RAZUMKOV CENTRE

# THE ROLE AND PLACE OF UKRAINE'S ENERGY SECTOR IN GLOBAL ENERGY PROCESSES

- Global Energy Trends by Sector: Challenges and Opportunities for Ukraine
- Global Energy Sector until 2035 and Beyond
- Mainstreaming Climate Policy in the Energy Sector: Global and Ukrainian Dimensions
- Ukraine's Energy Sector until 2035

KYIV – 2018

# ACRONYMS AND ABBREVIATIONS

| Acronyms and abbreviations | | Interpretation |
|---|---|---|
| **$2005** | – | U.S. dollars at constant exchange rate, price and purchasing power parity as of 2005 |
| **°C** | – | Temperature on the Celsius scale |
| **AAU** | – | Assigned Amount Unit (greenhouse gases) |
| **ACER** | – | The EU Agency for the Cooperation of Energy Regulators |
| **b** | – | barrel |
| **BaU** | – | Business as Usual |
| **bcf/d** | – | Billion cubic feet per day |
| **bcm** | – | Billion cubic metres |
| **CCS** | – | Carbon capture and storage |
| **CDM** | – | Clean Development Mechanism |
| **CER** | – | Certified Emission Reduction (1 MTCDE by CDM) |
| **CESA** | – | Continental Europe Synchronous Area |
| **CHPP** | – | Combined heat and power plant |
| **CNG** | – | Compressed natural gas |
| **Coll.** | – | Collection (body) of laws |
| **DC link** | – | direct current link |
| **DNO** | – | Distribution Network Operator |
| **DSO** | – | Distribution System Operator |
| **EC** | – | The European Commission |
| **EEX** | – | The European Energy Exchange AG – Leipzig, Germany |
| **e.g.** | – | for example |
| **EITI** | – | The Extractive Industries Transparency Initiative |
| **ENTSO-E** | – | The European Network of Transmission System Operators for Electricity (as of 1 May 2017 unites 43 system operators from 36 European countries) |
| **EPI** | – | Energy Performance Index for buildings |
| **ERD** | – | Emission Reduction Unit (greenhouse gases) |
| **ESCO** | – | Energy service company |
| **ESU-2035** | – | The Energy Strategy of Ukraine until 2035: Safety, Energy Efficiency, Competitiveness (approved by the Cabinet of Ministers of Ukraine Resolution No.605-r of 18 August 2017) |
| **EU** | – | The European Union |
| **EUR** | – | Euro |
| **EXAA** | – | Energy Exchange – Vienna, Austria |
| **FDI** | – | Foreign direct investments |
| **FEC** | – | Fuel and energy complex |
| **FER** | – | Fuel and energy resources |
| **GFS** | – | Gas-filling station |
| **GHG** | – | Greenhouse gases |
| **GJ** | – | Gigajoule |
| **g s.f.** | – | Grams of standard fuel |
| **GWh** | – | Gigawatt-hour |
| **HPP** | – | Hydro power plant |

| | | |
|---|---|---|
| **INDC** | – | Intended Nationally Determined Contribution |
| **IPCC** | – | Intergovernmental Panel on Climate Change |
| **JI** | – | Joint Implementation mechanism (the Kyoto Protocol) |
| **kgoe** | – | Kilograms of oil equivalent |
| **km** | – | Kilometre |
| **kt** | – | Kiloton (one thousand tonnes) |
| **kV** | – | Kilovolt (one thousand volts) |
| **LNG** | – | Liquified natural gas (methane at least 90%) |
| **LPG** | – | Liquified petroleum gas |
| **mcm** | – | Million cubic metres |
| **mln** | – | Million |
| **mln MWh** | – | Million megawatt-hour |
| **mt** | – | Million tonnes |
| **MTCDE** | – | Metric tonne of carbon dioxide equivalent |
| **mtoe** | – | Million tonnes of oil equivalent |
| **MVA** | – | Mega Volt Ampere (one million Volt Amperes) |
| **MWe** | – | Megawatt electrical |
| **NDC** | – | Nationally Determined Contribution |
| **NEURC** | – | The National Energy and Utilities Regulatory Commission of Ukraine, the state regulator |
| **NGCA** | – | Non-government-controlled area |
| **NGL** | – | Natural gas liquid |
| **NGO** | – | Non-governmental organisation |
| **NPP** | – | Nuclear power plant |
| **OECD** | – | The Organisation for Economic Co-operation and Development |
| **POLPX (TGE)** | – | Polish Power Exchange – Warsaw, Poland |
| **PSPP** | – | Pumped storage power plant |
| **RCP** | – | Representative Concentration Pathways – greenhouse gas concentration trajectories by IPCC |
| **RES** | – | Renewable energy source (renewables) |
| **RF** | – | Russian Federation |
| **SAIDI** | – | System Average Interruption Duration Index (the average outage duration for each customer served by electric power utilities) |
| **toe** | – | tonnes of oil equivalent |
| **TPES** | – | Total primary energy supply |
| **TPP** | – | Thermal power plant |
| **TrSO** | – | Transportation System Operator |
| **TSO** | – | Transmission System Operator |
| **TWh** | – | Terawatt-hour |
| **UEM** | – | Unified electricity market |
| **UES** | – | Unified energy system (of Ukraine) |
| **UGS** | – | Underground gas storage |
| **UN** | – | The United Nations |
| **UNFCCC** | – | The United Nations Framework Convention on Climate Change |
| **VEH** | – | Vehicle |
| **V4** | – | The Visegrad Group – an alliance of four Eastern European States – the Czech Republic, Hungary, Poland and Slovakia |
| **WEP** | – | Wholesale electricity market price |
| **4IR** | – | The Fourth Industrial Revolution |

# TABLE OF CONTENT


**INTRODUCTION** ..... 6

**SUMMARY** ..... 8

**1. GLOBAL ENERGY TRENDS IN 2000-2016 BY SECTOR: CHALLENGES AND OPPORTUNITIES FOR UKRAINE** ..... 10

1.1. THE NEW ENERGY STRATEGY OF UKRAINE UNTIL 2035 AND GLOBAL ENERGY TRENDS ..... 10

1.2. GLOBAL PRIMARY ENERGY CONSUMPTION: GENERAL TRENDS ..... 10

1.3. STRUCTURAL CHANGES IN GLOBAL PRIMARY ENERGY CONSUMPTION IN 2006-2016 ..... 13

1.4. GLOBAL OIL MARKET ..... 15

1.4.1. Demand ..... 15

1.4.2. Reserves and production ..... 15

1.4.3. Prices ..... 17

1.5. GLOBAL GAS MARKET ..... 19

1.5.1. Demand ..... 19

1.5.2. Reserves and production ..... 20

1.5.3. Prices ..... 21

1.6. GLOBAL COAL MARKET ..... 24

1.6.1. Demand ..... 24

1.6.2. Reserves and production ..... 25

1.6.3. Prices ..... 26

1.7. ELECTRIC POWER SECTOR ..... 27

1.7.1. Prices ..... 29

1.8. RENEWABLE ENERGY ..... 31

**2. GLOBAL ENERGY SECTOR UNTIL 2035 AND BEYOND** ..... 38

2.1. THE GLOBAL ENERGY SECTOR TRANSITION: KEY FACTORS ..... 38

2.2. DECARBONISATION OF GLOBAL ENERGY SECTOR AND INVESTMENT OUTLOOK UNTIL 2035 ..... 40

2.3. ENERGY SECTOR OUTLOOK UNTIL 2035 BY SECTOR ..... 41

2.3.1. Oil sector ..... 41

2.3.2. Gas sector ..... 42

2.3.3. Coal sector ..... 46
2.3.4. Nuclear and hydro generation ..... 47
2.3.5. Renewable energy ..... 48
2.4. KEY INNOVATIVE TECHNOLOGIES IN THE ENERGY SECTOR ..... 49
2.4.1. Electric vehicle outlook ..... 50
**3. MAINSTREAMING CLIMATE POLICY IN THE ENERGY SECTOR: GLOBAL AND UKRAINIAN DIMENSIONS** ..... 52
3.1. THE IMPACT OF ANTHROPOGENIC FACTORS ON CLIMATE CHANGE ..... 52
3.2. CLIMATE POLICY: GLOBAL DIMENSION ..... 57
3.3. CLIMATE POLICY IN UKRAINE ..... 58
**4. UKRAINE'S ENERGY SECTOR UNTIL 2035** ..... 61
4.1. ENERGY POLICY IN UKRAINE: KEY TASKS AND PHASES ..... 61
4.2. UKRAINE'S ENERGY MARKET REFORM: A STEP TOWARDS JOINING EU ENERGY MARKET ..... 62
4.3. TOTAL PRIMARY ENERGY SUPPLY AND POWER GENERATION ..... 66
4.4. OIL AND GAS SECTOR OUTLOOK ..... 68
4.5. COAL SECTOR OUTLOOK ..... 70
4.6. ELECTRIC POWER INDUSTRY OUTLOOK ..... 72
4.7. KEY PARAMETERS FOR IMPLEMENTING THE ENERGY STRATEGY UNTIL 2035 ..... 74
4.8. INCREASED ENERGY EFFICIENCY, RENEWABLES EXPANSION, MODERNISATION AND INNOVATIVE TECHNOLOGIES ..... 76
**UKRAINE'S ENERGY SECTOR TRANSITION: CONCLUSIONS AND RECOMMENDATIONS** ..... 80

# INTRODUCTION

The energy market transition is currently one of the most important global energy trends. In this context, positive changes in the functioning of European energy market deserve special attention. Analysing the consequences of energy market transformations in line with the EU's Third Energy Package, the spread of innovative technologies and the rise of renewable energy helps to define the main features and trends shaping modern power industry and relations between energy market actors for the next 10-20 years and beyond.

These include the following key peculiarities and trends:

- consistent reduction of specific energy consumption and increasing energy efficiency;
- the expansion of renewable energy sources (RES) and gradual displacement of fossil fuels by renewables;
- universal introduction of information and digital technologies across the entire energy chain, management and energy metering, including fuel extraction and processing (preparation), energy generation and transformation, transportation, distribution, storage and consumption;
- the incorporation of low or zero carbon technologies into industry, transport and households, thus contributing to decarbonisation of the built environment;
- moving towards decentralisation of energy supply with enhanced autonomation and opportunities for alternative energy supply to consumers amid diversification of sources and routes of energy and fuel supply; the development of renewables, smart grids and digital technologies;
- de-monopolisation and creation of competitive energy markets, including electricity and natural gas markets, through a separation between sales and distribution;
- promoting energy service companies focused on serving end-users;
- gradual re-focus from holding extensive rights to exploit natural resources to prioritising efforts to expand the share of energy market at the end-user level in a particular market segment or region;
- introducing economic and mathematical methods and models for qualitative assessment, forecasting and optimisation of energy infrastructure development.

**The performance of Ukraine's energy sector in 2016* placed the country among the top 30 global and top 10 European states based on the total primary energy supply. Not only the country's energy sector is the key component of the national economy, but also an integral part of a pan-European economic space as significant volumes of energy resources still pass through Ukraine.**

Today Ukraine's energy sector is undergoing profound changes, which are to shape the national energy industry for decades to come. **Changes in global environment, technological innovations and the search for new alternative energy sources, as well as the increasing use of renewables, require domestic and international energy companies, governments and international organisations to answer the question "What will the future energy society be like?"**

The Razumkov Centre attaches great importance to the role of state policy in shaping the energy sector. The Centre has always stressed the need to create a new energy strategy for Ukraine. Its experts together with leading think tanks, companies, international non-governmental organisations, the Energy Community Secretariat and the Support Group for Ukraine at the European Commission,

* This publication is based on 2016 world energy statistics as the latest summarised data available as of February 2018.

industry specialists and government institutions developed the Energy Strategy of Ukraine until 2035,[1] which was approved by the Government in August 2017. Therefore, we often refer to the Strategy in this publication.

Sections 1 and 2 of this publication were prepared by Volodymyr Omelchenko, Director for Energy Programmes of the Razumkov Centre; Sections 3 and 4 – Victor Logatskiy, Leading Expert at Energy Programmes.

This publication is our attempt to contribute to the formation of a well-informed and responsible Ukrainian consumer who would be able to consciously shape its energy consumption and achieve the desired level of energy efficiency, both at the level of an individual household and large industrial enterprises. The most critical step in this process is to make sure the consumer understands major benchmarks in developing national energy policy, that is, "in which direction", "why" and "how" the Ukrainian energy sector will evolve. Ensuring quality dialogue between energy market participants, energy suppliers and consumers and state institutions should be a priority at the time when energy markets are transforming and the new energy strategy is being implemented in Ukraine.

Most of the leading domestic companies of all types of ownership recognise the responsibility to Ukrainian consumers, take into account current trends and peculiarities of the global energy industry as well as bearing in mind the local context and specifics. Also, as business-oriented players in energy markets, socially responsible businesses are called upon **to do whatever they can to ensure proper, uninterrupted, high-quality energy provision, first of all, to domestic consumers with energy products and services in adequate quantity and at affordable and reasonable prices.**

**Therefore, this publication is specifically designed to identify the main development trends in the global and domestic energy sector, to determine Ukraine's role – both current and future – in global energy processes, and to share this knowledge, first of all, with energy consumers, government institutions and industry specialists. In broader terms, this publication is about why and how Ukraine's energy outlook is being formed.**

[1] The Energy Strategy of Ukraine until 2035: Safety, Energy Efficiency, Competitiveness. Available at: *http://mpe.kmu.gov.ua/minugol/control/uk/doccatalog/list?currDir=50358*.

# SUMMARY

This publication is based on the analysis of statistical data and forecasts of the global and Ukrainian energy sector, obtained from national and international statistical agencies, international organisations and financial institutions, leading energy companies, and a number of foreign and domestic think tanks.

**Section 1** offers important statistics that allows us to assess the overall situation in the energy sector. In fact, it portrays a global energy profile that is shaped by the use of primary energy resources – oil, natural gas, and coal. For these three types of sources, we provide a detailed analysis of energy supply and demand, reserves, production volumes and pricing trends.

A distinctive feature of the period from 2006 to 2016 was the fact that global oil demand rose by about 1% per year. Meanwhile, the annual growth rates of coal consumption and natural gas over the past 10 years were 1.9% and 2.3% respectively. This section also contains regional analysis of oil, natural gas and coal markets, and data on their Ukrainian component. Electric power industry is placed in a separate subsection owning to the unique qualities of electricity as a commodity. Essentially, electricity derives from the use of primary energy sources such as fossil fuels and renewables.

Over the past decade, not only the renewable energy became a tool for achieving a low carbon society but also it has been increasingly regarded as an economically viable alternative to fossil fuels. Specifically, in 2006-2016, global RES consumption grew from 93.2 mtoe to 419.6 mtoe, or 4.5 times; while in 2015 global renewable capacity growth exceeded the same indicator for traditional power generation, thus emphasising that energy production from RES is a competitive industry.

**Section 2** of the publication offers general and sectoral outlook for global energy markets until 2035 based on the analysis of key societal changes such as: doubling of the volume of the global economy by purchasing power parity (predicted average annual growth rate of 3.4%); improved labour productivity; increase in the world's population by 25% or 1.5 billion people – up to 8.8 billion; projected improvements in living conditions for about 2 billion people as a result of improved labour productivity and increased income; decarbonisation efforts that promote energy efficiency and RES development and limit the growth in energy consumption to only 31% against a twofold increase in global GDP. The long-term forecast is based on the above-mentioned factors.

**In the forecast period, global primary energy consumption will increase from 13.15 billion toe in 2015 to 17.16 billion toe, or by 31%. The share of oil in global energy consumption in 2015-2035 will drop from 32% to 27%, and that of coal – from 29% to 22%. Instead, the share of renewables will increase substantially from 3% to 14%. Therefore, it is projected that the total share of fossil fuels in global energy use will decrease from 85% in 2015 to 74% in 2035, making a significant contribution to the global community's action on climate change.**

Falling global demand for crude oil (up to 0.7%) will define the oil industry until 2035. The average annual growth rate of natural gas production is expected to exceed more than twice the dynamics of oil and coal production, as during 2015-2035 they both will amount to 1.6%. However, this is half as much as the growth observed in the previous decade. By 2035, the demand for coal will increase by a mere 5%, mostly due to growing Asian markets.

**Therefore, RES expansion and decarbonisation in many spheres of life is a fundamental feature of the energy sector outlook until 2035.** To this end, **Section 3** of the publication offers an extensive analysis of the impact that the energy industry has on climate change. Having systemised the data for over 150 years, we observe positive correlation between primary energy consumption, the population size and energy consumption growth, especially in industrial and post-industrial societies.

In the second half of the 20$^{th}$ century, the growth rates of global energy consumption have exceeded that of the population, suggesting that global average per capita energy consumption will be consistently increasing, at least until 2035. The analysis of GHG emissions statistics together with energy consumption data explicitly confirms that the use of fossil fuels results in the production of carbon dioxide, thereby increasing the greenhouse effect. This section further concludes that the greenhouse

effect strongly contributes to rising temperatures as the global average surface temperature has increased between 0.6 °C and 0.9 °C in the last 50 years.

If human civilisation continues to follow the "Business as Usual" scenario, the global average temperature can increase by at least 1.2 °C in the next 50 years. In this regard, we share concerns of the international community on the need to prevent further increase in daily mean temperature in line with the terms of the Paris Agreement and based on a set of measures and tools to tackle climate change, described in this section, taking into account the Ukrainian context.

**Ukraine was one of the first countries to join the Paris Agreement and to submit proposals for INDC. The National Emissions Reduction Plan for large combustion plants, endorsed by the Government of Ukraine in November 2017, became an important practical measure pursuant to the Paris Agreement, and a step forward in adopting European environmental standards, as it gradually and significantly reduces $CO_2$ emissions from power plants.**

**Section 4** contains projections of Ukraine's energy sector development. It is based on key provisions of the ESU-2035, taking into account the prospects of Ukraine's transition to new energy market models in particular, natural gas and electricity markets. This transition is expected to be completed by 2020, which in fact matches the deadline of the first stage of the ESU-2035 – energy sector reform. Even though the Law on the natural gas market introducing the separation of functions (at least formally) between retailors and network operators was adopted in 2015, Ukraine's gas retail market is yet to become truly competitive, and requires improvements and arrival of new players at the regional level. At the same time, the wholesale natural gas market seems more dynamic, attracting even foreign gas suppliers.

The transition to a new model of the electricity market was made possible after the adoption of a relevant Law in April 2017. Section 4 offers a brief description and structure of the new electricity market model. This model also separates between the functions of the operator and the retailor and between such key markets as the day-ahead market, the intraday market, the balancing market, the market of bilateral contracts, and the market of ancillary services. However, the formation of a new market model will be impossible without secondary regulatory framework, which needs to be developed in short order.

**It is obvious that Ukraine's willingness to link its power system to continental Europe's power grid (*ENTSO-E*) is a strong incentive to modify its market model. The signing of the Connection Agreement on synchronisation was an important step in this direction. To enable integration of transmission systems, Ukraine has to comply with a number of regulatory, technical and organisational requirements, enshrined in a special document called a "catalogue of measures". Prior to the commencement of the integrated energy system of Ukraine and the ENTSO-E, scheduled for 2022, Ukraine must first test the functionality of its power system for at least one year in an isolated operational mode.**

This section also makes a projection of the total primary energy supply (TPES) by fuel until 2035, starting from the baseline year 2015. It is important to note that despite notable RES expansion (the share of energy from renewable sources is expected to reach 25%), Ukraine's energy mix until 2035 will depend on the traditional "triad" – natural gas, nuclear energy and coal that account for about 68% of primary energy sources.

Obviously, the Ukrainian energy sector cannot be transformed in isolation from global energy markets and innovation trends that promote energy efficiency of households, large enterprises, industries and impact the entire economy. In view of this, promoting electric mobility in Ukraine is seen as important, yet one of many directions for innovative development of our energy society.

All in all, the publication covers all major global energy trends and assesses their impact and possible application in the Ukrainian context. Each section also presents a substantial collection of tables and infographics to provide visual support for the material, encouraging the readers to better understand the ways and objectives of the national energy sector reform and, ultimately, to use energy resources more efficiently in their everyday lives.

The final section "The Role and Place of Ukraine's Energy Sector in Global Energy Processes" provides conclusions and recommendations for the Government and the Verkhovna Rada of Ukraine on setting benchmarks and developing national policy that is aimed at improving the national energy sector.

# 1. GLOBAL ENERGY TRENDS IN 2000-2016 BY SECTOR: CHALLENGES AND OPPORTUNITIES FOR UKRAINE

## 1.1. THE NEW ENERGY STRATEGY OF UKRAINE UNTIL 2035 AND GLOBAL ENERGY TRENDS

The updated Energy Strategy of Ukraine until 2035: Safety, Energy Efficiency, Competitiveness says that the world is moving away from an outdated energy sector model dominated by large producers, fossil fuels, inefficient networks, and inadequate competition in the natural gas, electricity and coal markets towards a new model that creates a more competitive environment, offers equal opportunities for development and minimises dominance of any specific type of energy generation, sources and/or routs of fuel supply. At the same time, it promotes better energy efficiency and greater policy push to renewable and alternative energy, as well as achieving the Paris climate goals.

**The Ukrainian energy sector as an integral part of the global energy industry cannot stand aside and ignore the global energy transformations underway. Ukraine should focus not only on present-day priorities but also on meeting challenges that will shape its future transition, taking into account global energy trends.**

These key global energy trends include:

- growing competition for energy resources that triggers contradiction between the main players in international markets;
- the need to limit climate change by decarbonising the electricity sector, accelerating the renewable energy generation and reducing its carbon intensity;
- transition towards mass manufacturing of electric vehicles;
- decentralisation of energy supply, especially through the renewable energy deployment and energy consumption management;
- regional disparities in energy consumption with growing demand in countries such as China and India significantly exceeding the global average;
- the growth of global trade in energy products along with the development and integration of infrastructure for energy transmission and supply;
- price volatility in energy markets;
- digitalisation of energy production and distribution, including cloud computing, Big Data processing and analysis, Blockchain, the Internet of Things;
- introduction of cyber systems in all aspects of energy production, such as robotics, artificial intelligence, 3D printing.

**Therefore, taking into account energy market transformation and global energy trends, Ukraine needs to ensure relevant regulatory and legal mechanisms, as well as socio-economic conditions, in order to take the same development path. The ESU-2035 is projected to become a reliable roadmap for developing the national energy sector.**

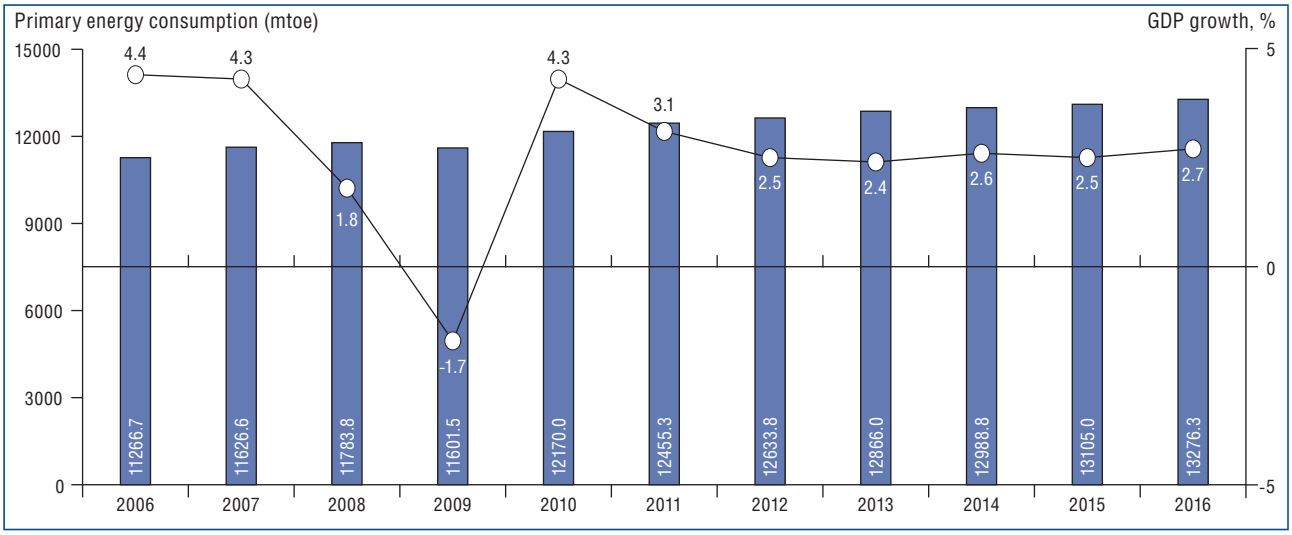
## 1.2. GLOBAL PRIMARY ENERGY CONSUMPTION: GENERAL TRENDS

The global primary energy consumption over the past 10 years has been grown at an average of 1.8% per year. Meanwhile, from 2014 to 2016, global energy demand nearly halved to 0.9-1% per year. The main factors contributing to the fall in energy consumption over the past years include: global economic slowdown (mainly due to reduced energy use in China and India) and the decrease in energy intensity owing to wider use of new technologies.

In the past 6 years, world growth in GDP has dropped dramatically from 4.3% in 2010 to 2.7% in 2016 (Figure "*Growth in GDP and primary energy consumption*").[2] If in 2005-2015 the primary energy consumption growth in China reached an average of 5%, in 2015-2016 it grew by only 1.5% and 1.3% respectively (Table "*Global primary energy consumption in 2006-2016*", p.12). That is the lowest indicator in the past 20 years. Nevertheless, **China remains (in absolute terms) the world's largest**

[2] Global Energy Trends Through the Prism of Ukraine's National Interests – the Razumkov Centre, 2016, p.7; BP Statistical Review, June 2017 – *https://www.bp.com/content/dam/bp/en/corporate/pdf/energyeconomics/statisticalreview2017/bpstatisticalreviewofworldenergy2017fullreport.pdf*.

**Growth in GDP and primary energy consumption (2006-2016)**




**growth market for energy for a 16th consecutive year. In 2016, it accounted for 23% of global primary energy consumption, which is almost twice the share of the EU and 6% more than that of the US**.

Rather paradoxical dynamics of primary energy consumption can be observed in the EU. Despite slight increase in the energy use in the past 2 years, the overall energy consumption over the past 10 years has dropped by 10.2% with GDP increasing by roughly the same rate. This is happening thanks to significant changes from introduction of energy efficient technologies, growing importance of the innovative component in the economy and efforts to reduce energy intensity.

**As for Ukraine, -36% rate makes it a global leader in reducing energy use in 2006-2016. However, this had occurred because of dramatic drop in GDP rather than increased energy efficiency measures.** The largest fall in energy consumption took place when Ukraine lost control over its territories following Russia's annexation of the Crimea and military intervention in the Donbas. Therefore, in 2014-2015 Ukraine's primary energy consumption declined by 27% with GDP decreasing by 16.3%. Given these critical indicators, the 3.6% increase in energy use and 3% GDP growth in 2016 were insignificant compared to 2015. The fact that energy consumption exceeds the economic growth in 2016 highlights the problem of energy efficiency in Ukraine.

Instead, **even when the energy intensity of GDP was as high as 0.28 mtoe/$1,000 in 2015 (twice the average of the EU), the energy supply per capita in Ukraine was approximately 1.5 times lower than the EU average** (Table "*Energy supply per capita in selected countries*", p.13). In addition to the problem of efficient energy use, Ukraine is lagging behind many countries in terms of energy intensity of the economy that negatively affects labour productivity and competitiveness of products.

In 2016 the global primary energy consumption reached 13.28 billion toe, which is 2 billion toe (or 18%) more than in 2006. The largest energy consumers are China, the United States, India, Russia and Japan. Altogether they accounted for 54.1% of the total energy use in 2016. China and India are the main drivers of increasing global energy consumption. Meanwhile, Ukraine's share was 0.7%. Over the past decade, most of the growth in energy consumption (3.7%) comes from developing economies. By contrast, the developed nations (OECD countries) have steadily reduced the annual use of energy resources by an average of 0.3%.

**Renewable energy is the fastest-growing energy source with annual growth rate of 16% over the period under study.** For example, the same indicator for natural gas in 2006-2016 was only about 2.3%. During these years, renewable energy consumption increased from 93.2 to 419.6 mtoe, or by 4.5 times. This clearly demonstrates competitive advantages of RES over traditional energy sources. Renewables (including hydropower) have become a large share of the global energy mix in 2016 (10%). During 2006-2016 China demonstrated the most impressive annual growth of renewable energy generation (at around 44%), which allowed the country to surpass the United States and become the world leader in renewable energy. **Germany – the European leader in renewable energy – consumed 37.9 mtoe of renewable energy in 2016. For comparison, Ukraine managed to consume only 0.3 mtoe. In other words, despite the fact that renewable energy deployment has been officially**

**Global primary energy consumption in 2006-2016** (mtoe)

| Country/Region | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | % of total in 2016 | Changes in 2016 | Changes during 2005-2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| United States | 2 331.6 | 2370.2 | 2318.8 | 2205.1 | 2 284.1 | 2 264.5 | 2 209.3 | 2 270.6 | 2 296.5 | 2 275.9 | 2 272.7 | 17.1 | -0.41% | -0.31% |
| Total North America | **2 824.1** | **2 866.5** | **2 819.2** | **2 689.7** | **2 777.8** | **2 778.6** | **2 724.3** | **2 795.9** | **2 821.2** | **2 792.4** | **2 788.9** | **21.0** | **-0.40%** | **-0.17%** |
| Brazil | 216.8 | 231.8 | 243.9 | 243.0 | 267.6 | 279.7 | 284.8 | 296.8 | 304.9 | 302.6 | 297.8 | 2.2 | -1.84% | 3.66% |
| Total South and Central America | **567.8** | **593.9** | **613.2** | **606.0** | **641.7** | **665.4** | **680.9** | **696.7** | **704.1** | **710.4** | **705.3** | **5.3** | **-0.98%** | **2.83%** |
| United Kingdom | 226.3 | 219.7 | 216.4 | 205.2 | 210.5 | 198.8 | 202.1 | 200.9 | 188.6 | 190.9 | 188.1 | 1.4 | -1.75% | -1.80% |
| Spain | 154.1 | 158.0 | 153.7 | 142.8 | 146.2 | 143.1 | 142.4 | 134.2 | 132.2 | 134.4 | 135.0 | 1.0 | 0.16% | -1.24% |
| Italy | 184.9 | 181.0 | 179.2 | 167.1 | 172.2 | 168.5 | 162.2 | 155.7 | 146.9 | 149.9 | 151.3 | 1.1 | 0.69% | -2.12% |
| Poland | 94.1 | 93.7 | 95.4 | 92.0 | 98.2 | 98.7 | 95.7 | 96.0 | 92.4 | 93.4 | 96.7 | 0.7 | 3.20% | 0.30% |
| Russian Federation | 676.1 | 680.5 | 683.5 | 648.0 | 673.3 | 694.9 | 695.2 | 686.8 | 689.2 | 681.7 | 673.9 | 5.1 | -1.41% | 0.52% |
| Ukraine | 137.7 | 134.4 | 132.9 | 112.9 | 121.0 | 125.7 | 122.6 | 114.7 | 101.2 | 83.9 | 87.0 | 0.7 | 3.44% | -4.74% |
| France | 261.2 | 257.5 | 259.1 | 245.4 | 253.4 | 244.7 | 244.8 | 247.2 | 237.6 | 239.4 | 235.9 | 1.8 | -1.75% | -0.92% |
| Germany | 341.3 | 327.2 | 330.7 | 310.2 | 323.6 | 312.1 | 316.4 | 325.5 | 312.1 | 317.8 | 322.5 | 2.4 | 1.19% | -0.45% |
| Total Europe and Eurasia | **3 023.5** | **3 017.7** | **3 022.2** | **2 839.8** | **2 952.6** | **2 937.9** | **2 936.3** | **2 900.6** | **2 838.3** | **2 846.6** | **2 867.1** | **21.6** | **0.45%** | **-0.41%** |
| Iran | 194.2 | 208.2 | 215.9 | 223.5 | 224.6 | 234.6 | 235.2 | 246.0 | 261.9 | 262.8 | 270.7 | 2.0 | 2.71% | 4.00% |
| Saudi Arabia | 164.5 | 171.4 | 186.9 | 196.5 | 216.1 | 222.2 | 235.7 | 237.4 | 252.1 | 260.8 | 266.5 | 2.0 | 1.92% | 5.11% |
| Total Middle East | **592.2** | **625.6** | **667.6** | **690.3** | **734.2** | **750.3** | **780.8** | **812.4** | **840.0** | **874.6** | **895.1** | **6.7** | **2.07%** | **4.47%** |
| South Africa | 113.2 | 115.4 | 124.4 | 124.3 | 125.3 | 123.6 | 121.9 | 123.6 | 125.2 | 120.1 | 122.3 | 0.9 | 1.52% | 0.83% |
| Total Africa | **334.8** | **347.9** | **369.5** | **373.4** | **388.9** | **388.0** | **402.9** | **415.4** | **427.9** | **433.5** | **440.1** | **3.3** | **1.24%** | **2.85%** |
| China | 1 974.7 | 2 147.8 | 2 229.0 | 2 328.1 | 2 491.1 | 2 690.3 | 2 797.4 | 2 905.3 | 2 970.6 | 3 005.9 | 3 053.0 | 23.0 | 1.29% | 5.26% |
| India | 414.0 | 450.2 | 475.7 | 513.2 | 537.1 | 568.7 | 611.6 | 621.5 | 663.6 | 685.1 | 723.9 | 5.5 | 5.38% | 5.70% |
| Japan | 520.4 | 516.0 | 509.3 | 467.2 | 496.0 | 470.4 | 467.7 | 464.0 | 452.3 | 445.8 | 445.3 | 3.4 | -0.39% | -1.55% |
| Total Asia Pacific | **3 924.3** | **4 175.0** | **4292.1** | **4 402.2** | **4 674.7** | **4 935.1** | **5 108.6** | **5 245.0** | **5 357.2** | **5 447.4** | **5 579.7** | **42.0** | **2.15%** | **3.93%** |
| **Total World** | **11 266.7** | **11 626.6** | **11 783.8** | **11 601.5** | **12 170.0** | **12 455.3** | **12 633.8** | **12 866.0** | **12 988.8** | **13 105.0** | **1 3276.3** | **100** | **1.03%** | **1.82%** |
| **Of which European Union** | **1 830.2** | **1 804.2** | **1 796.7** | **1 691.3** | **1 754.5** | **1 695.9** | **1 681.2** | **1 669.3** | **1 605.0** | **1 626.7** | **1 642.0** | **12.4** | **0.67%** | **-1.11%** |

**Energy supply per capita in selected countries**

| | Toe/person |
|---|---|
| United States | 7.1 |
| Total North America | 7.8 |
| Brazil | 1.4 |
| Total South and Central America | 1.2 |
| United Kingdom | 2.9 |
| Spain | 2.9 |
| Italy | 2.5 |
| Poland | 2.5 |
| Russian Federation | 4.7 |
| Ukraine | 2.0 |
| France | 3.6 |
| Germany | 3.9 |
| Total Europe and Eurasia | 0.6 |
| Iran | 3.4 |
| Saudi Arabia | 8.3 |
| Total Middle East | 2.1 |
| South Africa | 1.9 |
| Total Africa | 0.4 |
| China | 2.2 |
| India | 0.5 |
| Japan | 3.5 |
| **Total World** | 1.8 |
| **Of which European Union** | 3.2 |

**recognised as a priority, this type of energy generation in Ukraine is still in its infancy.**

Over the past two years, the demand for coal in global markets has dropped from 3.89 to 3.73 billion toe, or by 4%, although it grew steadily by an average of 2% annually during 8 years before that. **This may suggest the emergence of a growing trend towards reduced global demand for coal, linked to measures aimed at combating climate change globally**.

In the meantime, the United States have achieved impressive results in gas production. Having introduced innovations and new technologies in shale gas extraction, the Americans were able to increase production by 27% over the past 10 years. This allowed the US energy companies to gradually expand gas export programmes.

## 1.3. STRUCTURAL CHANGES IN GLOBAL PRIMARY ENERGY CONSUMPTION IN 2006-2016

Fossil fuels continued to dominate the global primary energy consumption during the past 10 years. In 2016 they accounted for 85.7% of total energy consumption, decreasing by only 1.7% compared to 2006.[3] Specifically, the share of natural gas increased from 22.9% to 24.1%, while the share of oil fell from 35.2% to 33.3% and of coal from 29.4% to 28.1% (Table "*Global primary energy consumption in 2006 and 2016 by energy source*", p.14). This means that despite the growth in RES, the global energy mix is still governed by inertia and we should not expect drastic changes when making projections to 2035.

Among all fossil fuels, only natural gas has good chances of improving its position in the global energy mix owing to its environmentally friendly benefits.

The nuclear energy consumption falling by 1.2% to 4.5% is explained by mass demonstrations in many developed OECD countries calling the government to abandon the nuclear power generation that only intensified after the Fukushima nuclear accident in 2011. Following the accident, the consumption of nuclear power in Japan has dropped from 66.2 mtoe in 2010 to 4 mtoe in 2016. The nuclear power consumption in OECD countries decreased by an average of 1.7%, while in the developing countries it grew by 3.8%. Particularly noticeable was the nuclear energy consumption by China with an average annual growth of 12.4%. Since nuclear power is one of the most cost-effective and low carbon energy sources, the chances of its further development are very high, especially in the developing world.

**It should be noted that the demand for low carbon energy over the past decade was significantly more dynamic compared with the demand for fossil fuels. As a result, the share of hydropower in the structure of global energy consumption increased from 6.2% to 6.8%, and that of RES – from 0.8% to 3.0%. There are all reasons to believe that this trend will only accelerate due to a steady decline in renewable energy generation costs by solar and wind power plants and storage systems for electric energy.**

The primary energy consumption in Ukraine in 2006-2016 has changed substantially. First of all, there was a twofold decrease in the share of natural gas – from 60.3% to 30% (Table "*Primary energy consumption in Ukraine in 2006 and 2016*", p.15). The same is true for oil, which fell from 14.2% to 10.5%. By contrast, the share of nuclear energy has increased from 14.8% to 21.1%, which is mainly due to a general decrease in primary energy consumption, rather than the improved efficiency of nuclear power use. In the context of decarbonisation, more than 7% increase in coal consumption (from 29% to 36.3%) raises concern. Yet this negative trend in the Ukrainian energy industry was offset by a 20% decrease of coal consumption in 2006-2016 (from 39.8 mtoe to 31.5 mtoe). **If we compare the consumption of low**

[3] The analysis of global energy sectors development in this section is based on the statistics presented in the BP Statistical Review, June 2017 – *https://www.bp.com/content/dam/bp/en/corporate/pdf/energy-economics/statistical-review-2017/bp-statistical-review-of-world-energy-2017-full-report.pdf.*

**Global primary energy consumption in 2006 and 2016 by energy source**

| Country/Fuel | 2006 | | | | | | 2016 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Oil | Natural gas | Coal | Nuclear energy | Hydro-electricity | Total | Oil | Natural gas | Coal | Nuclear energy | Hydro-electricity | Renewable energy | Total |
| United States | 938.8 | 566.9 | 567.3 | 187.5 | 65.9 | 2 326.4 | 863.1 | 716.3 | 358.4 | 191.8 | 59.2 | 83.8 | 2 272.7 |
| Total North America | **1 124.6** | **702.5** | **611.6** | **212.3** | **152.0** | **2 803.0** | **1 046.9** | **886.8** | **386.9** | **217.4** | **153.9** | **97.1** | **2 788.9** |
| Brazil | 92.1 | 19.0 | 13.1 | 3.1 | 79.2 | 206.5 | 138.8 | 32.9 | 16.5 | 3.6 | 86.9 | 19.0 | 297.8 |
| Total South and Central America | **2 36.5** | **117.5** | **21.8** | **4.9** | **147.9** | **528.6** | **326.2** | **154.7** | **34.7** | **5.5** | **156.0** | **28.2** | **705.3** |
| United Kingdom | 82.2 | 81.7 | 43.8 | 17.0 | 1.9 | 226.6 | 73.1 | 69.0 | 11.0 | 16.2 | 1.2 | 17.5 | 188.1 |
| Spain | 78.1 | 30.0 | 18.3 | 13.6 | 5.7 | 145.8 | 62.5 | 25.2 | 10.4 | 13.3 | 8.1 | 15.5 | 135.0 |
| Italy | 85.7 | 69.4 | 17.4 | - | 9.7 | 182.2 | 58.1 | 58.1 | 10.9 | - | 9.3 | 15.0 | 151.3 |
| Poland | 23.1 | 12.3 | 58.4 | - | 0.7 | 94.5 | 27.2 | 15.6 | 48.8 | - | 0.5 | 4.6 | 96.7 |
| Russian Federation | 128.5 | 388.9 | 112.5 | 35.4 | 39.6 | 704.9 | 148.0 | 351.8 | 87.3 | 44.5 | 42.2 | 0.2 | 673.9 |
| France | 92.8 | 40.6 | 13.1 | 102.1 | 13.9 | 262.6 | 76.4 | 38.3 | 8.3 | 91.2 | 13.5 | 8.2 | 235.9 |
| Germany | 123.5 | 78.5 | 82.4 | 37.9 | 6.3 | 328.5 | 113.0 | 72.4 | 75.3 | 19.1 | 4.8 | 37.9 | 322.5 |
| Total Europe and Eurasia | **970.1** | **1 031.7** | **552.9** | **287.8** | **184.6** | **3 027.2** | **884.6** | **926.9** | **451.6** | **258.2** | **201.8** | **144.0** | **2 867.1** |
| Iran | 79.3 | 94.6 | 1.1 | - | 3.8 | 178.8 | 83.8 | 180.7 | 1.7 | 1.4 | 2.9 | 0.1 | 270.7 |
| Saudi Arabia | 92.6 | 66.3 | - | - | - | 158.9 | 167.9 | 98.4 | 0.1 | - | - | ^ | 266.5 |
| Total Middle East | **280.1** | **260.3** | **8.9** | **-** | **4.9** | **554.2** | **417.8** | **461.1** | **9.3** | **1.4** | **4.7** | **0.7** | **895.1** |
| South Africa | 23.2 | - | 93.8 | 2.4 | 0.8 | 120.2 | 26.9 | 4.6 | 85.1 | 3.6 | 0.2 | 1.8 | 122.3 |
| Total Africa | **130.5** | **68.2** | **102.8** | **2.4** | **20.2** | **324.1** | **185.4** | **124.3** | **95.9** | **3.6** | **25.8** | **5.0** | **440.1** |
| India | 120.3 | 35.8 | 237.7 | 4.0 | 25.4 | 423.2 | 212.7 | 45.1 | 411.9 | 8.6 | 29.1 | 16.5 | 723.9 |
| China | 349.8 | 50.0 | 1 191.3 | 12.3 | 94.3 | 1 697.8 | 578.7 | 189.3 | 1 887.6 | 48.2 | 263.1 | 86.1 | 3 053.0 |
| Japan | 235.0 | 76.1 | 119.1 | 68.6 | 21.5 | 520.3 | 184.3 | 100.1 | 119.9 | 4.0 | 18.1 | 18.8 | 445.3 |
| **Total World** | **3 889.8** | **2 574.9** | **3 090.1** | **635.5** | **688.1** | **1 0878.5** | **4418.2** | **3 204.1** | **3 732.0** | **592.1** | **910.3** | **419.6** | **13 276.3** |
| **Of which European Union** | **721.8** | **438.6** | **320.0** | **225.1** | **76.3** | **1 781.9** | **613.3** | **385.9** | **238.4** | **190.0** | **78.7** | **135.6** | **1 642.0** |

**carbon fuels in Ukraine with global data, we will see that Ukraine has a significant advantage in this respect, as the share of low carbon energy in Ukraine is 53% vs 38.6% globally**.

## 1.4. GLOBAL OIL MARKET

### 1.4.1. Demand

International oil market continues to have a big influence on the world's energy industry, not only because oil plays a leading role in global energy mix (about one-third), but also because oil pricing historically has a part in determining prices for other fuels and to a certain degree the dynamics of global energy demand.

In 2006-2016, the global demand for oil grew by an average of 1% per year. During this period, the total oil consumption increased by 434 million tonnes per year reaching 4,418.2 million tonnes per year. Therefore, the global oil demand in absolute value significantly exceeds the corresponding indicator for other types of energy sources. Specifically, global consumption of coal and natural gas, ranked second and third by demand in 2016, amounted to 3,732.0 mtoe and 3,204.1 mtoe respectively. However, the annual growth of coal (1.9%) and natural gas (2.3%) over the past decade excelled that of oil.

The United States, a global leader in oil consumption, remains way ahead of other countries. In 2015 this country consumed 863.1 million tonnes of oil equivalent – a 19.5% of global oil demand. Having consumed 578.7 million tonnes (or 13.1% of global demand), China took a firm hold of the second place. Unlike the United States, where consumption has dropped by an average annual rate of 0.9%, the oil demand in China over the past decade has been growing an average of 5.5% per year. Although the growth of oil consumption in China over the past 2 years almost halved, its huge market makes this country the largest driver of global oil demand. India is the third largest oil consumer with 212.7 million tonnes of oil (or 4.8% of global demand) used in 2016 (Table "*Oil consumption by countries*",[4] p.16).

The differences in oil consumption between the developed and developing nations marked the global oil markets in 2006-2016. Particularly, a significant decline in oil consumption since 2006 has been observed in such developed countries as Japan (-23%), Germany (-8.6%), and the US (-7.3%). Instead, the developing economies have been increasing their oil consumption at an accelerated pace, i.e. China (+64%), India (+66%), and Indonesia (+24.7%). As for the regional specifics, Asia Pacific countries account for 35.2% of the global oil consumption. This region is followed by North America (23.7%) and Europe and Eurasia (20%). China, the US and India will retain the maximum demand for oil until 2035.

Over the past decade, Ukraine's oil demand fell from 14.2 to 9.1 million tonnes per year, or by almost 40%. The share of oil in the country's energy balance makes up only 10% – three times below the global figures. Such insignificance of oil for the national economy should be considered as a positive factor as Ukraine imports more than 80% of crude oil and petroleum products.[5]

**The above-mentioned changes in Ukraine's oil demand since 2006 are unusual for developing economies, as this trend is more typical for developed countries, to which Ukraine does not belong. However, unlike the most advanced nations in the world, where the demand for oil falls thanks to the spread of innovative technologies aimed at optimising energy consumption and the development of RES, Ukraine has reduced its oil use largely due to the deep economic crisis.**

### 1.4.2. Reserves and production

Some experts in geological exploration and oil extraction, especially in 1970s and 1980s, have been advocating theories of rapid depletion of oil reserves due to their natural exhaustibility, which could create significant energy deficit for human civilisation. The most popular among them was the controversial theory by the American geophysicist M. King Hubbert, who predicted the oil production to reach its peak in 2000 with rapid fall in subsequent years. However, the statistical data analysis does not support this theory. For example, the world's proved oil reserves in 2006-2016 have increased from 195.8 billion tonnes to 240.7 billion tonnes or by 23%, growing by 48% since 1996 (Table "*Oil production by countries*",[6] p.16). This growth in proved reserves allowed to increase global oil production by 10.5% over the past

**Primary energy consumption in Ukraine in 2006 and 2016**

| | Oil | Natural gas | Coal | Nuclear energy | Hydro-electricity | Renewable energy | Total |
|---|---|---|---|---|---|---|---|
| 2006 | 15.0 | 59.8 | 39.6 | 20.4 | 2.9 | - | 137.8 |
| 2016 | 9.1 | 26.1 | 31.5 | 18.3 | 1.6 | 0.3 | 87.0 |

[4] Global Energy Trends Through the Prism of Ukraine's National Interests – the Razumkov Centre, 2016, p.15.
[5] BP Statistical Review of World Energy 2017 – *https://www.bp.com/content/dam/bp/en/corporate/pdf/energy-economics/statistical-review-2017/bp-statistical-review-of-world-energy-2017-full-report.pdf.*
[6] Ibid.

