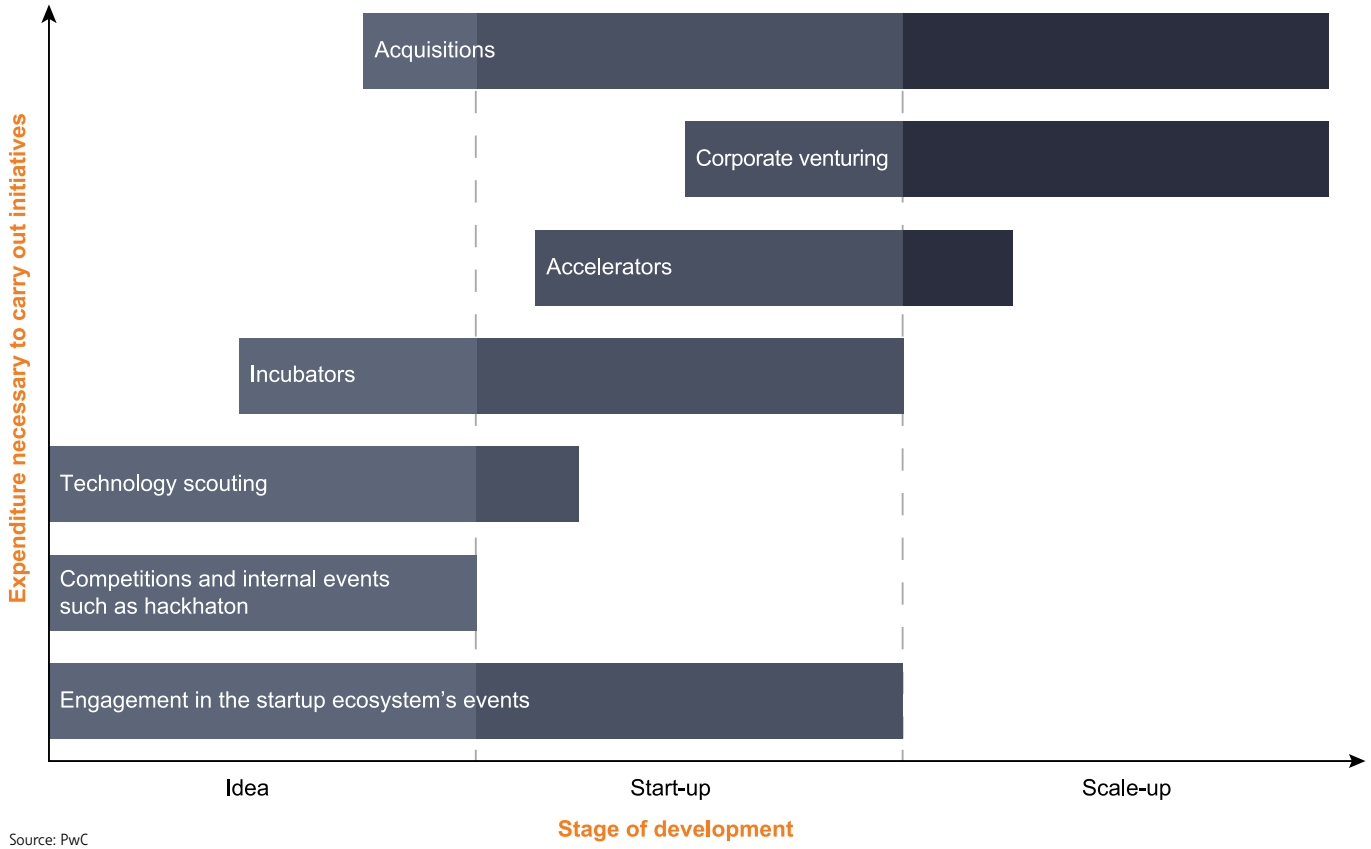
Source: „World Energy Investment 2019" IEA

Engagement in the startup ecosystem's events

One of the simplest methods for entering the startup world is sponsoring and participating in various startup events. The TusStar Cleantech startup competition is an example of an event in which an entity from the energy sector was both the sponsor and was also technically involved. BP Ventures engaged as a sponsor in an event organized by one of the largest incubators for Cleantech industry startups in China. The company provided money prizes and technical support for the best startups participating in the competition.[79]

Alternatively, more and more initiatives which fall within the boundaries of both innovation and CSR activities are observed on the market, as shown by the competition "Startupper of the year by Total Challenge" organized by Total.[80] Young entrepreneurs can participate in the competition, irrespective of the operating sector, and projects are evaluated, among other things, according to criteria such as innovation, feasibility, their impact on the environment and on the local community. Such initiatives build the image of an enterprise not only as an innovative one but mainly as one acting on behalf of local communities and caring for sustainable development.

Drawing 2: Selected corporate venturing tools from the perspective of capital expenditure required to implement them and the addressees of the startup ecosystem



Source: PwC

Competitions for ideas and events dedicated to creating innovations

These types of initiatives usually take one of the forms known and universally used on the market. One of them is a simple competition in which the topical areas or issues to be resolved are specified. The initiative of Chevron Tech Challenge is an example; it allows everyone to report their ideas for a technology which is compliant with the topical areas specified by Chevron, which change from time to time.[81]

Energy sector leaders also organize special events aimed at creating innovative ideas within a short period. Such an event can take the form of a hackathon, i.e. a sprint-like event usually lasting 2–3 days, addressed mainly to software developers, during which they have to solve the programming problem posed by the organizer. Shell GameChanger Hackweek 2019 is an example of a hackathon in the energy sector, during which students, entrepreneurs and startups worked for 5 days on an algorithm optimizing the production of gas based on actual data provided by Shell.[82]

Technology scouting

Technology scouting comprises activities aimed at an active search for technologies required to satisfy the current needs of the corporation. The scouting may be a continuing process which is then conducted mainly by on-going monitoring of particular technologies which are being developed e.g. in friendly research centres. However, an enterprise often creates a time-restricted detailed scouting plan which is then pursued using proprietary resources or with the support of an external entity specialized in such activities.

As a result of scouting, the owners of the technology can be identified and presented with an offer for a suitable form of cooperation (e.g. purchase of the technology, conducting a joint R&D project, invitation to a corporate acceleration program). Scouting, apart from the technology itself, offers an enterprise the possibility of gaining knowledge about current technological trends, which may enable it to independently follow R&D&I work in a direction that is worth considering.

The InnVento program conducted by PGNiG is an example of scouting activities conducted directly by energy sector enterprises in Poland. The program is constant and open, and allows not only startups but also more developed firms to enter into close collaboration with the company in selected innovative areas.

Accelerators

An accelerator, to explain it simply, is a time-restricted program based on cohorts (i.e. groups of startups), supporting the development of young, innovative firms, with educational elements. The purpose of corporate accelerators is mainly checking during close, several-month-long cooperation, the potential of a given startup as to the possibility of further commercial cooperation. Acceleration may also be a form of due diligence conducted before investing or acquiring a startup by a corporation. For this reason more mature startups are recruited to accelerators, and one of the key criteria is for them to have already had an implemented or sold project.

Corporations launch their own accelerators or act as partners in programs organized by global leaders of the startup ecosystem. An example of an acceleration program is E.ON.'s agile program. Under the program startups can count on networking not only with E.ON. itself, but also with the partners that have been invited to cooperate in the program. What is interesting is that after the acceleration stage, startups have a chance of an additional 12–18 month incubation process.[83]

An example of a partnership engagement is ExxonMobil's share in the acceleration program Plug and Play Supply Chain. During the 12-week program startups operating in areas such as Internet of things, Artificial Intelligence or blockchain, worked on developing their business models. Apart from ExxonMobil, other corporations were also engaged in the program, such as BASF, ArcelorMittal, and Panasonic.[84]

Sometimes corporations can count on support in the form of external financing for the development of acceleration activities. In Poland the Polish Agency for Enterprise Development (PARP) animates cooperation between corporations and startups, among others, through the Scale Up program. Under the program selected accelerators chose the best startups to connect them with large enterprises which play the role of the recipients of innovative technologies. Startups have a chance to cooperate with experienced enterprises, which make available to them their infrastructure and experienced employees, and the collaboration itself should lead to the pilot implementations of the startup's innovations at the recipients of the technology. In the pilot edition of the program, 10 accelerators supported 250 startups, leading to more than 190 implementations in large firms.[85]

PGNiG was one of the technology recipients in the aforementioned program and became a partner in the acceleration path developed by MIT Enterprise Forum Poland. Young innovative firms provided PGNiG with solutions relating to – among other things – using unmanned aerial systems, optimization of business processes, using artificial intelligence and improving the effectiveness of oil and gas extraction.