10 years – up to 4,382.4 million tonnes per year. As of today, global markets have secured oil resources for the next 50.6 years (Table "*Global proved oil reserves*").

Outstanding achievements of the US oil industry over the past decade deserve a mention. During this period, proved oil reserves in this country grew by more than 3 billion tonnes or by 63%, reaching the 1972 level. This allowed the United States to regain leadership among the world's largest mining countries in a short time. These results became possible due to effective application of horizontal drilling and hydraulic fracturing, which contributed to a rapid increase in shale oil extraction.

Today it is safe to say that the world's proved oil reserves can secure global markets, while oil and gas companies can respond promptly to fluctuations in prices and demand. However, the distribution of proved reserves is characterised by regional disparities. For example, the EU countries account for only 0.3% of global oil reserves, while the Middle East countries possess more than 47% of oil reserves. At the same time, the EU-28 accounts for 13.9% of global demand, and the Middle East – only for 9.5%.

70% of global proved oil reserves belong to OPEC. Following the inclusion of heavy oil from Venezuela's Orinoco Belt into official international statistics, Venezuela has the largest amount of proved oil reserves in the world. As of 2016, Venezuela's proved oil reserves have been 47 billion tonnes, which is 10.4 billion tonnes (or 28%) more than that of Saudi Arabia. The top five nations by oil reserves also include Canada, Iran and Iraq. Russia, which had been among the top three global oil producers over the past decade, holds only sixth place (15 billion tonnes of proved reserves).

Despite the OPEC's efforts to curb oil output to slow down the "shale revolution" and to maintain higher oil prices, the global oil extraction in 2015-2016 increased

**Oil consumption by countries**, mln tonnes

| | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | % of total in 2016 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| United States | 930.7 | 928.8 | 875.4 | 833.2 | 850.1 | 834.9 | 817.0 | 832.1 | 838.1 | 856.5 | **863.1** | 19.5 |
| China | 353.1 | 370.7 | 378.1 | 392.8 | 448.5 | 465.1 | 487.1 | 508.1 | 528.0 | 561.8 | **578.7** | 13.1 |
| India | 128.3 | 138.1 | 144.7 | 152.6 | 155.4 | 163.0 | 173.6 | 175.3 | 180.8 | 195.8 | **212.7** | 4.8 |
| Japan | 238.0 | 230.9 | 224.8 | 200.3 | 202.7 | 203.7 | 217.7 | 207.4 | 197.0 | 189.0 | **184.3** | 4.2 |
| Saudi Arabia | 98.4 | 104.4 | 114.4 | 125.9 | 137.1 | 139.1 | 146.2 | 147.3 | 159.8 | 166.6 | **167.9** | 3.8 |
| Russian Federation | 130.4 | 130.0 | 133.6 | 128.2 | 133.3 | 142.2 | 144.6 | 144.3 | 152.3 | 144.2 | **148.0** | 3.3 |
| Brazil | 100.0 | 107.5 | 116.2 | 117.0 | 126.8 | 131.9 | 134.3 | 144.2 | 150.6 | 146.6 | **138.8** | 3.1 |
| South Korea | 104.7 | 107.6 | 103.1 | 103.7 | 105.0 | 105.8 | 108.8 | 108.3 | 107.9 | 113.8 | **122.1** | 2.8 |
| Germany | 123.6 | 112.5 | 118.9 | 113.9 | 115.4 | 112.0 | 111.4 | 113.4 | 110.4 | 110.0 | **113.0** | 2.6 |
| Canada | 98.7 | 101.7 | 100.6 | 94.4 | 101.0 | 104.2 | 102.3 | 103.5 | 103.1 | 99.1 | **100.9** | 2.3 |
| **Other countries** | 1 678.3 | 1 709.9 | 1 715.6 | 1 693.7 | 1 710.2 | 1 723.8 | 1 733.2 | 1 736.9 | 1 726.8 | 1 757.4 | **1 788.6** | 40.5 |
| **Total World** | **3 984.2** | **4 041.9** | **4 025.3** | **3 955.7** | **4 085.4** | **4 125.7** | **4 176.2** | **4 220.9** | **4 254.8** | **4 341.0** | **4 418.2** | **100.0** |

**Oil production by countries**, mln tonnes

| | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | % of total in 2016 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Saudi Arabia | 508.9 | 488.9 | 509.9 | 456.7 | 473.8 | 525.9 | 549.8 | 538.4 | 543.4 | 567.8 | **585.7** | 13.4 |
| United States | 304.5 | 305.1 | 302.3 | 322.4 | 332.7 | 344.9 | 393.2 | 446.9 | 522.7 | 565.1 | **543.0** | 12.4 |
| Russian Federation | 485.6 | 496.8 | 493.7 | 500.8 | 511.8 | 518.8 | 526.2 | 531.1 | 534.1 | 540.7 | **554.3** | 12.6 |
| Canada | 150.6 | 155.3 | 152.9 | 152.8 | 160.3 | 169.8 | 182.6 | 195.1 | 209.4 | 215.6 | **218.2** | 5.0 |
| China | 184.8 | 186.3 | 190.4 | 189.5 | 203.0 | 202.9 | 207.5 | 210.0 | 211.4 | 214.6 | **199.7** | 4.6 |
| Iraq | 98.0 | 105.1 | 119.3 | 119.9 | 121.5 | 136.7 | 152.5 | 153.2 | 160.3 | 197.0 | **218.9** | 5.0 |
| Iran | 210.7 | 213.3 | 215.6 | 207.4 | 211.7 | 212.7 | 180.7 | 169.8 | 174.2 | 181.6 | **216.4** | 4.9 |
| United Arab Emirates | 144.3 | 139.6 | 141.4 | 126.2 | 133.3 | 151.3 | 154.8 | 165.1 | 166.2 | 176.2 | **182.4** | 4.2 |
| Kuwait | 133.7 | 129.9 | 136.1 | 120.9 | 123.3 | 140.8 | 153.9 | 151.3 | 150.1 | 148.2 | **152.7** | 3.5 |
| Venezuela | 171.2 | 165.5 | 165.6 | 156.0 | 145.8 | 141.5 | 139.3 | 137.8 | 138.5 | 135.9 | **124.1** | 2.8 |
| **Other countries** | 1 572.5 | 1 567.4 | 1 562.5 | 1 535.0 | 1 559.3 | 1 462.6 | 1 476.0 | 1 426.6 | 1 415.8 | 1 416.7 | **1 386.9** | 31.6 |
| **Total World** | **3 964.8** | **3 953.2** | **3 989.6** | **3 887.8** | **3 976.5** | **4 007.9** | **4 116.4** | **4 125.3** | **4 226.2** | **4 359.5** | **4 382.4** | **100.0** |

**Global proved oil reserves**, bln tonnes

| | 1996 | 2006 | 2015 | 2016 | % of total reserves in 2016 |
|---|---|---|---|---|---|
| **OPEC countries, including** | 112.9 | 131.3 | 169.7 | **171.2** | 71.1 |
| Venezuela | 11.3 | 13.6 | 47.0 | **47.0** | 19.5 |
| Saudi Arabia | 35.9 | 36.3 | 36.6 | **36.6** | 15.2 |
| Iran | 12.7 | 19.0 | 21.8 | **21.8** | 9.0 |
| Iraq | 15.1 | 15.5 | 19.2 | **20.6** | 8.6 |
| Kuwait | 13.3 | 14.0 | 14.0 | **14.0** | 5.8 |
| United Arab Emirates | 13.0 | 13.0 | 13.0 | **13.0** | 5.4 |
| **Other OPEC countries** | 11.5 | 19.9 | 18.2 | **18.2** | 7.6 |
| **Canada** | 7.9 | 28.9 | 27.6 | **27.6** | 11.5 |
| **Russian Federation** | 15.6 | 14.3 | 14.0 | **15.0** | 6.2 |
| **Other countries** | 25.7 | 21.4 | 27.2 | **26.9** | 11.2 |
| **Total World** | **162.0** | **195.8** | **238.6** | **240.7** | **100.0** |

by 156.2 million tonnes, or by 3.7%. Saudi Arabia was the world's largest oil producer in 2016 with 585.7 million tonnes, followed by Russia (554.3 million tonnes) and the United States (543 million tonnes).

In 2016, Ukraine managed to produce only 2.3 million tonnes of oil – a 8% drop from 2015. Since 2006, Ukraine's oil output almost halved to 2.2 million tonnes per year.[7] It would be wrong to explain this steep fall by limited proved reserves, as they are estimated at 80-110 million tonnes, while Ukraine's projected resources reach almost 1 billion tonnes. In other words, the country's supply of oil reserves under current production model matches the global average. **The main causes of crisis in the national oil industry include poor corporate management of the key Ukrainian oil company – PJSC *Ukrnafta*, and ineffective government policy for subsoil use. As a consequence, despite gradual exhaustion of basic oil fields, potential sources to increase oil production are not developed because of the lack of investment. In case of substantial investment in exploration and extraction, the existing resource base would be able to increase oil production to 3 million tonnes per year by 2030.**

### 1.4.3. Prices

With the exception of individual countries, the global oil market is exclusively governed by a market-based pricing mechanism. The most common mechanism for price determination is stock trading, which defines an equilibrium price (which brings demand and supply into balance) for specific benchmark oils. The distinctive feature of trading involving benchmark crude oil is that it occurs only under futures contracts for a clearly defined period.

The list of benchmark crudes includes *Brent Blend* (oil fields in the North Sea), *Dubai Crude* (United Arab Emirates) and *West Texas Intermediate* (the US territory). These crude oils were globally recognised as benchmark or marker crudes – thanks to the reliability of supplies and a significant number of those ready to buy and process these crudes.

In addition to these benchmark oils, there are many different varieties and grades of crude oil determined by the region, or rather the country of origin. Some crudes, such as *Arab Light* (Saudi Arabia), *Basra Light* (Iraq), *Bonny Light* (Nigeria), *Es Sider* (Libya), *Girassol* (Angola), *Iran Heavy* (Iran), *Kuwait Export* (Kuwait), *Merey* (Venezuela), *Murban* (UAE), *Oriente* (Ecuador), *Qatar Marine* (Qatar), *Saharan Blend* (Algeria) are included in the so-called OPEC Reference Basket. The price indicator for the OPEC Basket is bound to contracts traded on the spot market. Albeit not always stock-based, the pricing still follows the principle of a supply-demand equilibrium. The price of OPEC basket crudes are mostly affected by price quotes for benchmark crudes.

As for other crudes, such as Russian *URALS*, *REBCO*, *Siberian Light*, *ESPO*, *Arctic Oil*, or Azerbaijan's *Azeri Light*, their pricing is decided relative to *Brent*. Quotations of these crudes directly replicate the pricing dynamics of benchmark crudes. The Russian *URALS* oil blend is traditionally viewed as the most proximal for Ukraine. In 2006-2016, the oil prices were characterised by significant volatility. The highest average annual *Brent* price was observed in 2012, reaching $109 per barrel. Since then, however, the oil prices have been consistently decreasing on international exchanges for four consecutive years. Particularly sharp fall in oil prices was recorded in 2015, when *Brent* averaged $43.7/barrel – down by $45.9/barrel in 2014, or by 47% (Figure "*Brent oil prices in 2007-2017*"[8]).

[7] Oil and gas industry of Ukraine in figures: use, production, transportation – NJSC Naftogaz Ukrainy, *http://www.naftogaz.com*.

[8] Global energy trends through the prism of Ukraine's national interests – the Razumkov Centre, 2016, p.16.; Brent Oil Historical Data – *http://www.investing.com/commodities/brent-oil-historical-data*.

Key factors contributing to a fall in oil prices in 2013-2016 include:[9]

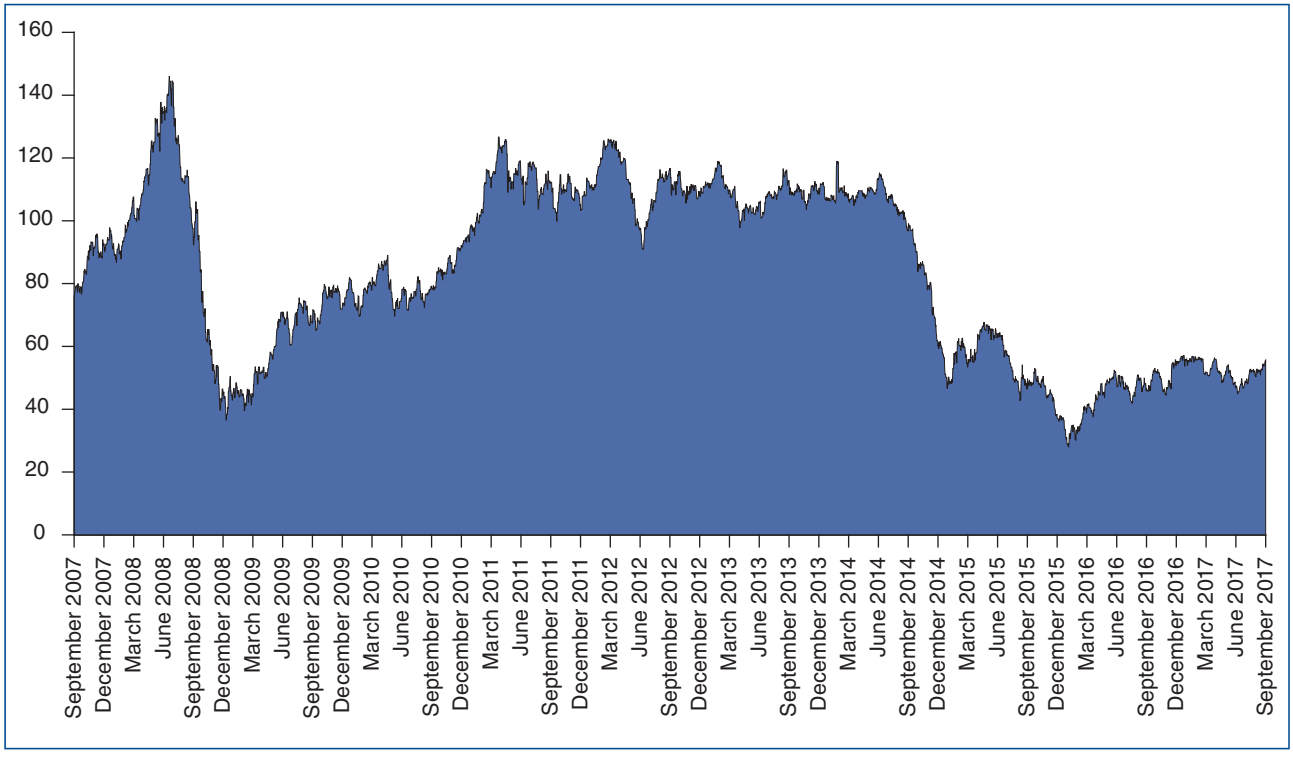
- increased shale oil production in the US;
- lifting of international sanctions against Iranian oil;
- removal of embargo on the US oil exports by the President Obama's Administration;
- discount rate increase by the Fed (US Federal Reserve System);
- lower demand growth in China;
- high rates of renewable energy generation;
- slowdown of the global economic growth;
- Saudi Arabia setting quotas for oil export for OPEC countries.

**The market-related, financial, socio-economic and political factors that enable to make some kind of analysis and projections on their role in a changing pricing environment are not the only ones affecting oil prices. A subjective nature of low profile arrangements between oil market participants, where individual players seek additional commercial and political dividends, is another important factor that influences oil prices. This "invisible factor" brings about uncertainty and unpredictability in the global oil market.** Other unpredictable factors include outbreaks of armed conflicts close to major oil-producing regions. In this context, it is worthy to mention the war in Syria and the ISIS terrorist activity in the Middle East and North Africa. **So, one of the Russia's key foreign policy objectives in these regions is to create and maintain instability in order to raise oil prices, as the Russian economy remains critically dependent on the cost of hydrocarbons.**

The pricing policy in the global oil market can be also affected by:

- activities of the expanded oil cartel comprised of the OPEC and some other countries supporting oil production curbs. OPEC and a number of non-OPEC countries met in Vienna in late 2016 and agreed to reduce oil production by 1.8 million barrels per day (mb/d), adjusted to October 2016 level, including Russia reducing the output by 300 tb/d. The agreement covered the first half of 2017. In May 2017, its validity has been extended until the end of March 2018;
- increased oil output in the US, including the shale oil. American shale companies continue to ramp up extraction, which in 2017 can reach all-time highs, exceeding 9.8 mb/d;
- Iraqi Kurdistan independence referendum. In this case, the zone of instability extends to areas from where oil is being pumped to the Turkish port of Ceyhan;

**Brent oil prices in 2007-2017**, $ per barrel




[9] Global Energy Trends Through the Prism of Ukraine's National Interests – the Razumkov Centre, 2016, pp.16-17.

- the Atlantic hurricane season in the US that affects the country's oil market.

OPEC seeks to balance demand and supply in the oil market and consequently to achieve increase in oil prices, but according to experts, this situation is not likely to last.

According to the International Energy Agency (IEA) estimates, if average OPEC production capacity is now expected to rise to 32.7 mb/d, by the end of 2018 the market will have the excess supply of about 300 tb/d. This oversupply will be due to increased production in non-OPEC+ countries, primarily the United States, Canada, Brazil and Kazakhstan. At the same time, the on-going struggle between OPEC and the US shale oil producers can trigger a new steep drop in prices.

The exchange market can demonstrate its involvement in the realisation of that scenario, if, for example, the US Federal Reserve chooses to actively raise the rate. A review of the inflation threshold points at this course of events. The Fed Chair Janet Yellen believes that it is not necessary to intensify monetary policy after inflation reaches 2%. In turn, Donald Trump has several tax initiatives, which, if it comes to their practical realisation, can push the Fed rate up – in this case, stronger dollar will become another argument for reducing the oil price.

**However, if we consider objective trends only, then due to significant fluctuations, oil prices in the long run are more likely to gradually decline rather than grow. Still, oil prices may also surge in certain short periods of time. Considering the above, it is possible to predict that in 2017-2020 the average annual global oil prices will range within $70-80/barrel, and in 2020-2025 they are likely to drop to $50-60/barrel.**[10]

In Ukraine, the current oil pricing mechanism may be described as non-market. Certain provisions for determining the starting price at auctions for crude oil produced by PJSC *Ukrnafta* include terms that contradict the economic logic of pricing and create loopholes for price manipulations. For example, the automatic pricing for oil at the import price level 15 days before the auction, and its precedence over market quotations of *URALS* or "links" to the *Brent* price may lead to maximisation of prices through the mechanisms of manipulation with import contracts.

Ukraine is yet to develop a market pricing mechanisms for oil – either by amending current pricing regulations or by setting up a stock exchange by involving more potential oil suppliers and consumers.

## 1.5. GLOBAL GAS MARKET

### 1.5.1. Demand

Over the last decade, natural gas market demonstrated the fastest growth among all fossil fuels. First, this can be attributed to environmentally friendly benefits of gas and its more competitive prices compared to oil and coal. Another important trend in the gas market is its global integration due to the dynamic growth of the share of liquefied natural gas (LNG) in the global gas trade, which has increased from 17% to 32% over the past 10 years.[11] This has resulted in gradual formation of an independent global gas market with no strict oil-linked prices. It continues to transform into a more liberalised and transparent mechanism with the dominance of short-term contracts, while the geography of LNG suppliers and consumers is expanding constantly. Qatar is the world's largest LNG exporter – in 2016 it supplied 104.4 billion cubic meters (bcm) of liquified gas to international markets. In this regard, one should also take a note of Australia as an LNG exporter, as in 2016 this country increased sales at a record pace and managed to raise exports to 56.8 bcm – a 40% increase from 2015.

Global gas consumption grew in 2006-2016 from 2.85 trillion cubic meters to 3.54 trillion cubic meters, or by 24.2%. The United States is an absolute global leader in gas consumption, as in 2016 it consumed 778.6 bcm. Top five gas consumers also include Russia (390.9 bcm), China (210.3 bcm), Iran (200.8 bcm) and Japan (111.2 bcm) (Table "*The world's largest consumers of natural gas*", p.20). China remains the main driver of gas use, as it increased its consumption by 3.5 times over the period under study. Increasing gas consumption was also observed in India, Australia, Qatar and Israel. Among the regions, the highest average annual growth of gas consumption was recorded in the Middle East (5.9%) and the Asia Pacific (5.6%). Despite projections by leading international think tanks, the EU countries showed a decrease in natural gas demand (-2.2%). This has led to reduced consumption of this type of fuel over the past 10 years by 61.3 bcm, or 14.3%. Yet, in 2016, the demand for gas in the EU has increased substantially (by 7.1%), which is explained by its cheapening with simultaneous growth of coal prices and stricter environmental standards for coal use by thermal power plants. **In 2014-2016, the battle between Russia, Norway, Algeria and Qatar for the EU market – the most financially reliable and capacious global gas market for "blue fuel" exporters – has intensified. To date, the largest share of gas consumed in the EU comes from Russia (30.9%), followed by Norway (25.6%),**

[10] This forecast does not include possible unpredictable events in major oil and gas producing regions, linked to military action, intensified political and social tension, etc.

[11] Sources: Alternatives of gas supply to Ukraine: liquified natural gas (LNG) and unconventional gas. Analytical report by the Razumkov Centre – National Security and Defence, 2011, No.9, p.9, and BP Statistical Review of World Energy 2017 – *https://www.bp.com/content/dam/bp/en/corporate/pdf/energy-economics/statistical-review-2017/bp-statistical-review-of-world-energy-2017-full-report.pdf*.

**Algeria (10.8%) and Qatar (5.3%)** (Figure "*The share of the largest exporters in the EU gas consumption*").

The European market may soon welcome another strong player, as the President Trump's Administration actively promotes the idea of increasing LNG supplies from the US to world markets, and particularly to Europe. The "shale revolution" has enabled the United States to export up to 50 bcm of LNG to Europe over the next 5-7 years. The realisation of this potential, however, will depend on two key factors – commercial competitiveness of American LNG and the ability of the EU's leading political forces to recognise that reducing gas supplies from Russia is central to ensuring the energy security.

**In 2006-2016, Ukraine demonstrated the highest reduction in gas consumption in the world. During this period, it has dropped from 67 bcm to 29 bcm, or by 2.3 times.**[12] **The main reason for that was not energy efficiency but rather the decline in industrial production.** A significant rise in gas prices also resulted in reduced consumption. Increased efficiency of gas use should be based on technological and structural rebuilding of the economy with an emphasis on stimulating high-tech manufacturing and services instead of energy-intensive industries.

2016 was the first year ever when Ukraine ceased importing gas from Russia. This was achieved thanks to a continued and effective diversification of supplies from the EU. Ukraine's access to Polish LNG terminal *Swinoujscie* in the Baltic Sea by 2020 would be another effective step to diversification. To achieve this goal, Ukraine needs to build an interconnector with a capacity of 5 bcm/y, linking the gas distribution stations *Bilche Volitsa* (Ukraine) and *Hermanowice* (Poland). Energy security policy by Poland and Lithuania also deserves attention, as these countries are much more active in taking measures to reduce gas dependence from *Gazprom* compared with older EU states. Putting two LNG terminals – *Swinoujscie* and *Klaipeda* – into operation in 2015 is the evidence of such efforts that allow to significantly expand the geography of gas purchases.

### 1.5.2. Reserves and production

Over the past 10 years, global proved gas reserves have increased from 158.2 to 186.6 trillion cubic meters, or by 18%. As of the end of 2016, the global demand for natural gas is secured for the next 52.2 years. The highest growth in proved reserves was observed in Turkmenistan, Iran and China – by 15.2, 6.6 and 3.7 trillion cubic meters respectively. The United States also ensured significant growth by discovering new deposits of unconventional gas at 2.7 trillion cubic meters. Countries with the world's largest proved reserves of natural gas are Iran (33.5 trillion cubic meters), Russia (32.3), Qatar (24.3) and Turkmenistan (17.5). The total share of these four countries in the total gas reserves reaches 57.5% (Table "*Proved natural gas reserves by selected countries in 2016*", p.22). By regions, the Middle East holds the world's largest proved reserves of natural gas (42.5%). Instead, the EU countries are characterised by significant disproportions between proved reserves and consumption volumes. For example, if the EU accounts for only 0.7% of global gas reserves, its share in global demand is reaching 12.1%, making the EU members fully dependent on gas imports.

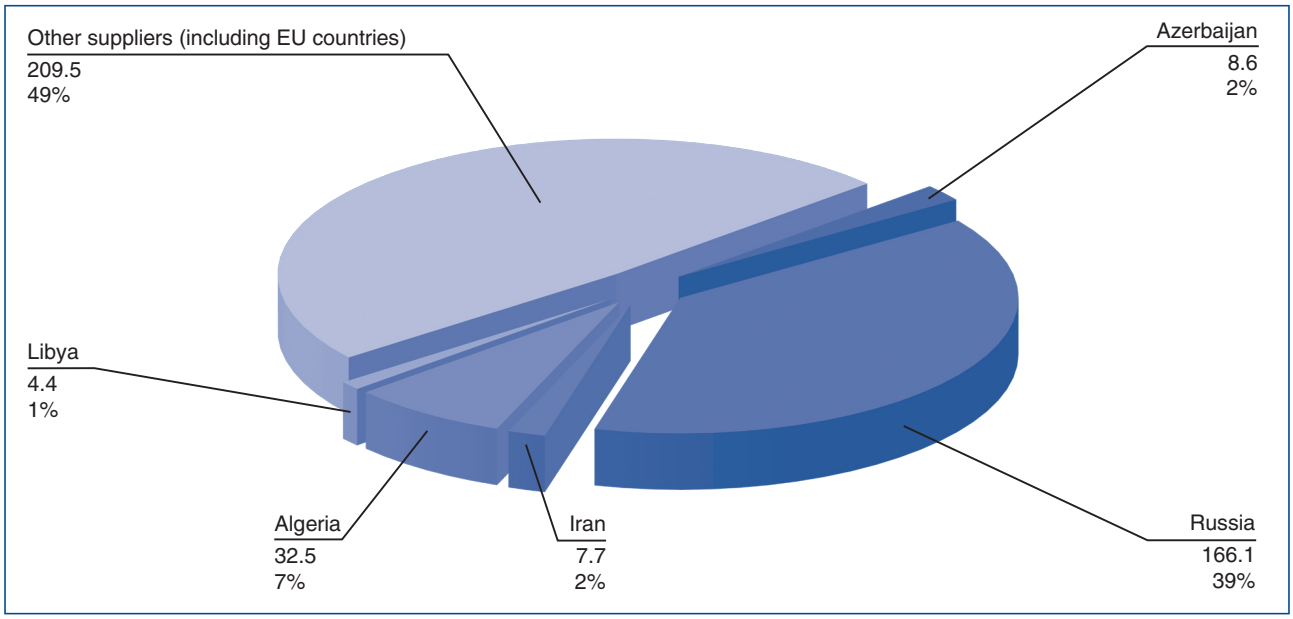
**The world's largest consumers of natural gas**, bcm

| | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | % of total in 2016 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1. United States** | 614.4 | 654.2 | 659.1 | 648.7 | 682.1 | 693.1 | 723.2 | 740.6 | 753.0 | 773.2 | **778.6** | 22.0 |
| **2. Russian Federation** | 415.0 | 422.0 | 416.0 | 389.6 | 414.1 | 424.6 | 416.2 | 413.5 | 409.7 | 402.8 | **390.9** | 11.0 |
| **3. China** | 59.3 | 73.0 | 84.1 | 92.6 | 111.2 | 137.1 | 150.9 | 171.9 | 188.4 | 194.8 | **210.3** | 5.9 |
| **4. Iran** | 112.0 | 125.5 | 133.2 | 142.7 | 152.9 | 162.2 | 161.5 | 162.9 | 183.7 | 190.8 | **200.8** | 5.7 |
| **5. Japan** | 83.7 | 90.2 | 93.7 | 87.4 | 94.5 | 105.5 | 116.9 | 116.9 | 118.0 | 113.4 | **111.2** | 3.1 |
| **6. Saudi Arabia** | 73.5 | 74.4 | 80.4 | 78.5 | 87.7 | 92.3 | 99.3 | 100.0 | 102.4 | 104.5 | **109.4** | 3.1 |
| **7. Mexico** | 66.6 | 63.4 | 66.3 | 72.2 | 72.5 | 76.6 | 79.9 | 83.3 | 86.8 | 87.1 | **89.5** | 2.5 |
| **8. Germany** | 87.9 | 84.7 | 85.5 | 80.7 | 84.1 | 77.3 | 77.5 | 81.2 | 70.6 | 73.5 | **80.5** | 2.3 |
| **9. United Kingdom** | 90.0 | 91.0 | 93.8 | 87.0 | 94.2 | 78.1 | 73.9 | 73.0 | 66.7 | 68.1 | **76.7** | 2.2 |
| **10. Italy** | 77.4 | 77.3 | 77.2 | 71.0 | 75.6 | 70.9 | 68.2 | 63.8 | 56.3 | 61.4 | **64.5** | 1.8 |
| **…** | | | | | | | | | | | | |
| **Ukraine*** | 67.0 | 63.2 | 60.0 | 46.8 | 52.2 | 53.7 | 49.6 | 43.3 | 36.8 | 28.8 | **29.0** | 0.8 |
| **Total World** | **2 850.6** | **2 967.3** | **3 044.9** | **2 965.9** | **3 187.6** | **3 245.9** | **3 337.7** | **3 383.8** | **3 400.8** | **3 480.1** | **3 542.9** | **100.0** |

* – excluding processed gas

[12] This does not include processed gas used by the Ukrainian GTS.

**The share of the largest exporters in the EU gas consumption**




**Ukraine owns 0.6 trillion cubic meters of proved gas reserves, and if compared with the EU countries, it is second only to the Netherlands in this regard. Ukraine's projected resources amount to 3.5 trillion cubic meters**[13] **allowing the country – given favourable investment climate – to increase production to 30-32 bcm/y by 2025 and almost fully meet the domestic demand for natural gas with own production.**

Global gas production in 2016 reached 3.54 trillion cubic meters, which is 692.3 bcm (or 24.3%) more than in 2006. Having increased production by 225.2 bcm (or by 43%), the United States became the global leader over this period (Table "*Natural gas production by countries*", p.22). This surge was largely due to the growth in shale gas production, while extraction of traditional gas has dropped. Production also increased in Qatar (+130.5 bcm), Iran (+ 87.2 bcm), China (+77.8 bcm) and Australia (+52 bcm). Instead, the United Kingdom (-39 bcm) and the Netherlands (-18.3 bcm) top the list of countries with reduced gas production. During 2006-2016 a noticeable decrease in gas production was also observed in Russia (-15.8 bcm).

**Over the past decade Ukraine was unable to use its considerable resource potential. Not only it failed to increase gas production, but eventually reduced it by 0.5 bcm (or by 2.4%), from 20.7 bcm in 2006 to 20.2 bcm in 2016. In this context, state-owned companies reduced gas production by 3.4 bcm (17.6%), while private enterprises rapidly increased production by more than 3 times (or by 2.9 bcm).** Ukraine's gas industry suffered a heavy blow after losing control over Crimea as a result of its annexation by Russia in 2014 as the Ukrainian Black Sea shelf was extremely promising in terms of gas production. Moreover, short-sighted fiscal policy on rental rates in 2014 has triggered the downfall in gas production in 2015 by 0.5 bcm[14] and contributed to deterioration of the investment climate in the gas sector. **However, in case of adequate realisation of the ESU-2035, which provides for a number of incentives to intensify domestic gas production, Ukraine will be able to reach self-sufficiency by 2025, as its resource base is rich enough to achieve that.**

Iran currently holds the best prospects for gas production growth with one of the world's largest gas fields – *South Pars*. In case of its successful commercial development, Iran's gas production will double, but this requires minimising risks linked to international sanctions on Iran in response to the alleged nuclear programme. Other new projects, that in addition to significant impact on international gas markets can strongly influence the political landscape in the Middle East, include the development of Israel's gigantic Leviathan gas field in the Mediterranean Sea with about 600 bcm of reserves.

### 1.5.3. Prices

It should be noted that during the last two decades the natural gas market has moved towards localising individual trading platforms based on geography or raw materials, that is, the development of the so-called gas hubs. As in case of oil, trading gas supply contracts that form equilibrium price have become an important pricing instrument. This approach applies to markets in all developed economies and works in almost all European countries.

[13] Global Energy Trends Through the Prism of Ukraine's National Interests – the Razumkov Centre, 2017, p.19.
[14] Oil and gas industry of Ukraine in figures: use, production, transportation – NJSC Naftogaz Ukrainy, *http://www.naftogaz.com*.

**Proved natural gas reserves by selected countries in 2016**, trillion cubic meters

| | 1996 | 2006 | 2015 | 2016 | % of total reserves 2016 |
|---|---|---|---|---|---|
| **1. Iran** | 23.0 | 26.9 | 33.5 | **33.5** | 18.0 |
| **2. Russia** | 30.9 | 31.2 | 32.3 | **32.3** | 17.3 |
| **3. Qatar** | 8.5 | 25.5 | 24.3 | **24.3** | 13.0 |
| **4. Turkmenistan** | N/a | 2.3 | 17.5 | **17.5** | 9.4 |
| **5. United States** | 4.7 | 6.0 | 8.7 | **8.7** | 4.7 |
| **6. United Arab Emirates** | 5.8 | 6.4 | 6.1 | **6.1** | 3.3 |
| **7. Venezuela** | 4.1 | 4.7 | 5.7 | **5.7** | 3.1 |
| **8. Algeria** | 3.7 | 4.5 | 4.5 | **4.5** | 2.4 |
| **9. China** | 1.2 | 1.7 | 4.8 | **5.4** | 2.9 |
| **10. Australia** | 1.3 | 2.3 | 3.5 | **3.5** | 1.9 |
| **…** | | | | | |
| **Ukraine** | N/a | 0.7 | 0.6 | **0.6** | 0.3 |
| **Other countries** | 40.4 | 46.0 | 44.0 | **44.6** | 23.9 |
| **Total World** | **123.5** | **158.2** | **185.4** | **186.6** | **100.0** |

**Natural gas production by countries**, billion cubic meters

| | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | % of total in 2016 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1. United States** | 524.0 | 545.6 | 570.8 | 584.0 | 603.6 | 648.5 | 680.5 | 685.4 | 733.1 | 766.2 | **749.2** | 21.1 |
| **2. Russian Federation** | 595.2 | 592.0 | 601.7 | 527.7 | 588.9 | 607.0 | 592.3 | 604.7 | 581.7 | 575.1 | **579.4** | 16.3 |
| **3. Iran** | 111.5 | 124.9 | 130.8 | 143.7 | 152.4 | 159.9 | 166.2 | 166.8 | 185.8 | 189.4 | **202.4** | 5.7 |
| **4. Qatar** | 50.7 | 63.2 | 77.0 | 89.3 | 131.2 | 145.3 | 157.0 | 177.6 | 174.1 | 178.5 | **181.2** | 5.1 |
| **5. Canada** | 171.7 | 165.5 | 159.3 | 147.6 | 144.5 | 144.4 | 141.1 | 141.4 | 147.2 | 149.1 | **152.0** | 4.3 |
| **6. Norway** | 88.7 | 90.3 | 100.1 | 104.4 | 107.3 | 101.3 | 114.7 | 108.7 | 108.8 | 117.2 | **116.6** | 3.3 |
| **7. China** | 60.6 | 71.6 | 83.1 | 88.2 | 99.1 | 109.0 | 111.8 | 122.2 | 131.6 | 136.1 | **138.4** | 3.9 |
| **8. Saudi Arabia** | 73.5 | 74.4 | 80.4 | 78.5 | 87.7 | 92.3 | 99.3 | 100.0 | 102.4 | 104.5 | **109.4** | 3.1 |
| **9. Algeria** | 84.5 | 84.8 | 85.8 | 79.6 | 80.4 | 82.7 | 81.5 | 82.4 | 83.3 | 84.6 | **91.3** | 2.6 |
| **10. Indonesia** | 74.3 | 71.5 | 73.7 | 76.9 | 85.7 | 81.5 | 77.1 | 76.5 | 75.3 | 75.0 | **69.7** | 2.0 |
| **…** | | | | | | | | | | | | |
| **Ukraine*** | 20.7 | 20.7 | 21.1 | 21.3 | 20.5 | 20.6 | 20.5 | 21.4 | 20.5 | 19.9 | **20.2** | 0.6 |
| **Total World** | **2 876.7** | **2 947.5** | **3 054.2** | **2 968.8** | **3 192.2** | **3 290.2** | **3 352.3** | **3 403.9** | **3 465.9** | **3 530.6** | **3 551.6** | **100.0** |

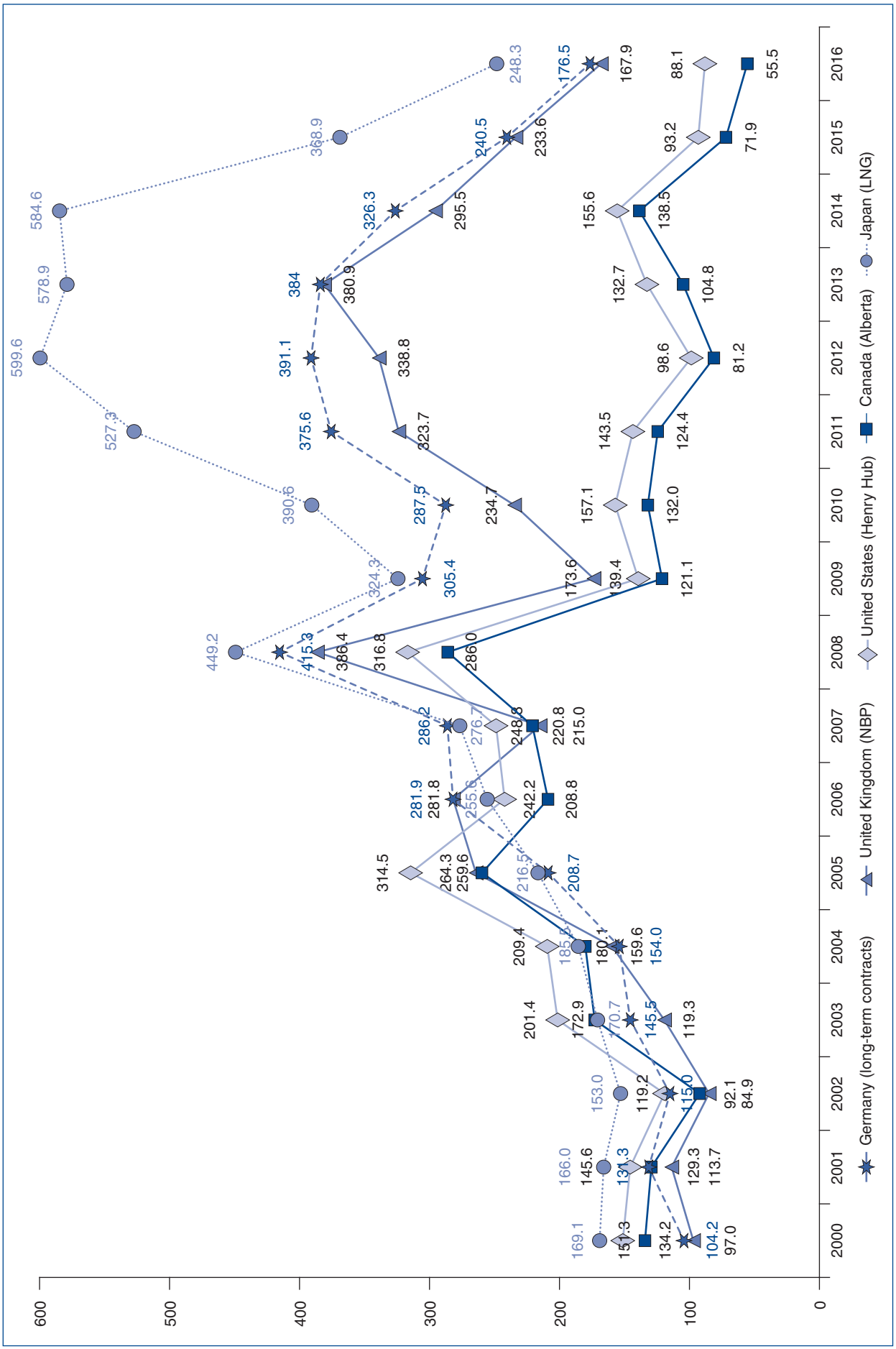
* *Source*: PJSC Naftogaz of Ukraine – *http://www.naftogaz.com/www/3/nakweb.nsf/0/74B2346ABA0CBC69C22570D80031A365?OpenDocument*.
The data published in the BR Statistics Review of World Energy differ from Ukraine official statistics because the latter includes process gas.

The analysis of price fluctuations in 2006-2016 highlights significant changes in international gas trading. Above all, they are linked to the increase in the price difference between different trading platforms. For example, if in 2000-2005 the gas price difference on the leading international exchanges and markets did not exceed $70 per one thousand cubic meters, in the last 10 years it, at times, reached $470. This difference was particularly evident between the North American and South-East Asian markets. For example, the average annual gas price in 2012 in Japan (*LNG cif*) was $499 higher than that at the *Henry Hub* trading platform (USA). In 2016 this difference decreased to $159, but still remained significant. Another aspect of gas markets is that gas prices somehow correlate with oil prices. Thus, after a stunning fall in oil prices by 47% in 2015, gas prices in different regions dropped by 20-40% (Figure and Table "*Average annual price for natural gas in the leading international trading hubs*",[15] p.23-24).

The gas price in Europe fell in 2015 as the supply exceeded the demand. Russia and Norway increased their natural gas supply to European countries by 16% and 7% respectively; additionally, the supply of liquefied natural gas to Europe also grew by about 10%. As a result, the spot price of natural gas has dropped in 2015 by more than 20% – to about $230 for one thousand cubic meters. According to the IMF, the German border price of Russian pipeline gas decreased by 30%, dropping to $263.

[15] Global Energy Trends Through the Prism of Ukraine's National Interests – the Razumkov Centre, 2016, p.27.

**Average annual price for natural gas in the leading international trading hubs**, $ per one thousand cubic meters



**Average annual price for natural gas in the leading international trading hubs,**
$ per one thousand cubic meters

| | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Germany (long-term contracts) | 104.2 | 131.3 | 115.0 | 145.5 | 154.0 | 208.7 | 281.9 | 286.2 | 415.3 | 305.4 | 287.5 | 375.6 | 391.1 | 384.0 | 326.3 | 240.5 | **176.5** |
| United Kingdom (NBP) | 97.0 | 113.7 | 84.9 | 119.3 | 159.6 | 264.3 | 281.8 | 215.0 | 386.4 | 173.6 | 234.7 | 323.7 | 338.8 | 380.9 | 295.5 | 233.6 | **167.9** |
| United States (Henry Hub) | 151.3 | 145.6 | 119.2 | 201.4 | 209.4 | 314.5 | 242.2 | 248.8 | 316.8 | 139.4 | 157.1 | 143.5 | 98.6 | 132.7 | 155.6 | 93.2 | **88.1** |
| Canada (Alberta) | 134.2 | 129.3 | 92.1 | 172.9 | 180.1 | 259.6 | 208.8 | 220.8 | 286.0 | 121.1 | 132.0 | 124.4 | 81.2 | 104.8 | 138.5 | 71.9 | **55.5** |
| Japan (LNG) | 169.1 | 166.0 | 153.0 | 170.7 | 185.5 | 216.5 | 255.6 | 276.7 | 449.2 | 324.3 | 390.6 | 527.3 | 599.6 | 578.9 | 584.6 | 368.9 | **248.3** |

In 2016, natural gas forward contracts in Europe in 2017 were sold for $150-167 per one thousand cubic meters. In 2018-2020 one can expect dumping by new gas suppliers. Market entry of Australia and the United States with substantial LNG volumes will undoubtedly affect the prices and geography of supplies.

As the gas price in North America is considerably lower than in Europe and the Asia Pacific countries, the American companies demonstrate a significant commercial interest in exporting gas from the United States. According to the base case scenario, LNG exports from the US in 2030 will reach 120 bcm/y, while in 2016 they amounted to only 4.4 bcm. To achieve this goal, it is planned to build seven gas liquefaction plants with a total capacity of 132 bcm. It will be difficult for American exporters to oust *Gazprom* from the EU market because Russia will do its best to prevent this from happening by dumping and employing previously established corrupt schemes with some representatives of European political and business elites. Intensified support of the *Nord Stream 2* gas pipeline project by Germany, France, Austria and the Netherlands with the involvement of individual Brussels bureaucrats is a vivid example of such actions.

**In 2015-2016, Ukraine's natural gas market was extensively liberalised, which among other things helped to increase the number of suppliers to more than twenty. A truly pivotal event for the development of domestic market occurred in April 2016, when the government decided to link its domestic gas prices to that of *NetConnect Germany* (NCG) hub (import parity price).[16] This decision helped to stabilise the macroeconomic situation by eliminating multi-billion subventions from State Budget to *Naftogaz*, thus becoming a significant step towards the European integration of Ukraine's gas sector.**

## 1.6. GLOBAL COAL MARKET

### 1.6.1. Demand

Despite decline in the global coal production for two consecutive years – from 3.89 billion toe in 2014 to 3.73 billion toe in 2016 (overall, by 4.1%), the global demand for coal during 2006-2016 has increased by 438.1 mtoe, or by 13.3%. Average annual growth of demand in the developing economies reached 3.7%, while developed OECD members, on the contrary, reduced coal consumption with an average annual rate of -1.9% (Table "*The world's largest coal consumers*"). This trend suggests that developed nations are more concerned with environmental problems and the quality of life of their citizens, while developing countries pursue economic growth and are less likely to care about the environment and public health.

China has been the largest market for coal for many years. Coal is China's main type of fuel, as its share in the total primary energy consumption amounts to 63.7%. Enormous reserves and production of coal in China have contributed to this country's extremely dynamic development in the past 30 years, but at the same time caused huge problems with air pollution in the cities. In 2016, China's coal consumption reached 1,887.6 mtoe, or 50.6% of global demand. The second-ranked India looks quite "modest" with its demand of 411.9 mtoe, which is 4.5 times less than China's. The United States is another large market for coal, but due to sharp fall in natural gas prices as a result of the "shale revolution", coal has been losing its positions in the US market over the last decade – the demand for coal during 2006-2016 fell by 36.6% to 358.4 mtoe.

In the past 10 years, Ukraine also demonstrated a downward trend in coal consumption, as it fell from 39.8 mtoe in 2006 to 31.5 mtoe in 2016 – a 20.8% reduction. **This decline in consumption was particularly noticeable in 2014-2015 as a result of hostilities in Donbas that led to a damage and in some cases – loss of mining assets. Ukraine suffered serious damages following the unlawful seizure of the DTEK property by militants in non-government-controlled areas in March-April 2017. The deficit of coal, especially anthracites, causes shortages at TPP, which in turn threatens the stability of the Unified Energy System of Ukraine (UES). All these factors force Ukraine to increase coal imports.** In 2016, Ukraine imported this fuel in the total amount of $1.47 billion – mostly from the Russian Federation, the United States, South Africa and Canada.[17] To reduce import dependency, DTEK increases investment in extraction of gas coal and in TPP

[16] The Cabinet of Ministers of Ukraine Resolution No.315 of 27 April 2016 "On Amending the Cabinet of Ministers of Ukraine Resolution No.758 of 1 October 2015".

[17] The Energy Industry of Ukraine in 2016 – the Razumkov Centre, 2017, pp.60-61.

**The world's largest coal consumers**, billion toe

| | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | % of total in 2016 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. China | 1 454.7 | 1 584.2 | 1 609.3 | 1 685.8 | 1 748.9 | 1 903.9 | 1 927.8 | 1 969.1 | 1 954.5 | 1 913.6 | **1 887.6** | 50.6 |
| 2. India | 219.4 | 240.1 | 259.3 | 280.8 | 290.4 | 304.8 | 330.0 | 352.8 | 387.5 | 396.6 | **411.9** | 11.0 |
| 3. United States | 565.7 | 573.3 | 564.2 | 496.2 | 525.0 | 495.4 | 437.9 | 454.6 | 453.5 | 391.8 | **358.4** | 9.6 |
| 4. Japan | 112.3 | 117.7 | 120.3 | 101.6 | 115.7 | 109.6 | 115.8 | 121.2 | 119.1 | 119.9 | **119.9** | 3.2 |
| 5. Russian Federation | 97.0 | 93.9 | 100.7 | 92.2 | 90.5 | 94.0 | 98.4 | 90.5 | 87.6 | 92.2 | **87.3** | 2.3 |
| 6. South Africa | 81.5 | 83.7 | 93.3 | 93.8 | 92.8 | 90.5 | 88.3 | 88.6 | 89.8 | 83.4 | **85.1** | 2.3 |
| 7. South Korea | 54.8 | 59.7 | 66.1 | 68.6 | 75.9 | 83.6 | 81.0 | 81.9 | 84.6 | 85.5 | **81.6** | 2.2 |
| 8. Indonesia | 28.9 | 36.2 | 31.5 | 33.2 | 39.5 | 46.9 | 53.0 | 57.0 | 45.1 | 51.2 | **62.7** | 1.7 |
| 9. Germany | 84.5 | 86.7 | 80.1 | 71.7 | 77.1 | 78.3 | 80.5 | 82.8 | 79.6 | 78.5 | **75.3** | 2.0 |
| 10. Poland | 57.4 | 55.9 | 55.2 | 51.8 | 55.1 | 55.0 | 51.2 | 53.4 | 49.4 | 48.7 | **48.8** | 1.3 |
| Other countries | 537.7 | 548.8 | 548.3 | 500.3 | 524.7 | 545.3 | 553.3 | 535.1 | 538.5 | 523.5 | **513.3** | 13.8 |
| **Total World** | **3 293.9** | **3 480.2** | **3 528.4** | **3 476.1** | **3 635.6** | **3 807.2** | **3 817.3** | **3 887.0** | **3 889.4** | **3 784.7** | **3 732.0** | **100.0** |

retrofitting to be able to use gas coal instead of anthracite. PJSC *Centrenergo* also invests heavily in TPP modernisation.

### 1.6.2. Reserves and production

Over the past 10 years, global proved coal reserves have increased significantly from 0.86 trillion tonnes in 2006 to 1.14 trillion tonnes, or by 32.6%. The list of global leaders by coal reserves includes the United States with 251.6 billion tonnes (22.1% of world reserves), China – 244.0 (21.4%), Russia – 160.4 (14.1%), Australia – 144.8 (12.7%) and India – 94.8 (8.3%). Ukraine's proved coal reserves are also quite significant – 34.4 billion tonnes (3%) (Table "*World proved coal reserves as of 2016*"). This makes Ukraine second in Europe behind Germany and 8th in the world. In other words, Ukraine has secured coal reserves for the next 500 years and beyond. At the same time, 100% of anthracites are deposited in NGCA, which makes Ukraine dependent on imports of this type of fuel. Speaking about imports of anthracite coal, it is expedient to consider shipments from the US, Canada, South Africa, Kazakhstan and China – countries with excessive supply of anthracites.

To date, more than 50 countries are involved in coal mining, but the six largest producers together account for 84.5% of global coal production. These include China (1.68 billion toe), the United States (364.8 mtoe), Australia (299.3 mtoe), India (288.5 mtoe), Indonesia (255.7 mtoe) and Russia (192.8 mtoe). In general, the average annual growth of coal production in 2006-2016 was not that low, reaching 2.5% (Table "*Global coal production in 2016*", p.26). However, in 2014-2016 this trend has reversed, and coal production fell by 344.6 mtoe, or 8.6%. Coal mining in Ukraine over the past three years showed more than a twofold reduction – from 36.6 mtoe

**World proved coal reserves as of 2016**, million toe

| Country/Region | Anthracite and bituminous coal | Sub-bituminous coal and lignite | Total | % of total |
|---|---|---|---|---|
| America, incl. | **235 849.0** | **37 542.0** | **273 391.0** | **24.0** |
| United States | 221 400.0 | 30 182.0 | 251 582.0 | 22.1 |
| Europe and Asia, incl. | **153 283.0** | **168 841.0** | **322 124.0** | **28.3** |
| Russian Federation | 69 634.0 | 90 730.0 | 160 364.0 | 14.1 |
| Germany | 12.0 | 36 200.0 | 36 212.0 | 3.2 |
| Ukraine | 32 039.0 | 2 336.0 | 34 375.0 | 3.0 |
| Kazakhstan | 25 605.0 | 0.0 | 25 605.0 | 2.2 |
| Middle East and Africa, incl. | **14354.0** | **66.0** | **14 420.0** | **1.3** |
| South Africa | 9893.0 | 0.0 | 9 893.0 | 0.9 |
| Asia Pacific, incl. | **412 728.0** | **116 668.0** | **529 396.0** | **46.5** |
| China | 230 004.0 | 14 006.0 | 244 010.0 | 21.4 |
| India | 89 782.0 | 4 987.0 | 94 769.0 | 8.3 |
| Australia | 68 310.0 | 76 508.0 | 144 818.0 | 12.7 |
| Indonesia | 17 326.0 | 8 247.0 | 25 573.0 | 2.2 |
| **Total World** | **816 214.0** | **323 117.0** | **1 139 331.0** | **100.0** |

in 2013 to just 17.1 mtoe, which makes Ukraine the "leader" among top coal mining nations in terms of production decline.

**Coal holds the top spot among other fossil fuels by proved reserves, as under current consumption levels, the global economy has secured coal reserves for the next 153 years – three times more than oil and natural gas. However, this advantage is totally "cancelled out" by coal's chemical properties that make it the least environmentally friendly fuel in in the process of thermal generation. In order to bring the level of TPPs' harmful emissions down to certain international standards, it is necessary to further invest such significant amounts of money so that business activity associated with coal-fired generation will lose its commercial attractiveness.**

**Following the adoption of the Paris Agreement and refusal of the leading international banks to finance the coal industry, it became risky for business and dependent on government support.** Such increasing risks proved correct in 2016 with the bankruptcy of *Peabody Energy* (USA) – the largest private coal company in the world. During 2015-2016, a number of other major coal mining companies went bankrupt, including *Arch Coal*, *Alpha Natural Resources*, *Walter Energy*. France, Spain and Germany have plans to abandon the state support for coalminers.[18] Meanwhile, despite the shortage of energy resources, United Kingdom, Japan, Portugal and the Netherlands refused to further develop the coal industry. Among all EU countries, coal mining will continue playing a significant role in the long run only in Poland.

### 1.6.3. Prices

Global coal market is similar to natural gas and oil markets in terms of pricing principles and trade instruments. However, it is notable for abundant geographical localisation and its division into the thermal (energy) and metallurgy segments, making its price dependent on various factors. Another peculiarity of the global coal market is the presence of only several full-featured exchanges: Northwest Europe trading hub (ARA – the Amsterdam, Rotterdam and Antwerp ports); the South African exchange within the Richards Bay Coal Terminal; and the Australian exchange in the Port of Newcastle. Coal is traded in all these platforms, but at the same time their prices are indicative of individual local markets. The main difference between these trading platforms and other local markets is the possibility to trade in forward contracts, while in other markets only spot contracts are available for players. Currently, almost all local trading platforms are located within the borders of the exporting countries, excluding ARA and the trading platforms of south China and Indian ports.

As for geographical localisation, global coal market can be generally divided into two parts: the Atlantic coal market and the Pacific coal market. The main players in the Atlantic market include Colombia (supplies most gas coals), South Africa (mainly offers low volatile coals – lean and anthracite), Russian Federation (sells virtually all types of coal), and the United States. The American companies entered the market only recently because of the "shale revolution" and the country's reorientation towards increased natural gas consumption. In the Pacific market, Australia and Indonesia are historically the largest players. Also, this market comprises – although with lesser involvement – South Africa, Russian Federation, Colombia and the United States.

During 2006-2016, the lowest coal spot prices were recorded in the US market, and the highest – in Japan. Dynamic development of the Chinese economy drives up the demand for coal, thus leading to a gradual increase in coal prices in this country compared with other regions of the world. Stock prices in Europe were mostly lower

**Global coal production in 2016**, mtoe

| | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | % of total in 2016 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. China | 1 328.4 | 1439.3 | 1 491.8 | 1 537.9 | 1 665.3 | 1 851.7 | 1 873.5 | 1 894.6 | 1 864.2 | 1 825.6 | **1 685.7** | 46.1 |
| 2. United States | 595.1 | 587.7 | 596.7 | 540.8 | 551.2 | 556.1 | 517.8 | 500.9 | 507.7 | 449.3 | **364.8** | 10.0 |
| 3. India | 198.2 | 210.3 | 227.5 | 246.0 | 252.4 | 250.8 | 255.0 | 255.7 | 269.5 | 280.9 | **288.5** | 7.9 |
| 4. Australia | 220.4 | 227.0 | 234.2 | 242.5 | 250.6 | 245.1 | 265.9 | 285.8 | 305.7 | 305.8 | **299.3** | 8.2 |
| 5. Indonesia | 114.2 | 127.8 | 141.6 | 151.0 | 162.1 | 208.2 | 227.4 | 279.7 | 269.9 | 272.0 | **255.7** | 7.0 |
| 6. Russian Federation | 141.0 | 143.5 | 149.0 | 141.7 | 151.0 | 157.6 | 168.3 | 173.1 | 176.6 | 186.4 | **192.8** | 5.3 |
| 7. South Africa | 138.3 | 138.4 | 141.0 | 139.7 | 144.1 | 143.2 | 146.6 | 145.3 | 148.2 | 142.9 | **142.4** | 3.9 |
| 8. Colombia | 45.7 | 48.2 | 50.7 | 50.2 | 51.3 | 59.2 | 61.5 | 59.0 | 61.1 | 59.0 | **62.5** | 1.7 |
| 9. Poland | 68.0 | 62.5 | 60.9 | 56.4 | 55.4 | 55.7 | 57.8 | 57.2 | 54.0 | 53.0 | **52.3** | 1.4 |
| 10. Kazakhstan | 41.4 | 42.2 | 47.9 | 43.4 | 47.5 | 49.8 | 51.6 | 51.4 | 48.9 | 46.2 | **44.1** | 1.2 |
| **Other countries** | 304.1 | 304.9 | 299.6 | 291.4 | 302.4 | 319.9 | 313.4 | 303.6 | 286.5 | 266.3 | **268.3** | 7.3 |
| **Total World** | **3 194.7** | **3 331.9** | **3 440.8** | **3 441.1** | **3 633.3** | **3 897.3** | **3 938.9** | **4 006.1** | **3 992.4** | **3 887.3** | **3 656.4** | **100.0** |

[18] "Coal train goes downhill" – "Energobusiness", No.33, 22 August 2017, pp.13-16.

than in the Asia Pacific, but higher compared to the North American market. In 2015-2016, the cost of coal has fallen to its lowest level since 2003 – $57-60/tonne (Figure "*Prices at global coal trading markets*", p.28),[19] but nonetheless coal could not compete against other fuels because of their even steeper price reduction and more strict requirements for harmful emissions. **In order to meet this inter-fuel competition, coal mining companies will be forced to cut the cost of coal in relation to other types of fuel, which will further limit investments in the development of coal deposits and reduce the global production of coal products.**

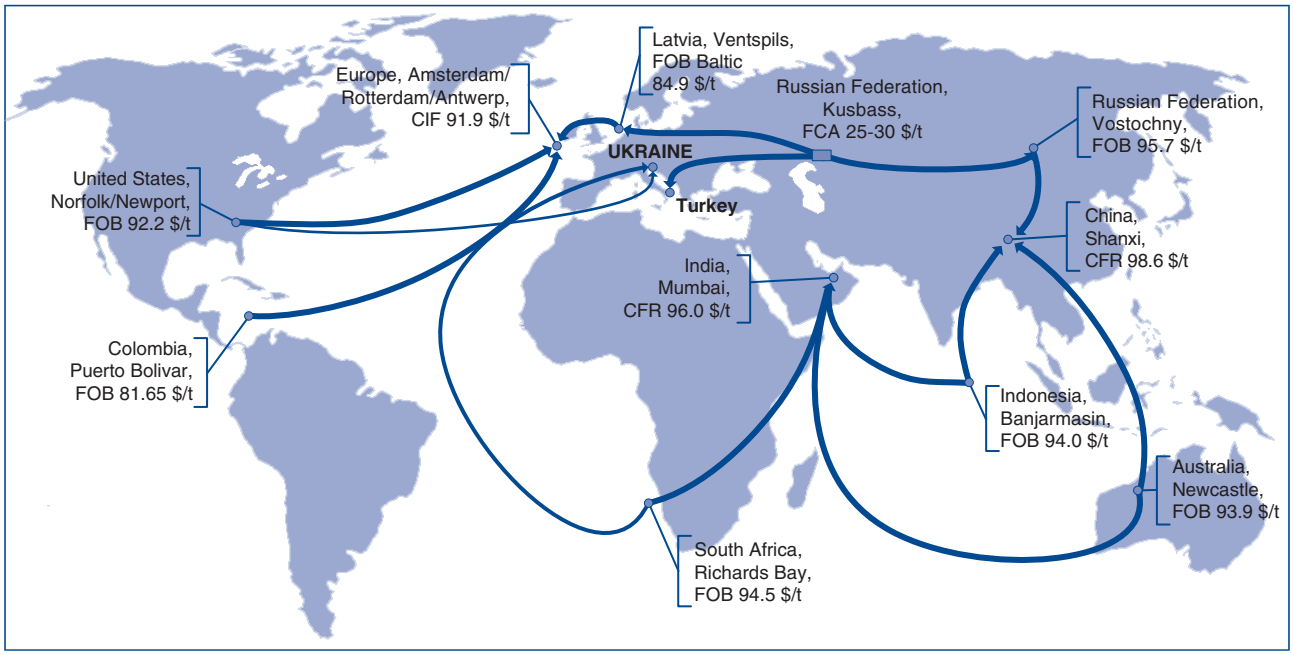
Amid shortage of anthracite coal in Ukraine in the past 2 years by reason of economic blockade and loss of control over the Donbas coal mines, users of this type of coal – mainly energy companies of Ukraine – are forced to procure power generating coals from abroad. (Figure "*Main routes and estimated prices for thermal* (*energy*) *coal supply as of December 2017*"). It is obvious that apart from possible supplies from Russia, Ukraine does not have too many options. These primarily concern coal supplies from the US and South Africa, and to a lesser extent – from Kazakhstan and Australia. But delivering coal from these markets has a number of limitations, including relatively high cost of transportation, which ultimately affects the wholesale power pricing.

Until 2016, the formation of coal prices in Ukraine was based on the "cost plus" approach, rather than on market principles. This approach negated any incentives for coal mining companies to reduce their costs, while industry revenues were not distributed efficiently. In 2015 NEURC proposed a pseudo-market pricing model, where the cost of coal was tied to the "Rotterdam+" price formula.[20] **The very idea of introducing domestic market prices based on the price parity with the European stock exchange (until fully functioning stock exchange is established in Ukraine) can be considered correct, as evidenced by a similar, rather effective model developed for the gas sector. However, this pricing model has certain flaws as it does not reflect current market situation in Europe. This complicates its practical application**, specifically to increase coal reserves at the TPP warehouses ahead of the cold period. In addition, the Rotterdam+ formula, due to certain methodological errors, causes waves of criticism from the expert community and it needs to be upgraded based on the expert consensus.

## 1.7. ELECTRIC POWER SECTOR

Global electricity generation in 2006-2016 has been dynamically growing from 19.1 trillion kWh to 24.8 trillion kWh, or by 30%. During this period, the largest growth (3.3 trillion kWh, or by 114%) was recorded in China. Currently, this country is one of the world's largest electricity producers. The electric power generation was largely driven by growth in the developing countries of the Asia Pacific region, (i.e. India, Indonesia, Vietnam, Malaysia and Bangladesh). The region accounted for 5.7% of the average annual growth in electricity production. The Middle East countries have demonstrated the same growth rate. Electricity generation in African countries has also increased by 3.3% per year, but these countries still remain the most disadvantaged nations in the world.

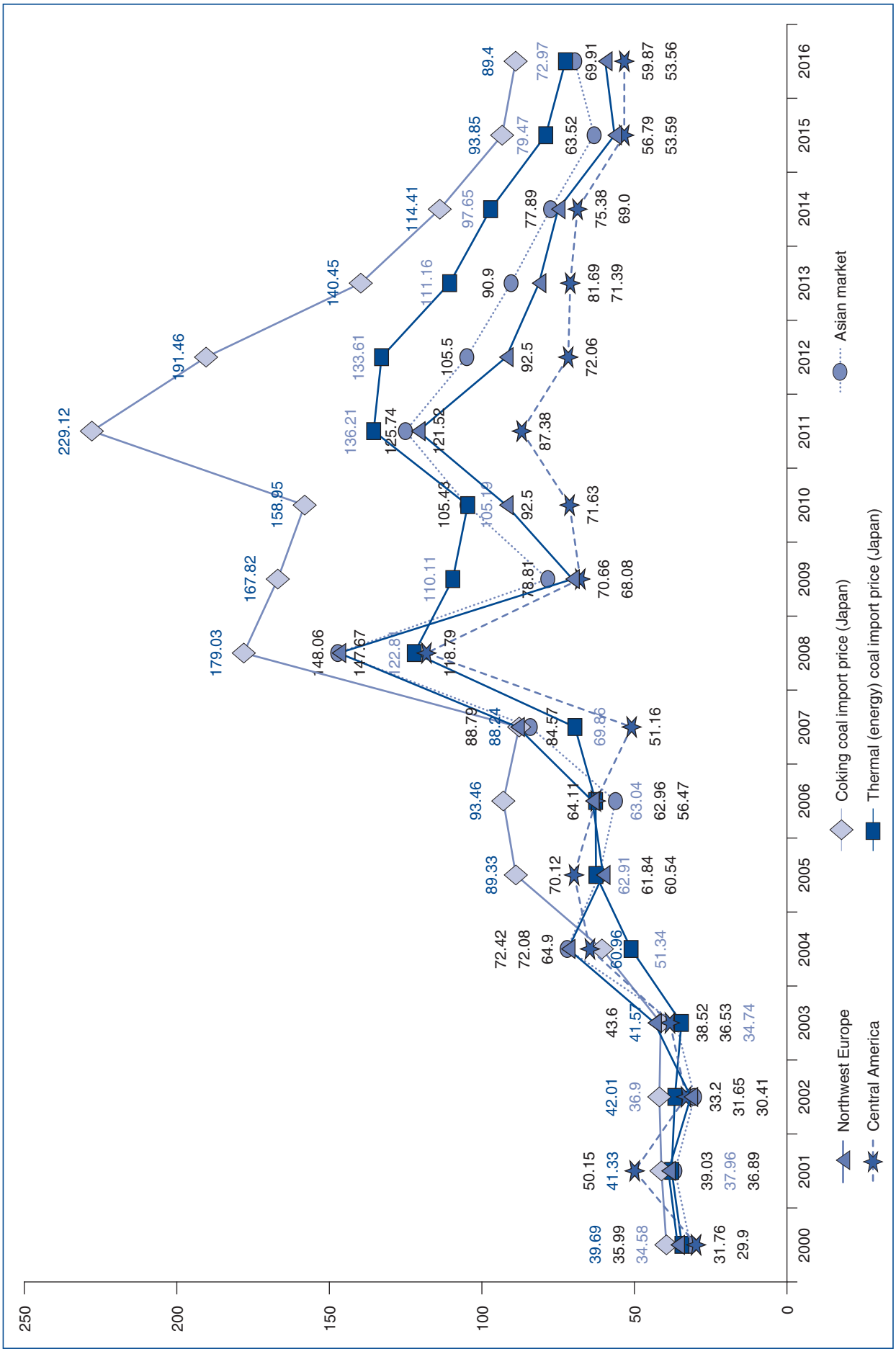
**Main routes and estimated prices for thermal (energy) coal supply as of December 2017**




[19] *Source:* BP Statistical Review of World Energy, June 2017 – *https://www.bp.com/content/dam/bp/en/corporate/pdf/energy-economics/statistical-review-2017/bp-statistical-review-of-world-energy-2017-full-report.pdf.*

[20] For more detail see: The Energy Industry of Ukraine in 2016 – the Razumkov Centre, 2017, pp.65-67.

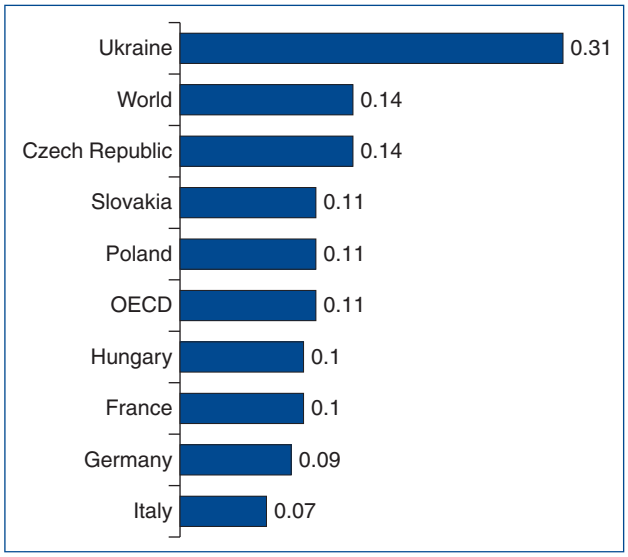
**Prices at global coal trading markets**, $ per tonne



Unlike the developing countries, OECD countries failed to increase electricity generation over the past decade, while electricity production in the EU countries has dropped by 127 million kWh, or by 3.8%. This reduction was particularly evident in Lithuania, Belgium, United Kingdom and Denmark. The decrease in electricity production in Japan was even greater than in the EU as the country is facing serious economic problems after the years of explosive GDP growth.

Over the last decade, Ukraine's electricity production has dropped considerably from 192.1 to 163.7 billion kWh/year, or by 14%. And if electricity generation in 2010-2013 had somewhat increased, in 2014-2015 it spiraled down again. Electricity generated in 2015 alone fell by 10.4% compared to 2014 as the demand for electricity sagged, especially in the industrial sector. The decrease in electricity generation as well as Ukraine's energy intensity being one of the highest in the world (Figure "*Energy intensity of selected countries in 2014*"[21]) have put the country at risk of "premature deindustrialisation" – one of the most serious threats to Ukraine's national security. Electricity consumption per capita in Ukraine is also notably lower than the EU average[22] (Table "*Per capita electricity consumption in Ukraine and the EU in 2015*") that also supports the above claim.

**Energy intensity of selected countries in 2014**, toe/$




**Per capita electricity consumption in Ukraine and the EU in 2015**, thousand kWh/person

| | **Per capita electricity consumption**, thousand kWh per person |
|---|---|
| Austria | 7.0 |
| Belgium | 7.2 |
| Bulgaria | 3.9 |
| United Kingdom | 4.6 |
| Greece | 4.5 |
| Denmark | 5.4 |
| Estonia | 5.2 |
| Ireland | 5.3 |
| Spain | 5.0 |
| Italy | 4.8 |
| Cyprus | 3.5 |
| Latvia | 3.2 |
| Lithuania | 3.2 |
| Luxemburg | 11.0 |
| Malta | 4.9 |
| The Netherlands | 6.1 |
| Poland | 3.3 |
| Portugal | 4.4 |
| Romania | 2.2 |
| Slovakia | 4.5 |
| Slovenia | 6.2 |
| Hungary | 3.7 |
| Finland | 14.3 |
| France | 6.6 |
| Germany | 6.3 |
| Croatia | 3.6 |
| Czech Republic | 5.1 |
| Sweden | 12.8 |
| **EU-28** | **6.2** |
| **Ukraine** | **2.7** |

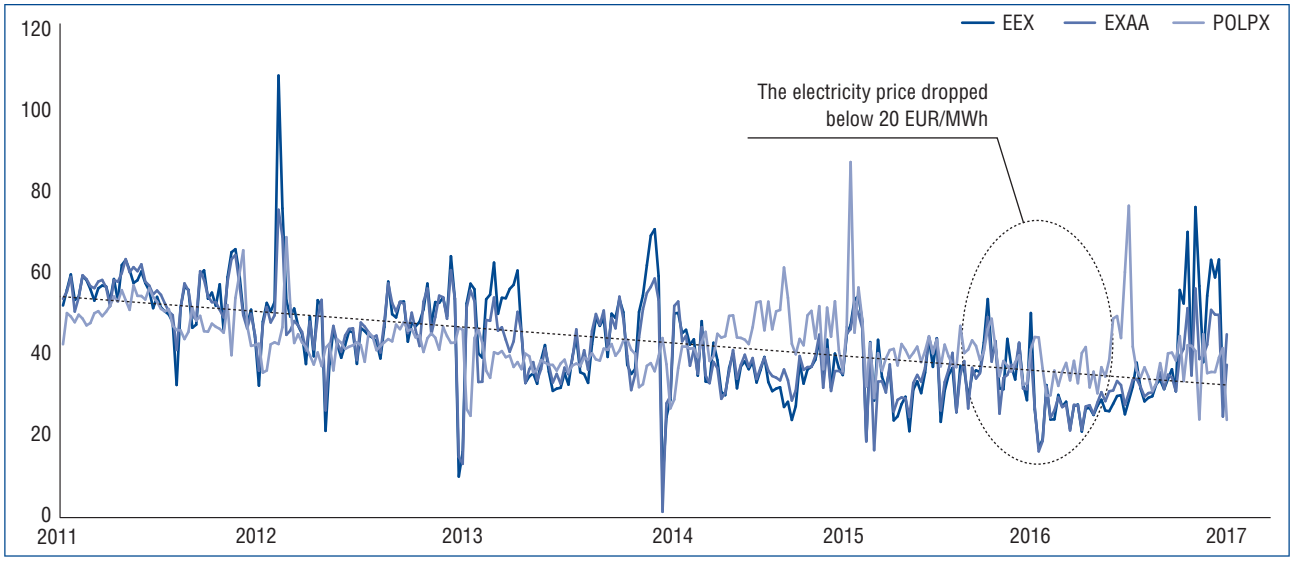
**Data sources for calculations:* Ukraine: *http://mpe.kmu.gov.ua/ minugol/control/uk/publish/article?art_id=245183431&cat_id=245183225;* EU countries: *http://ec.europa.eu/eurostat/statistics-explained/images/thumb/7/78/Electricity_consumption_and_trade %2C_GWh%2C_2015_new.png/459px-Electricity_consumption_and_trade %2C_GWh%2C_2015_new.png;* Population: *https://esa.un.org/unpd/wpp*.

### 1.7.1. Prices

**OECD countries have been in the process of liberalising their electricity markets for over 15 years. The development in electricity exchanges designed to improve competition and transparency for the benefit of consumers was one of the most important elements in this process.** Europe's leading energy exchanges – *EEX* (Germany), *EXAA* (Austria), and *POLPX* (TGE) (Poland) (Figure "*Electricity prices across leading European trading hubs*", p.30)[23] – reveal gradual decrease in electricity prices in 2011-2016 from €63/MWh to €17/MWh (in the first half of 2016).[24] The price fluctuation chart also highlights their high volatility. The decline in electricity prices in the European energy markets is explained by the cheapening of oil and

[21] The Energy Industry of Ukraine in 2016 – the Razumkov Centre, 2017, p.111.
[22] *Source*: European Commission – Eurostat statistics explained: *http://ec.europa.eu/eurostat/statistics-explained/images/7/78/Electricity_consumption_and_trade%2C_GWh%2C_2015_new.png*.
[23] The Energy Industry of Ukraine in 2016 – the Razumkov Centre, 2017, p.90.
[24] Ibid.

**Electricity prices across leading European trading hubs, €/MWh**

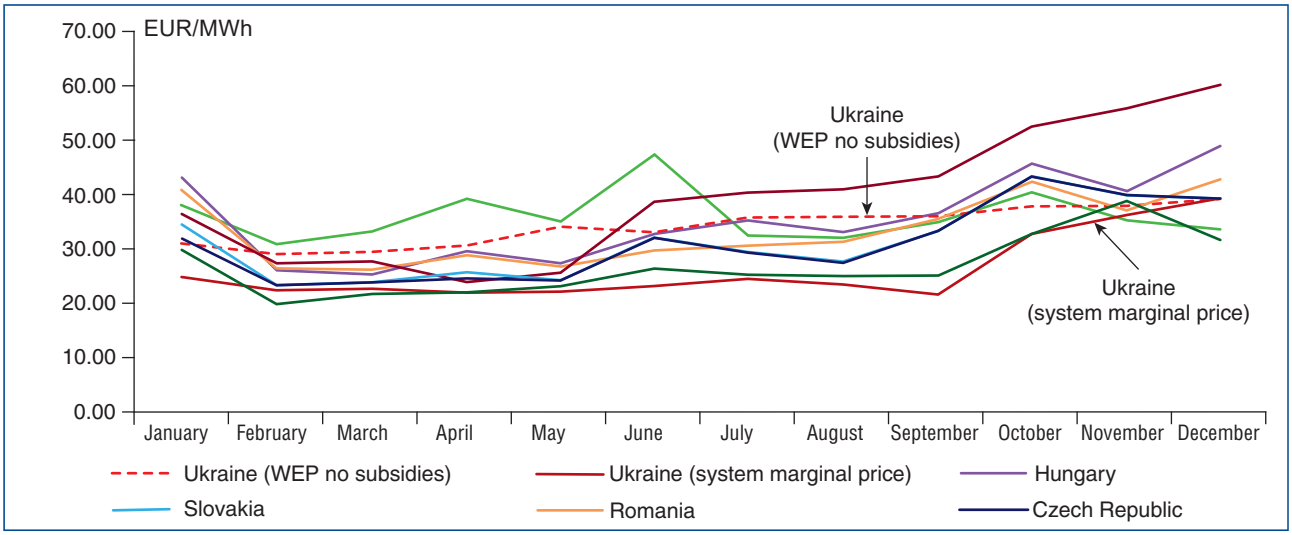



increasing competition. At the same time, from May 2016, the electricity prices have stabilised and demonstrated gradual growth.

**In Ukraine, the wholesale electricity price is a weighted average market price, which also includes the transmission tariff, WEM operational costs and additional national expenditures.**[25] **This model is obsolete today and has nothing in common with electricity market principles in OECD countries.** High wholesale electricity prices comparable to those in Europe, and low residential tariffs[26] are another two peculiarities of Ukraine's electricity market (Figures "*Average monthly electricity prices across European energy markets in 2016*", "*Household end-user electricity prices in Europe*" and "*Industrial end-user electricity prices in Europe*").

As we can see, Ukrainian households in 2016 enjoyed the lowest tariffs across all European countries – roughly 3.5 times below the EU average. In other words, the EU's official statistics shows that some experts and politicians have been falsely claiming that Rotterdam+ formula was used to make the Ukrainian consumers pay for Ukrainian coal the price of coal from Rotterdam. **Yet the process of liberalising Ukraine's energy market and deregulation of gas and coal prices in line with the Third Energy Package will depend on how effectively the country will implement the Law of Ukraine "On the Electricity Market" adopted in April 2017. In particular, this law**

**Average monthly electricity prices across European energy markets in 2016**

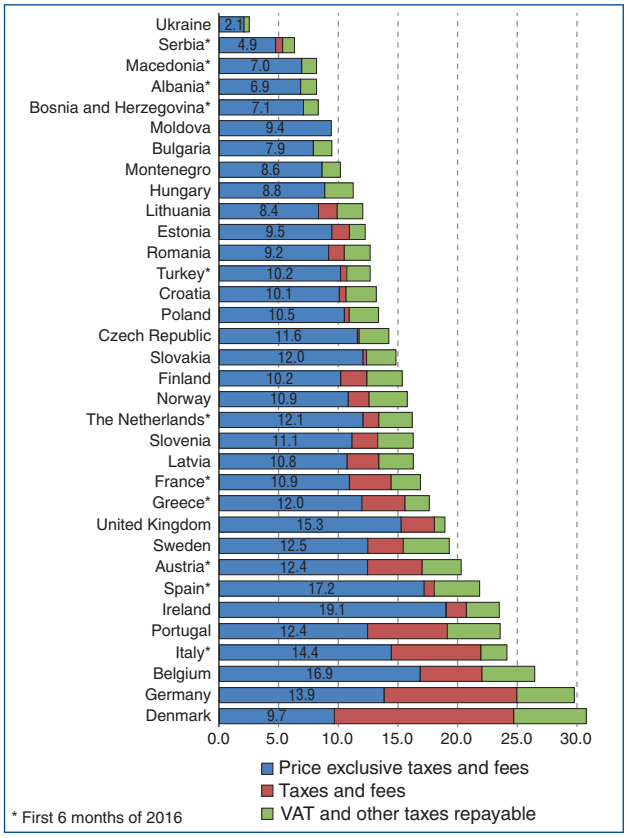



Prices for Ukraine presented in Euro (official UAH/EUR exchange rate – average rate for relevant month).
*Source*: HUPX, OPCOM, TGE, NordPool, OMIE data.

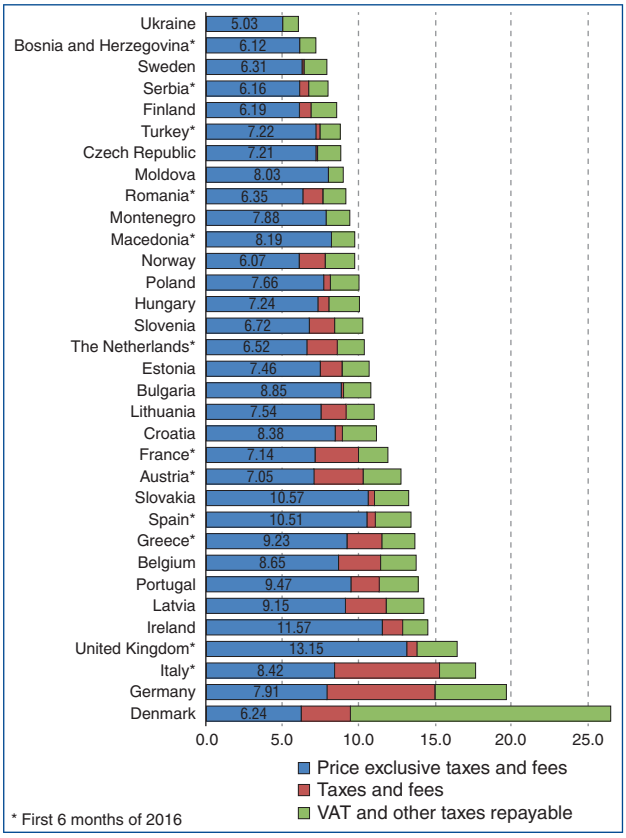
[25] The energy industry of Ukraine: 2016 results – the Razumkov Centre, 2017, p.92.

[26] *Source*: Report on the activities of the National Energy and Utilities Regulatory Commission of Ukraine in 2016 – NEURC, Kyiv, 2017, *http://www.nerc.gov.ua* and European Statistical Office (Eurostat), March 2017, – *http://ec.europa.eu/eurostat*.

**Household end-user electricity prices in Europe**, Eurocent/kWh




**Industrial end-user electricity prices in Europe**, Eurocent/kWh




**provides for the launch of all segments of electricity market, including the day-ahead market, the intraday market, the balancing market, the market of bilateral contracts, and the market of ancillary services.**

## 1.8. RENEWABLE ENERGY

**The Paris Agreement, which objective is to limit the increase in global average temperatures to well below 2 °C, was a milestone in accelerating the renewable energy industry. Through climate commitments (*Intended Nationally Determined Contributions*), more than 150 countries worldwide have formulated their policies to catalyse clean energy investment.** The concept "Transforming Our World: The 2030 Agenda for Sustainable Development" adopted at the 70th Session of the UN General Assembly in September 2015 is another event that deserves attention, as it calls to substantially increase the share of renewable energy in the global energy mix.[27]

Approximately 1.2 billion people (about 16% of the global population) still live without electricity. The vast majority of them are in sub-Saharan Africa and Oceania.[28] **Renewable energy sources are the most effective means to overcome energy poverty, since they can be effectively applied at the regional and local level using local preferences, primarily solar, wind and biofuel energy without the need to build additional high-voltage power networks.**

The growing support for environmental protection, enhanced generation technologies and lower production costs are the factors that have made the renewables the fastest growing energy source over the past decade. More specifically, the consumption of renewable energy around the world in 2006-2016 has increased from 93.2 mtoe to 419.6 mtoe, or by 4.5 times[29] (Table "*Global renewable energy consumption*", pp.32-33). Global energy sector reached a truly historic milestone in 2015, when the global renewable energy capacity exceeded that of traditional generation, thus confirming its competitiveness. Wind and solar power plants accounted for about 77% of total renewable power generation capacity.[30] During the period from 2007 to 2015, the share of renewables in the world's installed generating capacity and electrical power generation has doubled (Figure "*Global dynamics of renewable energy sources*", p.33).

From 2004 to 2016 global investments in renewable energy grew an average of 12.5% per year (Figure "*Global investment in renewable energy*"). An absolute

[27] *Source*: Transforming Our World: The 2030 Agenda for Sustainable Development – United Nations, *https://sustainabledevelopment.un.org/post2015/transformingourworld*.

[28] Renewables 2017 Global Status Report – REN21, *http://www.ren21.net/wp-content/uploads/2017/06/17-8399_GSR_2017_Full_Report_0621_Opt.pdf*.

[29] BP Statistical Review of World Energy, June 2017 – *https://www.bp.com/content/dam/bp/en/corporate/pdf/energy-economics/statistical-review-2017/bp-statistical-review-of-world-energy-2017-full-report.pdf*.

[30] Global Energy Trends Through the Prism of Ukraine's National Interests – the Razumkov Centre, 2017, p.44.

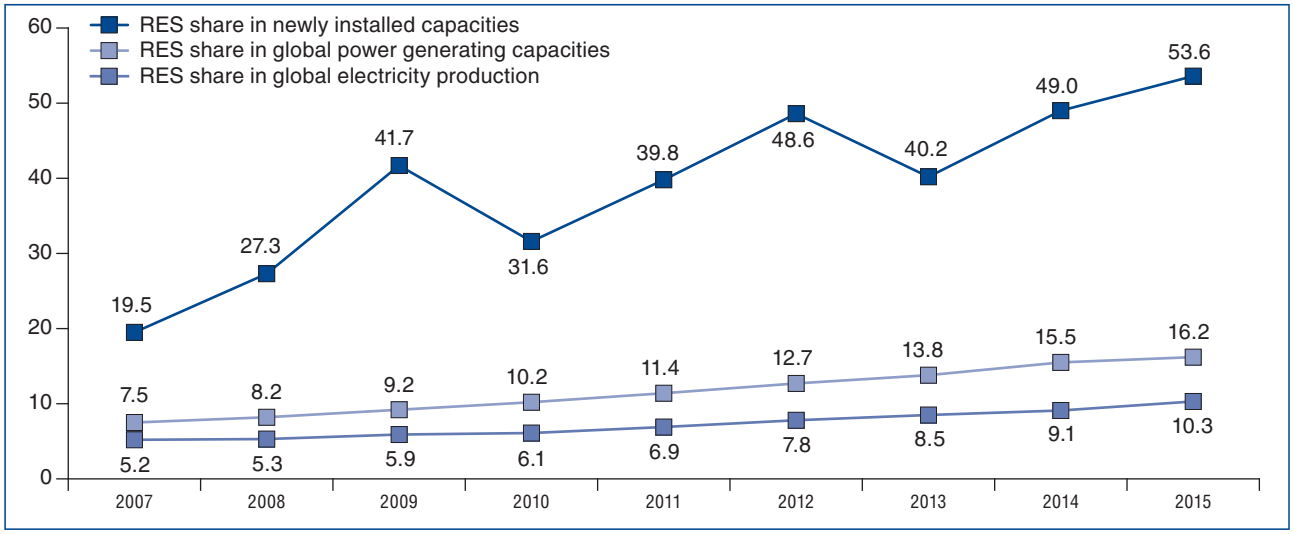
**Global renewable energy consumption**, mtoe

| Country (Region) | 2006 | | | 2007 | | | 2008 | | | 2009 | | | 2010 | | | 2011 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Hydro-electri-city | Other RES | Total | Hydro-electri-city | Other RES | Total | Hydro-electri-city | Other RES | Total | Hydro-electri-city | Other RES | Total | Hydro-electri-city | Other RES | Total | Hydro-electri-city | Other RES | Total |
| United States | 64.6 | 22.8 | 87.4 | 55.0 | 24.8 | 79.8 | 56.8 | 29.7 | 86.5 | 61.4 | 33.9 | 95.4 | 58.2 | 39.3 | 97.5 | 71.5 | 45.7 | 117.2 |
| Total North America | **151.4** | **27.0** | **178.4** | **144.3** | **29.4** | **173.7** | **151.1** | **34.1** | **185.2** | **151.0** | **39.2** | **190.1** | **146.2** | **45.5** | **191.7** | **164.8** | **52.5** | **217.2** |
| Brazil | 78.9 | 3.4 | 82.3 | 84.6 | 4.2 | 88.9 | 83.6 | 4.7 | 88.3 | 88.5 | 5.4 | 93.9 | 91.3 | 7.6 | 98.9 | 96.9 | 7.9 | 104.8 |
| Total South and Central America | **147.8** | **5.7** | **153.5** | **153.1** | **6.9** | **160.0** | **154.0** | **7.7** | **161.7** | **157.9** | **9.0** | **166.9** | **158.7** | **11.1** | **169.8** | **168.5** | **12.3** | **180.7** |
| France | 12.9 | 1.4 | 14.3 | 13.3 | 1.9 | 15.2 | 14.6 | 2.3 | 16.9 | 13.1 | 2.8 | 15.9 | 14.4 | 3.4 | 17.9 | 10.4 | 4.4 | 14.8 |
| Germany | 4.5 | 11.7 | 16.2 | 4.8 | 15.2 | 20.0 | 4.6 | 16.5 | 21.1 | 4.3 | 17.2 | 21.5 | 4.7 | 18.9 | 23.6 | 4.0 | 23.8 | 27.8 |
| Italy | 8.4 | 3.5 | 11.8 | 7.4 | 3.8 | 11.2 | 9.4 | 4.1 | 13.5 | 11.1 | 4.6 | 15.7 | 11.6 | 5.8 | 17.4 | 10.4 | 8.4 | 18.8 |
| Russian Federation | 39.6 | 0.1 | 39.8 | 40.5 | 0.1 | 40.6 | 37.7 | 0.1 | 37.8 | 39.9 | 0.1 | 40.0 | 38.1 | 0.1 | 38.2 | 37.3 | 0.1 | 37.4 |
| Spain | 5.8 | 6.2 | 12.0 | 6.2 | 7.2 | 13.4 | 5.3 | 8.7 | 14.0 | 6.0 | 10.7 | 16.7 | 9.6 | 12.5 | 22.0 | 6.9 | 12.6 | 19.5 |
| Ukraine | 2.9 | 0.0 | 2.9 | 2.3 | 0.1 | 2.4 | 2.6 | 0.1 | 2.6 | 2.7 | 0.0 | 2.7 | 2.9 | 0.1 | 3.0 | 2.4 | 0.1 | 2.4 |
| Poland | 0.5 | 0.5 | 1.0 | 0.5 | 0.7 | 1.2 | 0.5 | 1.0 | 1.5 | 0.5 | 1.4 | 2.0 | 0.7 | 1.8 | 2.5 | 0.5 | 2.4 | 3.0 |
| United Kingdom | 1.0 | 3.1 | 4.1 | 1.1 | 3.3 | 4.5 | 1.2 | 3.8 | 5.0 | 1.2 | 4.5 | 5.7 | 0.8 | 5.0 | 5.8 | 1.3 | 6.5 | 7.8 |
| Total Europe and Eurasia | **178.6** | **40.4** | **219.1** | **179.8** | **48.1** | **227.8** | **183.5** | **54.4** | **237.9** | **184.2** | **61.2** | **245.4** | **197.6** | **71.0** | **268.6** | **178.6** | **85.7** | **264.3** |
| Iran | 4.2 | 0.03 | 4.2 | 4.1 | 0.03 | 4.1 | 1.7 | 0.04 | 1.7 | 1.5 | 0.1 | 1.5 | 2.2 | 0.0 | 2.2 | 2.4 | 0.1 | 2.4 |
| Total Middle East | **6.6** | **0.0** | **6.7** | **6.3** | **0.0** | **6.3** | **3.2** | **0.1** | **3.3** | **2.8** | **0.1** | **2.8** | **4.0** | **0.1** | **4.1** | **4.3** | **0.1** | **4.4** |
| Egypt | 2.9 | 0.1 | 3.1 | 3.5 | 0.2 | 3.7 | 3.3 | 0.2 | 3.5 | 2.9 | 0.3 | 3.2 | 3.0 | 0.3 | 3.3 | 2.9 | 0.4 | 3.3 |
| Total Africa | **21.9** | **0.9** | **22.8** | **21.4** | **0.8** | **22.2** | **21.9** | **0.9** | **22.8** | **22.3** | **1.1** | **23.3** | **24.4** | **1.3** | **25.8** | **23.7** | **1.4** | **25.1** |
| China | 98.6 | 2.5 | 101.1 | 109.8 | 3.5 | 113.3 | 144.1 | 6.4 | 150.5 | 139.3 | 11.0 | 150.3 | 161.0 | 15.9 | 176.9 | 155.7 | 22.8 | 178.5 |
| India | 25.5 | 3.3 | 28.8 | 27.7 | 4.0 | 31.7 | 26.1 | 4.8 | 30.8 | 24.1 | 6.3 | 30.4 | 24.6 | 7.2 | 31.8 | 29.8 | 8.8 | 38.6 |
| Japan | 19.9 | 5.8 | 25.7 | 16.9 | 6.2 | 23.1 | 16.8 | 6.1 | 22.9 | 15.6 | 6.1 | 21.6 | 19.7 | 6.7 | 26.4 | 18.3 | 7.0 | 25.3 |
| Total Asia Pacific | **181.2** | **19.2** | **200.3** | **192.9** | **22.0** | **214.8** | **225.5** | **26.2** | **251.7** | **218.5** | **33.3** | **251.9** | **247.7** | **41.1** | **288.8** | **252.5** | **51.7** | **304.2** |
| **Total World** | **687.5** | **93.2** | **780.7** | **697.8** | **107.2** | **805.0** | **739.3** | **123.4** | **862.6** | **736.7** | **143.9** | **880.5** | **778.7** | **170.1** | **948.8** | **792.3** | **203.6** | **995.9** |
| **Of which European Union** | 71.5 | 39.1 | 110.6 | 71.4 | 46.3 | 117.7 | 75.4 | 52.4 | 127.9 | 76.1 | 58.9 | 135.0 | 85.6 | 68.2 | 153.8 | 71.1 | 82.3 | 153.4 |

**Global renewable energy consumption**, mtoe *(continued)*

| Country (Region) | 2012 | | | 2013 | | | 2014 | | | 2015 | | | 2016 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Hydro-electri-city | Other RES | Total | Hydro-electri-city | Other RES | Total | Hydro-electri-city | Other RES | Total | Hydro-electri-city | Other RES | Total | Hydro-electri-city | Other RES | Total |
| United States | 62.0 | 51.7 | 113.7 | 60.3 | 60.2 | 120.6 | 57.9 | 67.2 | 125.0 | 55.8 | 71.5 | 127.2 | **59.2** | **83.8** | **143.0** |
| Total North America | **155.3** | **59.6** | **214.8** | **155.3** | **69.3** | **224.6** | **153.2** | **77.2** | **230.5** | **148.2** | **83.6** | **231.9** | **153.9** | **97.1** | **250.9** |
| Brazil | 94.0 | 9.1 | 103.1 | 88.5 | 10.6 | 99.1 | 84.5 | 13.3 | 97.8 | 81.4 | 16.0 | 97.4 | **86.9** | **19.0** | **105.9** |
| Total South and Central America | **165.4** | **14.1** | **179.5** | **160.6** | **16.4** | **177.0** | **154.5** | **20.2** | **174.7** | **152.9** | **24.0** | **176.9** | **156.0** | **28.2** | **184.2** |
| France | 13.5 | 5.5 | 19.0 | 15.9 | 5.8 | 21.7 | 14.1 | 6.5 | 20.7 | 12.3 | 7.9 | 20.2 | **13.5** | **8.2** | **21.6** |
| Germany | 5.0 | 27.2 | 32.2 | 5.2 | 29.0 | 34.2 | 4.4 | 32.1 | 36.5 | 4.3 | 38.1 | 42.4 | **4.8** | **37.9** | **42.6** |
| Italy | 9.5 | 11.4 | 20.9 | 11.9 | 13.4 | 25.3 | 13.2 | 14.1 | 27.3 | 10.3 | 14.3 | 24.6 | **9.3** | **15.0** | **24.3** |
| Russian Federation | 37.2 | 0.1 | 37.3 | 40.6 | 0.1 | 40.7 | 39.6 | 0.1 | 39.7 | 38.5 | 0.2 | 38.6 | **42.2** | **0.2** | **42.4** |
| Spain | 4.6 | 15.0 | 19.7 | 8.3 | 16.3 | 24.6 | 8.9 | 16.1 | 25.0 | 6.3 | 15.6 | 21.9 | **8.1** | **15.5** | **23.6** |
| Ukraine | 2.4 | 0.2 | 2.5 | 3.1 | 0.3 | 3.4 | 1.9 | 0.4 | 2.3 | 1.2 | 0.4 | 1.6 | **1.6** | **0.3** | **2.0** |
| Poland | 0.5 | 3.4 | 3.8 | 0.6 | 3.3 | 3.9 | 0.5 | 4.0 | 4.5 | 0.4 | 4.7 | 5.1 | **0.5** | **4.6** | **5.1** |
| United Kingdom | 1.2 | 8.1 | 9.3 | 1.1 | 11.0 | 12.1 | 1.3 | 13.3 | 14.6 | 1.4 | 17.5 | 18.9 | **1.2** | **17.5** | **18.7** |
| Total Europe and Eurasia | **191.4** | **101.5** | **292.8** | **202.3** | **114.1** | **316.4** | **197.3** | **123.8** | **321.1** | **194.7** | **141.6** | **336.3** | **201.8** | **144.0** | **345.8** |
| Iran | 2.7 | 0.1 | 2.8 | 3.4 | 0.1 | 3.5 | 3.4 | 0.1 | 3.5 | 4.1 | 0.1 | 4.2 | **2.9** | **0.1** | **3.0** |
| Total Middle East | **5.0** | **0.2** | **5.2** | **5.4** | **0.3** | **5.7** | **4.8** | **0.4** | **5.2** | **5.9** | **0.5** | **6.4** | **4.7** | **0.7** | **5.5** |
| Egypt | 3.2 | 0.3 | 3.5 | 2.9 | 0.3 | 3.2 | 3.2 | 0.3 | 3.5 | 3.2 | 0.4 | 3.6 | **3.2** | **0.6** | **3.8** |
| Total Africa | **25.5** | **1.4** | **27.0** | **26.8** | **1.7** | **28.5** | **28.0** | **2.7** | **30.7** | **26.9** | **4.2** | **31.1** | **25.8** | **5.0** | **30.8** |
| China | 195.2 | 29.4 | 224.7 | 205.8 | 42.3 | 248.1 | 237.8 | 50.8 | 288.6 | 252.2 | 64.4 | 316.6 | **263.1** | **86.1** | **349.2** |
| India | 26.2 | 10.4 | 36.6 | 29.9 | 11.6 | 41.5 | 31.5 | 12.0 | 43.4 | 30.2 | 12.7 | 42.9 | **29.1** | **16.5** | **45.6** |
| Japan | 17.2 | 7.7 | 25.0 | 17.7 | 9.3 | 27.0 | 18.1 | 11.8 | 29.9 | 19.0 | 14.8 | 33.8 | **18.1** | **18.8** | **36.9** |
| Total Asia Pacific | **289.4** | **61.8** | **351.2** | **308.8** | **79.0** | **387.8** | **341.5** | **93.0** | **434.5** | **354.7** | **112.7** | **467.4** | **368.1** | **144.5** | **512.6** |
| **Total World** | **832.1** | **238.5** | **1 070.6** | **859.2** | **280.7** | **1 140.0** | **879.3** | **317.3** | **1 196.6** | **883.2** | **366.7** | **1 249.9** | **910.3** | **419.6** | **1 329.9** |
| **Of which European Union** | 76.3 | 97.4 | 173.7 | 83.9 | 109.1 | 193.0 | 84.7 | 118.0 | 202.8 | 77.2 | 134.6 | 211.8 | **78.7** | **135.6** | **214.3** |

**Global dynamics of renewable energy sources**



record was set in 2015, when investments in renewable energy hit $349 billion, while world oil prices dropped to a record low.