Currently the second edition of the program is in progress, in which 10 accelerators have over PLN 150 million to spend (of which over PLN 133 million is a PARP subsidy) in order to support a minimum of 400 startups and their cooperation with large companies.[86]

PARP also organizes the Poland Prize – the first Polish program aimed at encouraging foreign startups to run their businesses in Poland, among other things, thanks to subsidizing the commencement of operations and inclusion in the Polish startup ecosystem. The program is conducted by operators acting in cooperation with Polish technology recipients. The operator's tasks include scouting, evaluation of projects in terms of their commercialization chances and talent acceleration. One of the firms in the sector which actively participates in the program is PGNiG, which became the strategic partner of the Startup Hub Poland Foundation, the accelerator chosen as one of six program operators.

Under the Poland Prize each of the foreign teams that meets all the Accelerator's requirements and is invited to participate in the program, will receive appropriate technical support and a chance to win up to PLN 200,000 of non-reimbursable financial support for the development of the product.

Incubators

The essence of Incubators is supporting startups at the early stage of their development, over a period of even several years. Incubators constantly recruit startups, accepting them individually, and not like Accelerators – in groups. Early-stage enterprises accepted for incubation receive access to, among other things, office space, simple R&D infrastructure, legal and accounting support, and to IT solutions at attractive prices. Incubators' partners include corporations which on the one hand want to monitor the businesses developed in the Incubators, and on the other have a chance to offer their products or services to young entrepreneurs.

Due to the differences between the degree of development of startups recruited for both types of programs, corporations more frequently launch their own Accelerators, wishing to cooperate with more mature startups. It may different in the energy sector, where industry specification and high entry barriers limit the possibilities of finding startups with their first commercial successes. For this reason market leaders organize programs which combine the features of Incubators and Accelerators. The Shell GameChanger initiative is an example of such initiative where innovative technologies are sought at the earliest stages of development. Submissions are accepted both on a constant basis and under periodic topical calls. The projects developed under the program usually last 12–18 months. The program offers technical support and seed capital.[87]

Table 2: Differences between incubator and accelerator programs

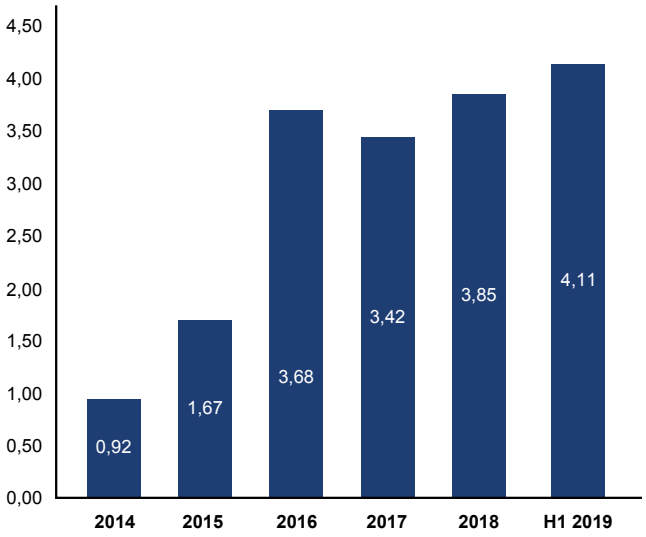
Compared aspect	Incubator	Accelerator
Average duration of the program for a startup	1–3 years	3–6 months
Recruitment in cohorts	No	Yes
Selection	Constant, without an element of competition between the startups	Cyclical, strong competition in the selection of startups
Key elements of the value proposal for startups	Office space, legal services, attractive offers from the Incubator's partners (e.g. software at promotional prices)	Mentoring, networking, seminars/ topical training, promotion

Source: PwC

Corporate Venture Capital (CVC) and acquisitions

To guarantee at least partial rights to the most attractive technologies at an early stage of development, corporations decide to invest their capital in startups in which they usually become minority shareholders. Such an investment connects the startup to the corporate investor more strongly than e.g. cooperation in an Accelerator or a joint R&D&I project. Most often the purpose of conducting venture capital investment activities by large companies (CVC – Corporate Venture Capital) is to support the development of solutions compliant with their strategic goals which can ultimately be used in their current operations. Investments in startups are also a method of exploring new business models, which are at least partly related to the core operations of the corporation or which can develop thanks to its key resources and unique know-how.

Chart 15: Global investments of corporations from different sectors in technological enterprises in the energy sector, in USD billions



Source: IEA 2019[92]

Giants such as Shell (Shell Ventures), BP (BP Ventures), Saudi Aramco (Saudi Aramco Energy Ventures), Total (Total Energy Ventures) and Chevron (Chevron Technology Ventures) have their own CVCs. Corporate Venture Capital is no novelty in the industry, e.g. Shell Ventures was established as early as in 1996.[88] The further funds earmarked for Chevron Technology Ventures is an example confirming that capital investments bring value to energy sector enterprises. In March 2019 the entity announced the launch of a seventh fund with funds amounting to USD 90 million. From the beginning of its operations in 1999 Chevron Technology Ventures has made more than 90 investments.[89] The allocation of funds to subsequent funds attests to the fact that the investment direction chosen 20 years ago, according to the CVC formula, must generate profits for Chevron. Chevron Technology Ventures also boasts of a list of companies which were the subject of investment, and which were then sold to other enterprises or made their debut on an exchange.[90] This shows that Chevron, through its investments in innovative technological companies, may not only acquire innovations for its operations, but also earn money on its investments as a typical financial investor.

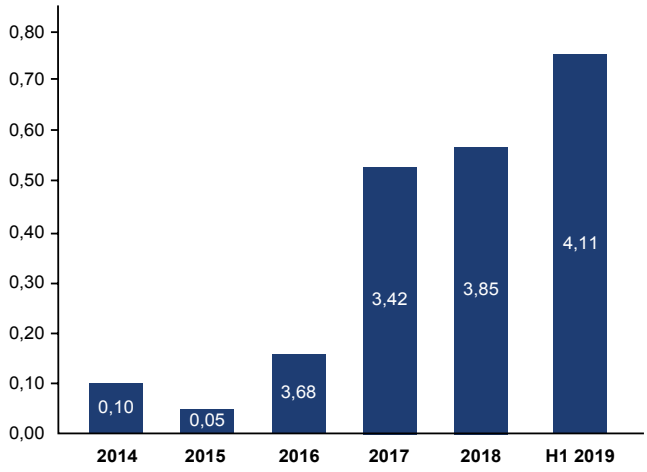
As shown in the statistics (chart 15), enterprises operating in the energy sector, using their own CVC funds, are prepared to spend more and more money on financing innovative ideas. This follows from the fact that this type of approach enables companies to limit the risks and costs of the internal development of new technological areas, in particular in the context of the current market uncertainty related to the large number of technical innovations.

The above is reflected in data relating to the number of corporate investments undertaken in technological firms in the energy sector in the years 2014 – 2019 (first half). Taking 2014 as the base year, compared to the first half of 2019, the value of investments made by corporations increased over fourfold, and by the end of 2019 this ratio is expected

to increase as more investments are made. It is important to note that in the context of corporate investments in technological enterprises from the energy sector, the increasing impact of corporate investors from outside the traditional energy sector is visible. In 2018 over 35% of these types of investments were made by corporations from the widely-understood ICT sector.[91]

It is also worth looking at the sector of enterprises engaged in producing and processing crude oil and natural gas itself. It follows from the data shown in chart 16 that the value of corporate investments from the sector in technological enterprises in the energy sector reached USD 0.75 billion in the first half of 2019. Compared with 2014 it increased over sevenfold. Therefore, taking into consideration data from the period 2014–2019 it can be concluded that corporations from this segment of the energy sector develop their investment potential most dynamically in innovative startups from the energy industry. Apart from investing in minority shares in the venture capital formula, corporations from the energy sector also acquire innovative entities. The purchase

Chart 16: Global investments in technological enterprises in the energy sector, made by enterprises in the oil and gas production and processing sector, in USD billions



Source: IEA 2019[93]

of Sonnen Group by Shell is an example of the acquisition of an innovative entity by one of the sector leaders. Sonnen, a leader on the market of smart energy storage systems, was an attractive target for Shell, enabling it to expand its operations in this dynamically developing technological area. What is interesting is that Shell announced that despite being acquired, the company will retain its brand and management team.[94] This approach is becoming increasingly popular with industry leaders; it enables the target to retain its organizational culture and identity, which has a positive impact on its further development and perception on the market as a young, agile and innovative enterprise.

Poland vs the rest of the world – startups in fashion

The area of corporate venturing shows noticeable differences in terms of the use of tools dedicated by world leaders compared to those used in Poland. World and European leaders usually have a whole portfolio of initiatives dedicated to cooperation with startups, which result in a synergy effect. In Poland entrepreneurs in the sector are currently testing various new forms of cooperation, such as startup Incubators and Accelerators. Polish sector leaders are working on launching their own CVCs or have been operating them for no more than a few years, while Chevron or Shell have had their own venture vehicles for 20 years.