The EU is a global leader in renewable energy, as together the EU member states produce almost one-third of global renewable energy (Tables "*Electricity generation in the EU*" and "*Energy production by source in the EU and Eurozone*"; Figures "*Installed and decommissioned capacity in the EU in 2016*" and "*Installed and decommissioned capacities in the EU in 2000-2016*").

**During 2000-2016, the EU developed a steady trend towards replacement of traditional power generation (especially nuclear, fuel oil and coal) with renewables. Over the course of 16 years, the renewable energy capacities with the total output of 256 GW were built, while a number of nuclear (15.5 GW), coal (37.3 GW) and fuel oil (37.6 GW) generation capacities were decommissioned.**

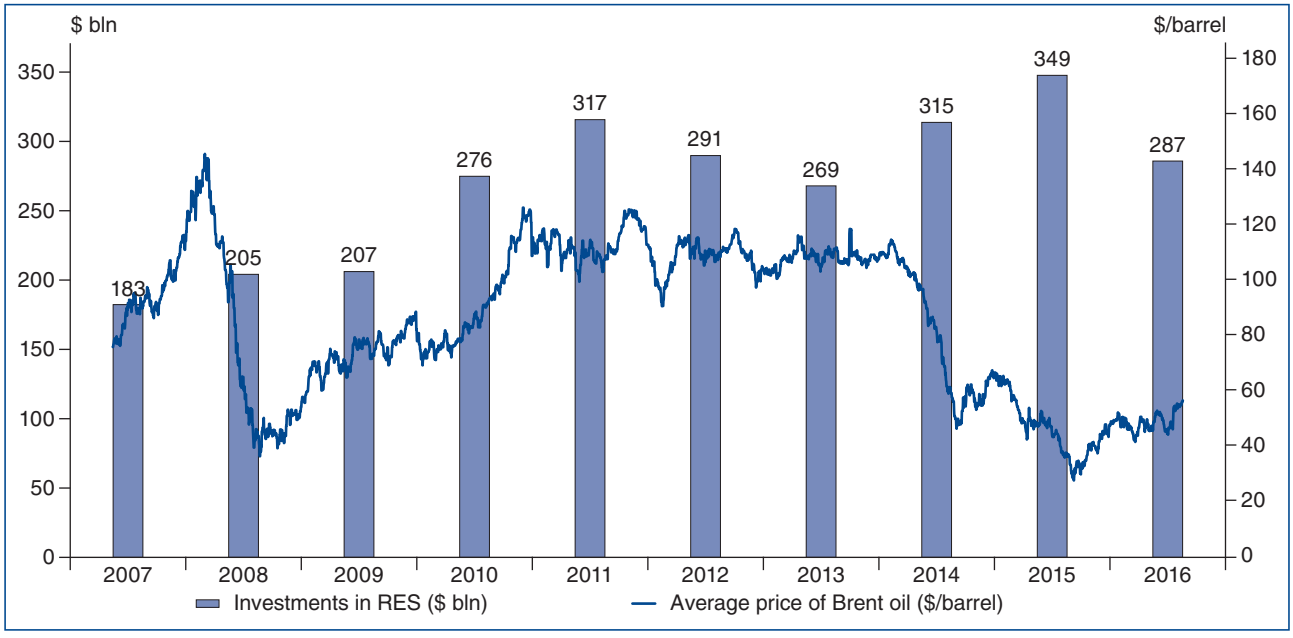
China continues to dominate the renewables market. Over the past decade it was able to increase the "green power" use by more than 34 times – up to 86.1 mtoe. This helped China to become the largest consumer of renewable energy. In the nearest future China is likely to surpass the EU in renewable power generation. Other leaders in renewable energy consumption include the United States, Germany, Italy, Spain, Japan and India. The share of OECD countries (64.4%) in global energy consumption from renewable sources is twice the share of the developing countries (35.6%). However, the analysis of global data gives good reasons to believe that this gap is gradually closing.

**If compared to 2015, the global renewable energy generation capacity increased by 161 gigawatts (GW) (or by almost 9%) in 2016. It was the largest growth ever, in absolute terms. Inclusive of hydropower, renewable energy accounted for over 30% of the global installed power generation capacity and reached 2,017 GW.** The amount of solar power added worldwide soared by 47% in 2016, while wind and hydropower accounted for 34.5% and 15% of new capacity. Wind power has the largest share in the energy mix of Denmark (37.6%), Ireland (27%), Portugal (24%) and Cyprus (19.7%); and solar makes up around 10% of electricity generation in Honduras, 7.3% in Italy, 7.2% in Greece and 6.4% in Germany.[31]

The global share of renewable sources used for power generation in 2016 reached 24.5% (incl. hydro power plants) including: 16.6% – hydroelectric power, 4% – wind, 1.5 – solar, 2% – biomass, and 0.4% – geothermal energy, ocean energy and concentrated solar power[32] (Figure "*The share of renewables in gross electricity production in 2016*", p.37).

**Ukraine's renewable energy sector is set to play a decisive role in implementing the ESU-2035. Above all, this concerns decarbonisation of the energy sector, reduction of the country's dependence on fuel imports, and renovation of the industry's core assets.** Despite the enormous potential of renewable sources estimated at 68 mtoe, Ukraine currently uses it at 5%. According to the Energy Strategy (and in line with the Energy Community Treaty, and the National Renewable Energy Action Plan until 2020), the share of renewables in final energy consumption should reach 11%. It is clear, however, that this task was politically motivated with no prior

**Global investment in renewable energy**




[22] Renewables 2017 Global Status Report – REN21, *http://www.ren21.net/wp-content/uploads/2017/06/17-8399_GSR_2017_Full_Report_0621_Opt.pdf*.
[23] Ibid.

assessment of realistic investment opportunities. In other words, Ukraine is unlikely to reach this target.

As of 1 January 2017, the installed generation capacity from renewables operating under the "green tariff" was 1.12 GW (excluding the occupied territory of Crimea). Back in 2006 the renewable energy in Ukraine was almost non-existent, but after the adoption of a "green tariff" policy at the legislative level, it started to grow rapidly by an average of 31% per year. In 2009-2013, the installed capacity of renewable power generation facilities increased

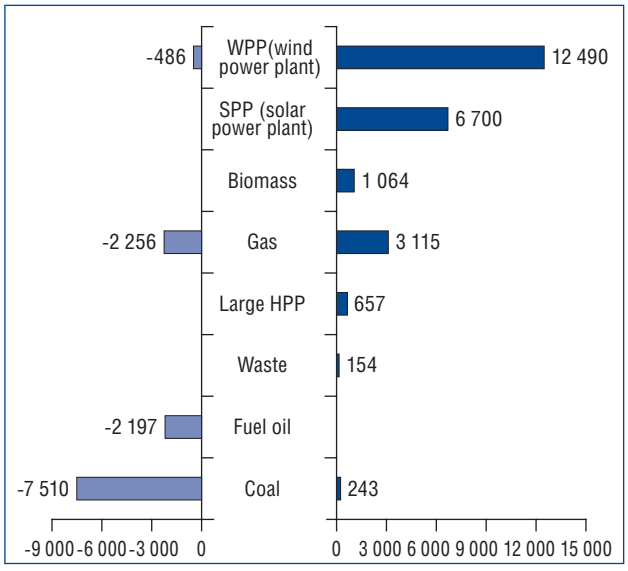
**Electricity generation in the EU**, GWh

| | EU-28 | | | | | Eurozone-19 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2014 | 2015 | 2016 | Increment in 2015 to 2014, % | Increment in 2016 to 2015, % | 2014 | 2015 | 2016 | Increment in 2015 to 2014, % | Increment in 2016 to 2015, % |
| **Total net electricity generation, including:** | 3 031 616 | 3 072 184 | 3 084 269 | 1.3 | 0.4 | 2 160 604 | 2 190 336 | 2 213 707 | 1.4 | 1.1 |
| Conventional thermal | 1 441 774 | 1 476 422 | 1 498 805 | 2.4 | 1.5 | 954 443 | 1 003 500 | 1 023 803 | 5.1 | -5.6 |
| **Nuclear** | 830 839 | 812 535 | 796 563 | -2.2 | -2.0 | 641 587 | 628 776 | 607 678 | -2.9 | -3.4 |
| **Hydro** | 400 720 | 365 258 | 370 661 | -8.8 | 1.5 | 268 429 | 246 279 | 269 079 | -14.9 | 9.3 |
| Including pumped storage | 30 884 | 29 549 | 28 795 | -4.3 | -2.6 | 25186 | 23 820 | 24 002 | -5.4 | 0.8 |
| **Wind** | 25 1235 | 29 9463 | 29 8532 | 19.2 | -0.3 | 178 124 | 207 555 | 210 534 | 16.5 | 1.4 |
| **Solar** | 96 733 | 106 957 | - | 10.6 | 0.0 | 4 223 | 5 188 | - | 22.9 | 0.0 |
| **Geothermal** | 5 917 | 5 098 | 6 174 | 4.8 | 1.2 | 5 817 | 6 098 | 6 174 | 4.8 | 1.2 |
| **Other** | 4 497 | 5 451 | - | 21.2 | 0.0 | 4 223 | 5 188 | - | 22.9 | 0.0 |

**Energy production by source in the EU and Eurozone**, %

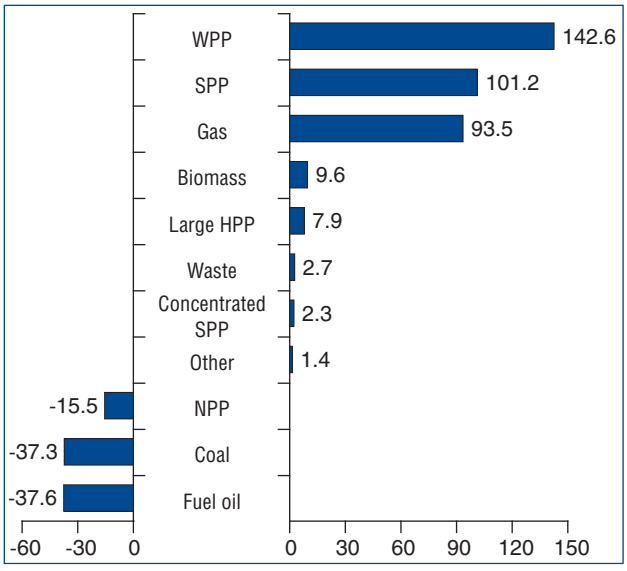
| | EU-28 | | | Eurozone-19 | | |
|---|---|---|---|---|---|---|
| | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 |
| **Conventional thermal** | 47.6 | 48.1 | 48.6 | 44.2 | 45.8 | 46.2 |
| **Nuclear** | 27.4 | 26.4 | 25.8 | 29.7 | 28.7 | 27.5 |
| **Hydro** | 13.2 | 11.9 | 12.0 | 13.4 | 11.2 | 12.2 |
| **Wind** | 8.3 | 9.7 | 9.7 | 8.2 | 9.5 | 9.5 |
| **Solar** | 3.2 | 3.5 | - | 4.0 | 4.2 | - |
| **Geothermal** | 0.2 | 0.2 | 0.2 | 0.3 | 0.3 | 0.3 |
| **Other** | 0.1 | 0.2 | - | 0.2 | 0.2 | - |

**Installed and decommissioned capacity in the EU in 2016**, MW




*Source:* WindEurope.

**Installed and decommissioned capacity in the EU from in 2000-2016**, GW




*Source:* WindEurope.

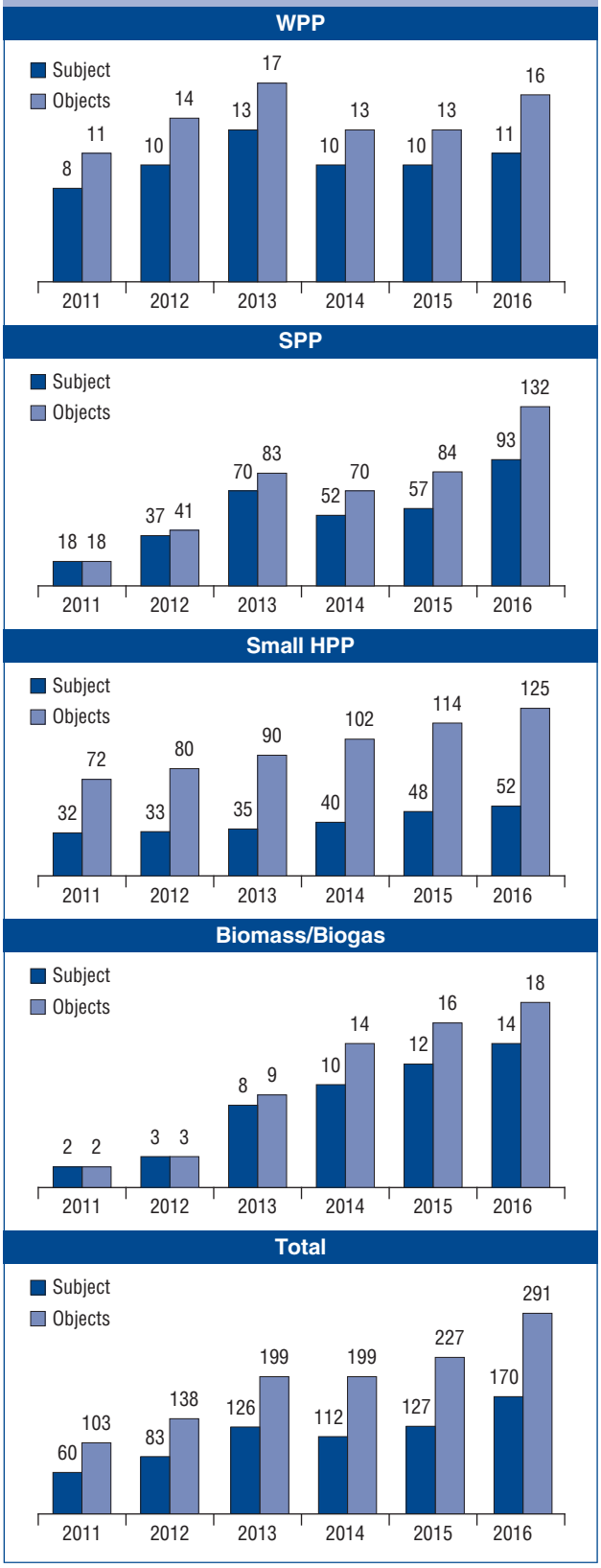
from 0.13 GW to 1.19 GW, or more than 9 times[33] (Figure "*Installed renewable energy capacity in 2009-2016*"). On 1 January 2017, the installed capacity of wind and solar power generation facilities amounted to 968.5 MW, or 86% of total RES capacity[34] (Figure "*The installed renewable energy capacity of units operating under the "green tariff" in Ukraine*").

In 2014-2015, due to Russia's military aggression, Ukraine did not provide any new renewable energy capacity. On the contrary, it lost 407 MW of solar power plants in the Autonomous Republic of Crimea. The economic situation has somewhat improved in 2016. Ukraine was able to build 120.6 MW of new capacity. Most of them are solar (99.1 MW) and wind (11.6 MW) power facilities. New small hydropower plants and facilities generating biomass and biogas energy have an installed capacity of 3 MW each. According to NEURC, Ukraine's RES industry at the end of 2016 already included 170 companies and 291 energy facilities (Figure "*Subjects and objects generating electricity from RES in Ukraine*"). During 2016 the solar energy market showed the largest growth by adding 47 new generating facilities.

Despite rapid growth in the development and construction of new RES facilities over the past 8 years, their role in generation remains insignificant – 1,800 MWh, or 1.3% of total electricity produced in Ukraine. The lion's share of this production falls on wind (920 MWh) and solar power plants (492 MWh).[35]

**It should be noted that the tariff policy for renewables currently has serious defects, as it does not reflect the global trend towards rapidly falling renewable power generation costs. The share of RES in UEM revenues, which is derived from the WEP structure, more than 3.5 times exceeds the share of electricity produced under the "green tariff"** (Figure "*The structure of total revenues of UEM Ukraine by types of generation and specific expenditure/revenue items in 2016, based on the WEP structure*"). Therefore, the Ukrainian practice of stimulating the renewable sector by introducing high tariffs on RES-generated electricity and their "linking to Euro" has increased the weighted-average wholesale electricity price. This should be seen as a negative factor inhibiting the demand for electric power and ultimately reducing the attractiveness of investment in the construction of new electric power generating facilities.

**Subjects and objects generating electricity from RES in Ukraine**

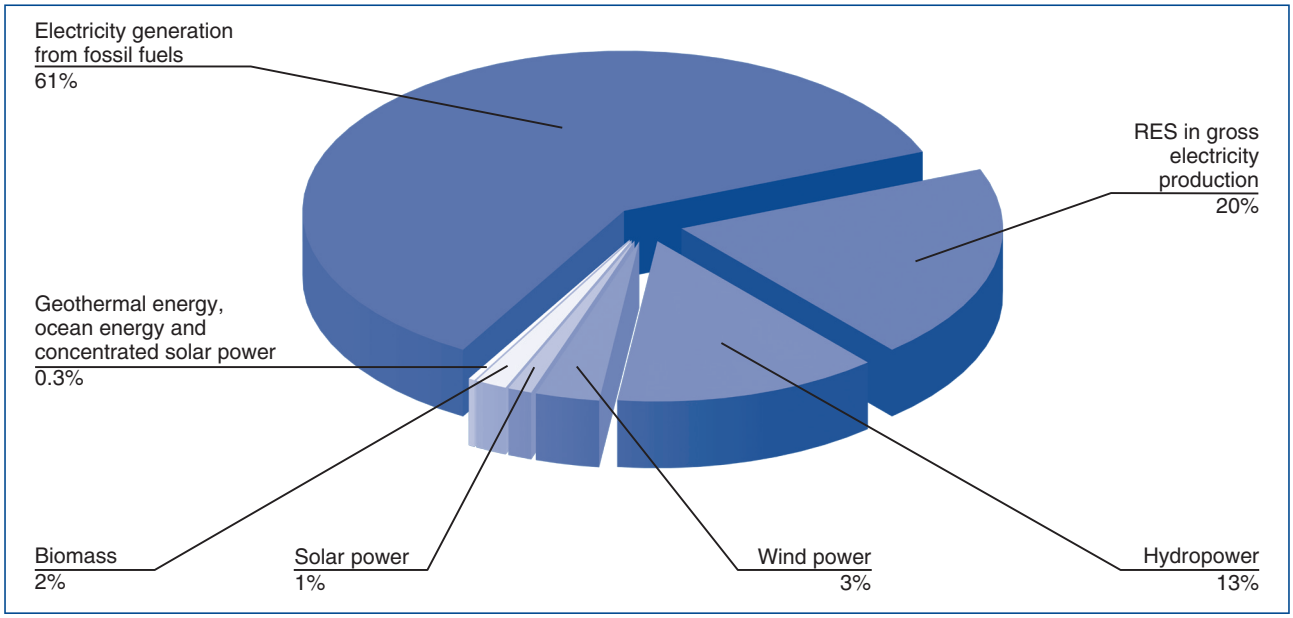



[33] The development of renewable energy sources in Ukraine – The Ministry of Regional Development of Ukraine, SlovakAID, UNDP Ukraine, 2017, p.14, *http://energymagazine.com.ua/wp-content/uploads/2017/03/Rozvitok-VDE-v-Ukrai-ni.pdf*.

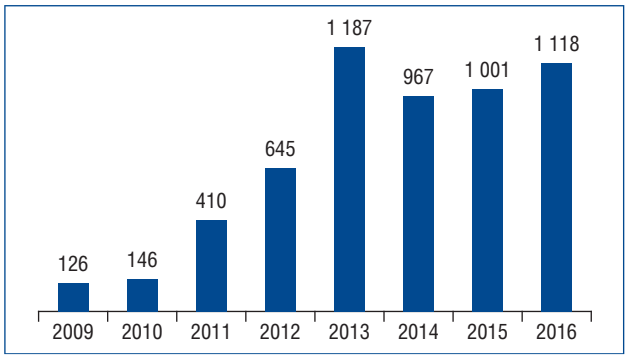
[34] Statistical data on the capacity and generation volumes by the renewable energy facilities working under the "green tariff" (as of 1 January 2017) – The State Agency on Energy Efficiency and Energy Saving of Ukraine, *http://saee.gov.ua/uk/content/informatsiyni-materialy*.

[35] Report on the activities of the National Energy and Utilities Regulatory Commission of Ukraine in 2016 – NEURC, Kyiv, 2017, *http://www.nerc.gov.ua*.

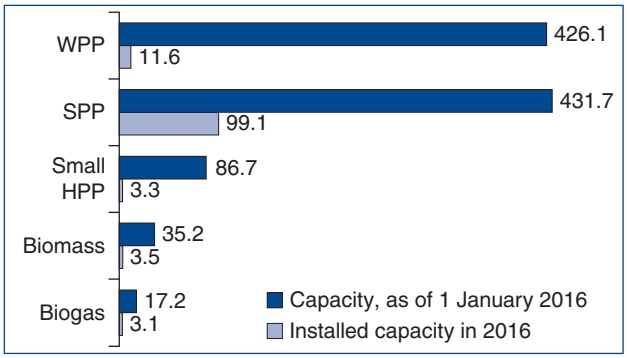
**The share of renewables (RES) in gross electricity production in 2016**




**Installed renewable energy capacity in 2009-2016 (operating under the "green tariff")**, MW

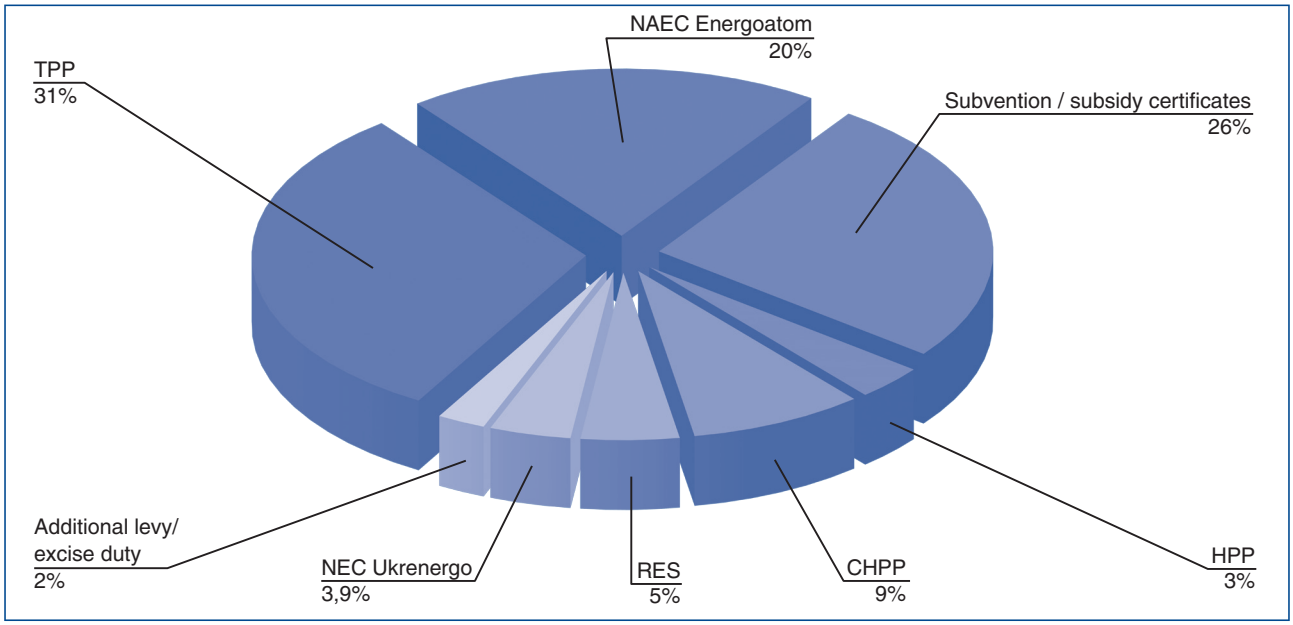



**The installed renewable energy capacity of units operating under the "green tariff" in Ukraine** as of 1 January 2017, MW




* Data for 2014-2016 does not take into account the Crimea and the ATO zone.
*Sourse*: NEURC, SAEE.

**The structure of total revenues of UEM Ukraine by types of generation and some expenditure/revenue items in 2016, based on the WEP structure**



# 2. GLOBAL ENERGY SECTOR UNTIL 2035 AND BEYOND

## 2.1. THE GLOBAL ENERGY SECTOR TRANSITION: KEY FACTORS

The long-term energy projections are based on the analysis of global energy trends, global decarbonisation scenarios, new technologies and socio-economic changes. At the same time, it is necessary to take into account some uncertainties emerging in the process of the energy sector transformation, primarily those linked to the pace of scientific and technological progress, the penetration of alternative energy sources, mobile revolution, digitalisation and decentralisation of the energy industry.

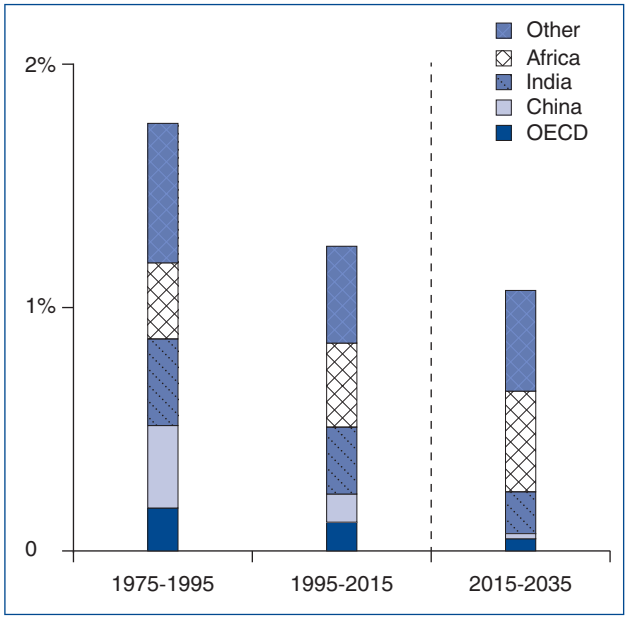
**Over the next 20 years, the global energy sector will undergo radical transformation. It is expected that demand for energy in developing economies will exceed the demand in developed countries, whereas energy mix is to change significantly under the growing competitiveness of "green" energy and technological advances. Thanks to the decarbonisation policy in most countries, the "clean" energy consumption (renewable energy, hydropower, nuclear power) is expected to account for 50% of the primary energy consumption growth by 2035.**

The biggest challenge of the world energy sector is the need to meet the targets set out in the Paris climate agreement, while meeting the global energy demand, that is projected to have an average annual increase of 1.3% over the next 20 years.[1] This figure is much lower compared to a 2.2% growth in 1995-2015. China, India, Brazil, as well as Middle East and African countries, will lead the global energy demand growth (Figure "*Population growth by region*"). China will remain the largest growth market for energy until 2030, although it is likely to be overtaken by India by 2035. Together, China and India will account for over half of the world's growth in energy demand. It is anticipated that increased demand for energy in developed OECD countries will be barely noticeable (Figure "*Energy consumption by region*").

The main socio-economic factors affecting the primary energy demand by 2035:

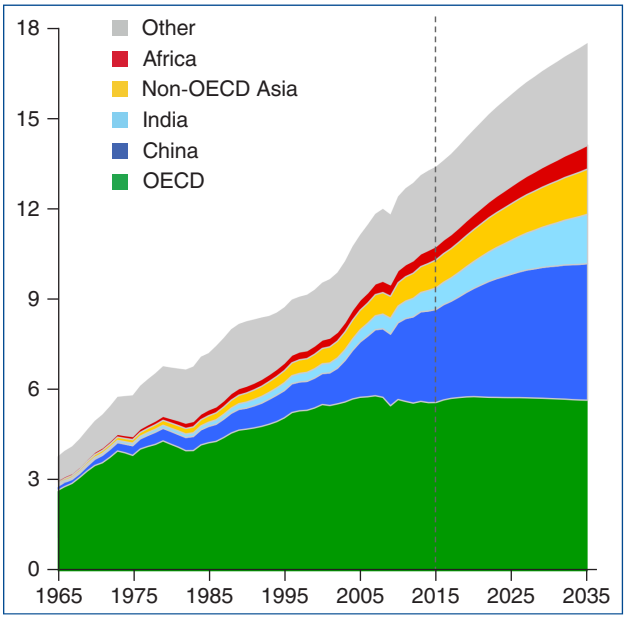
- Global GDP growth is projected to average around 3.4% per year (at Purchasing Power Parity exchange rates) (Figure "*Real GDP growth by region*");

**Population growth by region,** %




*Source:* BP Energy Outlook 2017 edition.

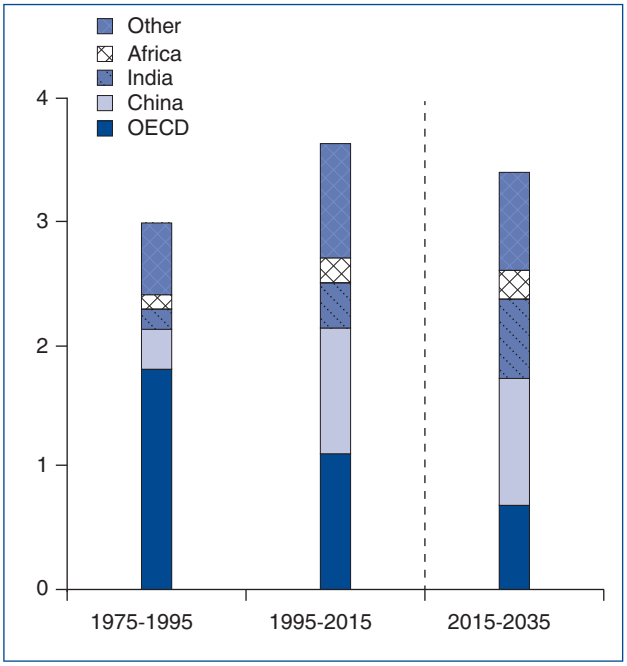
**Energy consumption by region,** billion toe




*Source:* BP Energy Outlook 2017 edition.

[1] In drafting this section certain materials and indicators from BP Energy Outlook 2017 were used, *https://www.bp.com/content/dam/bp/pdf/energy-economics/energy-outlook-2017/bp-energy-outlook-2017.pdf*.

**Real GDP growth by region,**
% per year




*Source:* BP Energy Outlook 2017 edition.

- growing energy demand will be driven by increases in productivity by 75%, with the world population growth accounting for only 25%;
- global population is expected to increase by around 1.5 billion reaching 8.8 billion people;
- close to 2 billion people will be lifted from low incomes owing to gains in productivity;

**Decarbonisation efforts will further stimulate energy efficiency and the deployment of renewable energy sources, thus contributing to the growth of energy consumption by only 31% with a twofold increase in global GDP.**

A growing productivity is expected to increase the demand for energy. At the same time, the role of a demographic factor will diminish. This, on the one hand, is explained by a substantial fall in the average annual population growth to less than 1%, and on the other – by significant gains in productivity as the global economy gradually moves to incorporate technological advances. The impact of increased productivity on GDP growth and energy consumption related to socio-demographic variables is more pronounced among African countries.

This continent accounts for almost half of the world population growth by 2035 but contributes less than 10% of the projected increase in global GDP and energy demand. Africa is also expected to increase its global energy role beyond 2035 due to a synergistic effect – high population growth coupled with gains in productivity.

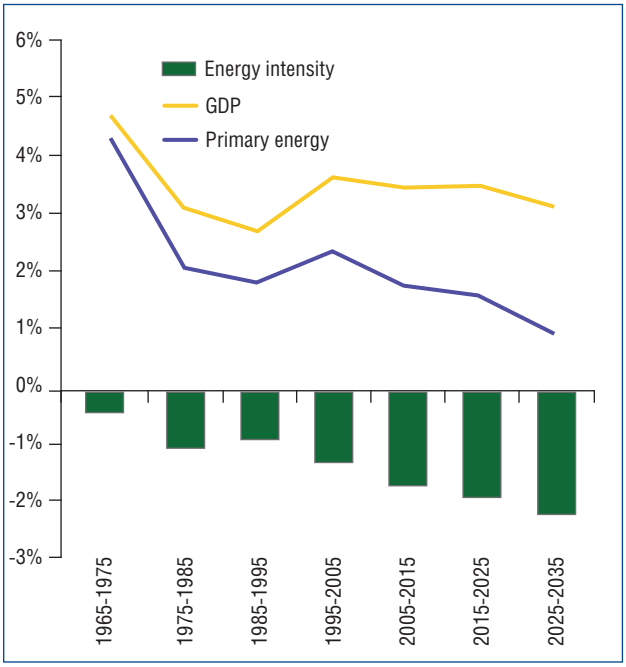
A continuing decline in energy intensity is one of the key factors affecting the global energy demand. If compared to 1985-1995, this indicator over the period under study is expected to decrease to 2% per year (Figure "*Growth in GDP and primary energy*").

According to *BP Energy Outlook 2017*, despite the fact that non-fossil fuels are expected to account for half of the growth in energy supplies in 2015-2035, oil, gas and coal will remain the dominant sources of energy – their share is expected to fall by 7% over the next 20 years, still accounting for 78% of the global consumption mix.

Among fossil fuels, only natural gas will increase its share in the energy mix (up to 25%) owing to a high average annual growth rate of 1.6%. By 2035, it will overtake coal by 1% to become the second largest fuel in the world after oil. The demand for oil is expected to grow, although moderately – by 0.7% per year with its share in the global energy mix to decline from 32% to 29%. **Coal will undergo the most significant change as its 2.7% consumption growth over the past 20 years is expected to decrease by an average of 0.2% per year**. As a result, the share of coal in global energy mix will decrease from 29% to 24%.

Ground-breaking changes are expected in the renewables sector, as their consumption in the forecast period will almost quadruple, from 439 mtoe to 1,715 mtoe (average annual growth of 7.1%). The share of renewables in global energy mix will increase from 3% to 10%. Hydropower will demonstrate a steady development, as its share in global energy mix will remain intact at 7% with the nominal increase in hydropower consumption from 893 to 1,272 mtoe, or by 43%. We should also highlight the increasing role of nuclear power in tackling climate change over the next 20 years. The use of this

**Growth in GDP and primary energy,**
% per year



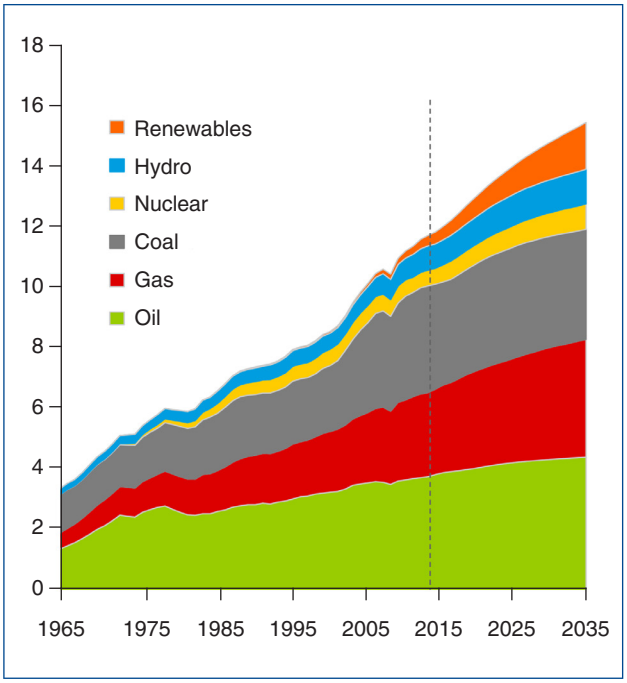

*Source:* BP Energy Outlook 2017 edition.

type of energy will grow by 344 mtoe (or by 60%), accounting for 5% of primary energy consumption.

The *BP Energy Outlook 2017* that explores the global energy transition until 2035 is based on reliable statistical data.[2] Also, these projections until 2035 (Figure "*Primary energy consumption by fuel*") are generally in line with the main global energy trends underway over the past decade. The *British Petroleum* (*BP*) as one of the largest oil and gas companies in the world cannot remain absolutely objective because of its obvious interest in growing demand in oil and gas markets. In addition, the BP's "base case" outlook is rather conservative in terms of renewable energy sources as the need to meet the targets of the Paris climate agreement as well as advancing science and technology will increase the renewable energy share in the global energy mix. Therefore, presented below are the long-term projections of the *BP Energy Outlook 2017* adjusted against the above-mentioned factors.

**Consistent with adjusted forecast, global primary energy consumption will increase from 13.15 billion toe 2015 to 17.16 billion toe in 2035, or by 31%** (Table "*The projected global energy mix by 2035*"). **According to the forecast, during 2015-2035 the share of oil consumption in the global mix will fall from 32% to 27%, and that of coal – from 29% to 22%.**

**Primary energy consumption by fuel,**
billion toe




*Source:* BP Energy Outlook 2017 edition.

**Instead, the share of renewable energy is set to grow more substantially compared to the *BP Energy Outlook 2017* – from 3% to 14%. In quantitative terms the share of renewable energy will increase from 439 mtoe to 2,400 mtoe, or by 5.5 times. Therefore, it is projected that the total share of fossil fuels in global energy mix will decrease to 74% in 2035. This will significantly help the global community in tackling the climate change.**

Profound changes are also expected in the structure of primary energy consumption, especially for power generating and industry sectors. If the share of energy for electricity and heat production is expected to increase from 42% to 47%, then the energy use in industry will decrease from 24% to 21%.

## 2.2. DECARBONISATION OF GLOBAL ENERGY SECTOR AND INVESTMENT OUTLOOK UNTIL 2035

The analytical review *World Energy Outlook 2014* by the International Energy Agency (*IEA*) presents the scenarios for global energy development – the *New Policies Scenario* and *450 Scenario*.[3] According to them, world energy investment by 2035 is expected to increase by 1.72 times compared to the period of 2000-2013. **This amounts to $48 trillion of total investment, including over $39 trillion going to the power sector, and over $8 trillion spent on energy efficiency**[4] (Table "*Global energy investment outlook until 2035*", pp.43-45). Transport and buildings sector dominate global investment in energy efficiency until 2035, accounting for 90% of the world total. **As for reaching decarbonisation goals, IEA places high emphasis on investment in power sector, which according to the New Policies Scenario will amount to $16.4 trillion, or 40% of total investment in energy supply infrastructure, and according to 450 Scenario – $19.3 trillion, or 49% of investment.**

According to the New Policies Scenario, the renewable energy sources will receive $5.9 trillion of total investment in energy supply systems, and $8.8 trillion in line with 450 Scenario.

In its special report "Energy and Climate Change" (2015), IEA sets a number of investment priorities to secure the long-term decarbonisation of the global energy system, which include:

- increasing energy efficiency in the industry, buildings and transport sectors;
- increasing investment in renewable energy technologies;

[2] *Sources*: BP Statistical Review of World Energy, London, United Kingdom, June 2017; International Energy Agency, Energy Balances of Non-OECD Countries, Paris, France, 2016; UN Population Division, World Population Prospects: The 2015 Revision, New York, United States, 2016; IEA: International Energy Agency, World Energy Outlook 2016, Paris, France, November 2016; IHS: IHS Energy, Rivalry: the IHS Planning Scenario, July 2016.

[3] *Source*: World Energy Investment Outlook 2014.

[4] Key provisions of the European Union's energy strategies and programmes for the energy sector development under formation of pan-European energy market – R&DC UES Ukraine, 2017, p.82.

**The projected global energy mix by 2035**

| | Consumption (mtoe) | | Shares (%) | | Change (mtoe) | | Change (%) | | Annual growth (%) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2015 | 2035 | 2015 | 2035 | 1995-2015 | 2015-2035 | 1995-2015 | 2015-2035 | 1995-2015 | 2015-2035 |
| **Primary energy** | **13 147** | **17 327** | **100** | **100** | **4 559** | **4 180** | **53** | **31** | **2.2** | **1.3** |
| **By fuel:** | | | | | | | | | | |
| Oil | 4 257 | 4 632 | 32 | 27 | 971 | 375 | 30 | 9 | 1.3 | 0.7 |
| Gas | 3 135 | 4 319 | 24 | 25 | 1 211 | 1 184 | 63 | 38 | 2.5 | 1.6 |
| Coal | 3 840 | 3 775 | 29 | 22 | 1 595 | -65 | 71 | -2 | 2.7 | -0.15 |
| Nuclear | 583 | 927 | 4 | 5 | 57 | 344 | 11 | 59 | 0.5 | 2.3 |
| Hydro | 893 | 1 272 | 7 | 7 | 330 | 379 | 59 | 42 | 2.3 | 1.8 |
| Renewables (wind, solar, geothermal, biomass, biofuels) | 439 | 2 402 | 3 | 14 | 394 | 1 963 | 870 | 447 | 12.0 | 7.1 |
| **By sector:** | | | | | | | | | | |
| Transport | 2 472 | 3 052 | 19 | 18 | 898 | 580 | 57 | 24 | 2.3 | 1.0 |
| Industry | 3 117 | 3 640 | 24 | 21 | 1 060 | 523 | 52 | 17 | 2.1 | 0.7 |
| Non-combusted (petrochemicals) | 817 | 1 232 | 6 | 7 | 300 | 415 | 58 | 51 | 2.3 | 2.1 |
| Buildings | 1 222 | 1 296 | 9 | 7 | 61 | 74 | 5 | 6 | 0.3 | 0.3 |
| Power | 5 519 | 8 107 | 42 | 47 | 2 241 | 2 588 | 68 | 47 | 2.6 | 1.9 |

* *Source:* BP Energy Outlook 2017 edition.

- gradual phasing out of fossil fuel subsidies to end-users by 2030;
- reducing methane emissions in oil and gas production;
- reducing pollutant emissions from coal-fired power plants (TPP) by investing in filtration technology;
- reducing investment in coal mining and coal- and fuel oil-fired power plants.

If the world is to keep open the possibility of limiting the increase in global average temperatures to well below 2°C agreed at COP21, global climate protection efforts need to be consistently ramped up by new climate pledges of individual countries to reduce emissions.

## 2.3. ENERGY SECTOR OUTLOOK UNTIL 2035 BY SECTOR

### 2.3.1. Oil sector

Global liquids demand (oil, biofuels, other liquid carbohydrates) in 2015-2035 is expected to grow at a slower pace compared with the past 20 years – from 1.1% to 0.7% per year. Global oil demand increases by around 15 mb/d up to 110 mb/d, or by 16%[5] (Figure "*Global oil demand and supply by 2035*", p.42). All of the demand growth, however, comes from emerging economies, as rising GDP and prosperity leads to increased oil demand. China and India will account for the lion's share of this growth. In contrast, oil demand in the OECD countries will continue to decline (-8 mb/d over the projection period).

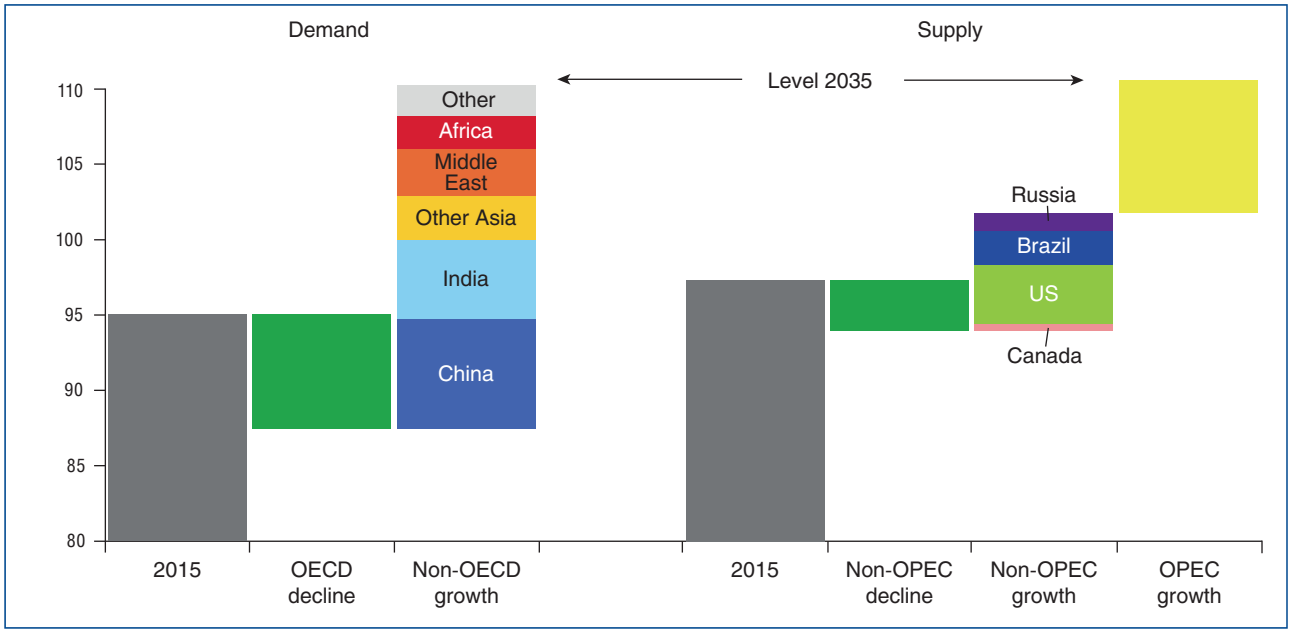
The transport sector will consume most of the world's liquid fuel, with its share of global demand remaining just under 60% by 2035. Transport accounts for most of the growth in overall demand by 10 mb/d, with that increase split almost evenly between cars (4 mb/d), trucks (mb/d) and ships, trains and airplanes (3 mb/d) (Figure "*Global oil demand by sector*", p.42).

It is important to note, however, that decelerating transport demand for oil will gradually slow down the total oil demand growth from around 1 mb/d per year to 0.4 mb/d by 2035, as fuel efficiency improves significantly and there is an increasing penetration of non-oil fuels, such as electricity, natural gas and biofuels. Together they will account for 13% of transport fuel demand in 2035 (from 7% in 2015). Non-combusted use, especially in the petrochemicals sector, will take over as the main source of growth in demand for liquid fuels. According to forecasts, the demand for non-combusted use will increase by 6 mb/d.

**World oil industry is capable of fully meeting the global growth in oil use at reasonable prices. After all, there are no problems with proved and projected oil reserves in the world. Proved oil reserves alone can support the current level of oil consumption by the global economy for more than 50 years, while introduction of new technologies in many cases may reduce production costs.**

[5] Based on BP Energy Outlook 2017. However, according to *DTEK Energy Outlook 2017*, the oil demand will be somewhat lower.

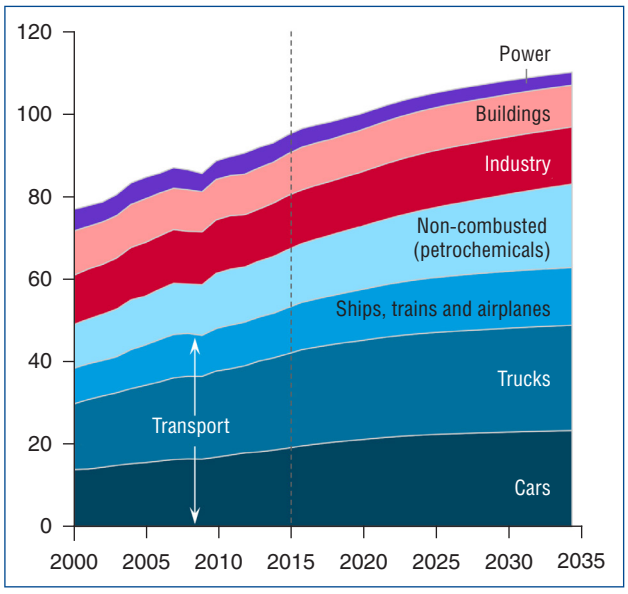
**Global oil demand and supply by 2035**, mb/d




*Source:* BP Energy Outlook 2017 edition.

The Middle East countries, the United States, Canada and Russia have the most competitive oil sectors to dominate the oil market over the next 25 years. OPEC is expected to account for nearly 70% of the global supply growth, increasing by 9 mb/d to 48 mb/d by 2035. Meanwhile, non-OPEC growth in the global market will be just over 7.5 mb/d – the US (4 mb/d), Brazil (2 mb/d), Russia (1 mb/d), and Canada (0.5 mb/d). **The fact of dynamic growth in the US oil output after years-long decline is remarkable. The "shale revolution"[6] and the use of innovative technologies helped the US to increase oil production in 2006-2016 by 5.5 mb/d, or by more than 80%. This trend is expected to continue over the next 20 years, allowing the US to remain the world's oil production leader.**

**Global oil demand by sector**, mb/d




*Source:* BP Energy Outlook 2017 edition.

### 2.3.2. Gas sector

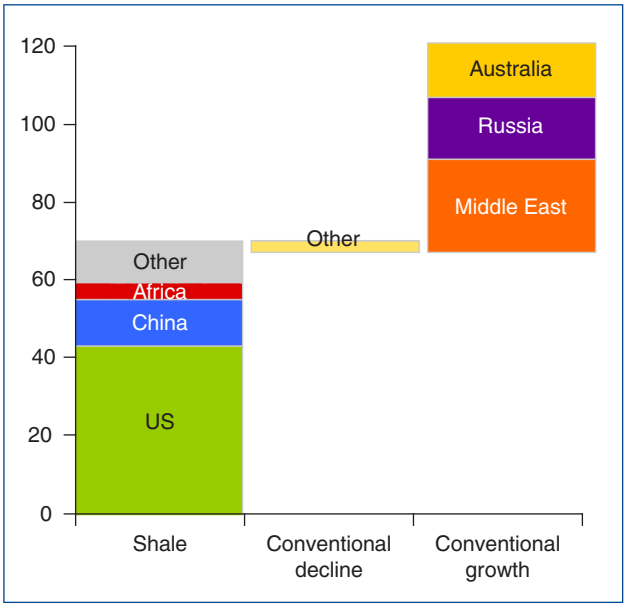
The global natural gas production is expected to grow at an average of 1.6% per year during 2015-2035 (two times faster than oil, and eight times – than coal). This, however, is half of the growth over the past decade. At the same time, the "shale revolution" will contribute to increase in unconventional gas production by 5.2% per year.

**Increase in unconventional gas supplies will be driven by the US, where shale output is expected to double – up to 43 bcf/d**, or 516 bcm/y (Figure "*Gas supply growth in 2015-2035*"). Significant investment in the development of unconventional gas fields will help Chile to emerge as the second largest shale producer. Nonetheless, the gap between China and the US – the pioneer in developing shale gas deposits, will remain significant.

Increases in conventional gas production globally in 2015-2035 will be led by the Middle East, Russia and Australia. These countries will make the largest contribution to an average growth of natural gas production (0.7% per year). Further development of China's industry and power generation sectors will drive the global demand growth. The Middle East countries and the US with their

[6] The "shale revolution" refers to extraction of nonconventional oil – shale oil, as well as oil recovered from bituminous sands.

**Gas supply growth in 2015-2035,** bcf/d

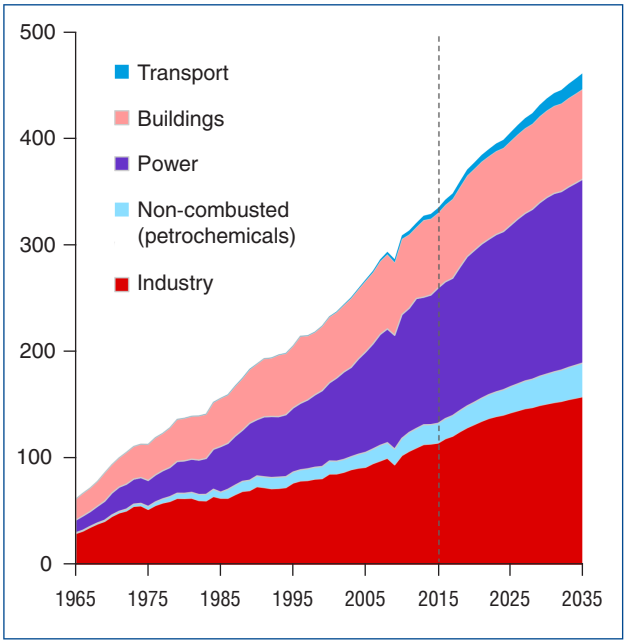



*Source:* BP Energy Outlook 2017 edition.

abundant proved gas reserves will use this competitive advantage to boost demand primarily in the power generation. By sector, the largest contribution to the global consumption growth will come from the industrial sector (45%) followed by power (36%). Gas consumption by buildings and transport sectors will also grow, albeit less dynamically (Figure "*Dynamics of global gas demand by sector*").

The key global markets – China and Europe – will not be able to meet the increasing demand with their own resources. In China, growth in gas consumption

**Global gas demand by sector,** bcf/d




*Source:* BP Energy Outlook 2017 edition.

**Global energy investment outlook until 2035,** $ billion

| | World | | |
|---|---|---|---|
| | Average annual investments | Cumulative investments | |
| | | New Policy Scenario | 450 Scenario |
| | 2000-2013 | 2014-2035 | 2014-2035 |
| **Energy supply** (billion, year-2012 US dollars) | | | |
| Total energy supply | 1 230.0 | 40 165.0 | 39 387.0 |
| **Oil** | 427.0 | 13 671.0 | 11 062.0 |
| Upstream | 320.0 | 11 284.0 | 9 014.0 |
| Transport | 54.0 | 986.0 | 902.0 |
| Refining | 52.0 | 1 401.0 | 1 146.0 |
| **Gas** | 252.0 | 8 771.0 | 7 457.0 |
| Upstream | 152.0 | 6 138.0 | 5 135.0 |
| Refining | 100.0 | 2 633.0 | 2 322.0 |
| **Coal** | 61.0 | 1 034.0 | 690.0 |
| Mining | 31.0 | 736.0 | 508.0 |
| Transport | 30.0 | 298.0 | 181.0 |
| **Power** | 479.0 | 1 6370.0 | 19 258.0 |
| Fossil fuels | 106.0 | 2 635.0 | 2 877.0 |
| Coal | 55.0 | 1 528.0 | 1 918.0 |
| Gas | 46.0 | 1 054.0 | 930.0 |
| **Nuclear** | 8.0 | 1 061.0 | 1 722.0 |
| **Renewables** | 153.0 | 5 857.0 | 8 809.0 |
| Bioenergy | 17.0 | 639.0 | 892.0 |
| Hydro | 52.0 | 1 507.0 | 2 097.0 |
| Wind | 43.0 | 1 989.0 | 3 027.0 |
| Solar | 37.0 | 1 276.0 | 1 724.0 |
| Transmission | 48.0 | 1 787.0 | 1 586.0 |
| Distribution | 164.0 | 5 030.0 | 4 265.0 |
| **Biofuels** | 10.0 | 320.0 | 920.0 |
| **Energy efficiency** (billion, year-2012 US dollars) | | | |
| Total | | 8 002.0 | 13 531.0 |
| **Industry** | | 739.0 | 1 371.0 |
| Energy intensive | | 284.0 | 529.0 |
| Non-energy intensive | | 455.0 | 842.0 |
| **Transport** | | 4 928.0 | 8 120.0 |
| Road | | 4 496.0 | 7 267.0 |
| Aviation, navigation and rail | | 432.0 | 854.0 |
| Buildings | | 2 334.0 | 4 040.0 |
| **Total energy efficiency and energy supply** (billion year-2012 US dollars) | | | |
| Total amount | | 48 167.0 | 52 918.0 |

*Source:* World Energy Investment 2014.

**Global energy investment outlook until 2035, $** billion (*continued*)

| | OECD | | | European Union | | |
|---|---|---|---|---|---|---|
| | Average annual investments | Cumulative investments | | Average annual investments | Cumulative investments | |
| | | New Policy Scenario | 450 Scenario | | New Policy Scenario | 450 Scenario |
| | 2000-2013 | 2014-2035 | 2014-2035 | 2000-2013 | 2014-2035 | 2014-2035 |
| **Energy supply** (billion, year-2012 US dollars) | | | | | | |
| Total energy supply | 500.0 | 14 494.0 | 14 883.0 | 152.0 | 3214.0 | 3 528.0 |
| **Oil** | 129.0 | 4 645.0 | 3 840.0 | 20.0 | 394.0 | 358.0 |
| Upstream | 102.0 | 4 087.0 | 3 334.0 | 13.0 | 242.0 | 223.0 |
| Transport | 9.0 | 124.0 | 113.0 | 1.0 | 15.0 | 13.0 |
| Refining | 19.0 | 434.0 | 393.0 | 6.0 | 136.0 | 122.0 |
| **Gas** | 112.0 | 3 296.0 | 2 801.0 | 30.0 | 531.0 | 453.0 |
| Upstream | 70.0 | 2 177.0 | 1 867.0 | 12.0 | 254.0 | 336.0 |
| Refining | 42.0 | 1 119.0 | 934.0 | 19.0 | 276.0 | 217.0 |
| **Coal** | 16.0 | 250.0 | 167.0 | 3.0 | 19.0 | 16.0 |
| Mining | 9.0 | 202.0 | 131.0 | 1.0 | 12.0 | 9.0 |
| Transport | 7.0 | 47.0 | 36.0 | 2.0 | 7.0 | 7.0 |
| **Power** | 236.0 | 6 157.0 | 7 608.0 | 96.0 | 2 227.0 | 2 566.0 |
| Fossil fuels | 44.0 | 852.0 | 1046.0 | 12.0 | 324.0 | 161.0 |
| Coal | 12.0 | 367.0 | 676.0 | 3.0 | 103.0 | 76.0 |
| Gas | 30.0 | 471.0 | 422.0 | 9.0 | 117.0 | 82.0 |
| **Nuclear** | 4.0 | 389.0 | 643.0 | 1.0 | 166.0 | 242.0 |
| **Renewables** | 87.0 | 2 736.0 | 3915.0 | 53.0 | 1 182.0 | 1 513.0 |
| Bioenergy | 11.0 | 371.0 | 450.0 | 8.0 | 160.0 | 178.0 |
| Hydro | 11.0 | 303.0 | 446.0 | 3.0 | 100.0 | 147.0 |
| Wind | 29.0 | 1 112.0 | 1 600.0 | 17.0 | 574.0 | 727.0 |
| Solar | 33.0 | 720.0 | 886.0 | 23.0 | 254.0 | 306.0 |
| Transmission | 22.0 | 546.0 | 527.0 | 4.0 | 139.0 | 153.0 |
| Distribution | 80.0 | 1 635.0 | 1 478.0 | 26.0 | 516.0 | 497.0 |
| **Biofuels** | 7.0 | 146.0 | 467.0 | 2.0 | 44.0 | 136.0 |
| **Energy efficiency** (billion, year-2012 US dollars) | | | | | | |
| Total | | 4 630.0 | 6 807.0 | | 2470.0 | 2998.0 |
| **Industry** | | 219.0 | 425.0 | | 82.0 | 154.0 |
| Energy intensive | | 85.0 | 196.0 | | 29.0 | 77.0 |
| Non-energy intensive | | 134.0 | 229.0 | | 53.0 | 77.0 |
| **Transport** | | 2 629.0 | 3 540.0 | | 1 187.0 | 1 560.0 |
| Road | | 2 536.0 | 3 406.0 | | 1 175.0 | 1 535.0 |
| Aviation, navigation and rail | | 93.0 | 134.0 | | 13.0 | 25.0 |
| Buildings | | 1 782.0 | 2 842.0 | | 900.0 | 1 285.0 |
| **Total energy efficiency and energy supply** (billion year-2012 US dollars) | | | | | | |
| Total amount | | 19 124.0 | 216 690.0 | | 5 384.0 | 6 526.0 |

*Source:* World Energy Investment 2014.

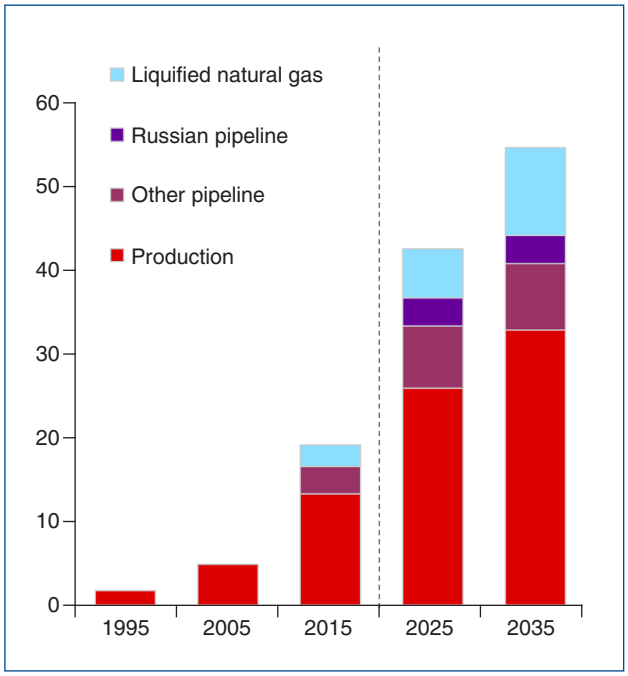
**Global energy investment outlook until 2035, $** billion (*continued*)

| | United States | | | China | | |
|---|---|---|---|---|---|---|
| | Average annual investments | Cumulative investments | | Average annual investments | Cumulative investments | |
| | | New Policy Scenario | 450 Scenario | | New Policy Scenario | 450 Scenario |
| | 2000-2013 | 2014-2035 | 2014-2035 | 2000-2013 | 2014-2035 | 2014-2035 |
| **Energy supply** (billion, year-2012 US dollars) | | | | | | |
| Total energy supply | 188.0 | 6 012.0 | 6 468.0 | 176.0 | 5 745.0 | 6 218.0 |
| **Oil** | 53.0 | 2 260.0 | 1 903.0 | 38.0 | 1072.0 | 828.0 |
| Upstream | 41.0 | 2 021.0 | 1 683.0 | 22.0 | 715.0 | 587.0 |
| Transport | 5.0 | 46.0 | 45.0 | 4.0 | 83.0 | 79.0 |
| Refining | 7.0 | 193.0 | 176.0 | 12.0 | 274.0 | 162.0 |
| **Gas** | 49.0 | 1 500.0 | 1 261.0 | 9.0 | 657.0 | 654.0 |
| Upstream | 35.0 | 1 057.0 | 863.0 | 6.0 | 448.0 | 417.0 |
| Refining | 14.0 | 443.0 | 398.0 | 3.0 | 209.0 | 236.0 |
| **Coal** | 6.0 | 102.0 | 65.0 | 26.0 | 404.0 | 283.0 |
| Mining | 4.0 | 89.0 | 52.0 | 15.0 | 335.0 | 239.0 |
| Transport | 2.0 | 14.0 | 13.0 | 11.0 | 69.0 | 44.0 |
| **Power** | 75.0 | 2 052.0 | 2 968.0 | 103.0 | 3 587.0 | 4 361.0 |
| Fossil fuels | 19.0 | 373.0 | 705.0 | 33.0 | 404.0 | 727.0 |
| Coal | 4.0 | 185.0 | 472.0 | 31.0 | 332.0 | 623.0 |
| Gas | 15.0 | 183.0 | 230.0 | 2.0 | 70.0 | 103.0 |
| **Nuclear** | - | 90.0 | 180.0 | 2.0 | 293.0 | 510.0 |
| **Renewables** | 16.0 | 771.0 | 1 344.0 | 36.0 | 1 174.0 | 1 720.0 |
| Bioenergy | 2.0 | 143.0 | 192.0 | 2.0 | 87.0 | 157.0 |
| Hydro | 1.0 | 57.0 | 71.0 | 22.0 | 311.0 | 339.0 |
| Wind | 9.0 | 292.0 | 514.0 | 9.0 | 508.0 | 744.0 |
| Solar | 4.0 | 212.0 | 286.0 | 3.0 | 207.0 | 320.0 |
| Transmission | 12.0 | 254.0 | 235.0 | 9.0 | 548.0 | 452.0 |
| Distribution | 28.0 | 564.0 | 503.0 | 23.0 | 1 169.0 | 351.0 |
| **Biofuels** | 5.0 | 98.0 | 270.0 | - | 26.0 | 93.0 |
| **Energy efficiency** (billion, year-2012 US dollars) | | | | | | |
| Total | | 1 331.0 | 1 930.0 | | 1 566.0 | 2 526.0 |
| **Industry** | | 70.0 | 140.0 | | 270.0 | 420.0 |
| Energy intensive | | 35.0 | 68.0 | | 125.0 | 165.0 |
| Non-energy intensive | | 35.0 | 73.0 | | 154.0 | 256.0 |
| **Transport** | | 778.0 | 904.0 | | 1 106.0 | 1 660.0 |
| Road | | 710.0 | 816.0 | | 1 091.0 | 1 614.0 |
| Aviation, navigation and rail | | 69.0 | 88.0 | | 14.0 | 46.0 |
| Buildings | | 483.0 | 886.0 | | 190.0 | 446.0 |
| **Total energy efficiency and energy supply** (billion year-2012 US dollars) | | | | | | |
| Total amount | | 7 343.0 | 8 398.0 | | 7311.0 | 8 744.0 |

*Source:* World Energy Investment 2014.

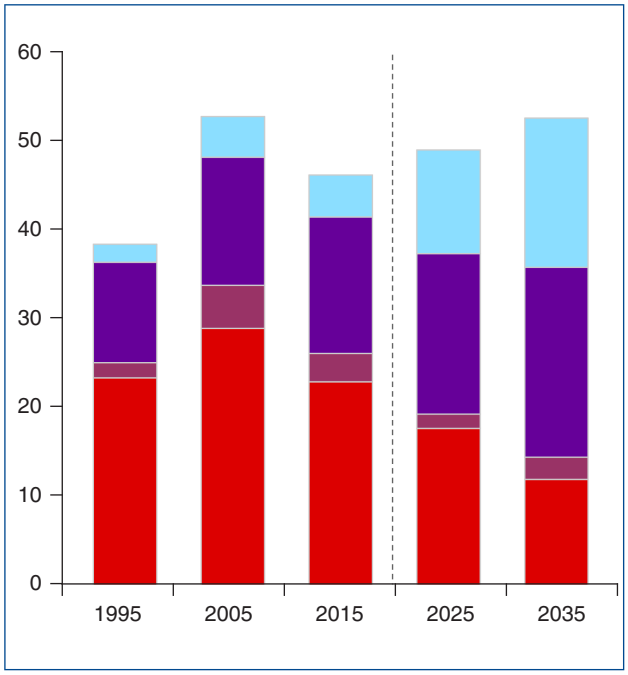
(5.4%, or at 36 bcf/d or 432 bcm/y by 2035) will outstrip domestic production, so that by 2035 the share of imported gas in total consumption will increase from 30% in 2015 to nearly 40%. (Figures "*Imported gas supply to China*" and "*Imported gas supply to Europe*"). Around half of these increased imports to China will be met by LNG, with rising pipeline imports from Russia and the Central Asia countries providing the remainder.

**Imported gas supply to China**, bcf/d




*Source:* BP Energy Outlook 2017 edition.

**Imported gas supply to Europe**, bcf/d




*Source:* BP Energy Outlook 2017 edition.

**In Europe, domestic production is set to decline sharply to -3.2% per year as existing fields mature and are not replaced with proved reserves. As a result, the share of imported gas in total consumption will rise from around 50% in 2015 to 80% in 2035. To cover the increasing gas deficit, Europe will import additional 15 bcf/d, or 180 bcm/y. LNG imports are expected to supply 67% of the increase in imports, with rising pipeline imports from Russia providing the remaining 33%.**

Significant investment in gas production and the construction of LNG terminals in Australia will contribute to growing LNG supplies to the Asia Pacific countries. This will substantially increase competition between exporters in the region, forcing the US and Qatari suppliers to refocus on the European market, thus holding back the Russian pipeline gas expansion.

### 2.3.3. Coal sector

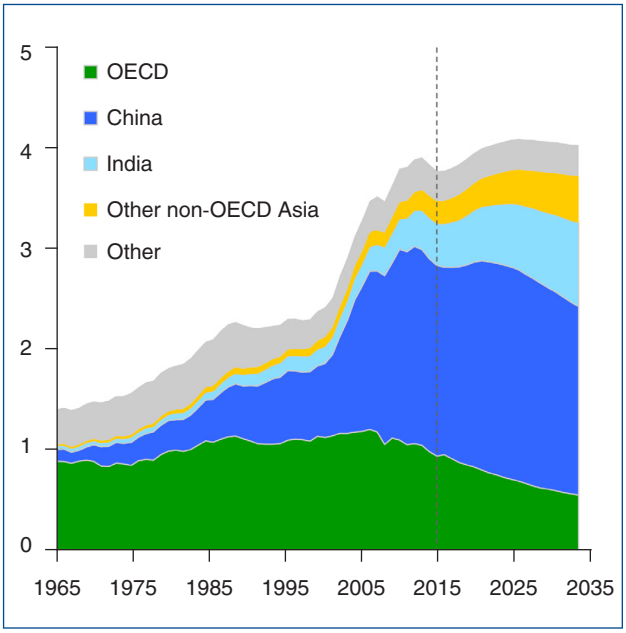
In the next 20 years the global coal industry is expected to substantially reduce coal production due to significant slowdown in the average annual demand in world markets – from 2.7% over the past 20 years to 0.2% in the projection period. World coal production is expected to peak in mid-2020s with subsequent irreversible decline of the importance of coal as power generation fuel for the global economy. The priority of decarbonisation of the fuel and energy sector for most countries will lead to the replacement of coal with more environmentally friendly fuels, primarily renewables and natural gas.

China will remain the world's largest market for coal, accounting for nearly half of global coal consumption in 2035, however the dynamics of coal demand in this country will slow sharply as China's economy shifts towards cleaner, lower-carbon fuels (Figure "*Global coal consumption until 2035 by region*"). In the period under study, global coal production is expected to grow by only 5% (from 3.8 to 4.0 billion toe), while its share in the structure of global consumption to drop from 29% to 22%. China, India, Indonesia and Australia will account for 70% of global coal production until 2035.

Despite this global "depreciation" of the coal industry, there exists one important exception. Due to significant growth of India's economy and the population size, this country is unlikely to cover most of its growing demand with "clean" energy and therefore will be forced to increase coal consumption to address its energy needs.

As a result, India will become the largest growth market, with its share of world coal demand doubling from 10% in 2015 to 20% in 2035. Instead, **coal demand in the OECD countries in 2015-2035 is expected to**

**Global coal consumption until 2035 by region,** billion toe




*Source:* BP Energy Outlook 2017 edition.

**decrease by 40%, because unlike the emerging economies, developed countries will be much more active in replacing coal with renewables and natural gas. The fall in coal consumption will be particularly evident in the US as more than 30% of country's TPPs shift from coal to gas.**

Current relatively low coal prices affect producers around the world, forcing them to cut their investment in the coal industry. However, the introduction of high performance technologies in coal-fired power plants, especially for capturing and storing carbon dioxide emissions, can become effective in slowing down the reduction of coal demand.

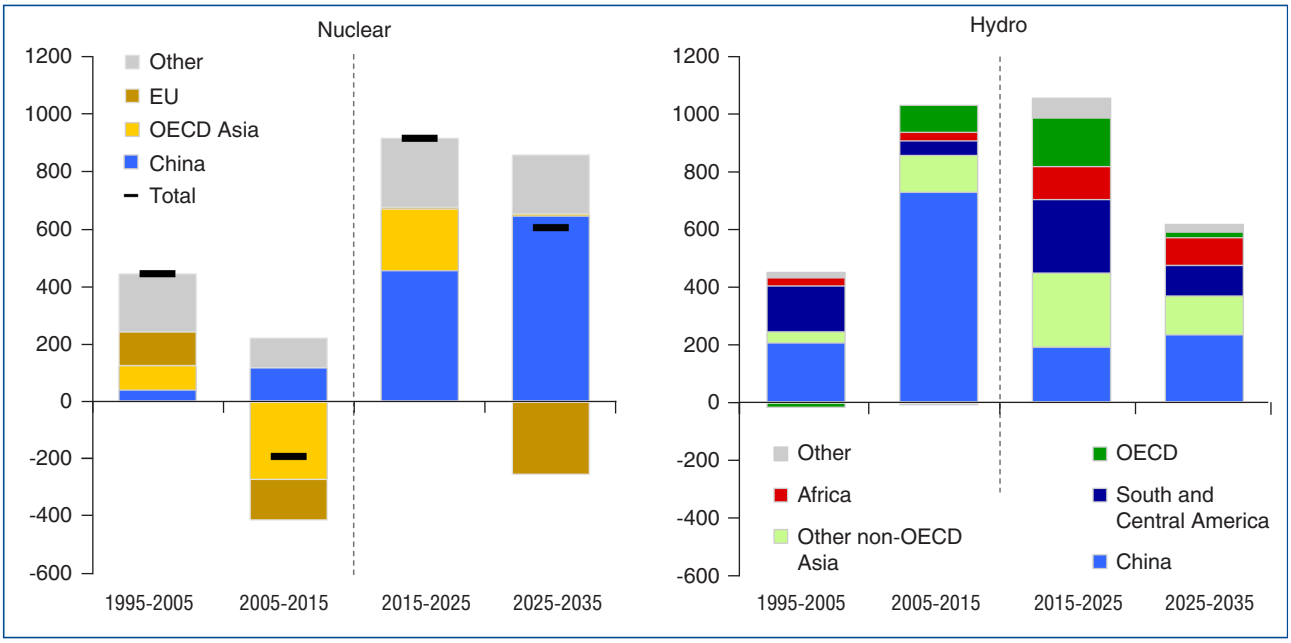
### 2.3.4. Nuclear and hydro generation

Nuclear and hydro power generation are expected to grow steadily over the period under study. **Projected average growth of power generation at NPP and HPP will reach 2.3% and 1.8% respectively. Combined share of these types of energy in the global energy mix will remain steady at 11-12%. Nuclear power generation in 2015-2035 will increase from 583 to 927 mtoe, or by 59%, while hydro power generation is expected to rise from 893 to 1,272 mtoe, or by 42%.**

Nuclear capacity in Europe is to decline as ageing plants are gradually being decommissioned, and investment in the construction of new nuclear power facilities is limited. As a result, the EU nuclear power generation by 2035 will be 30% lower than in 2015. Japan is expected to gradually restart some of its reactors that were shut down following the Fukushima nuclear accident (2011) over the next 10 years, but full utilisation of the country's nuclear industry potential and its recovery to pre-Fukushima level is unlikely.

Health-threatening air pollution in China's industrial regions forces its government to take urgent measures aimed at replacing coal fired power plants. In this context, China's nuclear expansion programme looks very ambitious as by 2035 it seeks to achieve 11% of average annual growth, or 1,100 TWh (Figure "*Global growth of*

**Global growth of nuclear and hydro power generation,** TWh




*Source:* BP Energy Outlook 2017 edition.

*nuclear and hydro power generation*"). The share of Chinese nuclear industry will account for nearly 75% of the global increase in nuclear generation. This is roughly equivalent to China introducing a new reactor every three months for the next 20 years.

In contrast, the growth of China's hydro power generation (430 TWh) in 2015-2035 will slow down sharply relative to the last decade as the availability of water resources falls. Brazil and India, however, will make up some of this gap, with each country expanding output by more than 100 TWh over this period.

### 2.3.5. Renewable energy

Renewables are projected to be the fastest growing source of energy in global electricity generation. During 2015-2035, the annual increase in primary production from renewable sources is expected to reach 7.1%, increasing "green power" production by 5.5 times – from 439 to 2,400 mtoe. As a result, the share of renewables in the global primary energy consumption will increase from 3% to 14%, and their share in electricity generation is set to rise from 7% to over 20%. By 2035, RES will account for 40% of the growth in global electricity generation.

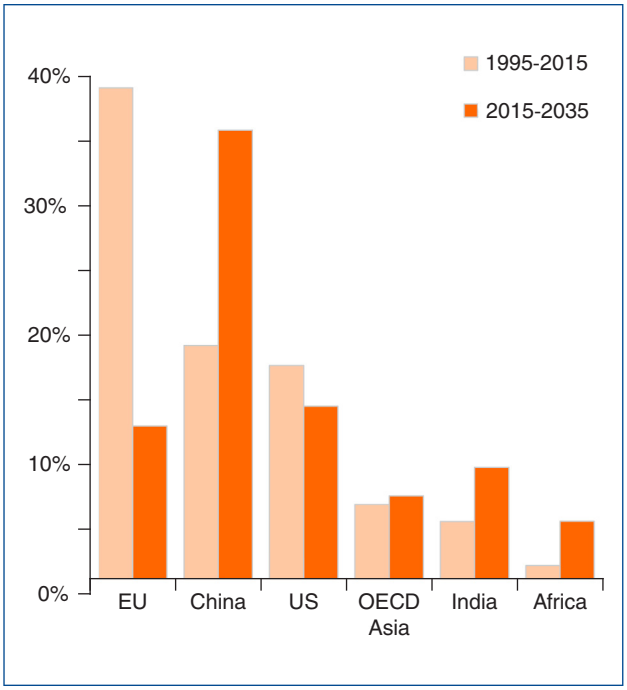
Such a dynamic expansion in renewable energy is due to their competitiveness in the age of decarbonisation, primarily for the following reasons:

1. Environmentally friendly. Virtually no GHG, sulphur dioxide and nitrogen emissions; no waste disposal.
2. Inexhaustibility. Regularly renewable compared to fossil fuels.
3. Decentralisation. Decentralised location (development of distributed generation).
4. Investment attractiveness.
5. Ongoing reduction in the cost of solar and wind energy; short investment cycle; government subsidies; no emission fees.

The need for flexible capability to ensure grid operation is an issue that stands in the way of an even more dynamic deployment of renewables. Leading electric motor manufacturers and tech hubs are currently working to solve the issue. **It is projected that as soon as early 2020s the cost and energy storage technologies will allow to switch between generation capacities by accumulating large amounts of energy. This will greenlight further deployment of renewable energy sources and ensure their long-term dominance beyond 2035.**

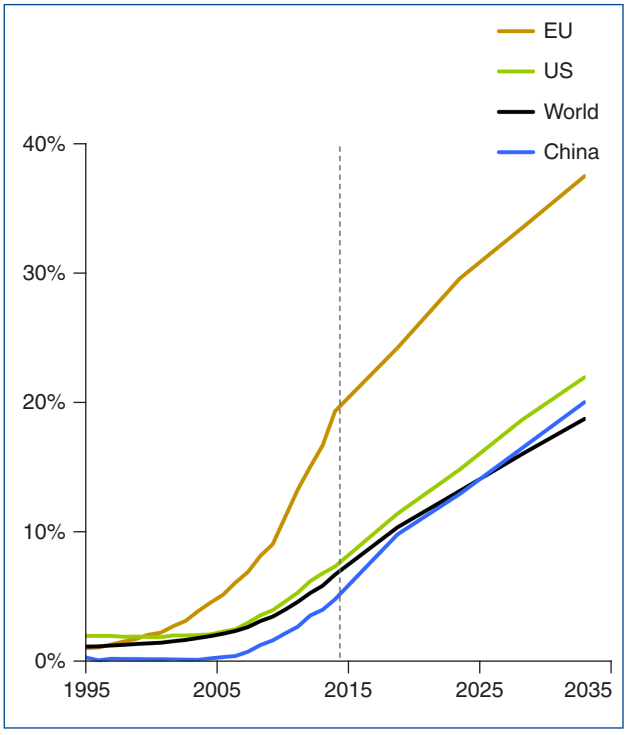
The EU will remain the global leader in renewable energy. The renewable electricity generation in the EU is expected to double, reaching almost 40% of total electricity generation (Figure "*Renewables share of power generation*"). However, China will be the largest source of growth over the next 20 years, adding more renewable power than the EU and US combined (Figure "*Shares of renewable power growth*").

**Shares of renewable power growth**




*Source:* BP Energy Outlook 2017 edition.

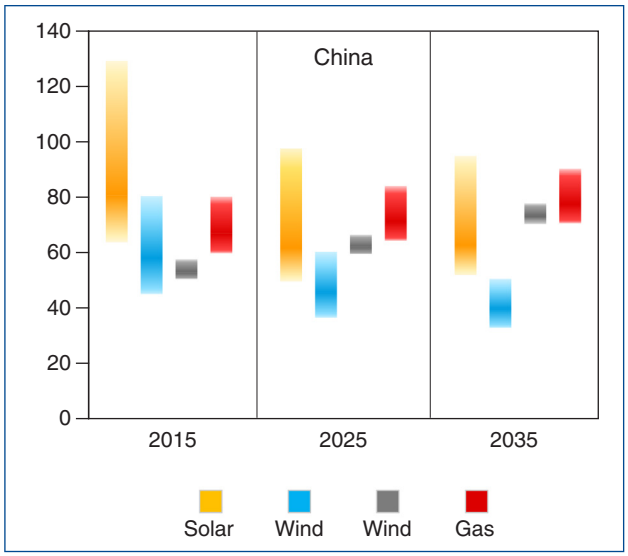
**Renewables share of power generation**




*Source:* BP Energy Outlook 2017 edition.

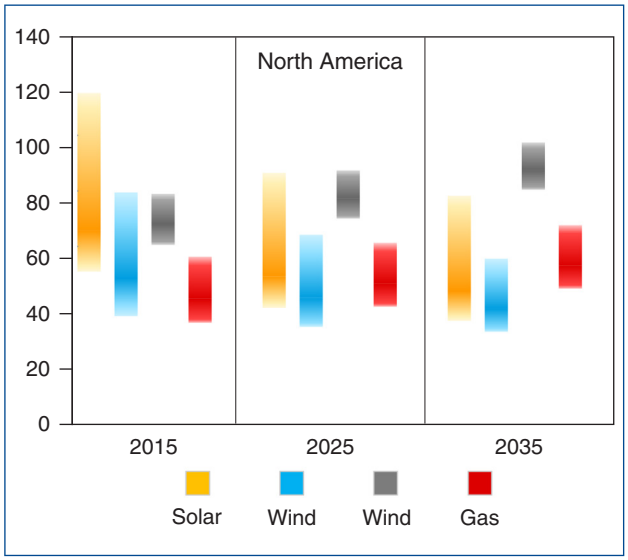
The cost of building new solar and wind power plants is expected to decline (Figures "*Cost of power generation in China by energy source*" and "*Cost of power generation in North America by energy source*"). The cost of solar power projects will reduce at a much slower pace compared with wind power generation, because the innovative potential of wind turbines are currently thought to be higher than that of solar PV modules. The onshore wind turbines are particularly competitive in this regard.

**Cost of power generation in China by energy source,** $2015/MWh




*Source:* BP Energy Outlook 2017 edition.

**Cost of power generation in North America by energy source,** $2015/MWh




*Source:* BP Energy Outlook 2017 edition.

## 2.4. KEY INNOVATIVE TECHNOLOGIES IN THE ENERGY SECTOR

Forecast of the global energy transition should include the assessment of the impact innovative technologies have on the industry. In addition to innovations in the energy sector that directly affect the distribution of fuel and energy production with subsequent delivery to consumers, this also concerns innovations influencing energy behaviours.

Explosive innovation over the past 20 years allowed futurologists and later the general public to discuss the phenomenon of the Fourth Industrial Revolution (4IR). The executive chairman of the World Economic Forum in Davos, Klaus Schwab,[7] in February 2016, presented the report named "The Fourth Industrial Revolution". According to Schwab's vision, a synthesis of information technology, biotechnology and physical nanotechnology is the 4IR's distinctive feature. It fosters an extraordinary individualisation and diversification of huge volumes of information. At the same time, introduction of new means of mobile communication leads to the unprecedented growth in socialisation of all human activities. In his report Mr. Schwab highlighted key technological changes of the future.

Unlike previous industrial revolutions, 4IR seeks to transition from exploiting natural resources by people to harmonising human relations with nature based on sustainable economic development for conservation of integrated ecosystems. For 4IR outcomes to be positive, human beings need to make a quality breakthrough in the organisation of all their activities. For energy sector, this implies special focus on efficient production, transmission and distribution of energy with robust development of renewables and electric transport using appropriate 4IR-specific technological innovation.

The World Economic Forum and the Organisation for Economic Co-operation and Development initiated in-depth research that identified the most important 4IR technologies directly related to the future of the energy sector:

- *Nanosensors and the Internet of Nano Things* – will ensure miniaturisation of network connection for more than 30 billion devices by 2020 to become integral components of the Internet of Things. This will allow bringing energy efficiency to a fundamentally new level;
- *Next generation batteries* – will be capable of storing and transmitting significant volumes of energy at a competitive price, thus helping solar and wind

[7] Schwab, Klaus. The Fourth Industrial revolution. Available at: *https://www.weforum.org/about/the-fourth-industrial-revolution-by-klaus-schwab*.

generation to oust fossil fuels from energy markets even faster. Based on sodium, aluminium and zinc, these batteries will eliminate the use of environmentally harmful heavy metals and caustic chemicals. They will be able to ensure functioning of entire enterprises, towns and mini grids linking isolated rural communities;

- *Blockchain technologies* as revolutionary decentralised systems based on trust – will ensure maintenance of decentralised public registry of transactions beyond regulation of any single entity and with access to all users. This technology will help to remove any intermediaries from commercial transactions, thus significantly reducing transaction costs and ensuring higher level of privacy protection and security of transactions;
- *Two-dimensional or "wonder" materials* refer to materials consisting of one layer of atoms (graphene, borophene, germanene, etc.) and offering unique features in terms of strength, weight, flexibility, electrical conductivity, optical properties, permeability, low toxicity, etc. Dramatic reduction in their production cost makes some of them commercially viable. Special (targeted) production of materials with predetermined properties is expected shortly;
- *Autonomous vehicles* capable of navigating without human input – will allow up to 10% fuel economy. Equipped with on-board radars, cameras, ultrasonic distance measuring devices, electronic navigation systems and built-in maps, autonomous cars will be able to obtain enormous amounts of external information through the sensors to ensure safe travel;
- *Perovskite solar cells* are expected to mainstream solar power plants by eliminating restrictions associated with application of current silicon elements;
- *Systems metabolic engineering* builds on chemicals derived from microorganisms. It should result in replacement of traditional raw materials for chemical industry (coal, oil, gas) with microorganisms "working" in bioreactors;
- *Hydrogen energy* uses fuel cells that produce electricity directly in the process of chemical water splitting. It is assumed that a significant number of automobiles can switch to hydrogen engines after 2030;
- *Smart grids* provide for improved efficiency and reliability of power supply, also increasing the system failure free operations and protecting environment;
- *Direct air capture* technology enables air cleaning from carbon dioxide, its storage and industrial use.

Further development of 4IR within the next 20 years presents a fundamental challenge for all national economies, regional associations, entrepreneurs and employees. **Countries capable of developing and applying innovative technologies promptly and without bureaucratic obstacles will be the first to benefit from 4IR. The focus of all government agencies and non-governmental institutions on meeting people's needs in quality education, cultural development, free enterprise, scientific work and other reasonable social needs is essential for effective use of 4IR benefits.** Countries failing to accomplish these tasks will become outsiders, lagging behind innovative nations by socio-economic indicators.

Not only job cuts but also closure of entire branches, following their replacement with new technologies, will represent a serious challenge for the world economy. According to the World Economic Forum forecasts, workforce reductions may reach 50% and affect industry and service sector alike. Nations with cheap labour will no longer have a comparative advantage. This will intensify re-industrialisation in technologically advanced countries that will prioritise technological advantages over cheap labour of less developed economies.

### 2.4.1. Electric vehicle outlook

Electric vehicles still have a long way to go before reaching deployment scales capable of making a significant dent in the development of global demand for oil and petroleum.

**The global electric car stock surpassed 2 million vehicles in 2016 after crossing the 1-million threshold in 2015. The achievements of electric car market are still insignificant, as the current global electric car fleet makes up only 0.2% of the total number of cars in the world.**

According to IEA,[8] new registrations of electric cars hit a new record in 2016, with over 750 thousand sales worldwide. Norway is a global leader with a 29% market share. It is followed by the Netherlands with a 6.4% electric car market share, and Sweden with 3.4%. China, France and the United Kingdom all have electric car

[8] Global EV Outlook 2017. Available at: *https://www.iea.org/publications/freepublications/publication/global-ev-outlook-2017.html*.

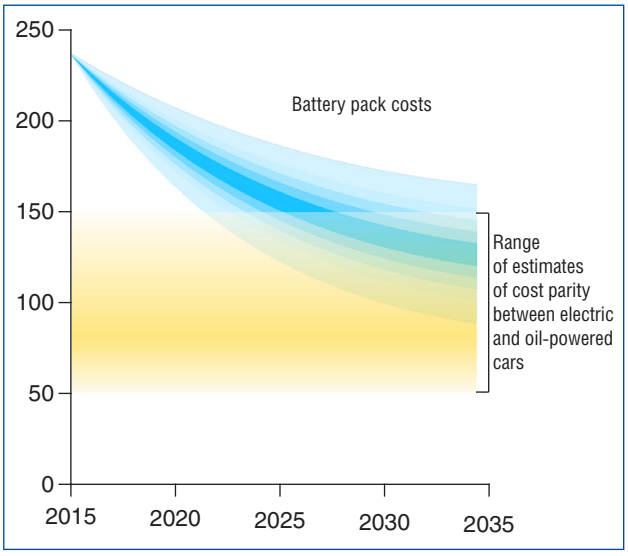
market shares close to 1.5%. In 2016, China was by far the largest electric car market, accounting for more than 40% of the electric cars sold in the world; more than double the amount sold in the United States. Until 2015 the situation was different – the US accounted for the largest portion of the global car stock. With more than 200 million electric two-wheelers, 3 to 4 million low speed electric vehicles and more than 300 thousand electric buses, China is also the global leader in the electrification of other transport modes.

As the number of electric cars on the road increases, relevant charging infrastructure also continues to grow. In 2016, the annual growth of publicly available charging (72%) was higher than the electric car stock growth rate in the same year (60%).

It is important to note, however, that despite a continuous and impressive increase in the electric car fleet, EV equipment supplies and electric car sales in the past five years, annual growth rates have been declining. In 2016, the electric car stock growth was 60% (down from 77% in 2015 and 85% in 2014). As expected, the developing markets account for the largest growth in EV use.

**Research, development and deployment (*RD&D*) and mass production prospects are leading to rapid battery cost declines and increases in energy density. Continuous technological development confirms that this trend will continue, narrowing the cost competitiveness gap between EVs and internal combustion engines (ICE), thus improving competitiveness of electric cars** (Figure "*Illustrative path for battery pack costs*").

**Illustrative path for battery pack costs**, $/kWh




*Source:* Global EV Outlook 2017.