The factor that determines the development of cooperation with startups among enterprises in the energy sector, which may help them catch up with countries where the corporate venturing culture is already mature, is the support of cooperation between corporations and startups through dedicated external financing programs. Apart from the Scale Up program mentioned above, the Elektro ScaleUp dedicated to electromobility is worth mentioning; it is a program which supports startups with financing of up to PLN 550,000. Firms in the Polish energy sector – TAURON and PKN ORLEN – have engaged in the program.[95] Activities relating to corporations investing in startups may also be subsidized. Two of the three funds in which PGE Ventures is engaged received financial support from the National Centre of Research and Development and Polish Development Fund.[96]

The Polish startup ecosystem also allows an optimistic approach – the results of the Startup Poland Foundation survey showed that 1 in 3 startups cooperate with a corporation and as much as 83% declares a wish to cooperate with such partners.[97] Therefore, corporations in Poland only have to open up to startups as a source of interesting and often not immediately apparent solutions.

Innovation mix – proprietary projects supported by open innovations

Looking at the tools used throughout the world by enterprises in the sector to generate and develop innovations, one can see that internal research and development activities are doing well and will continue to be the basic source of innovation in the sector. However, more and more often various forms of cooperation with external partners are used. If truth be told, all the players indicated above as representatives of the innovation ecosystem have an impact on R&D&I projects conducted by energy sector leaders. On the other hand, the specific nature of startups, their culture, working methods and operating profile aimed at state-of-the-art technologies force enterprises to change not only their procedures or forms of cooperation, but also the philosophy of their cooperation with such different profile entities.

5

Challenges for innovation development in the energy sector

Is it as good as we think?

Having such a wide range of tools dedicated to innovation, and knowing the key problems of the sector, at the same time having the necessary capital resources, it would seem that generating and developing innovations by enterprises in the energy sector is an easy, simple and quick process. Unfortunately, as usual, reality differs from theory, and the complexity of the sector and its environment requires that firms throughout the world have to overcome many challenges to be able to profit from innovations.

There are many barriers to implementing innovations in the sector. However, special emphasis should be placed on the problems of the Polish energy sector, which – although lately it is more active in the area of innovation – still has a lot to do to catch up with the world leaders.

The fact that the barriers identified, such as access to highly qualified personnel with competencies in new technologies or the ability to prioritize R&D&I activities, are not only the problem of the energy sector, but also other sectors of the global economy, is only small consolation.

Key challenges for innovation in the energy sector

Personnel of the future – new competencies for innovation

One of the significant challenges for the global energy sector is the increasingly perceptible lack of human resources with appropriate competencies that would meet the requirements of the highly-specialized technological and scientific area to which operations in the energy sector are related. It follows from Forbes data[98] that 90% of the representatives of the management of enterprises in the sector believe that the lack of talents is an evident problem in their firm. Furthermore, current data shows there is a problem with replacements – on average two retiring employees in the sector are replaced by one employee who is taking the first steps on his/her career path.[99] In the longer perspective, this could lead to problems with filling practically all the important positions.

Another issue related to the deficit in human resources are the competency gaps that have appeared in the energy sector. For many years, the sector was neither the first nor ultimate choice, for example, for persons from the ICT technology area, where young talented specialists preferred to operate as freelancers or join technological giants which were associated mainly with outstanding innovations and which had a much larger impact on the global environment. This had led to a situation in which the entire energy sector is one of the least digitized sectors in the world economy.[100] This is a significant barrier and it impacts the possibilities related to the implementation of innovations, in particular at times when IT technologies play a fundamental role in nearly every business.

To address this challenge enterprises in the sector should chose cooperation models which enable absorbing innovations from outside. In an age of the unfading fashion for establishing startups, contrary to working at a job in international organizations, developing mechanisms to absorb external innovations allows firms from the sector to gain partial independence from the problem of internal human resources. External innovations are understood in this context as all initiatives assuming cooperation with young technological firms, but also actions aimed at tightening cooperation with scientific entities, in particular university-level colleges which are an important source of young and gifted employees.

Another solution is to cooperate with world technological leaders which allows access to the newest technologies and to resources with appropriate competencies. The partnership between ExxonMobil and Microsoft commenced in 2019 aimed at increasing profitability thanks to using state-of-the-art digital technologies in one of the largest deposits of crude oil and natural gas in the world – the Permian Basin – is an example.[101]

Selection of R&D&I projects

R&D&I projects are naturally exposed to higher risk than typical, well-known, on-going activities. The process of selecting such projects is also ruled by different laws.

In view of the sector's gradual transformation and the risk of losing stability in terms of conducting business according to proven and well-known models, many enterprises face the key challenge of determining the priorities of R&D&I work. This in particular refers to enterprises that do not belong to the "majors" group, whose R&D&I budgets are significantly lower. In respect of such firms, sometimes focusing on the development and implementation of process changes or new technologies already available on the market may be a more profitable strategy than attempts at implementing grass-root crucial product innovations. Another important factor is not to fall into the trap of creating everything independently, in particular when the market offers a wide range of solution that have already been verified. Various types of partnerships gain material importance, including entering into cooperation with new suppliers, e.g. in the area of cybersecurity services. The above may constitute an effective alternative to internal R&D&I efforts and influence the selection of the portfolio of projects performed by the enterprise.