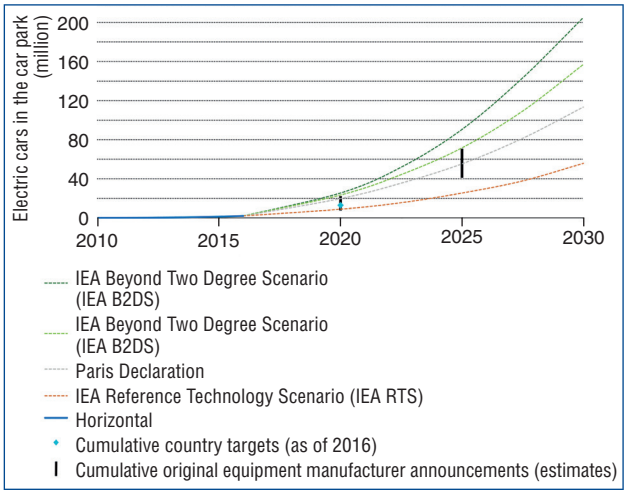
Assessments of country targets, original equipment manufacturer announcements and scenarios on electric car deployment seem to confirm these positive signals, indicating a good chance that the electric car stock will range between 9 to 20 million by 2020, and between 40 and 70 million in 2025.

IEA notes that despite this positive outlook, it is undeniable that the current electric car market uptake is largely influenced by the policy environment (Figure "*Deployment scenarios for the stock of electric cars to 2030*").

A key driver of the pace at which EVs penetrate the global car fleet is the extent to which fuel economy standards are tightened. It will also depend on the number of other factors including:

- the pace at which battery costs continue to fall;
- the size and durability of subsidies and other government policies supporting EV ownership;
- the dynamics of supporting infrastructure development (charging, service stations, etc.).
- the speed at which the efficiency of conventional vehicles improves vs. EV advantages.

**Deployment scenarios for the stock of electric cars to 2030**, $/kWh




*Source:* Global EV Outlook 2017.

As for efficiency of ICE-powered vehicles, an average passenger car is expected to achieve 21 km per 1 litre of fuel by 2035, compared to less than 13 km in 2015. Therefore, improvements in fuel efficiency of conventional cars potentially reduces the growth of oil demand by 850 million tonnes per year, while the effect of the growth of electric cars is much smaller: the 100-million increase in electric cars reduces oil demand growth by 60 million tonnes per year.

# 3. MAINSTREAMING CLIMATE POLICY IN THE ENERGY SECTOR: GLOBAL AND UKRAINIAN DIMENSIONS

## 3.1. THE IMPACT OF ANTHROPOGENIC FACTORS ON CLIMATE CHANGE

The global climate is a product of interaction between various climate forming factors, including the intensity of solar radiation depending on the average distance of the Earth from the Sun, ocean currents, the movement of air masses, volcanic activity and biosphere processes, which together affect the formation and spread of the so-called greenhouse gases[1] in the Earth's atmosphere. In turn, greenhouse gases mainly consisting of carbon dioxide ($CO_2$) also have a particular impact on the global climate formation. It is called the "greenhouse effect". **From the process physics standpoint, the greenhouse effect means that the energy of sun rays, reflecting from the planet's surface, cannot return to space as it is retained by molecules of various gases, leading to an increase in the biosphere temperatures**.

At the same time, the impact of human activity as a part of global biosphere processes on climate change has been gaining increasingly more scientific evidence. If current global warming was caused by increased solar radiation, then the temperature of higher layers of Earth's atmosphere (stratosphere, mesosphere, ionosphere) would increase. Observations over several past decades, however, suggest that these atmospheric layers tend to cool down. At the same time, the temperature of troposphere – the lowest, surface layer of the Earth's atmosphere – rises due to the growing impact of the greenhouse effect. According to IPCC's[2] Fifth Assessment Report, the average level of carbon dioxide in the air has increased by 40%, reaching its historic maximum. This has increased the temperature of atmospheric air, which primarily manifested itself in the melting of glaciers and the rise of sea level by 19 cm over the past 110 years.

Scientists associate the growing human-induced impact on the climate change primarily with sharp increases in fossil fuels consumption during the industrial and post-industrial periods of human history, both in connection with the population growth and people's willingness to have more comfortable living conditions via urbanisation (Figure "*Changes in world population and primary energy consumption*").

It is worth noting that in the second half of the 20th century the increase in global energy consumption exceeded the population growth rate, as evidenced by intersection of the two curves. This means that in the long run – or at least until 2050 – every additional average Earth inhabitant, especially in transition economies, will require increasingly more energy to meet his or her needs.

The curves in Figure "*Changes in primary energy consumption and $CO_2$ emissions*" demonstrate a relationship between energy consumption and GHG emissions in metric tonnes of carbon dioxide equivalent (MTCDE).[3] The baseline scenario assumes that behaviour of economic entities follows the *Business as Usual* (*BaU*) scenario, suggesting no significant modifications to current economic proportions and moderate structural changes.

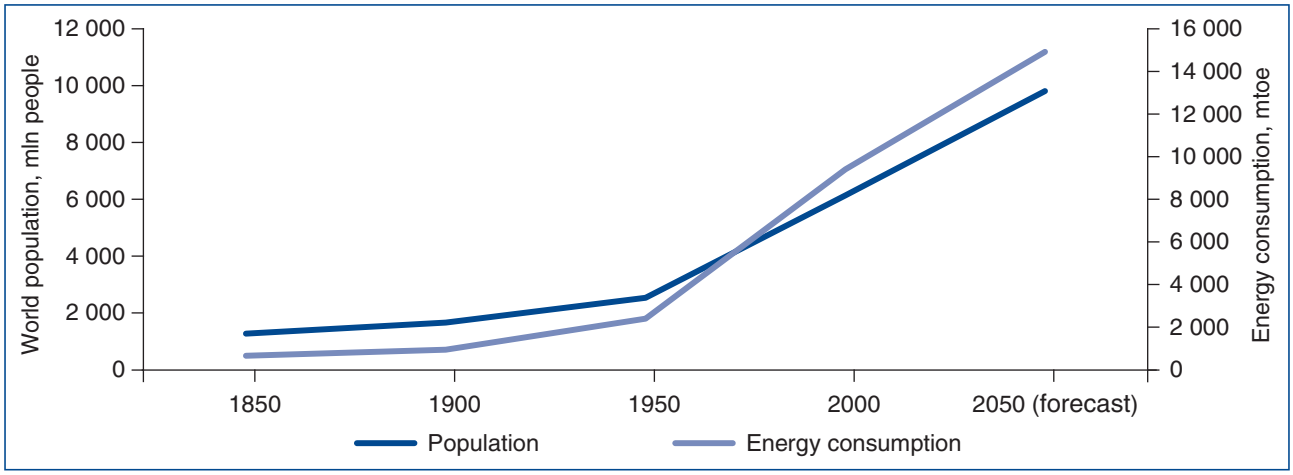
Therefore, changes in consumption of primary energy sources and GHG emissions within the period under study (roughly 200 years) have almost identical trajectories, reaffirming the opinion of most distinguished scientists, according to which human activity, particularly the use of fossil fuels, is a major contributor to intensified formation and emission of carbon dioxide and increased greenhouse effect.

[1] Greenhouse gases (GHG) refer to gaseous substances that absorb the infrared radiation from the Earth's surface, cause an increase in the air temperature and produce the strongest greenhouse effect. The GHG group includes carbon dioxide ($CO_2$), methane ($CH_4$), nitrous oxide ($N_2O$), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride ($SF_6$), nitrogen trifluoride ($NF_3$). Since carbon dioxide is the dominant greenhouse gas, the authors, when using the term "carbon dioxide" ($CO_2$) or e$CO_2$ in this section, refer to the entire GHG group.

[2] The Intergovernmental Panel on Climate Change (IPCC) is the leading international body for the assessment of climate change. IPCC was established by the United Nations Environment Programme and the World Meteorological Organisation in 1988.

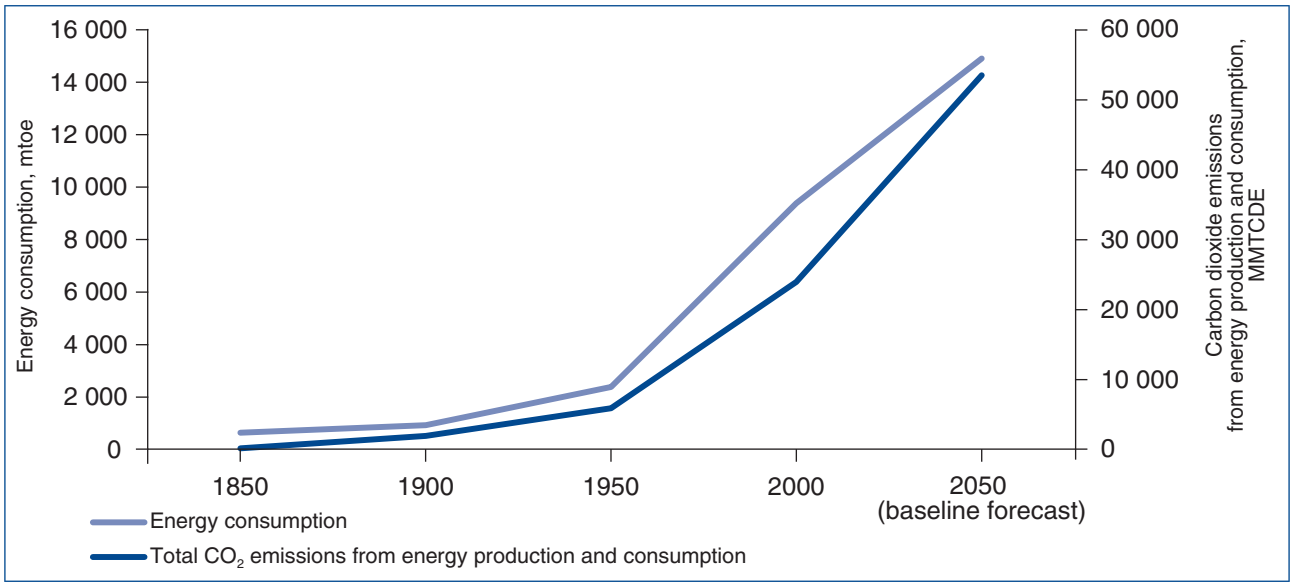
[3] Carbon dioxide ($CO_2$) equivalent is a measure that determines the impact of specific greenhouse gases on global warming, using the functionally equivalent amount or concentration of carbon dioxide as a reference.

**Changes in world population and primary energy consumption,**
TWh




*Source*: The Razumkov Centre's estimates are based on: Max Roser and Esteban Ortiz-Ospina (2017) – "World Population Growth". Available at: *https://ourworldindata.org/world-population-growth/*; Gail Tverberg (2012) – "World Energy Consumption Since 1820 in Charts". Available at: *https://ourfiniteworld.com/2012/03/12/world-energy-consumption-since-1820-in-charts/*; Ron Patterson (2016) – "World Energy 2016-2050: Annual Report". The University of Utah. Available at: *http://content.csbs.utah.edu/~mli/Economies%205430-30/World%20Energy%202016-2050.pdf*; BP Statistical Review of World Energy 2017. Available at: *http://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html*.

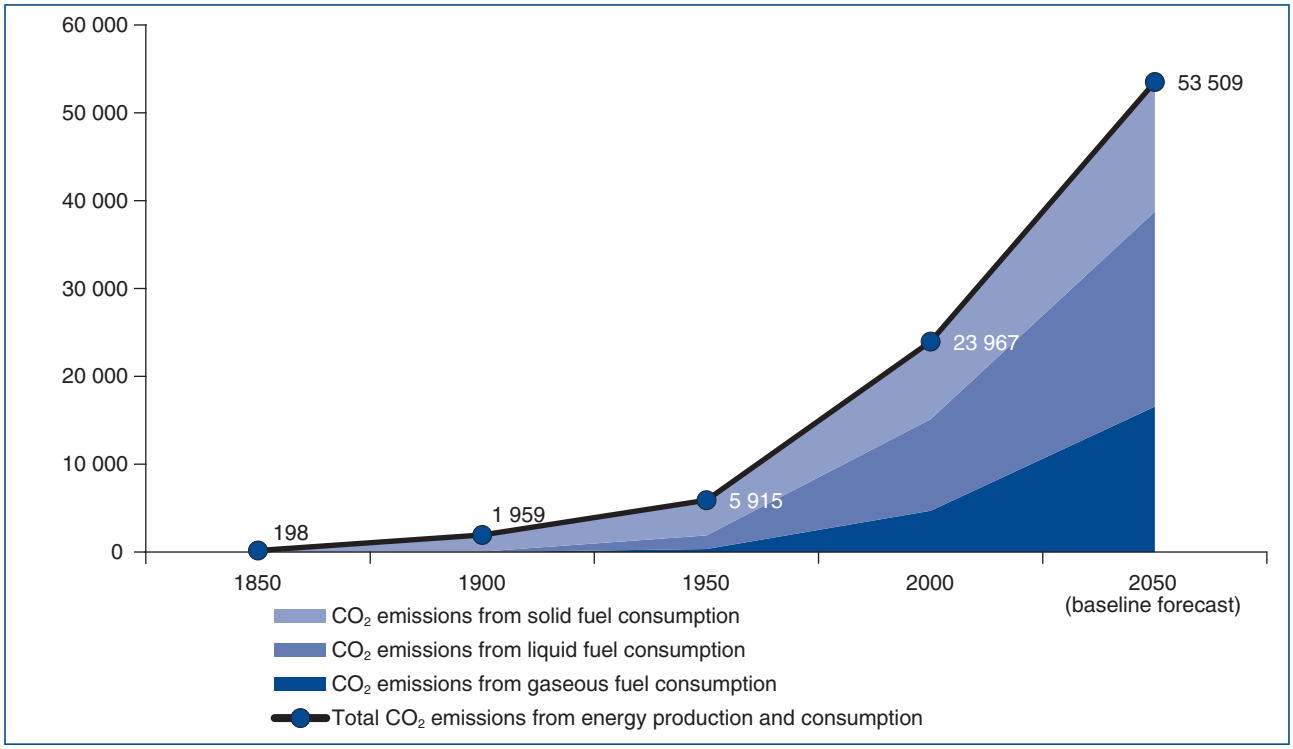
**Changes in primary energy consumption and $CO_2$ emissions**




*Source*: The Razumkov Centre's projections are based on: Gail Tverberg (2012) – "World Energy Consumption Since 1820 in Charts". Available at: *https://ourfiniteworld.com/2012/03/12/world-energy-consumption-since-1820-in-charts/*; Ron Patterson (2016) – "World Energy 2016-2050: Annual Report". The University of Utah. Available at: *http://content.csbs.utah.edu/~mli/Economies% 205430-6430/World%20Energy%202016-2050.pdf*; BP Statistical Review of World Energy 2017. Available at: *http://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html*; Boden, T.A., G. Marland, and R.J. Andres (2015) – "Global, Regional, and National Fossil-Fuel $CO_2$ Emissions". Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tenn., USA. Available at: *http://cdiac.ornl.gov/trends/emis/tre_glob_2011.html*.

At the same time, it is important to identify the main groups of fossil fuels and to determine their contribution to GHG generation. Figure "*$CO_2$ emissions from energy production and consumption by fuel*" suggests that since the onset of the industrial era – roughly from mid-1800s and up to mid-1900s – solid fuels, mainly coal, dominated the use of fossil fuels. Consequently, coal combustion during the first 100 years of the industrial era was the main source of carbon dioxide emissions. With the spread of internal combustion engines in early 20th century, the role of liquid fuels – mainly products of oil refining – as a source of atmospheric pollution with GHG became increasingly visible. Currently combustion of petroleum products is the most important factor of carbon dioxide formation. About fifty years later, in mid-1900s, large pipeline construction and liquefaction and transport of LNG have turned combustion of natural gas into one of the largest air pollutants.

**$CO_2$ emissions from energy production and consumption by fuel,**
MMTCDE

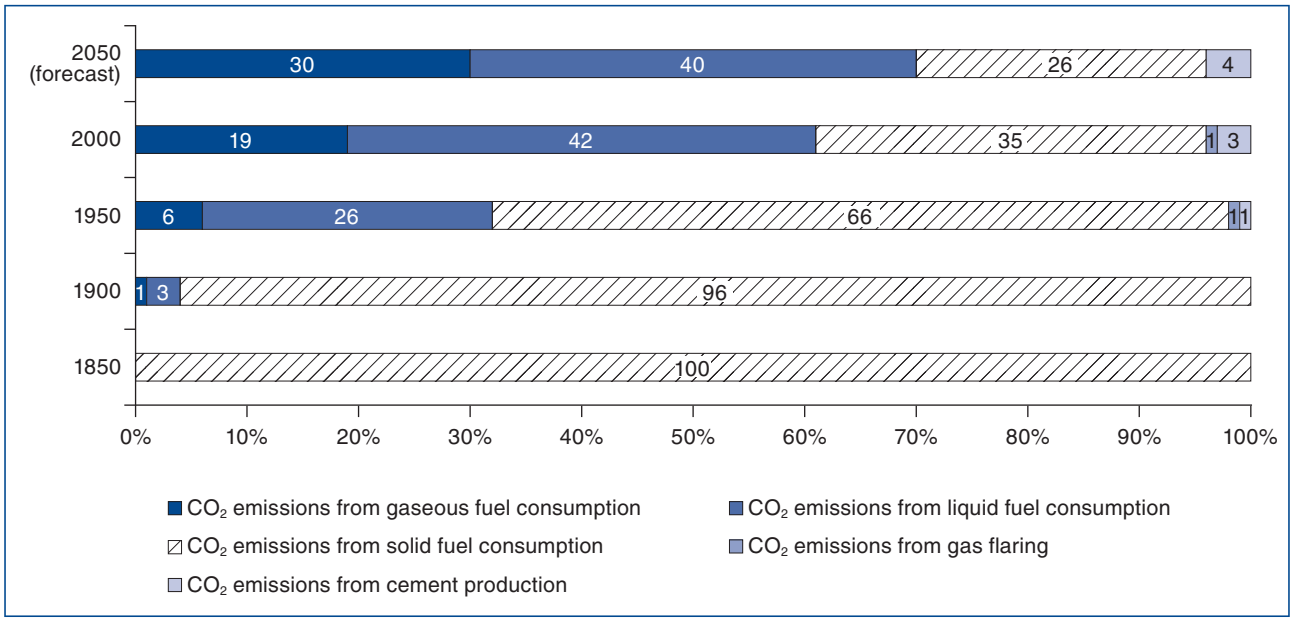



*Source*: The Razumkov Centre's projections are based on: Boden, T.A., G. Marland, and R.J. Andres (2015) – "Global, Regional, and National Fossil-Fuel $CO_2$ Emissions". Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tenn., USA. Available at: *http://cdiac.ornl.gov/trends/emis/tre_glob_2011.html*.

According to the baseline scenario, the impact of the use of all main groups of fossil fuels on carbon dioxide emissions by 2050 will increase in absolute terms, with total emissions reaching 53.5 billion MTCDE.

**The impact of the fuel and energy sector on the formation of carbon dioxide emissions over the past two centuries should be viewed as dominant. Other types of industrial activity account for only 3-4% of total GHG emissions, including, for example, cement**

**The share of $CO_2$ emissions from energy production and consumption by fuel, and from cement production**




*Source*: The Razumkov Centre's estimates and projections are based on: Boden, T.A., G. Marland, and R.J. Andres (2015) – "Global, Regional, and National Fossil-Fuel $CO_2$ Emissions". Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tenn., USA. Available at: *http://cdiac.ornl.gov/trends/emis/tre_glob_2011.html*.

**production. The remaining 96% to 97% of emissions are linked to the use and combustion of fossil fuels, as evidenced by Figure** "*The share of $CO_2$ emissions from energy production and consumption by fuel, and from cement production*".

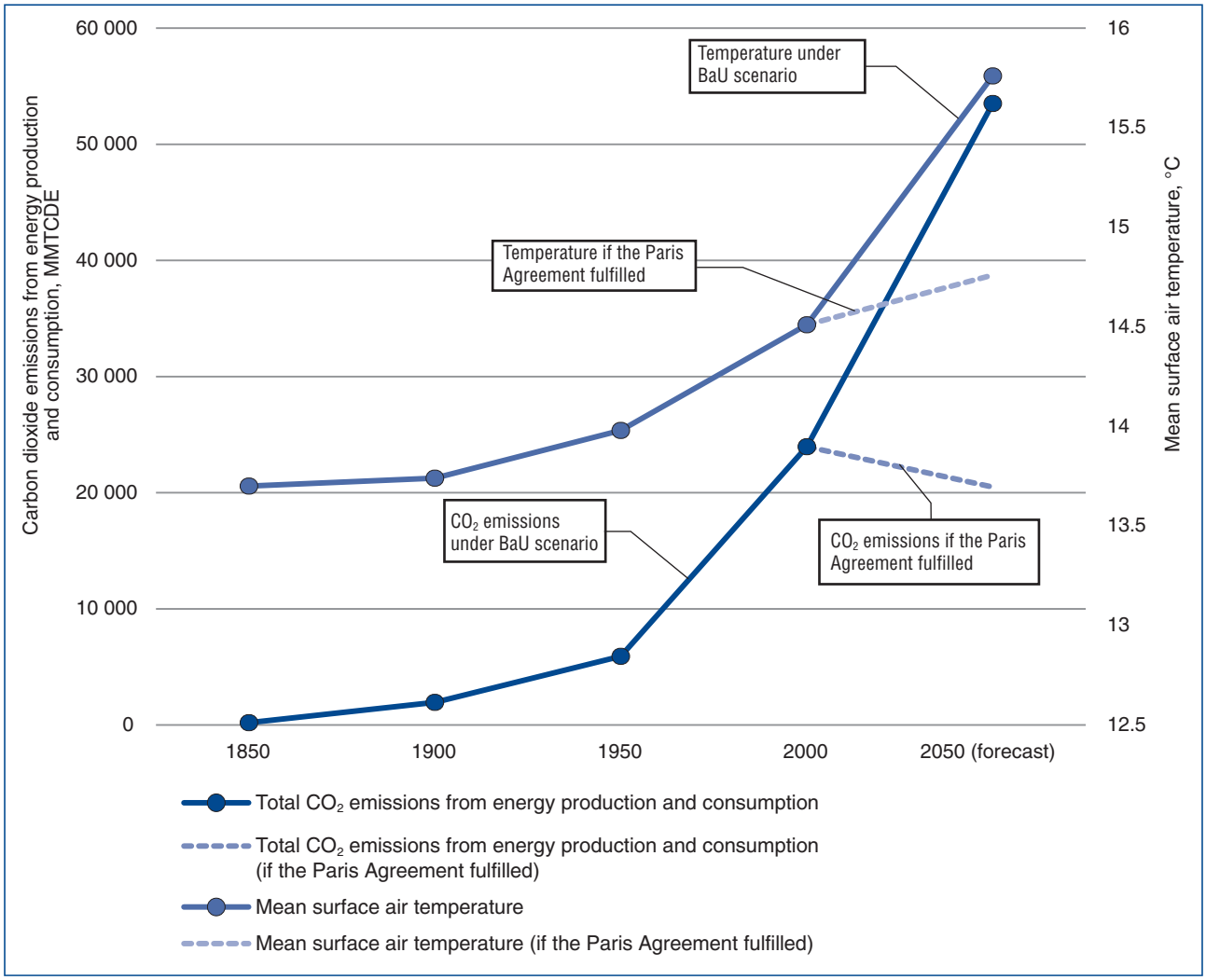
Scientists believe that increase in the annual mean surface air temperature is one of the major effects of greenhouse gas emissions and increasing carbon dioxide concentration in the atmosphere. Figure "*Projected variations in carbon dioxide volumes and annual mean surface air temperature*" considers several scenarios of possible surface air temperature variations depending on GHG emissions by 2050.

For example, under the BaU scenario, greenhouse gas emissions will increase by 2050 to about 55 billion MTCDE, which can raise annual mean temperature by 1.2°C – this correlates with IPCC's RCP6.0 scenario of $CO_2$ concentration trajectory.[4]

To implement the Paris climate agreement,[5] which aims to strengthen the global response to climate change in the context of sustainable development, based on RCP6.0 scenario, it is necessary by 2050 to triple zero- and low-carbon energy supply compared with 2010, while global GHG emissions have to be reduced by at least 35%.

Obviously, by 2050 even the implementation of the Paris Agreement will not immediately reverse the global warming trends. But appropriate measures to promote zero- and low-carbon energy sources will make it possible to significantly mitigate the global warming and to halt this trend by 2100, thus allowing the humankind to buy some time and adapt to climate change.

**Projected variations in carbon dioxide volumes and annual mean surface air temperature**




*Source*: The Razumkov Centre's estimates and projections are based on: Intergovernmental Panel on Climate Change "Climate Change 2014, Synthesis Report". Available at: *http://ipcc.ch/pdf/ assessment-report/ar5/syr/SYR_AR5_FINAL_full_wcover.pdf*; Boden, T.A., G. Marland, and R.J. Andres (2015) – "Global, Regional, and National Fossil-Fuel CO2 Emissions". Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tenn., USA. Available at: *http://cdiac.ornl.gov/trends/emis/tre_glob_2011.html*; BP Statistical Review of World Energy 2017. Available at: *http://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html*; the NASA Goddard Institute for Space Studies. Available at: *https://data.giss.nasa.gov/gistemp/*.

[4] IPCC Fifth Assessment Report "Climate Change 2014, Synthesis Report". Available at: *http://ipcc.ch/pdf/ assessment-report/ar5/syr/SYR_AR5_FINAL_full_wcover.pdf*.

[5] The Paris Agreement, ratified by the Law of Ukraine No.1469-VIII of 14 July 2016. Available at: *http://zakon3.rada.gov.ua/laws/show/995_l61*.

Key global impacts of climate change include:

- increase in *global surface air temperature* and upper waters of oceans and seas;
- alarming rates of glacial retreat;
- sea level rise and coastal flooding;
- increased frequency and strength of cyclones, hurricanes, typhoons, extreme precipitation, as well as increasing range and duration of seasonal temperature anomalies;
- depleted biodiversity and reduced productivity of ecosystems and farmlands.

According to IPCC's Fifth Assessment Report,[6] over the period 1901-2010, global mean sea level rose from 0.17 to 0.21 m; Arctic sea-ice extent has decreased in every season and in every successive decade since 1979; the number of storms of categories 4 and 5 has increased by about 75% from 1970, with the largest increase observed in northern and southwest Pacific and Indian Ocean, while the number of hurricanes in the North Atlantic also exceeded the norm in 9 of the last 11 years; the frequency and duration of droughts in tropical and subtropical regions has increased, as did the number of extreme precipitation events in mid-latitude land areas over the past 50 years.

According to forecasts, polar and subpolar regions, the tropical and subtropical deserts are at high risk of climate change. The highest rate of temperature rise is expected by mid-21st century when the global population reaches its projected peak.

In view of the climate change impact on human health and livelihoods,[7] it should be noted that despite some local positive effects (such as lower mortality from hypothermia in winter), the overall influence of global warming on human health in mostly negative. Globally, the number of natural disasters associated with the weather has tripled since 1960, and each year these disasters take more than 60 thousand lives.

Extreme temperatures produce excessive health problems and contribute to increased mortality. Above all, this concerns the elderly suffering from cardiovascular and respiratory diseases (in summer 2003 heatwaves caused more than 70 thousand deaths in Europe alone). High temperatures escalate the risk of surface ozone and other pollutants that adversely affect populations (air pollution in urban areas leads to about 1.2 million deaths annually).

More frequent changes in precipitation patterns can affect the situation with drinking water supplies. Lack of water can deteriorate hygiene and increase the risk of gastrointestinal diseases, which kill close to 2.2 million people every year. Floods cause pollution of drinking water sources, thus increasing the risk of waterborne contamination. In addition, floods are also the cause of drowning and injuries, and may lead to delays in medical care through access restrictions.

In Ukraine, the effects of climate change can be felt in the growing number of heavy rainfalls and in increasing quantity, range and duration of seasonal temperature anomalies, which have already caused decline in the productivity of farmlands and forests. According to the Ukrainian Hydrometeorological Institute[8] forecasts for the period of 2011-2030, the highest rate of warming in summer should be expected in north-eastern Ukraine. Over the next 20 years, the maximum summer warming will occur in southern regions.

The analysis of changes and projected absolute values of average maximum surface air temperatures that characterise the warmest half of the day (daytime highs), and the average minimum temperatures that correspond to the night-time lows, showed that:

1) in the nearest future, the maximum rise in night-time lows (> 0.9°C) is expected in the north-eastern parts of the country in winter, and in the Luhansk oblast in summer and autumn; and in daytime highs (> 0.8°C) – in the northern regions (the Chernihiv and Sumy oblasts) in summer and autumn. Only minor changes are projected for the Carpathians and the Crimea;
2) in the next period of 2031-2050 minimum temperatures are more likely to rise in the cold season from October to April; changes in May and September will be virtually the same, while the rise in temperature in summer will be due to increasing daytime highs;
3) by the end of the century (in 2081-2100) one can expect maximum rise in all temperatures with absolute maximum to be observed in the northern region in December for the night-time lows (+4.8°C). Annual change in both temperatures will have two highs in August and December, while minimum changes are expected in April (for highs), May (for lows) and October (for both).

Therefore, in the context of climate change, Ukraine should join the global community in its efforts to improve organisational, legal and socio-economic mechanisms in order to adapt to and tackle climate change, to mitigate its negative impact on the environment and human lives.

[6] IPCC Fifth Assessment Report "Climate Change 2014, Synthesis Report". Available at: *http://ipcc.ch/pdf/assessment-report/ar5/syr/SYR_AR5_FINAL_full_wcover.pdf*.

[7] Adaptation to climate change / The Carpathian Development Institute, FORZA Agency for Sustainable Development of the Carpathian Region", 2015. Available at: *http://www.forza.org.ua/sites/default/files/adaptation_climate_change_brochure_ua_screen_final.pdf*.

[8] Report on the research "Development of medium- and long-term climate change scenarios in Ukraine based on the data of global and regional models", 2013 – The Ukrainian Hydrometeorological Institute (UkrHMI), Kyiv – 135 pages Available at: *http://uhmi.org.ua/project/rvndr/climate.pdf*.

## 3.2. CLIMATE POLICY: GLOBAL DIMENSION

Being aware of the decisive impact of anthropogenic factors on climate change and its possible global adverse effects, the United Nations as the largest representative institution in the world has initiated the development and introduction of the first global climate change document – the United Nations Framework Convention on Climate Change[9] (UNFCCC), which was adopted in Rio de Janeiro, Brazil on 11 December 1990. The UNFCCC has entered into force on 21 March 1994, and Ukraine ratified it on 29 October 1996. The main objective of this document is to achieve stabilisation of GHG concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. The UNFCCC further states that such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change to enable, among other things, economic development to proceed in a sustainable manner. As of 15 July 2017, the Framework Convention on Climate Change has been ratified by 197 countries. The Conference of the Parties is the highest governing body of the UNFCCC that regularly reviews the Convention implementation and any related legal documents that may be adopted by the Conference of the Parties.

The adoption of the Kyoto Protocol[10] to the UNFCCC on 11 December 1997 in Kyoto, Japan was the next important milestone in shaping the global climate change mitigation mechanisms. Ukraine ratified the Protocol on 4 February 2004 – long before this document entered into force (became legally binding for the Parties) on 16 February 2005. As of 15 July 2017, the Kyoto Protocol has been ratified by 192 Parties (191 states and 1 regional economic association). The Kyoto Protocol sets a commitment to limit greenhouse gas emissions during 2008-2012 for 39 developed countries and transition economies. The latter also included Ukraine. Each country in the list received the so-called "Assigned Amount Units" (AAUs) with the nominal value of 1 MTCDE each. By the end of the commitment period that ended in 2012, countries were required to have their assigned amount correspond to national GHG emissions. After fulfilment of commitment, the AAU balance (the remaining emission reduction units) could be transferred and used in the next commitment period (2013-2020) under the Doha Amendment to the Kyoto Protocol.[11] Unfortunately, the Doha Amendment has not entered into force yet and was not ratified by Ukraine.

The Kyoto Protocol also offered flexible economic mechanisms to help reduce GHG emissions depending on the level of the countries' socio-economic development. Relatively less developed countries – primarily African nations and a number of countries in Asia and Latin America, could benefit from the *Clean Development Mechanism* (CDM), which offered the market mechanism for implementing projects involving developed and developing economies that provided the latter with finances and technology for sustainable development, and helped the former to meet their emission reduction targets. In other words, the investing country received from the recipient country additional quotas of the so-called "Certified Emission Reductions" (CERs). The CER unit is equal to one metric tonne of carbon dioxide equivalent.

The transition economies, including Ukraine, made a good use of the *Joint Implementation* (JI) mechanism that allowed implementing projects to reduce emissions or improve carbon sequestration through the use of carbon storage (changes in land use or rational use of forests). Within the JI mechanism, an investment project aimed at energy saving or more efficient electricity or heat generation could expect receiving certain amount of "Emission Reduction Units" (ERUs). One ERU equals one metric tonne of carbon dioxide equivalent. ERU required the observance of additionality principle, completion of an independent audit, as well as approvals by the host and the buyer countries. ERUs could be used by states to meet their commitments under the Kyoto Protocol, as well as by private companies or specialised funds within the regional emission trading schemes.

Therefore, stating from 2008 the international community received a number of mechanisms to stimulate development through the use of technologies aimed at reducing GHG emissions. First, the governments that were able to "save" their Assigned Amount Units during the Kyoto Protocol commitment period could sell parts of the unused AAUs to other governments. Second, through the CDM, the donor countries could receive additional quotas for their AAUs through investment in emission-free projects in the developing countries. Third, both government and individual companies could use the JI mechanism to obtain ERUs and use them both as additional quotas and instruments for carbon dioxide emissions trading. If the Doha Amendment to the Kyoto Protocol entered into force, these mechanisms could have been utilised to the full extent by 2020.

The 20th and 21st sessions of the Conference of the Parties to the UNFCCC have become important interrelated events in setting up the global climate change mitigation mechanism, designed to replace the Kyoto Protocol. Based on the results of the 20th Conference (COP20), held in Lima, Peru, and pursuant to ensuing

[9] The United Nations Framework Convention on Climate Change, Available at: *http://zakon3.rada.gov.ua/laws/show/995_044*.
[10] The Kyoto Protocol to the United Nations Framework Convention on Climate Change. Available at: *http://zakon4.rada.gov.ua/laws/show/995_801*.
[11] Doha Amendment to the Kyoto Protocol. Available at: *http://unfccc.int/files/kyoto_protocol/application/pdf/kp_doha_amendment_english.pdf*.
The Doha Amendment has not yet come into force and has not been ratified by Ukraine.

Lima Call for Climate Action of 14 December 2014,[12] the nations initiated the mechanism called *Intended Nationally Determined Contributions* (*INDCs*) for determining GHG emission commitments in MTCDE. These were designed to become new benchmarks for climate change commitments and action of the UNFCCC Parties beyond 2020 – that is, in the post-Kyoto period. The above efforts continued on the next – 21st session of the Conference of the Parties, held in Paris, France, and resulted in the adoption of the new climate change treaty, now known as the Paris Agreement.[13] As of 15 July 2017, as many as 197 parties have signed this document, of which 153 have already ratified it, including Ukraine (on 14 July 2017).

**The Paris Agreement has entered into force on 4 November 2016. Its main aim is to strengthen the global response to the threat of climate change, including by holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C. The main objective of the Paris Agreement is to build capacity of the Parties in combating consequences of climate change. To achieve these ambitious goals, the Agreement offers flexible opportunities for funding, technology sharing and institutional strengthening to be used by countries with different economic development levels.**

The Paris Agreement is truly flexible as it allows each Party to independently determine individual obligations in the form of INDCs or the so-called "absolute limitation targets" for the country's GHG emissions and submit them to the UNFCCC Secretariat. As of 15 July 2017, the Secretariat has already registered submissions from 162 counties, including Ukraine, or about 82% of the signatories to the Agreement.

To achieve climate targets, the Paris Agreement urges the Parties to focus more efforts on renewables development, improved energy efficiency, reforestation and foresting, and provides a basis for introducing flexible market and intergovernmental mechanisms based on voluntary collaboration within the so-called "common approaches". These allow the Parties to the Paris Agreement to use any form of cooperation in order to meet their INDC obligations, but subject to the UNFCCC requirements for transparency, monitoring, reporting and verification. It should be noted that although the Paris Agreement does not include any regulations and implementation procedures that are yet to be developed and approved internationally, it also does not envisage any restrictions concerning the existing market mechanisms and practices used to counter climate change. Such market mechanisms build on the international trade of emission allowances.

**The Directive 2003/87/EC of the European Parliament and "Establishing a scheme for greenhouse gas emission allowance trading within the Community" of the Council have direct GHG relevance. This directive should have been implemented in Ukraine since 1 January 2017, but neither the government nor domestic companies were ready for it. Currently Ukraine lacks basic legislation in this area, which makes it impossible to develop and implement appropriate algorithms and a platform for GHG emission trading. At the initiative of the Ministry of Ecology and Natural Resources of Ukraine requested the EU to postpone realisation of this Directive.**

*The European Union Emissions Trading Scheme* (EU ETS)[14] is one of the largest emission trading systems. Launched pursuant to the Kyoto Protocol commitments, it is currently being adapted to accommodate both the Paris Agreement and the EU's climate and energy directives and initiatives, including the most recent *Clean Energy For All Europeans*[15] (30 November 2016), ambitiously called the Fourth Energy Package.

**The Clean Energy For All Europeans package is seeking to boost the EU's clean energy transition, thus ensuring sustainable development for its members in the future. This package is expected to generate up to 1% increase in GDP over the next decade, creating around 900,000 new jobs, and mobilising up to €177 billion in public and private investment from 2021.**

### 3.3. CLIMATE POLICY IN UKRAINE

Despite the reduced energy intensity and greenhouse gases emissions, Ukraine's economy remains excessively energy-intensive compared with European neighbours, specifically the Visegrad Group (V4), let alone the world's most developed economies. Figure "*Energy intensity of V4 countries and Ukraine at PPP*" shows that Ukraine's GDP energy intensity in 2000-2014 was 2-3 times higher than that of V4 countries. Generally speaking, Ukraine and the V4 Group follow the global trend towards reducing energy intensity, although in different ranges. Ukraine's range is much higher than

[12] CP.20 outcome document Lima Call for Climate Action. Available at: *http://unfccc.int/files/meetings/lima_dec_2014/application/pdf/auv_cop20_lima_call_for_climate_action.pdf*.

[13] The Paris Agreement, available at: *http://zakon5.rada.gov.ua/laws/show/995_l61/paran2#n2*.

[14] European Union Emissions Trading Scheme (EU ETS). Available at: *https://ec.europa.eu/clima/policies/ets_en#tab-0-0*.

[15] COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE, THE COMMITTEE OF THE REGIONS AND THE EUROPEAN INVESTMENT BANK Clean Energy For All Europeans. Available at: *http://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX:52016DC0860*.

that of V4. At the same time, the annual decline in energy intensity in Ukraine is 3.1% vs. 2.6% in V4 countries.

According to the BaU scenario, if these average rates for Ukraine and V4 persist, then Ukraine will reach the energy intensity of the V4 countries only in 22 years.

The situation with GDP per greenhouse gas emissions is even more critical (Figure "*GDP of V4 countries and Ukraine per greenhouse gas emissions by PPP GDP*"), as Ukraine's GDP per greenhouse gas emissions in 2000 and 2014 was 3-4 times higher the level of V4. Ukraine, just as the Visegrad Group countries, has demonstrated a significant decrease in total $CO_2$ *emissions*/*GDP* ratio in 2000-2014. This reduction in Ukraine was largely due to de-industrialisation, whereas V4 countries were able to improve this indicator through a GDP growth.

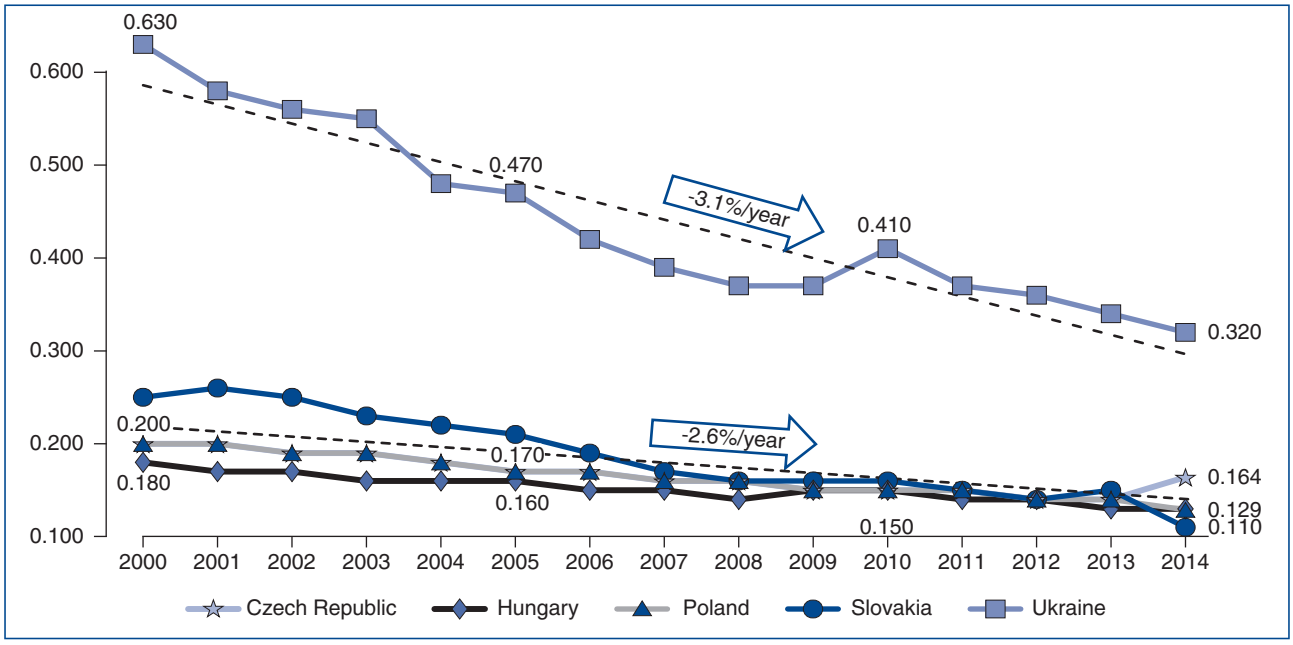
In pursuance of the objective of the Paris Agreement, in September 2015 Ukraine has updated the UNFCCC Secretariat on its INDC, setting the target not to exceed 60% of 1990 greenhouse gas emissions level by 2030.[16] It should be noted that the Paris Agreement calls on the parties to periodically review their emission reduction targets, and for this purpose introduces a cyclical mechanism for them to update their benchmarks. This means that each Party shall communicate a Nationally Determined Contribution (NDC) every five years to the UNFCCC Secretariat to replace the Intended Nationally Determined Contribution reported in 2015.

How ambitious is Ukraine's INDC? Obviously, not ambitious enough. After all, the country used the volumes of its GHG emissions for 1990 as a baseline – the year, when Ukraine's industrial sector, inherited from the Soviet Union, was at its peak. Yet, having the opportunity to renew its commitments thanks to the cyclical mechanism, Ukraine is likely to set more ambitious post-2020 targets, building on the potential for energy efficiency, RES expansion, energy infrastructure modernisation and taxation enhancements.

Recent important changes to the national legislation are the key to strengthening environmental focus in developing Ukraine's fuel and energy complex. The most important of them are the Laws of Ukraine "On the Energy Efficiency of Buildings" and "On the Energy Efficiency Fund" (both entered into force in July 2017) as they were developed in the context of relevant directives, regulations and recommendations of the EU and the Energy Community Secretariat.

The Law "On the Energy Efficiency of Buildings" initiates the energy efficiency certification of the construction projects and the existing buildings to

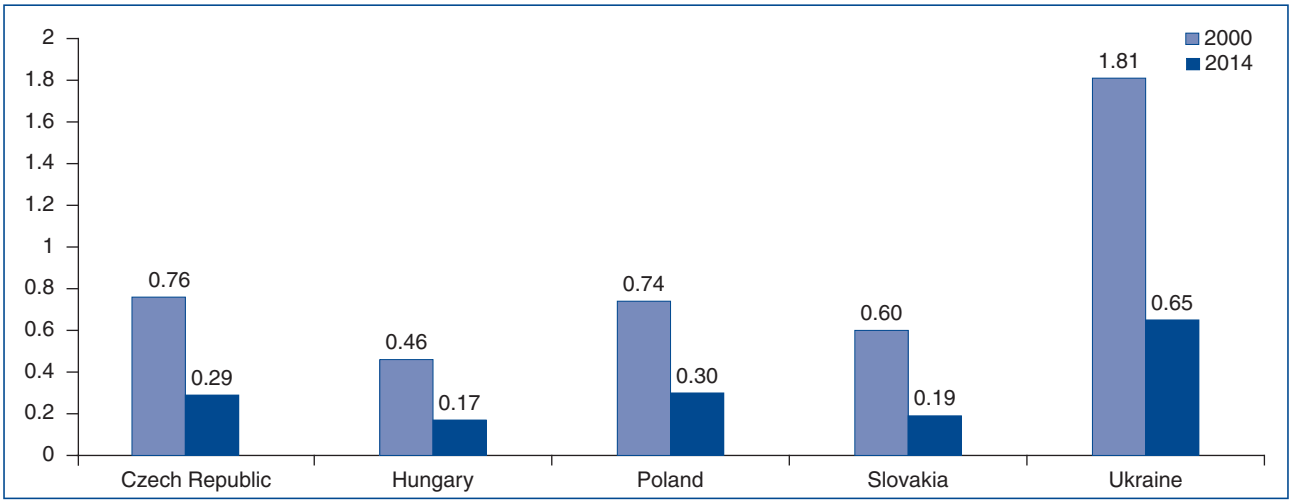
**Energy intensity of V4 countries and Ukraine at PPP**, kgoe/$2005




*Source*:
1. International Energy Agency – 2000-2013.
2. Enerdata – 2014 for Czech Republic, Poland and Ukraine.
3. 2014 estimates: ICDT data for Hungary, INEKO for Slovakia.
4. Average annual reduction in GDP energy intensity: The Razumkov Centre's calculations.

[16] Intended Nationally Determined Contribution (INDC) of Ukraine to a New Global Climate Agreement. Available at: *http://www4.unfccc.int/ndcregistry/PublishedDocuments/Ukraine%20First/Ukraine%20First%20NDC.pdf*.

**GDP of V4 countries and Ukraine per greenhouse gas emissions by PPP GDP,**
kg CDE/$2005




*Source*: The Razumkov Centre's estimates are based on the BP Statistical Review of World Energy. Available at: *http://www.bp.com/statisticalreview* (volumes of GHG emissions) and the World Bank. Available at: *http://data.worldbank.org/indicator/NY.GDP.MKTP.PP.CD* (GDP, Purchasing Power Parity in 2005 prices).

determine their actual and qualitative properties, and introduces the practice of energy efficiency labelling. The latter will help to identify ways to increase energy efficiency of buildings through their modernisation, as Ukraine's untapped potential for energy efficiency is currently estimated at 30-40% of the actual use of energy resources for heating residential and public buildings.

The Law "On the Energy Efficiency Fund" stipulates the establishment of a special institution and introduces financial incentives to accelerate the development of Ukrainian society, promoting energy efficiency in all activities of daily life. Creating such a Fund will help to attract significant investments in energy efficiency from various financing sources, including public and private, domestic and foreign. In particular, it is planned to attract about €100 million in grants from the German Government, as well as funds from the State Budget of Ukraine.