Key challenges for the development of innovations on the Polish energy market

Climate for innovation

The energy sector in Poland has already done much for the development of innovative activities. It spares no expenses and effort to catch up with the global players. All market participants should actively engage in cooperation in the area of innovation, and government regulations and administration should support such actions. It is important to undertake intense action externally, without forgetting the enormous potential present in the firm's employees. These employees often have not only valuable experience but also

unique practical knowledge acquired over the years. The open innovation model assumes drawing on external and internal potential at the same time. The good climate for creativity and innovation in the firm should be nurtured and smart external partnerships should be built. This is a good start to create innovations –both the incremental and the crucial ones.

Adapting processes and procedures to the specifics of innovative actions

Flexible, friendly internal procedures adapted to the performance of R&D&I projects, should follow the work on developing an innovation culture in the organization. In Polish reality very often R&D&I projects go through the standard path of investment project assessment. Therefore, many innovative projects are wrongly assessed because they do not fit into the traditional frames specifying the assumed timeframe for the project, the amount of costs or possible return on the investment, which should be known in advance. As a result of such an approach only derivative solutions can be implemented, with a quick and measurable effect, while innovations aimed at achieving long-term strategic goals, and thus enabling breakthrough changes, will be omitted.

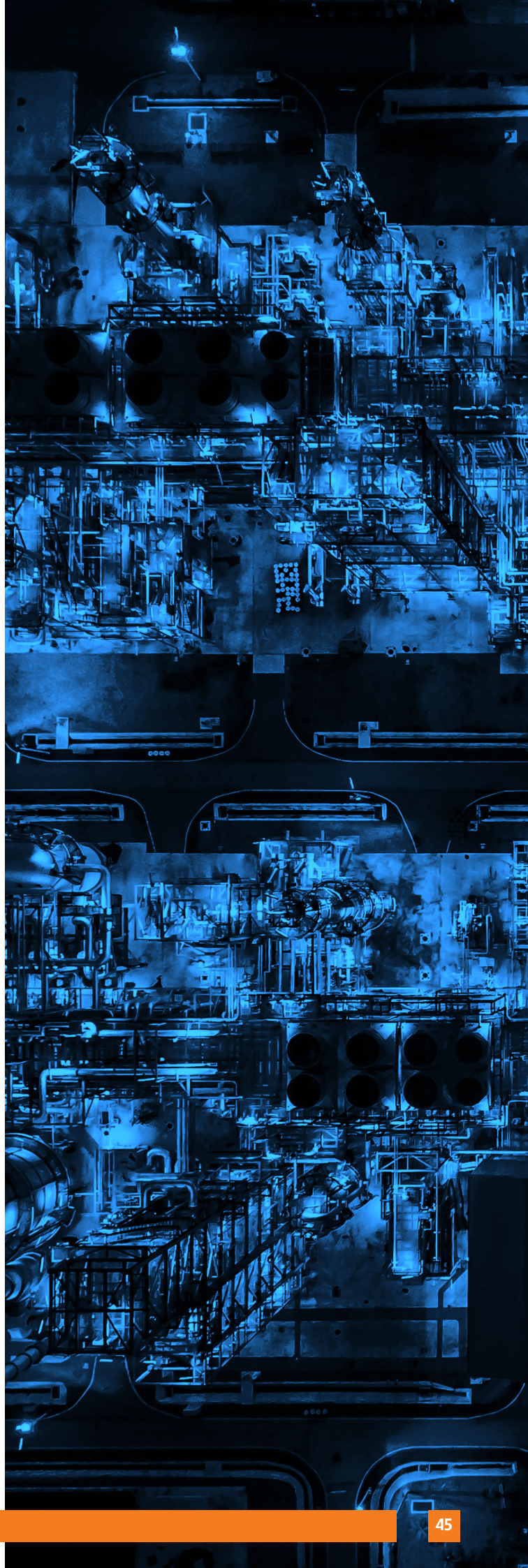
Further, in respect of widely-understood innovative projects, corporate procedures related to e.g. purchases or corporate consent often lead to the inability to maintain the dynamic typical of many innovative projects, which in consequence leads to business interruptions or even to the loss of an opportunity to enter an area which will be important for the organization in the future.