These examples of updated national legislation obviously strengthen the legal basis for a more energy efficient and environmentally friendly transition of the country. At the same time, mere adoption of energy efficiency laws will hardly ensure effective implementation of Ukraine's multiple commitments to reduce carbon emissions and greenhouse gases given the archaic energy infrastructure. These commitments are the result of Ukraine's accession to the Energy Community in 2011 and enactment of the Association Agreement between Ukraine and the EU in 2017, as the latter provides for a phased implementation of 29 environmental directives and regulations. The most difficult for realisation are: Directive 2010/75/EU of the European Parliament; "On industrial emissions (integrated pollution prevention and control)" of the Council as of 24 November 2010; the Directive 2001/80/EC of the European Parliament; "On the limitation of emissions of certain pollutants into the air from large combustion plants" of the Council signed in 23 October 2001. According to these directives, Ukraine has to reduce dust emissions by 50 times, sulphur – by 25 times, and nitrogen oxides – by 5 times. Moreover, Ukraine is expected to reach these targets by 2018, which is obviously unrealistic. Therefore, pursuant to Directive 2001/80/EC, the Government of Ukraine has decided to develop a National Emissions Reduction Plan, which would set a certain target for the country, gradually reaching it over certain period of time.

Ukraine has eagerly embarked on the development of the National Emission Reduction Plan back in 2012. During these years, its final draft was agreed with the EU and approved by the Energy Community Secretariat with an intention to launch it in early 2018. And finally, in late November 2017, the national plan was approved by the Government of Ukraine. The plan applies to large combustion plants whose operators have voluntarily agreed to join this mechanism of postponing the immediate implementation of Directive 2010/75/EU. The Energy Strategy of Ukraine and the Government-approved Action Plan on the Implementation of the EU-Ukraine Association Agreement also stipulate its execution. Although Ukraine has finalised its National Emission Reduction Plan, so far it failed to completely close certain regulatory gaps and to address the institutional issue of monitoring and reporting to the Energy Community. These deficiencies can potentially create additional challenges for energy companies as they may need to comply with increased permission-related requirements over the short term – these can be detailed and additionally introduced by the government in line with the above-mentioned EU directives.

# 4. UKRAINE'S ENERGY SECTOR UNTIL 2035

## 4.1. ENERGY POLICY IN UKRAINE: KEY TASKS AND PHASES

The difficult political and socio-economic situation in Ukraine stemming from the annexation of Crimea and the protracted conflict in eastern Ukraine (loss of the important energy infrastructure) as well as the enduring economic crisis will have lasting consequences for Ukraine. To overcome these problems the government has to move towards systemic solutions.

To navigate the recovery from crisis and to implement vital reforms, on 12 January 2015, the President approved the Strategy for Sustainable Development "Ukraine 2020". The main goal is to achieve European standards and help Ukraine earn its rightful place in the world. The strategy includes more than 60 reform objectives and programmes, including the energy sector reform, energy independence programme, environmental protection and energy efficiency programme that seek to enhance Ukraine's energy security and move towards energy efficiency and innovative technologies. The list of energy sector reforms needs to be finalised in a single document outlining the government energy policy both in short- and long-term perspective. As of today, the updated Energy Strategy of Ukraine until 2035 (ESU-2035) represents such a systemic document.

According to ESU-2035, key objectives of the government's energy policy until 2035 include:

- developing conscious and energy efficient society;
- ensuring Ukraine's energy independence with reliable and stable functioning of its fuel and energy complex;
- developing energy markets;
- creating favourable conditions for investment;
- integrating Ukraine's power grids and energy markets in the EU;
- updating management system in line with the present-day challenges and global energy trends.

Ukraine's energy policy until 2035 is divided into three consecutive time frames provided below.

**Phase 1. Energy sector reforms (until 2020)**

Over the next three years, efforts will be focused on implementing the reforms and creating competitive and investment-friendly environment. During this phase, it is planned to implement the Third Energy Package that will allow to establish fully functional natural gas and electricity markets in line with the EU energy legislation. Ukraine's institutional integration in the ENTSO-G and completing most of the measures aimed at integrating the national UES into the ENTSO-E are expected during this period.

Reforming the energy companies in accordance with Ukraine's obligations under the Treaty establishing the Energy Community, increasing gas production, reducing the GDP energy intensity, and developing RES are the key tasks for Ukraine's energy policy during this phase.

Along with establishing the coal market, the restructuring of the coal industry will be accompanied by a set of measures to mitigate social and environmental effects of abandoned or mothballed mines and to rehabilitate closed mining sites in line with European best practices.

In the area of environmental protection, compliance with high environmental standards of energy production, transmission, transformation and consumption will be ensured; financing the investment projects within the National Emissions Reduction Plan for large combustion plants will be in line with Ukrainian legislation and obligations to the Energy Community.

During phase 1, it is expected to achieve radical progress in renewable energy by increasing their share in final consumption to 11% (8% of TPES) through consistent and predictable policy for stimulating RES deployment and attracting investment.

**Phase 2. Optimisation and innovative development of the energy infrastructure (until 2025)**

The second phase will focus on effective work in the new market environment and the complex task of integration with the EU's power system that will considerably influence the choice of energy facilities for reconstruction or new construction and improve the energy efficiency.

The tasks at this phase are aimed at introducing the mechanisms for attracting investment to implement the programme for replacing the facilities to be decommissioned with new energy infrastructure; enhancing the

level of corporate governance of economic entities and their ability to use tools available at internal and external capital markets and resources of Ukraine's energy market.

During this period, it is planned to:

- integrate the Ukrainian energy system into the continental Europe's ENTSO-E grid in operational mode;
- complete integration into the European gas transmission network ENTSO-G; further strengthen cooperation with Central European countries to improve reliability of energy supplies;
- implement investment projects within the National emissions reduction plan for large combustion plants;
- establish local heat supply systems using economically viable local fuels, supply logistics, regional and national energy infrastructure;
- improve the efficiency of the existing district heating systems;
- attract private investments.

In addition, this phase includes modernisation and improvement of metering systems and involvement of consumers in managing their own demand for energy. In gas sector, it is planned to achieve full coverage of domestic natural gas demand with own resources through increased production, and to optimise operation of the gas transmission system (GTS) depending on the utilisation scenario.

Also, it is planned to intensively attract investment in the renewables sector and distributed generation. In particular, this includes the development and the commencement of *smart grids* implementation plan and construction of extensive infrastructure for the electric transport.

**Phase 3. Ensuring sustainable development (until 2035)**

The third phase is aimed at the energy sector's innovative transition and building new generation capacity, as well as channelling investment towards new generating capacities to replace facilities that are to be decommissioned. The choice of the generation type will depend on the projected fuel costs, the intensity of development of each generation type (also encouraging the competition between them), and on the introduction of smart technologies to soften the consumption peaks.

## 4.2. UKRAINE'S ENERGY MARKET REFORM: A STEP TOWARDS JOINING EU ENERGY MARKET

The Memorandum of Understanding on Co-operation in the Field of Energy, signed by Ukraine and the EU on 24 November 2016 reaffirms the strategic role of Ukraine as a transit country, but in general, the EU strategy no longer views Ukraine as a key transit hub, since the interests of separate, more influential member states prevail over the commonly defined priorities.

**Mainstreaming European energy standards in Ukrainian legislation can significantly increase Ukraine's resistance to attempted politicisation of intergovernmental relations in the field of energy, while joining the pan-European market can liberalise and de-monopolise internal energy markets, making them more transparent and competitive. Market transformation and integration is only possible if a consumer becomes one of the key market players.**

The natural gas and electricity markets are the key drivers of Ukraine's European economic integration. The national legislation regulating the natural gas market is almost fully adapted to the Third Energy Package requirements. The Law of Ukraine "On the Natural Gas Market (as amended)" No.329 of 9 April 2015 has entered into force on 1 October 2015, abolishing the state regulation of gas prices for commercial consumers from this day on.

The natural gas market is regulated by a number of legal acts approved by the NEURC Regulations, including the Code of Gas Transmission System (No.2493 of 30 September 2015); the Code of Gas Distribution Systems (No.2494 of 30 September 2015); the Code of Gas Storage (No.2495 of 30 September 2015); the Rules for Supplying Natural Gas (No.2496 of 30 September 2015), and so on.

In pursuance of the Law on the Natural Gas Market, the Cabinet of Ministers of Ukraine by signing a Resolution "On Unbundling of Gas Transmission and Storage (Injection, Withdrawal) Activities" approved the plan for relevant restructuring of *Naftogaz* with a view to unbundle natural gas transmission and storage and selected the model for unbundling of natural gas transmission networks. The Cabinet of Ministers further established the public joint stock company "Mahustralny Gazoprovody Ukrayiny" (Main Gas Lines of Ukraine) (Resolution No.801 of 9 November 2016) and approved its charter (Resolution No.837 of 16 November 2016). The government has also introduced a transparent mechanism for capacity distribution auctions at cross-border entry- and exit-points. Therefore, if the natural gas market based on the EU principles is already underway despite some shortcomings (as the relevant law was adopted in Ukraine back in 2015), the electricity market is still awaiting reforms stipulated by recently adopted Law of Ukraine "On the Electricity Market of Ukraine" (summer 2017). That is why the concept of the electricity market and its potential key players require more detailed presentation.

The law imposes a number of obligations on Ukraine concerning the liberalisation of the domestic electricity

market in line with regulatory documents of the Energy Community (to which Ukraine is the party) and of the European Union (the so-called Third Energy Package). Indeed, key provisions of the law are in line with the following EU acts:

- Directive 2009/72/EC concerning common rules for the internal market in electricity;
- Directive 2005/89/EC concerning measures to safeguard security of electricity supply and infrastructure investment;
- Regulation (EC) No.714/2009 on conditions for access to the network for cross-border exchanges in electricity.

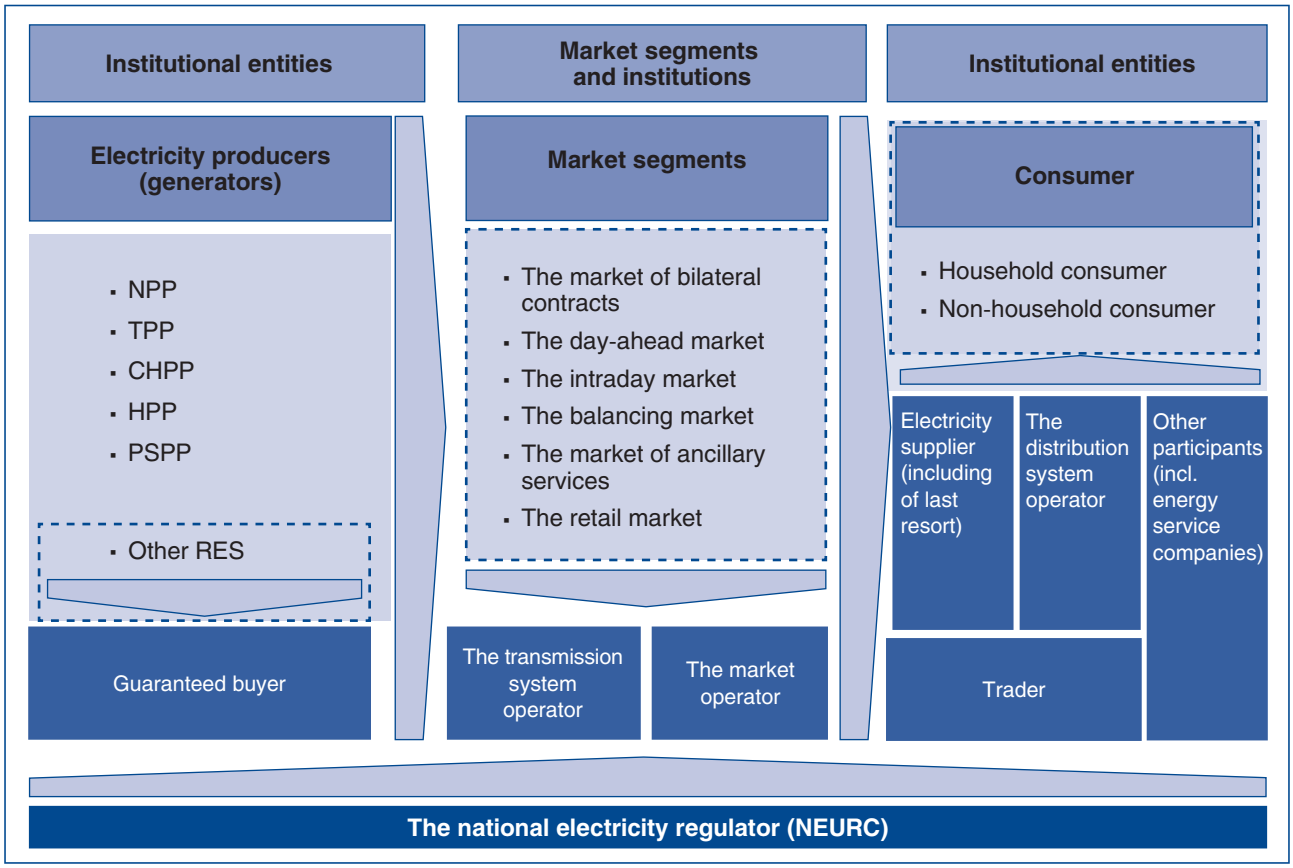
The law provides for a step-by-step liberalisation of the internal electricity market of Ukraine. Back in 2013, the Parliament attempted to reorganise the country's wholesale electricity market, which is still functioning based on the so-called "centralized pool" – the market model of a single wholesale electricity buyer, established on the basis and in line with the previous Law "On Basic Principles of the Electricity Market Functioning". The new law is expected to replace it. According to the new law, **the electricity market is a system of relations occurring between market participants during the sale and purchase of electricity and/or ancillary services, transmission and distribution, and electricity supply to consumers**.

The new electricity market model can be presented as follows (Figure "*The new electricity market model of Ukraine: The main institutional entities and market segments*")

**The national energy regulator.** Currently its functions are carried out by the National Energy and Utilities Regulatory Commission of Ukraine (NEURC) in line with the relevant law. The law on NEURC and the Law "On the Electricity Market" provide this government agency with broad regulatory powers, including issuing licensing, imposing sanctions, and approving basic methods for setting prices on electricity and services.

**According to the law, the electricity producers (generators), including NPP, TPP, CHPPs, HPP and PSPP, as well as renewables, must have licenses both for production and sales of electric power in various market segments, including the bilateral contracts, the day-ahead markets, the intraday markets, the balancing market and the market of ancillary services. As for the development of power generating capacities and guaranteed return on investment,**

**The new electricity market model of Ukraine:**
**The main institutional entities and market segments**



**these will be established on a competitive basis as determined by the Government of Ukraine.**

**The transmission system operator** is a joint-stock company, 100% of which is state-owned, with a licence to transmit electricity via trunk power grids. Currently these functions are performed by NEC *Ukrenergo*.

The law introduces a number of fundamental requirements to ensure independence and certification of the system operator, for example, such an operator shall be organised as an independent legal entity outside the vertically integrated undertaking and shall own the transmission system. The transmission system operator shall not be entitled to produce or sell electricity, and to distribute electricity to local networks. The law prescribes the transmission system operator to ensure the supply of electric power to residential areas and to perform the function of commercial metering administrator within the balancing electricity market, as well as the function of settlements administrator.

**The distribution system operators** are legal entities licensed to distribute electric power. They shall have no right to purchase and sell electricity, with the exception of buying it for internal technological needs and settling the imbalances. As of today, the domestic distribution system operators combine the functions of electricity sellers and distributors. According to the law, since these functions fall within one legal entity, they should be unbundled. Also, the law generally disallows the local network operators to combine the functions of production, transmission (via trunk lines) and sale of electricity. If the local operator is a part of vertically integrated company, then relevant corporate guidelines should be developed for such operators to enable independent management decisions in their day-to-day operations in line with the law and corporate requirements. Only small operators of local electric networks with no more than 100 thousand customers and average monthly distribution of electricity up to 20 million kWh, may be exempt from unbundling of activities upon the decision of the national energy regulator.

**The market operator** is a joint-stock company, 100% of which is state-owned, that ensures operation of the day-ahead and intraday electricity markets and organises the sale and purchase of power generated based on relevant license.

**Electricity suppliers** are legal entities licensed to supply electric power to end-users at non-regulated tariffs. The supply agreement shall be concluded between a supplier and end-user for a specified period and with established total volumes of electricity with an option of possible deviations from its nominal consumption.

**Traders** (wholesale buyers and sellers) of electricity have one license for resale only and shall not be entitled to sell electric power to end-users. Resale of electricity shall be based on bilateral purchase and sale agreements at all defined market segments. An individual or independent entrepreneur shall not perform functions of a trader.

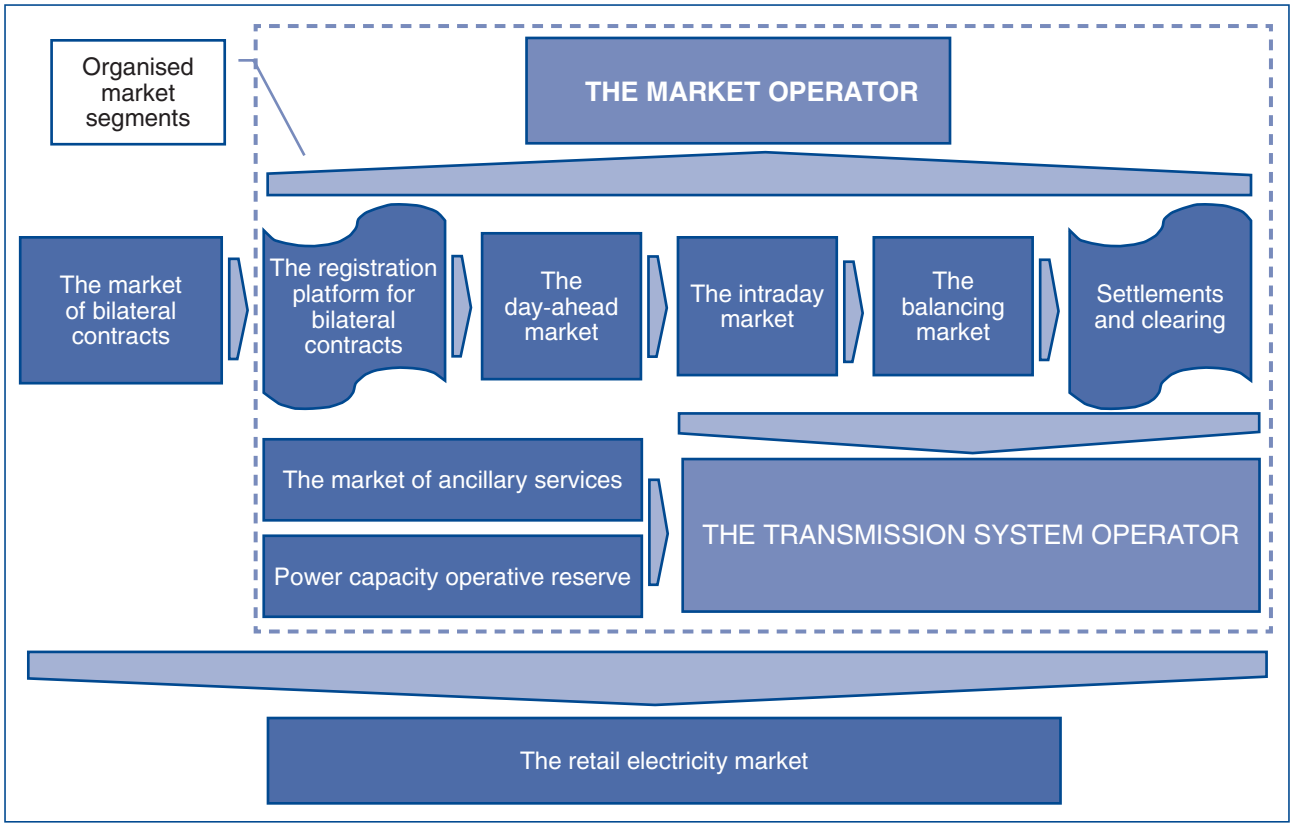
**Other market participants, including energy service companies (ESCO).** The law defines a number of other and derivative participants of the electricity market, for example, providers of ancillary, universal and "last resort" services, etc. The market for ancillary services occurs in connection with a purchase of ancillary services by the transmission system operator from ancillary service provider. The universal service is provided by the universal or "last resort" service providers to supply electricity to household and small non-household consumers, vulnerable categories of consumers, ensuring their right to be supplied with electricity of a specified quality within the entire territory of Ukraine subject to terms prescribed by the law.

Energy service companies (ESCO) that usually provide services to end-uses just like the distribution system operators, can also engage in the electricity market. The law does not set clear limits for ESCO operations and activities. Similar to the distribution system operators, energy service companies are not allowed to act as electricity suppliers or sellers (traders). However, ESCO can combine functions of a local networks operator with advanced services such as energy audit, energy management, design of grid connection, etc. Since the law introduces a number of institutional restrictions for the distribution system operators (e.g. the legal entity status), the European practice suggests that it would be expedient to set up energy service companies as independent legal entities and even to attract individual entrepreneurs with appropriate qualification.

According to the law, the terms and conditions for electricity market participants and their interrelations shall be determined by the accompanying regulatory and legal acts aimed at introducing the new electricity market model, including market rules that define functioning of the balancing market and the market of ancillary services; the rules for the day-ahead and intraday markets; the codes of the transmission and distribution systems; code of commercial metering; the rules for retail market, to name a few. The success of the new electricity market model fully depends not only on timeliness of elaboration and approval, but also on comprehensiveness and quality of this secondary regulatory framework.

As shown in the Figure "*The new electricity market model*" (p.65), **the law defines 1 July 2019 as the date of launching the new electricity market. On that day, the market of bilateral contracts, the market of ancillary services and the retail market will be introduced, including such market segments as the day-ahead and intraday markets.**

**The new electricity market model**




The electricity trading in **the market of bilateral contracts** will be based on purchase and sale contracts. It is expected that trading operations will be finalised as off-exchange deals, that is, without intermediaries.

The electricity trading in the **day-ahead market** will be based on competitive electricity prices, usually established following auctions to be held regularly one day prior to physical delivery.

**The intraday electricity market** involves purchase and sale of electricity on continuous basis after completion of trading in the day-ahead market and within the day of guaranteed physical delivery of electricity to the buyer. This will enable to track changes in current demand and supply in the electricity market and allow real-time response to such changes.

Therefore, the day-ahead and intraday markets are closely interlinked, requiring a centralised platform to be provided by the market operator. This institution will be responsible for collecting all offers for electricity sale and purchase and facilitating relevant auctions.

**The balancing market** is established for handling the imbalances recorded during the previous periods of operation of the electricity market players. The market is operated by the system operator, which is responsible for balancing and makes real-time decisions on the bids of market players for load increase or decrease. Acceptance of a particular bid by the system operator results in the sale and purchase of the relevant amounts of electricity. The law allows the market players responsible for balancing to form a group of balancing parties. Each member of such a group is responsible for energy balancing of all other members of the group.

**The market of ancillary services** includes various types of energy and capacity products to meet the reliability requirements of the market players. Power generators bid for a right to deliver ancillary services to the system operator.

**The retail electricity market** involves electricity trading between suppliers and end-users. Trading usually occurs at an unregulated rate with certain exceptions when providers of a universal or "last resort" service act as energy suppliers at the local level. In these cases, by government decision and in line with the law, the electricity supplier cannot, under certain conditions, unilaterally terminate energy supply to a particular consumer.

Best practices in electricity market reform demonstrate that effective and competitive markets allow a consumer to freely choose the energy supplier, thus contributing to increased competition for better services and paving the way to innovative technologies in deregulated electricity markets. At the same time, the government needs to be actively involved in the process of the electricity market liberalisation, regardless of its transformation and functioning model. One of the main

functions of the state is to set up a mechanism that encourages effective and consumer-oriented competition.

## 4.3. TOTAL PRIMARY ENERGY SUPPLY AND POWER GENERATION

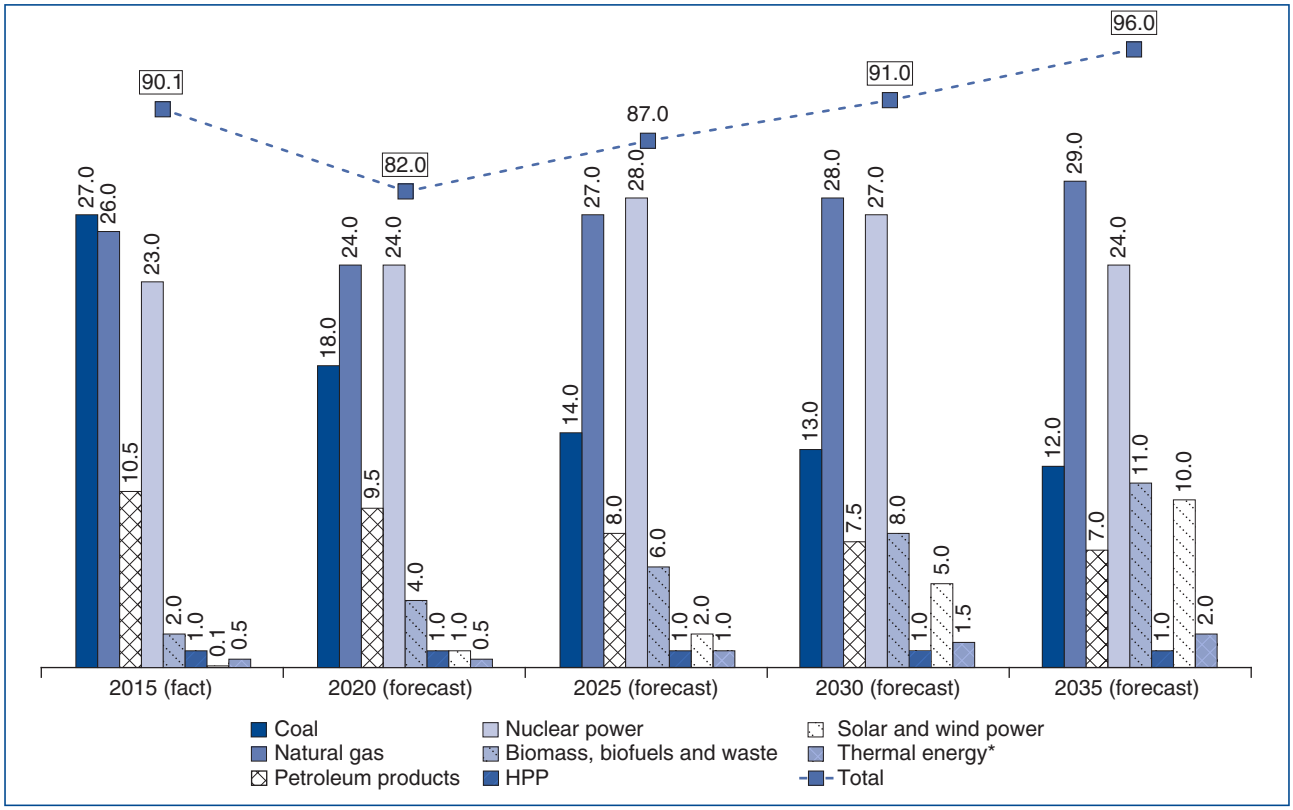
The volume and structure of the total primary energy supply (TPES) is the main criterion that shapes the country's fuel and energy complex transition and defines major sectoral proportions of the country's energy mix. It is expected that by 2020 Ukraine will gradually reduce TPES volume mostly by reducing the energy intensity via energy efficiency measures in industry, the utilities sector, and in households. Compared to 2015, the TPES volume is expected to fall from 90.1 mtoe to 82 mtoe, or by 9%.

**Diagrams "*Projected volume and structure of Ukraine's TPES*" and "*Projected TPES structure and RES share*" (p.66) characterise Ukraine's energy complex as based on the triad of energy sources that will also dominate its future development until 2035. These include: (1) nuclear power, (2) natural gas, and (3) coal. Although this triad is set to play a key role in shaping Ukraine's energy mix, the energy sector development strategy also provides for the expansion of renewables, with their share increasing by more than six times from 4% in 2015 to 25% in 2035. Meanwhile, the share of coal will reduce gradually from 30% in 2015 to 12.5% in 2035, or by 15 mtoe, which perfectly correlates with the European concept of low carbon development.**

Taking into account Ukraine's orientation towards the use of its own resources, natural gas will remain the primary source, accounting for 29% of TPES in 2035. As for the nuclear power, its share will be growing in the medium term (by 2025) due to a more intensive use of installed nuclear power capacity following lifetime extension of NPPs (32.2% in 2025). After 2025, however, the nuclear power capacity is expected to decline as existing generators retire. Eventually, the share of nuclear power will fall to 25% in 2035.

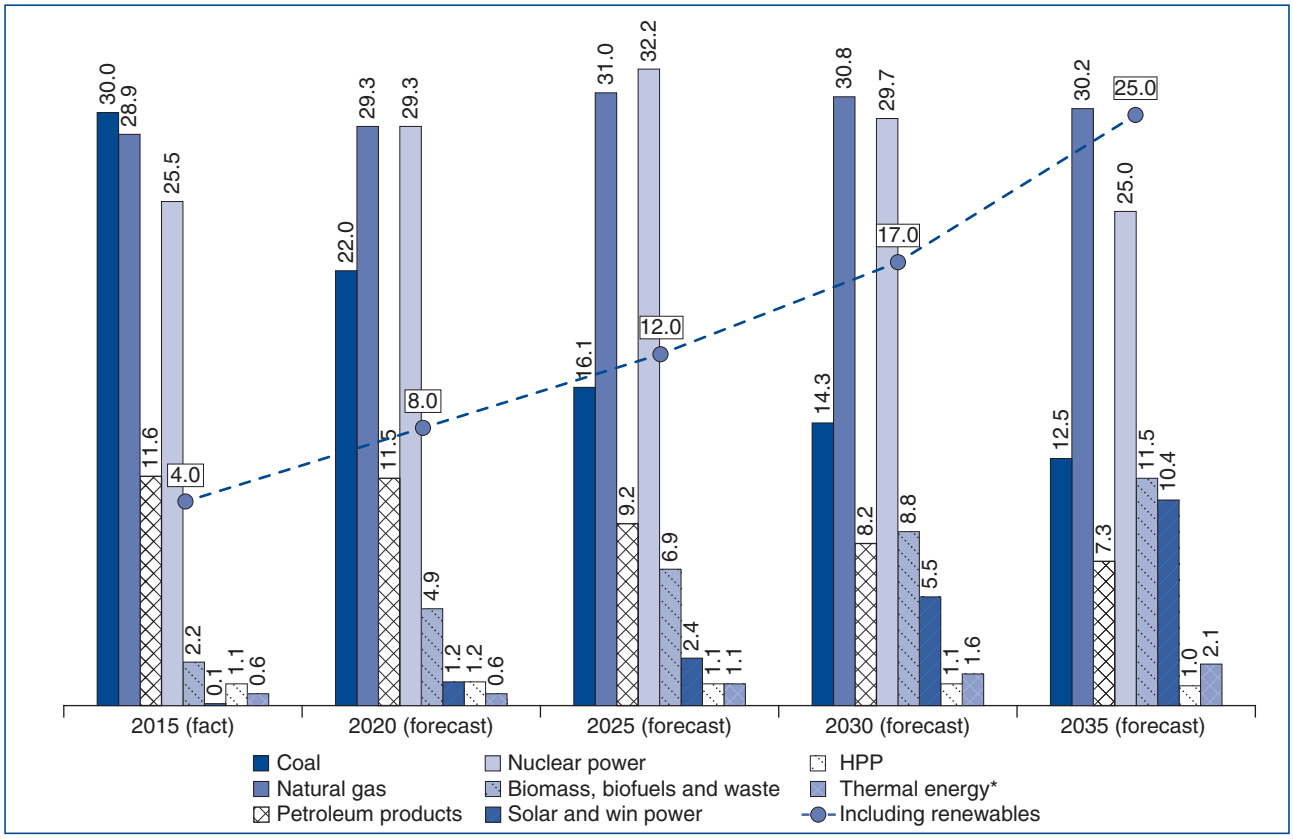
Projected volume and structure of electricity production in Ukraine until 2035 is presented in Figures "*Projected volume and structure of power generation in Ukraine*" and "*Projected structure of power generation and the share of non-fuel technologies in power generation in Ukraine*" (pp.67-68). During the period from 2015 to 2020, the situation with electricity generation is expected to stabilise at around 164 billion kWh. Following the expected economic recovery and integration of Ukrainian and EU energy systems that will bolster Ukraine's export opportunities, there will be a gradual growth in electricity demand leading to increased production. In 2020-2035, the average annual growth of electricity production is expected to slightly exceed 2%.

**Projected volume and structure of Ukraine's TPES,**
mtoe



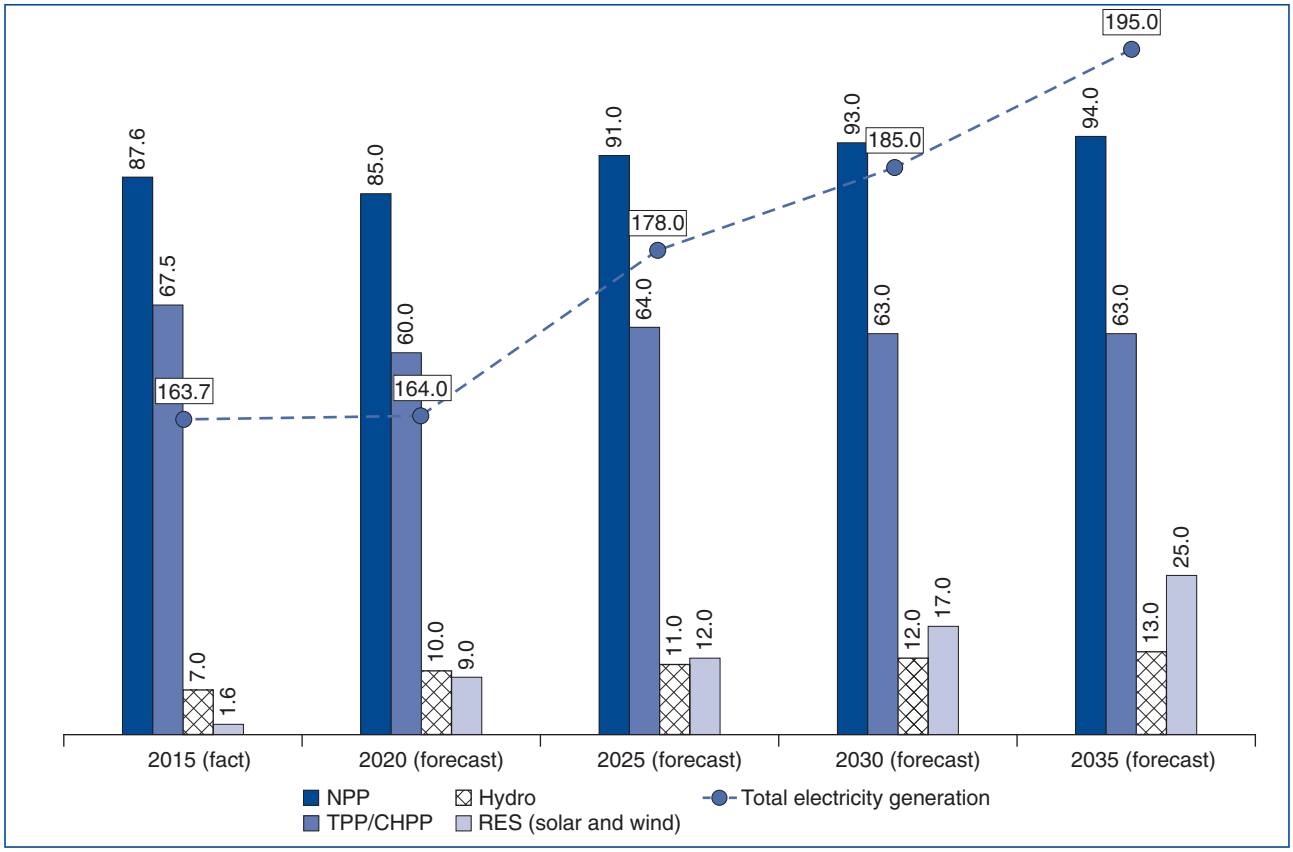

* Ambient thermal energy and anthropogenic discharges.

**Projected TRES structure and RES share,**
%

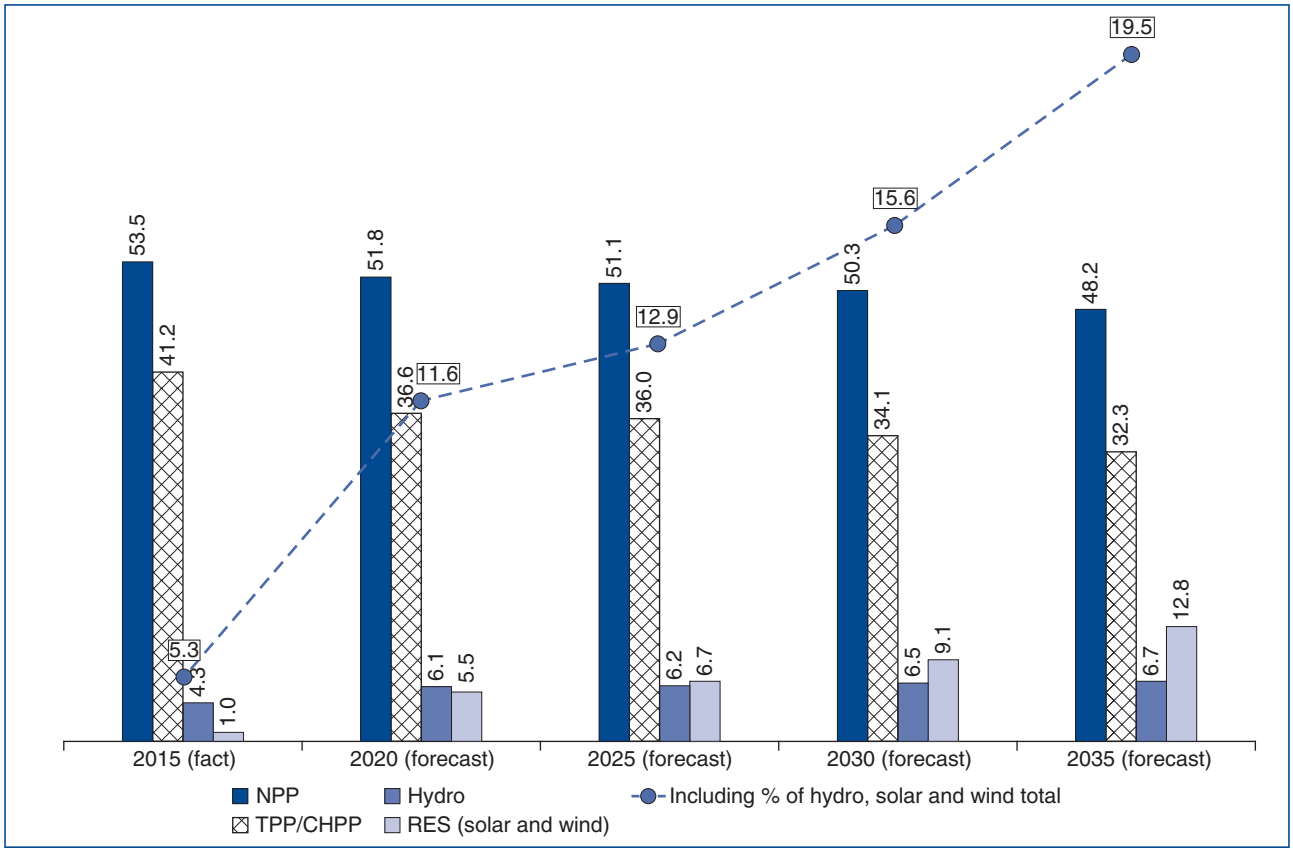



* Subsoil thermal energy and utilised thermal anthropogenic discharges.

**Projected volume and structure of power generation in Ukraine,**
billion kWh



**Projected structure of power generation and the share of non-fuel technologies in generation in Ukraine, %**




As for the generation structure, about half of electricity will be produced by nuclear power plants. The share of the TPP will be declining, as the share of non-fuel technologies grows (hydro, sun, and wind) from 5.3% in 2015 to 19.5% in 2035.

## 4.4. OIL AND GAS SECTOR OUTLOOK

By 2035, Ukraine's oil and gas sector has to achieve the following key objectives:

- creating favourable conditions to develop own raw material base for hydrocarbons production;
- optimising the balance of natural gas, oil and petroleum products consumption and their effective use;
- ensuring the efficient use of oil and gas infrastructure, in particular, main oil and gas pipelines, underground gas storage facilities (UGS), gas distribution networks, etc.

**As regards gas consumption, active measures aimed at ensuring the efficient use of thermal energy and gas both by households and industrial consumers will reduce gas consumption in the medium term and contribute to optimisation of future consumption with the possibility of its growth depending on the country's economic progress. In particular, by 2035 it is planned to increase domestic gas recovery to 30-35 bcm/y, including from unconventional sources.**

The development of country's own resource base and increased production should be achieved by increasing the volumes of exploration works; improving and stabilising the tax regime for hydrocarbon producers; conducting exploratory drilling and intensifying efforts to develop hard-to-recover hydrocarbon deposits; increasing exploration and operational drilling, as well as geophysical studies at the deposits under development; applying extraction intensification methods at available deposits; constructing booster compressors and pumping stations at deposits with remaining resources and reserves; improving accounting policy in the area of hydrocarbon extraction and introducing the EITI transparency standards for extractive industries, including development, approval and introduction of industry-specific cost accounting methodology in individual hydrocarbon deposits; increasing transparency and consistency of issuance of subsoil use permits; ensuring non-discriminatory access to geological information; developing the natural gas and oil extraction from the Black Sea and Azov Sea shelf, including in the offshore zone adjacent to Crimea (upon its return under the jurisdiction of Ukraine) with participation of the leading international oil and gas companies.

**For the short-term period, revising contractual relations with Russia via the negotiation process in a trilateral format (EU-Ukraine-Russia) is necessary for the purpose of changing the scheme of receiving and offtake of transit gas from the western to the eastern border of Ukraine with the European Union's support. Diversification of gas supply with minimisation of dependence on any individual supplier or specific route is one of Ukraine's recent major achievements. It should be maintained and further strengthened through the construction of additional pipelines – interconnectors between Ukraine and its EU neighbours.**

Due to unsatisfactory condition and substandard structure of the gas distribution system (GDS), there is a risk of increased accident rate and gas losses in the distribution networks. Moreover, given the lack of incentives to invest in GDS, addressing the issue of GDS ownership becomes a priority.

To achieve the ESU-2035 goals related to integration of the national gas transmission system (GTS) in the European network, a set of measures needs to be taken to ensure maximum reliability, openness and transparency of the national GTS operator. Implementing these measures requires, above all, separation of the GTS operator from the vertically integrated company, thus contributing to a non-discriminatory and transparent access for market participants. Clearly, it is also necessary to **optimise the capacity and technological parameters of GTS functioning in compliance with expected utilisation scenarios and to introduce the European energy legislation, including the EU network codes and guidelines and the best business practices of the European GTS operators.**

As of today, the use of underground gas storage (UGS) infrastructure is somewhat limited. This is due to reduction of seasonal variations in the cost of natural gas caused by reduced demand and increased pipeline capacity in the foreseeable future; availability of excessive UGS capacities in many European countries; current technological regimes of the domestic UGS; and improved cross-border links between some countries through interconnectors that help balancing their markets. **At the same time, the potential of Ukrainian UGS system is estimated as considerable, which allows attracting new partners, increasing efficiency of operation and technical parameters, and using the best international experience in managing thereof. In recent years, Ukraine has been using up to 60% of total UGS capacity for own needs (48% in 2016). Thus, available capacities of underground gas storage system for seasonal storage of natural gas by other companies, including foreign ones, reaches 8-15 billion cubic meters.**

Planned activities in the field of hydrocarbon processing include endorsing a favourable policy for technical refurbishment and upgrading of oil refineries and gas processing plants using advanced processing technologies; introducing positive tax conditions, tariffs and investment climate to supply crude oil for processing; covering at least 50% of the internal market needs not lower than Euro-5 standard with domestic output; improving the state system of oil product quality control (enhancing motor fuel quality standards and control over compliance); introducing a market surveillance system for motor fuel quality along with measures to promote compliance with defined quality standards and to raise public awareness about companies responsible for distribution of low-quality fuels. Therefore, in order to establish modern and consumer-oriented motor fuels market and to cover the country's needs in fuels, efforts will be aimed at implementing measures to ensure reliable energy supply and protection of the energy infrastructure, to diversify sources and routes of petroleum products supply, including overcoming dependence on the supply of energy resources from Russia. Other activities include creating conditions for reduction of dependence on import via expansion and use of domestic production capacities and diversification of imports (no more than 30% from every single source); establishing competitive prices for consumers reflecting real value and quality; introducing the state system of quality control for petroleum products and LPG; creating conditions and developing respective infrastructure for further expansion of LPG and compressed natural gas (CNG) as a motor and household fuel; ensuring Ukraine's transition towards the European gas quality standard EN 589; bringing Ukrainian legislation on technological, fire and environmental safety at companies to the requirements of European directives; restoring of intermodal logistic network (railway + motor transport) based on central terminals according to the scheme "producer – railway – gas-filling station (GFS) – low-tonnage motor transport – retail trade"; supporting further development of fuel supply through the Black and Azov Sea ports and western borders of Ukraine; ensuring the most efficient use of infrastructure and transport fleet for LPG import by rail; creating legislative incentives to raise economic attractiveness of purchasing, producing and using vehicles with CNG engines.

Creating oil and gas reserves is also essential, including rationalising the amount of strategic gas reserves and the concept of their creation based on international experience and setting sustainable rules for a certain period with the possibility for their revision and adjustment at least biennially; ensuring fulfilment of deadlines for commitments to establish a specialised agency responsible for stockpiling and managing these minimum reserves; creating a minimum oil and petroleum product reserves according to the 90 (or 61-day) standard and introducing the centralised management system; optimising reserves according to consumption structure by regions and by

usage scenarios; assessing and substantiating the LPG stock as an additional reserve fuel for the Ukrainian economy.

As regards management of companies with assets located in temporarily occupied territories, it is essential to preserve a legitimate legal entity *Chornomornaftogaz*, since it is a legitimate claimant against Russia for efficient protection of Ukraine's interests in international courts.

It is very likely that by 2019 inclusive the volume of the Russian gas transit will range within 60-90 bcm/y. At the same time, to date there is no documentary evidence confirming transit of the Russian gas through the territory of Ukraine beyond 2019. As of December 2017, the Stockholm arbitration proceedings relating to the gas transit contract were still under way. Currently, *Gazprom* is mum about signing a new contract, while implementing own projects to build alternative gas transmission routes to Europe (increased transmission via the *Nord Stream*, access to the *OPAL* pipeline, construction of the *Nord Stream 2* and *Turkish Stream*).