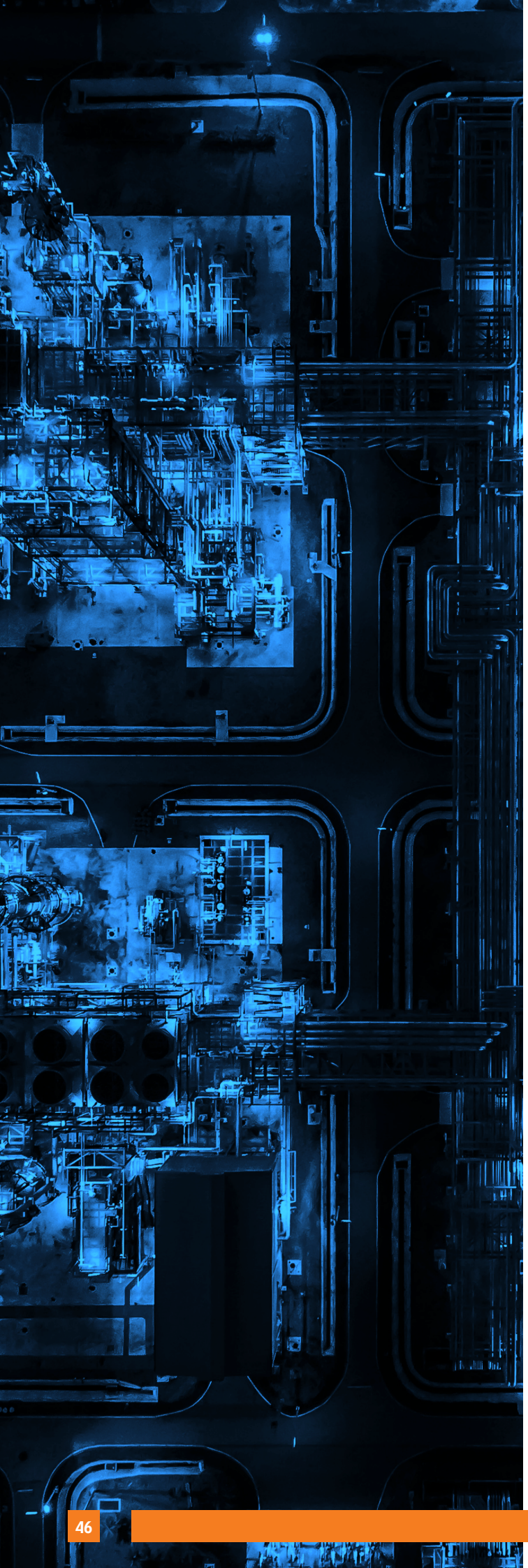
To meet this challenge, it is worth ensuring proper preparation and effectively implementing separate procedures within the organization for proceeding with R&D and innovative projects. It is also important to create a so-called short decision path which in the case of R&D&I projects enables avoiding the need to obtain the approval of many people in a complex organizational structure.

Determining priorities for R&D&I actions

Polish enterprises are under pressure from five key factors which determine their priorities in R&D&I activities:

1. trends set by global industry leaders;
2. legislation and regulations imposed by national authorities;
3. EU regulations and funds earmarked for the development of particular areas of the energy sector;
4. expectations of corporate and individual customers;
5. internal problems relating to the on-going operations of the enterprise.





The multiplicity of factors which condition innovative activities require, first and foremost, that research agendas and innovation strategies define priorities, and that the necessary resources follow. Secondly, priorities should be constantly monitored, verified and updated. The reason for all of this is to keep up with the dynamically changing environment and external conditions. In the accelerating world of innovations, flexibility, adaptability and courage in taking decisions on the need to change determine the effectiveness and competitiveness of an organization.

There is a challenge facing the leaders of the energy sector in Poland, relating to setting the direction for industry development, also in the area of innovation. Initiatives realized by national giants will have an impact on the development potential of business partners – suppliers, service providers, customers, research entities or the startup ecosystem. It is worth taking care of key partners in the value chain of large firms – this will translate into a greater potential for the development of innovations in the entire sector.

Selection of adequate corporate venturing tools

Building a corporate innovation ecosystem requires specific resources and tools. The principle "the more the better" will certainly fail to materialize. Tools and resources should be adapted to the level of an organization's readiness to enter higher levels of innovative activities. The greater the readiness, the more advanced the tools, and thus – larger dedicated resources. One can begin with the employee innovation program, through adding a proprietary startup project Incubator or Accelerator, ending with a CVC fund. It is also worth further developing internal R&D activities. This is the path taken by industry leaders.

The selection of particular innovation development tools should therefore be adapted to the needs and degree of development of the innovation culture in a given organization. This is not an easy task and often the process of building an ideal portfolio of initiatives or tools for conducting innovative work requires testing them and drawing conclusions. Physical counts should be performed regularly to determine the potential of the organization, which requires optimizing the inventory – what is lacking and what there is an excess of.

6

Towards energy of the future

The process of transformation in the energy sector is accelerating. Changes are made in various dimensions – globally and locally, and depend on the economic ecological and social aspects. These changes are dictated by the legislators, or society which expects ecological, effective and innovative producers and service producers.

The climate changes taking place before our very eyes and shrinking natural resources have a very strong influence on the sector. More than ever, green, sustainable energy is needed to ensure the well-being of future generations. The significance of alternative fuels and renewable energy sources are becoming ever more important in the energy mix. In this area, regulations are setting new, more ambitious goals. The energy policies of particular states are often the effect of socio-economic compromises. Each responsible market player declares a readiness to invest in renewable energy sources and to include them on a constant basis in its development strategies, as is confirmed by projects and investments that are already being pursued.

In parallel, changes are occurring in consumer needs, which show new expectations in respect of the use of and access to energy. Awareness is changing, and accordingly consumer requirements, as consumers in other industries have long been used to innovative and tailored solutions. The whole sector faces challenges to meet the expectations of new and aware customers, which will require transition and often an in-depth change in the business philosophy.

Wishing to adapt to the new rules of the game, enterprises in the energy sector are choosing innovations. Innovations determine the pace of the revolution. All factors enabling the optimization and improvement of current operations will be material. Equally important is the search for new solutions – both in terms of products and totally new business models which will allow the industry to set the directions for future energy generation. Renewable energy technologies, Industry 4.0 or eco-mobility and future fuels such as hydrogen or LNG to redefine the sector's operations. Therefore, R&D&I projects will play an ever more important role in pursuing the strategic goals of enterprises and will influence the future distribution of power in the sector. Those who have sufficient skills and determination, as well as resources, will be able to build their competitive advantages based on innovation and to adapt deftly to the new reality.

We should also keep in mind that innovation is important not only for the energy sector, but also for the economy as a whole. In a modern, globalized economy widely-understood innovations contribute materially to economic growth and are decisive for gaining competitive advantage. New technologies are an impetus which puts a whole sequence of changes in motion, both in business and on a wider scale – in social life. Innovations determine not only the scale but also the speed of these changes.

Experts at the European Central Bank indicate the fact that innovations contribute, in a specific way, to increased efficiency. This translates, among other things, into an increase in production without the need to increase expenditure, which in turn leads to an increase in the quality and volume of goods and services on the market. New or significantly improved products and services improve the quality of life of consumers. With an increase in efficiency the remuneration of the employees also increases, which allows them to buy more

goods and services – the increase in consumption supports economic growth. At the same time, enterprises earn higher profits and can employ more personnel.[102]

However, the increase in efficiency is not everything. Innovations may take the form of new products, services, processes, but also new organizational, marketing solutions, or even new business models. Innovations can lead to the creation of totally new businesses which did not exist before. This often results from the fact that innovation drives out or is an alternative to the value proposal which had been provided previously or creates a whole new value which must be made accessible to customers via a pioneering business model. An economy where new business models are being initiated or where new industries are being established is gaining a competitive edge on the international arena.

The development of innovative activities also has an impact on changes in the quality and the number of new jobs. Jobs created through innovation usually require high specialization and qualified experts. In consequence, innovation determines evolution in the direction of an economy based on knowledge and advanced technologies.

Modern, innovative economies draw investors and foreign capital, additionally stimulating economic growth. On the one hand, the plants of foreign investors ensure new jobs, often in smaller towns, which helps the area develop and which improves the quality of life of local communities. On the other hand, local innovative enterprises have the capability of international expansion and draw the best specialists from other countries who wish to work in them, which also drives growth.

An innovative economy is better adapted to changes and is more competitive, and in consequence, more effective both internally and on the international forum.

However, experts and practitioners in the energy sector think alike – transformation of the sector requires time and significant expenditure. Cooperation within and outside the sector is important as it opens up new possibilities. Developing and implementing innovation thanks to various forms of partnerships has never been as attractive and accessible as it is now.

It is difficult to say unequivocally whether the development needs of the sector drive the creation of innovations or whether innovations are the answer to the industry's current needs. However, it is certain that innovations in the energy sector have never been so wide-ranging and material as they are today, and t and they will undoubtedly set out the direction for the future development of energy.

Annotations

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