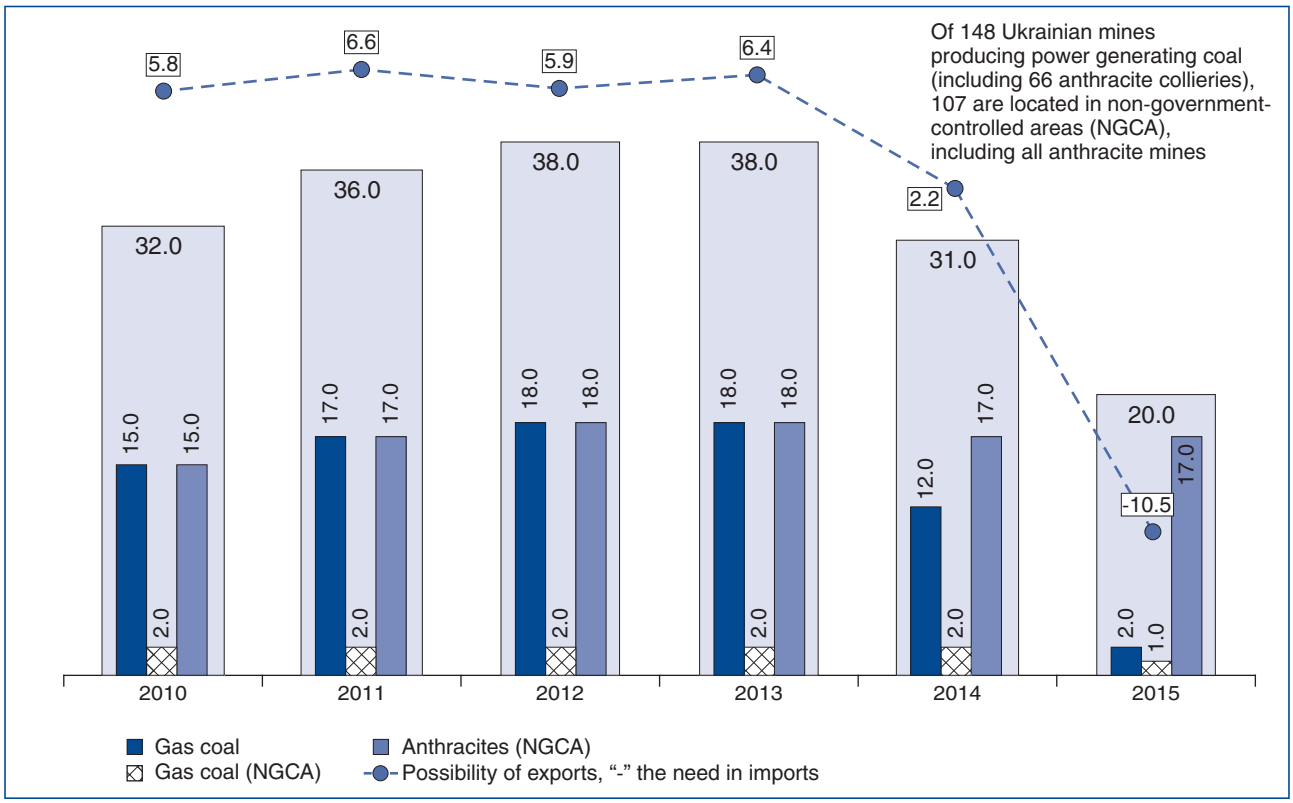
**Successful initiatives to increase Europe's dependence on the Russian gas supply, obtained permissions to build gas pipelines, signed contracts with subcontractors, announced plans for partial dismantling of the Russian GTS at the entry point to Ukraine suggest that further transmission of the Russian gas through Ukraine at current levels is very questionable. It appears that only current restrictions and sanctions against Russia and *Gazprom*, as well as efforts of the European Commission will keep the Ukrainian route for the Russian gas supply alive at 15-40 bcm/y (mostly in southern direction, e.g. the Balkans) and only until 2019, when the *Turkish Stream* will become operational.**

**It is expected that the volume of gas transmission for Ukrainian consumers will amount to 26-30 bcm/y with the share of European energy companies in gas transit through Ukraine exceeding 50%. At the same time, the share of foreign companies storing their gas in the Ukrainian UGS facilities will be no less than 20%.**

## 4.5. COAL SECTOR OUTLOOK

The loss of control over key coal assets – the anthracite collieries as a result of the armed conflict in Donbas was a huge blow for Ukraine, as it significantly complicated the overall operation of the country's energy complex and the thermal power generation sector. The latter was designed to use mostly anthracite coal. Figure "*Changes in the structure of power generating coal supply in Ukraine resulting from the loss of Donbas anthracite mines*" describes the structure of power generating coal supply before and after the loss of control over the anthracite extraction assets. Obviously, the deficit of specific types of coal can be removed either through imports or by retrofitting TPPs to use gas and/or lean coals that are extracted in the government-controlled areas of Ukraine. The linear graph in the Figure below shows the possibility of exports (or the need in imports of power

**Changes in the structure of power generating coal supply in Ukraine resulting from the loss of Donbas anthracite mines**




*Source*: McKinsey presentation.

generating coal if the figure is negative). Therefore, following the loss of coal assets, Ukraine in 2015 had to import about 10.5 million tonnes of power generating coal.

Under such circumstances, it is extremely important to raise the issue of government policy for the coal industry at the executive power level. Key questions related to the coal industry reform were addressed – although insufficiently – in the Concept of the coal industry development for the period until 2020, which encourages the coal sector to fully meet the thermal generation needs by replacing anthracites with gas coal and provides for the possibility to abandon the use of the anthracite coal types in power generation in 2019.

Implementation of the Concept will make it possible to systematically address problems of the coal industry functioning; to fulfil systemic measures aimed at building industry's potential to increase coal production; to improve efficiency of the industry and make it unsubsidised and self-sufficient, while resolving environmental and social problems of mining regions; and to create enabling conditions for attracting investment. The planned activities will enable establishing a service stations and a scientific base and initiate the process of increasing coal production. If properly implemented, the said measures will contribute to increasing coal production at the state-owned mines to 8.7 million tonnes by 2018.

**In addition to the Concept, the ESU-2035 sets more comprehensive tasks for coal industry reform, defining key government goals in the coal sector at each stage of the strategy implementation. In particular, the ESU-2035 provides for optimisation of the structure of mining and other state companies working in the coal industry; improvement of economic and technical performance indicators; reduction and elimination of government regulations and subsidies for operational activities of coal mining and processing enterprises; development of necessary infrastructure for building Ukraine's capacity to provide export and import operations with coal products.**

The main activities aimed at implementing the strategic goals in the coal sector include:

- reorganising coal extraction and other state-owned companies operating in the coal sector and subordinating them to a single legal entity;
- liquidating not-specialised assets;
- sector restructuring and preparing the most promising state-owned mines for privatisation with liquidation/conservation of loss-making mines;
- shifting towards self-sustaining extraction with re-orientation of state support to protection of labour, environment and industry restructuring measures;
- liquidating the public wholesale coal buyer and introducing the exchange trade of coal products;
- ensuring the development of domestic coal production.

Activities aimed at closure/conservation of loss-making state-owned mines are set to be completed by 2025. Social and environmental mitigation plan will be approved for each facility. Within these activities, the best international practice of mitigating social consequences will be applied involving large-scale international assistance, including severance pays, consultative assistance to dismissed staff and professional training and retraining.

A set of measures aimed at mitigating consequences of coal industry restructuring shall be coordinated with programmes for social reconversion of regions, where mines are being closed/conserved. Similarly, these efforts will be carried out with large-scale international assistance. In line with the best European practices programmes include arrangement of community works for infrastructure restoration, creation of new jobs, consultative and financial support to entrepreneurial initiatives, establishment of business incubators and introduction of temporary special economic regimes in the mine closure regions.

Additionally, in the course of mine conservation and liquidation, it is necessary to take measures aimed at reducing environmental risks, the most dangerous of which include burning waste banks and pit heaps and possible slides; violation of hydrological regime and flooding of soil surface; release of methane from closed mines.

Therefore, by 2035 it is planned to complete the coal industry reform programme, including reformation of the state-owned mines:

- privatisation of promising state-owned mines prepared during the first phase;
- optimisation of economic and technical performance indicators; reduction and elimination of government regulations and subsidies for operational activities of coal mining and processing enterprises following re-integration of NGCA in the Donetsk and Luhansk oblasts;
- liquidation/conservation of ineffective and loss-making mines with implementation of social and environmental mitigation plans for each facility;
- realisation of the social reconversion programmes for mine closure regions;
- attainment of the level of coal production sufficient to cover the demand for power generating coal with domestically produced fuel.

**In implementing provisions of Ukraine's energy strategy, due regard should be given to the fact that the vast majority of coal-mining assets in Ukraine have already been privatised and more than 85% of coal is produced in private mines. Therefore, in the process of reforming the coal industry, it is necessary to recognise**

**interests of private capital and coordinate the sector transformation efforts based on the balance of interests and public-private partnership principles.**

## 4.6. ELECTRIC POWER INDUSTRY OUTLOOK

Ukraine is projected to have an excess generation capacity by 2025 and will face the need for their rapid upgrading after 2025. In terms of possibilities for TPP reconstruction, taking into account environmental requirements and extension of the period of NPP operating life, these types of power generation will remain efficient enough in the nearest future. To meet the demand by 2025 it would be sufficient to extend the period of operation of nuclear power plants (by 6 GW) and thermal power plants (by 9 GW). In addition to meeting short- and medium-term demand, another strategic objective for the next decade is to make Ukraine's energy system prepared to a large-scale capacity upgrading beyond 2025.

On 16 February 2017 the Presidential Decree No.37/2017 enacted the decision of Ukraine's National Security and Defence Council on urgent measures to neutralize the threats to Ukraine's energy security and to reinforce protection of critical infrastructure, which among other things provides for the development and implementation of the programme for constructing new and reconstructing the existing anthracite-fired power units of the TPP and CHPP to be able to use domestically produced gas coal.

On 1 March 2017 the Cabinet of Ministers Directive No.133-r amended relevant Resolution No.648 dated 8 September 2004 "On Measures for reconstruction and modernisation of thermal power plants and combined heat and power plants for the period until 2020" and approved updated reconstruction and modernisation plan. The new version of the plan defines priority projects as initiatives implemented through the mechanism of the investment component accrual in the electricity tariffs, as well as other viable projects funded from other sources. Proper implementation of this plan will create conditions for appropriate reconstruction and commissioning of upgraded power units, while increasing the level of energy independence of Ukraine.

**The Ministry of Energy and Coal Industry of Ukraine recently reported on the completion of the first project on upgrading anthracite-fired TPP to use gas coal. In particular, retrofitting of just two boilers TP-100 in power units (PU) 2 and 5 of the *Zmiyiv* TPP allows replacing up to 1 million tonnes of anthracite coal with gas coal every year. Consistent with the project plan, power units 2 and 5 were relaunched in 2017 using gas coal. The total estimated cost of power units retrofitting amounted to UAH 240 million. Currently the government considers the issue of similar modernisation of the Trypilya TPP.**

Also pursuant to the Cabinet of Ministers of Resolution No.648, the Ministry of Energy and Coal Industry of Ukraine issued an Order No.221 dated 22 March 2017 approving the schedule for reconstruction of TPP power units of generating companies in 2017-2019. In particular, it is planned to complete the pilot project on installing sulphur purification facilities in PU2 of the *Trypilya* TPP and PU1 of the *Zmiyiv* TPP (JSC Centrenergo), which is in line with the Directive 2001/80/EC "On the limitation of emissions of certain pollutants into the air from large combustion plants". Other power units in the Trypilya TPP (PU1), *Zmiyiv* TPP (PU1), *Kryvyi Rih* TPP (PU1), *Slovyansk* TPP (PU6 and PU7) and *Burshtyn* TPP (PU10) are also to be upgraded shortly. Implementation of these projects will extend the lifetime of these power units by 15-20 years, increase their efficiency by 6-10%, and ensure consistency of their operation with the requirements of the European Network of Transmission System Operators for Electricity – ENTSO-E.

Pursuant to the "Procedure for the System Operator on elaborating the plan for the Unified Energy System of Ukraine development for the next ten years", approved by the Ministry of Energy and Coal Industry Order No.680 on 29 September 2014, NEC *Ukrenergo* developed the draft UES Development Plan for 2017-2026.

The NEURC Order No.2324 dated 20 December 2016 has approved the investment programme of NEC *Ukrenergo* for 2017 in the amount of UAH 3.2 billion, which allocates funds on the construction of power substations of 500/220 kV; reconstruction and technical re-equipment of overhead power lines; project works for the upcoming periods; procurement of dispatching control equipment, metering systems, measuring tools, etc.

On 14 September 2016, the scientific and technical board at the Ministry of Energy and Coal Industry has approved the power distribution networks development plan for 2016-2025. The main objectives of this plan include ensuring reliable and efficient electricity supply to consumers; supporting coordinated development, reconstruction and modernisation of distribution networks; and promoting development of alternative energy.

**The NEC *Ukrenergo* reform strategy has identified priority goals and objectives over the next 10 years to ensure long-term reliability of main power transmission lines and smooth functioning of Ukraine's UES, as well as integration of Ukrainian electricity market and main grids into the ENTSO-E with optimization of the Company's settlement rate.**

On 24 September 2010, Ukraine joined the Treaty establishing the Energy Community, becoming its full member on 1 February 2011. The Law of Ukraine No.2787-VI dated 15 December 2010 "On Ratification of the Protocol on Ukraine's Accession to the Treaty

Establishing the Energy Community" affirms Ukraine's commitment to integrate the EU's key energy acts in the national legislation. The main objective of the Treaty is to create an integrated energy market and legislation to enhance energy security, attract investment, improve the environmental component in the supply and use of energy resources.

Ukraine's integration into the European energy market entails implementation of the EU's Second and Third Energy Packages provisions and relevant European Union directives aimed at creating competitive and non-discriminatory conditions for business activity in the domestic energy market; increasing energy efficiency and renewable energy development; and connecting Ukraine's UES to the European Network of Transmission System Operators (ENTSO-E) to secure synchronised operation of power systems and to allow entry of the Ukrainian electricity producers to the European energy market, which is the medium-term project (Figure "*Main stages and terms of Ukraine energy system integration in CESA* (*ENTSO-E*)").

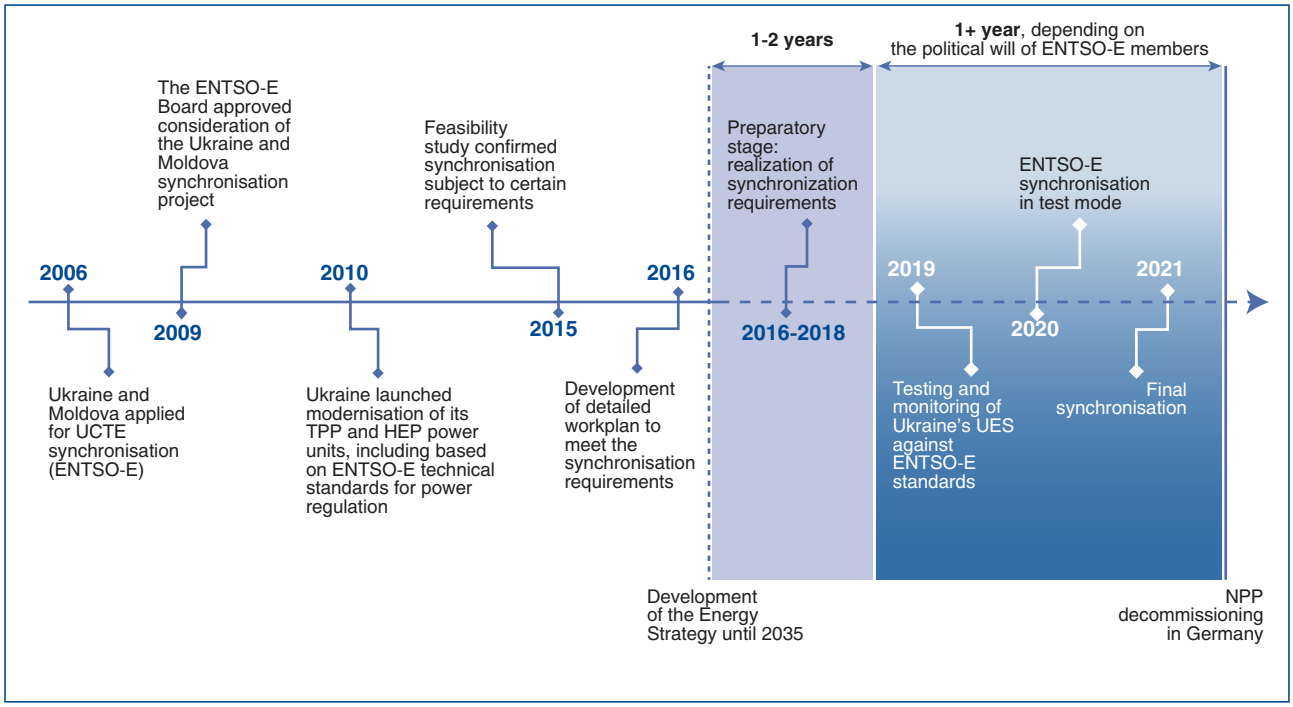
It is expected that in early 2018 the ENTSO-E will approve a list of measures to integrate power systems of Ukraine and Moldova in the Continental Europe Synchronous Area (CESA).

An international consortium has been set up to develop the feasibility study for the Ukrainian and Moldavian energy system integration project, which included system operators from *Romania* (Transelectrica), *Serbia* (EMS), *Bulgaria* (ESO EAD), *Hungary* (MAVIR) and *Poland* (PSE). The Brussels-based *Bernard Energy Advocacy* consulting company provided services on regulatory and legal issues. The overall management of the consortium was performed by *Transelectrica*, while feasibility study was financed by the European Commission within the Joint Operational Programme (Romania-Ukraine-Moldova) for 2007-2013.

The main objectives of the feasibility study included: revising technical capability of the Ukrainian and Moldovan power systems to operate in parallel with CESA; the possibility of applying the ENTSO-E technical and operational standards in the Ukrainian and Moldovan energy systems; and the analysis of variations in the energy legislation of Ukraine, Moldova and the EU members. The feasibility study commenced in November 2014 and was completed in January 2016. Based on its findings, the ENTSO-E Regional Group Continental Europe confirmed the technical feasibility of achieving parallel functioning of the Ukrainian and Moldovan energy systems with CESA grids by 2020, but stressed the need for further studies to explore the possibility of hybrid connection (direct and alternating currents) of Ukraine and Moldova's power systems.

Signing of the Connection Agreement between the ENTSO-E and the Ukrainian system operator was the next important step towards the power systems synchronization, as it defines technical, organisational and legal requirements for the accession of Ukraine's UES. This significant event took place on 28 June 2017 at the ENTSO-E Assembly meeting in Brussels. The Agreement stipulates that during the transition period Ukraine has to meet its obligations and bring the energy system in line with the European standards. The system has to demonstrate stable performance for one year, operating in isolation from Russia and Belarus, to which the Ukrainian grid is currently connected.

**Main stages and terms of Ukraine energy system integration in CESA (ENTSO-E)**



As of today, the *Burshtyn* Energy Island TPP is already in sync with ENTSO-E, while Ukraine and Moldova's entire power systems operate in parallel mode. The first ever annual/monthly/daily electronic one-way auctions between the *Burshtyn* Energy Island and ENTSO-E are planned for 2017. Other activities include considering the "Catalogue of Measures" for the Ukrainian and Moldovan energy systems to access ENTSO-E with the development of procedures for its endorsement and practical realisation. The Ukrainian operator NEC *Ukrenergo*, the Moldovan *Moldelectrika* and the European Network of Transmission System Operators for Electricity continue elaborating the synchronisation roadmap.

Connecting the Ukrainian and Moldovan energy systems to ENTSO-E will expand the range of power exchange to 2,350 MW towards Europe and up to 2,000 MW towards Ukraine and Moldova. According to the NEC *Ukrenergo*, **if appropriate measures are taken by Ukraine and relevant European system operators, the volume of mutual power exchange with ENTSO-E can increase to 4,000 MW, which means at least €1.5 billion of additional revenues from sale of both electricity and ancillary (system) services.**

**The ultimate goal of this process is to ensure uninterrupted operation of Ukraine and Moldova's power systems in full sync with the power grid of Continental Europe, and depending on "penetration" of the EU energy regulations in the national legislation of Ukraine and Moldova – full membership of these countries' transmission system operators in ENTSO-E.**

By 2035, capacities providing close to 80% of current production (20-25 GW) may be taken out of operation with no opportunity for operational period extension. Considering the time needed to design and construct new capacities to replace them (including flexible capacities) for balancing the energy system, decisions on the targeted configuration of capacities that will be operational after 2035 should be approved before 2020.

In pursuance of the Cabinet of Ministers Resolution No.671 dated 15 June 2015 "On the commencement of the pilot project 'Ukraine – EU Energy Bridge'", the Ministry of Energy and Coal Industry of Ukraine approved relevant Plan of Actions (Order No.89 as of 2 February 2017), which enlarges the "*Burshtyn* Energy Island" by delivering the output of the *Khmelnytsky* NPP (PU2) to the EU countries, securing long-term exports of electric power, and using funds from electricity exports on the construction of PU3 and PU4 of the *Khmelnytsky* NPP.

## 4.7. KEY PARAMETERS FOR IMPLEMENTING THE ENERGY STRATEGY UNTIL 2035

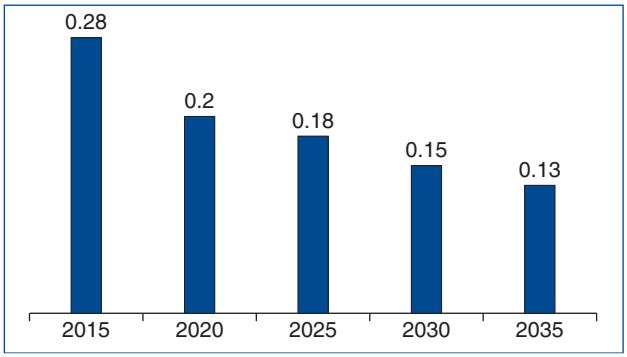
To assess progress in reforming the energy sector of Ukraine and approximation of its operating parameters to European standards, it is important to introduce a monitoring and evaluation system for verifying its performance indicators over time in the period until 2035. To this end, we distinguish the following key sets of performance indicators:

- energy efficiency indicators;
- energy independence indicators;
- security of service indicators;
- safety and environment indicators;
- share of exchange trade in energy resources.

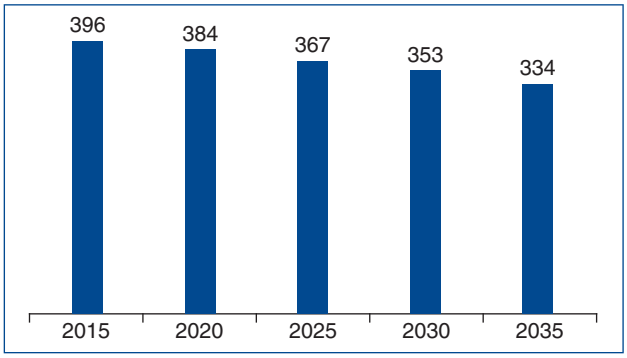
**The energy efficiency indicators** include: energy intensity at PPP; fuel consumption of electricity generated by TPPs and directed to the energy market; specific costs of heat production at boiler houses; loss percentage in electric networks; loss percentage in heat distribution networks (Figures "*Targets for energy intensity at PPP 2005*", "*Targets for fuel consumption of electricity sold to the energy market*", "*Targets for specific fuel consumption of heat production at boiler plants*", "*Targets for power loss in electric power transmission networks*", "*Targets for loss percentage in heat distribution networks*", pp.74-75).

**The energy independence indicators** include: timely integration with the continental part of the ENTSO-E; independence from gas imports from Russia; the share of a single supplier in the nuclear fuel market; imports dependence as gross imports of energy resources in TPES; level of integration between the electricity markets of Ukraine and the EU; level of integration between gas

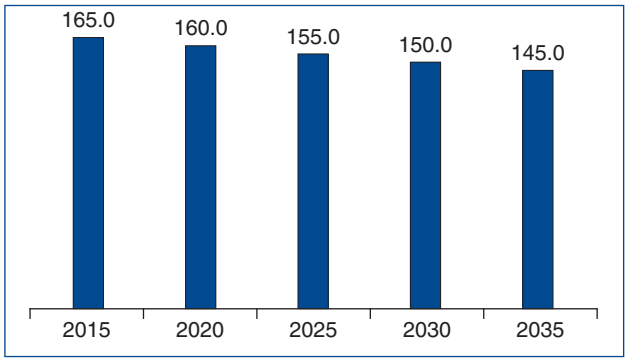
**Targets for energy intensity at PPP 2005,**
TPES in toe/thousand dollars of GDP (PPP)



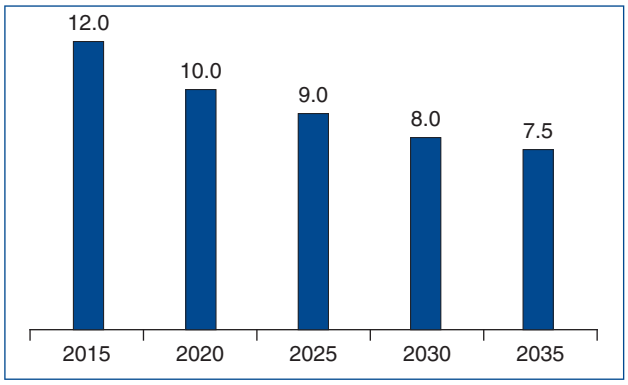

**Targets for fuel consumption of electricity sold to the energy market,**
g s.f./kWh



**Targets for specific fuel consumption of heat production at boiler plants**, kg s.f./Gcal



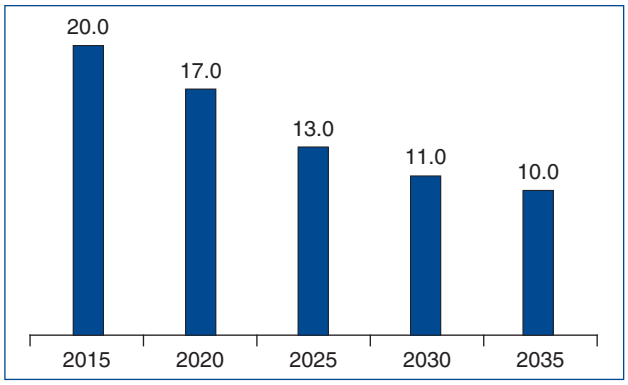

**Targets for power loss in electric power transmission networks**, %



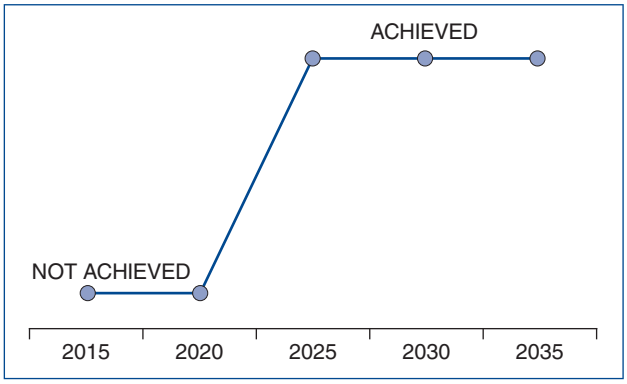

markets of Ukraine and the EU (Figures "*Schedule of real integration of Ukraine's energy system in CESA (ENTSO-E)*", "*Changes in Ukraine's need for gas imports from Russia*", "*Changes in the share of a single supplier in the nuclear fuelmarket*", "*Changes in imports dependence of TPES*", "*Changes in the level of integration between electricity markets of Ukraine and the EU*", "*Changes in the level of integration between gas markets of Ukraine and the EU*", pp.75-76).

**The security of service indicators** include the system average interruption duration index (SAIDI) as a result of unplanned interruptions for the energy company's fault; and heat distribution networks in emergency condition

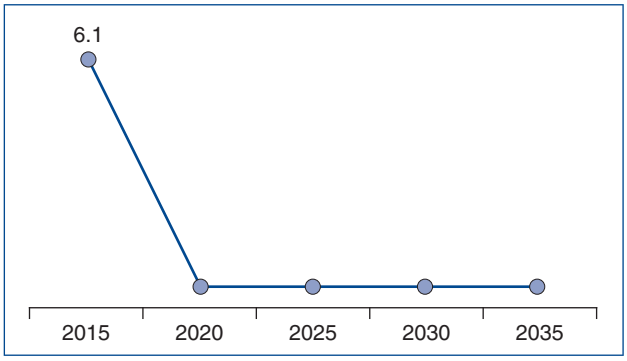
**Targets for loss percentage in heat distribution networks**, %



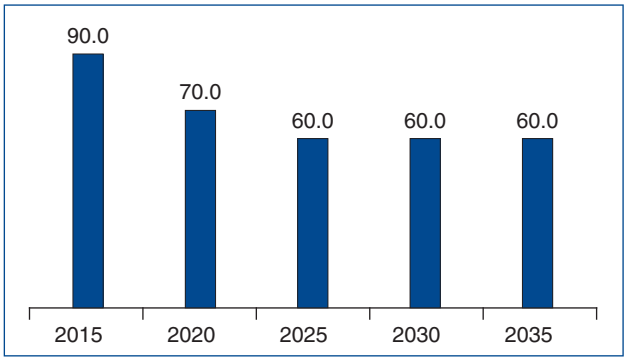

**Schedule of real integration of Ukraine's energy system in CESA (ENTSO-E)**



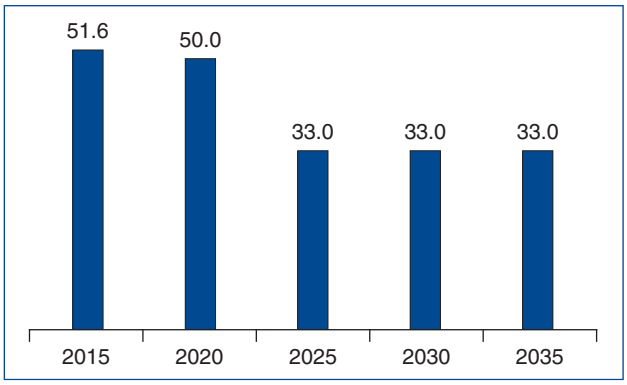

**Changes in Ukraine's need for gas imports from Russia**, bcm



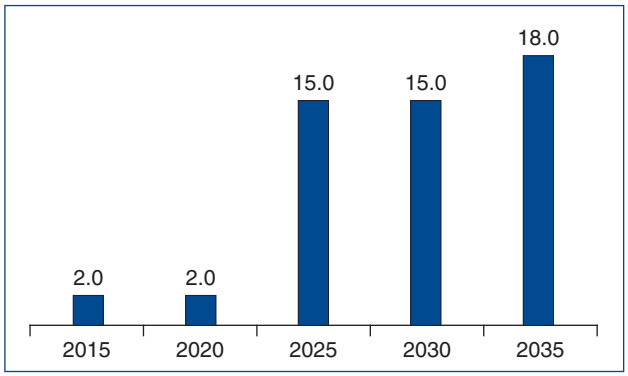

**Changes in the share of a single supplier in the nuclear fuel market**, %



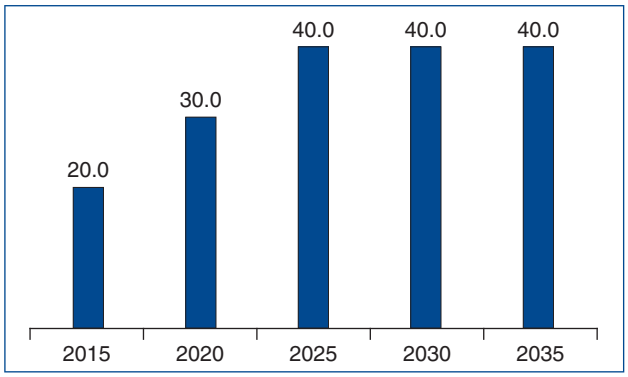

**Changes in imports dependence of TPES**, %



**Changes in the level of integration between the electricity markets of Ukraine and the EU**, %



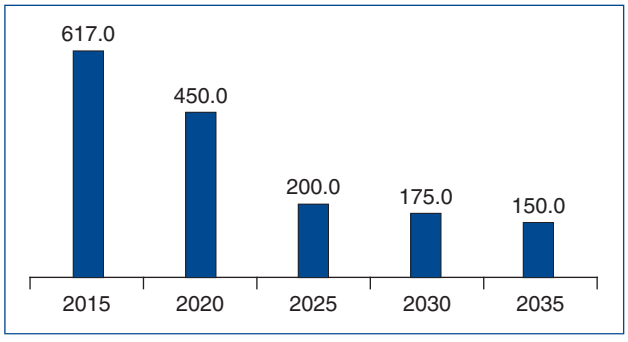

**Changes in the level of integration between gas markets of Ukraine and the EU**, %




(Figures "*Changes in the system average interruption duration index (SAIDI) as a result of unplanned interruptions for the energy company's fault*", "*Changes in the share of heat distribution networks in emergency conditions*").

**The safety and environment indicators** include access to energy resources in emergency situations; access to energy resources of private companies in emergency situations; strategic energy resource reserves; the share of RES in TPES; the share of RES in electricity generation; the share of local alternative fuels in local fuel and energy balances; $CO_2$ emissions compared to 1990; reduction of emission in $CO_2$ equivalent final fuel consumption and compared to 2010; the share of heat generation capacities meeting environmental requirements of the EU by $SO_2$, $NO_x$, ash emissions (Figures "*Changes in governmental access to energy resources in emergency situations*", "*Changes in governmental access to energy resources of private companies in emergency situations*", "*Changes in governmental strategic energy resource reserves in emergency situations*", "*Changes in the share of RES in TPES*", "*Changes in the share of RES in electricity generation*", "*Changes in the share of local alternative fuels in local fuel and energy mix*", "*Changes in $CO_2$ emissions compared to 1990*", "*The reduction of $CO_2$ emission in final fuel consumption as compared to 2010*", and "*Changes in the share of heat generation capacities meeting the EU environmental requirements*", pp.77-78).

**Changes in the system average interruption duration index (SAIDI) as a result of unplanned interruptions for the energy company's fault**, minute/year per client



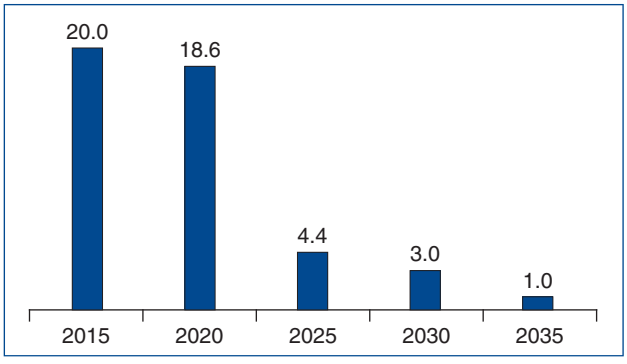

An indicator that characterises the market openness is the **share of exchange trade in energy resources**. Its targets are presented in Figure "*Changes in the share of exchange trade in energy resources*", p.78.

Therefore, with gradual approximation and proper observance of this performance indicators system within the defined period of time, one can argue that Ukraine will not only meet key criteria for energy security in the medium term but by 2035 it will also achieve the main parameters of its energy sector development typical for most of Ukraine's neighbours and the EU members.

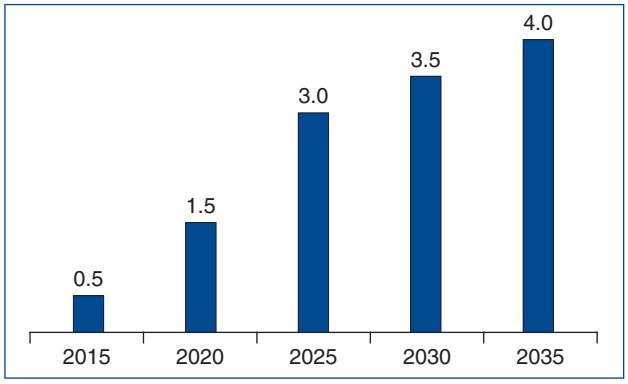
## 4.8. INCREASED ENERGY EFFICIENCY, RENEWABLES EXPANSION, MODERNISATION AND INNOVATIVE TECHNOLOGIES

Pursuant to the provisions of the EU's Third Energy Package in the area of energy efficiency Ukraine has adopted a number of laws to implement the following EU Directives in the national legislation: 2006/32/EC on energy end-use efficiency and energy services; 2010/31/EU on the energy performance of buildings; 2010/30/EU on labelling of energy products; 2012/27/EU on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC.

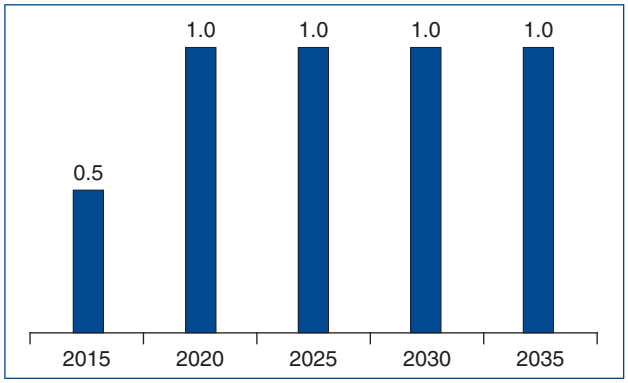
**Changes in the share of heat distribution networks in emergency conditions**, %



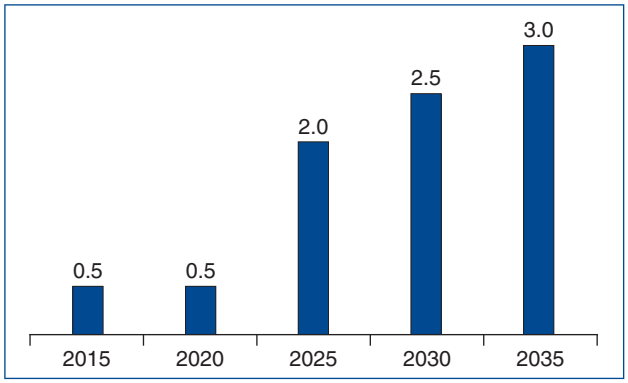
**Changes in governmental access to energy resources in emergency situations**



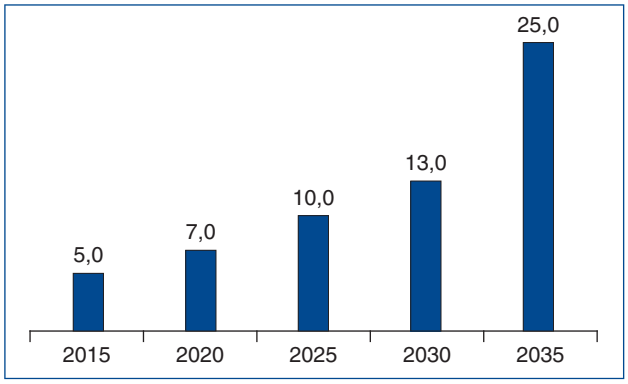

**Changes in governmental access to energy resources of private companies in emergency situations**



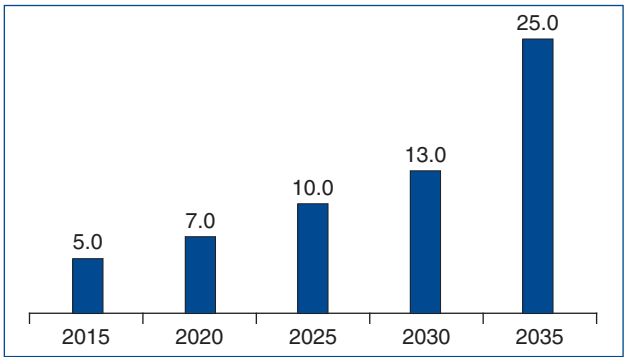

**Changes in governmental strategic energy resource reserves in emergency situations**



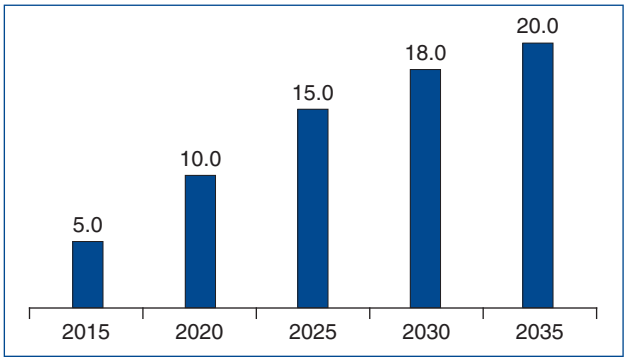

**Changes in the share of RES in TPES, %**



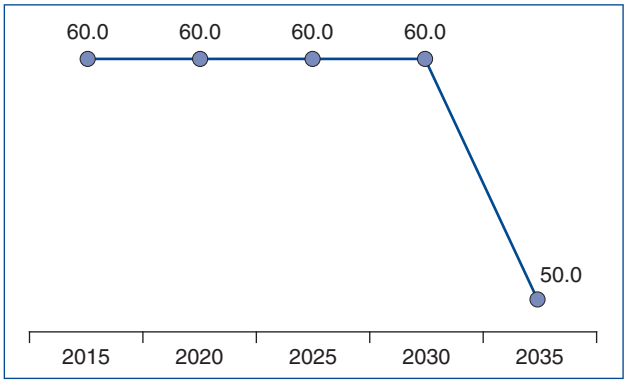

**Changes in the share of RES in electricity generation, %**



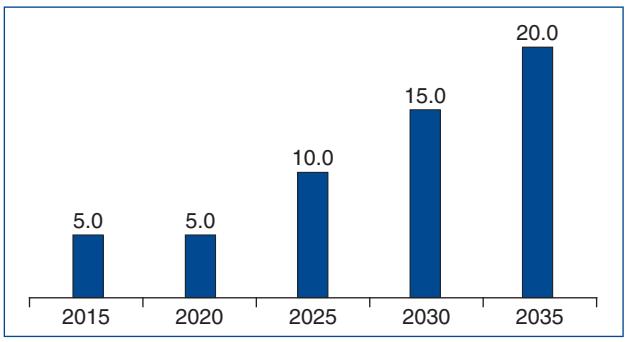

**Changes in the share of local alternative fuels in local fuel and energy mix, %**



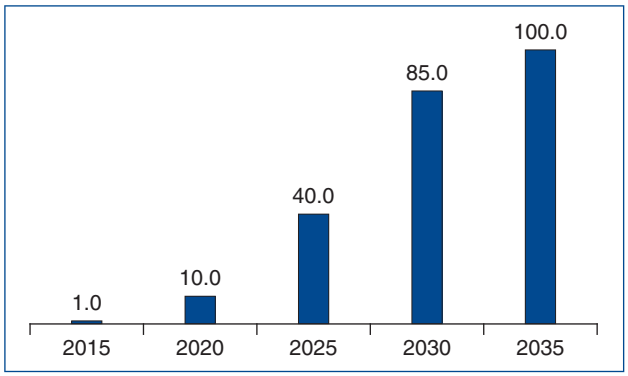

**Changes in $CO_2$ emissions compared to 1990, %**



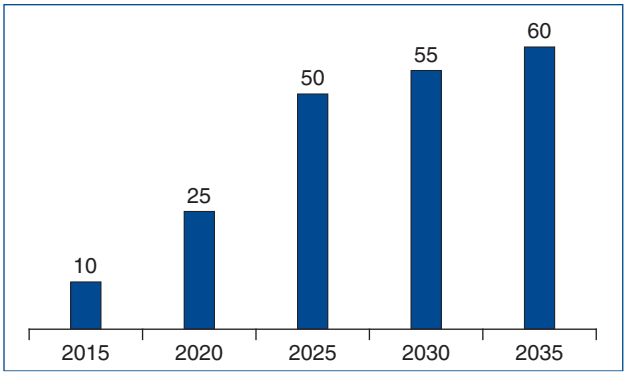

**The reduction of $CO_2$ emission in final fuel consumption as compared to 2010, %**



**Changes in the share of heat generation capacities meeting the EU environmental requirements, %**




**Changes in the share of exchange trade in energy resources, %**




It should be noted that according to the Ministerial Council of the Energy Community, Directive 2012/27/EU emphasises the need to increase energy efficiency to 20% by 2020 (instead of 9% set in previous directives) with annual decrease in total energy consumption. The directive also provides for renovation of buildings, energy audit, improvement of heating and air conditioning systems efficiency and introduction of energy efficiency financing mechanisms. According to the document, each Contracting Party should implement provisions of this Directive in its national law, defining the national energy efficiency targets and updating strategic objectives every three years – in 2017 and 2020.

The Cabinet of Ministers of Ukraine Directive No.1228-r dated 25 November 25 endorsed the National Energy Efficiency Action Plan (NEEAP) of Ukraine Until 2020. This important document introduces the European practice of mid-term planning of the state energy efficiency policy and approves the plan of measures to implement NEEAP until 2020, which is one of the key obligations under Directive 2006/32/EC. According to NEEAP, it is planned to achieve energy saving in 2020 at the level of 9% of average final energy consumption by implementing measures in four main sectors: household (residential buildings) – 50%; transport – 9%; public services sector (including public buildings) – 16%; and industry – 25%.

**Key energy saving measures include investment in thermal modernisation of residential buildings and construction of nearly zero-energy buildings; adapting the fuel standards and fuel use technologies to European ones; introducing the buildings energy efficiency certification, energy audit and energy management, as well as 100% commercial metering of gas, electricity, heat and water consumption.**

During 2015-2016, Ukraine adopted a regulatory framework to introduce energy service companies (ESCO) in the budget sphere. In particular, the Law of Ukraine "On Amendments to the Budget Code of Ukraine on Introducing New Investment Opportunities and Guaranteeing the Rights and Legitimate Interests of Business Entities for Large-scale Energy Modernisation" allowed budget holders to accept long-term obligations under the energy service. Also, several bylaws have introduced the sample energy service agreement, a methodology for determining basic consumption level, etc.

**Ukraine should expect a sustainable expansion of all renewable energy sources, which are to become an instrument for achieving the energy security of the state. The ESU-2035 projects that renewables will account for 12% of total primary energy supply in the short- and medium-term perspective (until 2025), and no less than 25% by 2035 (including all hydropower capacities and thermal energy).**

Wind and solar energy will continue to grow. Given further cheapening of renewables, their economic feasibility will increase. Moreover, growth in renewable energy among consumers shall not be subject to energy system restrictions and facilitate a dynamic local development. The state policy should encourage the initiative of private market players. Efforts to de-centralise renewable energy (e.g. photoelectrical systems and solar collectors on the roofs of residential buildings) with an estimated capacity of about 5% of electricity consumption by the population, should also be promoted.

The electricity and heat generation sector is expected to increase the use of biomass and biogas, which results from a relative production stability (if the resource base is available) and local generation development.

Preference is given to simultaneous production of thermal and electric power in co-generation facilities and replacement of hydrocarbon fuels.

Based on non-fuel technologies, hydropower will continue to play an important role in stable functioning of Ukraine's UES since it provides the energy system with highly flexible capacities for regulating daily load schedules covering peaks and filling night gaps. Moreover, it performs an important function of emergency capacity reserve.

By 2025 it is necessary to upgrade the existing HPPs and to build new hydroelectric generators in order to preserve the most economically viable and flexible units for power generation, as well as increasing their capacity.

Major activities aimed at implementing strategic goals in the renewables sector include: pursuing consistent and predictable policy as regards facilitation of SPP and PSPP construction; arranging international communication campaigns to attract international strategic and financial investors to Ukraine's renewable energy market; constructing and putting into operation of 5 GW RES capacity (excluding high-power HPP); increasing the use of biomass in electric and thermal generation by:

- promoting the use of biomass as a fuel by companies generating biomass as a residual product;
- informing about possible use of biomass as a fuel in individual heating;
- promoting competitive biomass markets.

Ukraine also needs to adopt a new European approach to research and development in the energy sector, as well as transport innovations and programmes designed to accelerate technological transformations in relevant industries.

All activities should focus on the following priorities:

- introducing technologies for the use of renewables, including environmentally friendly production and use of biomass and biofuels, as well as building powerful energy storage systems;
- introducing technologies and practices for attracting consumers for shifting towards smart grids and smart metering, smart home appliances, smart cities and home automation systems;
- introducing efficient energy systems and developing technologies to retrofit the existing housing stock to a high energy and gradual transition towards energy efficient buildings;
- introducing new carbon capture and storage (CCS) and carbon capture and utilisation (CCU) technologies in energy and industrial sectors, which will be essential and economically viable for achieving the climate goals to 2050. This would also require introducing a system for emission quotas trading, allocating funds for environmental programmes, and increasing business and investment transparency.
- introducing more sustainable and energy-efficient transport systems that consistently adopt innovative technologies and services to improve energy efficiency and reduce GHG emissions, as well as introducing municipal and individual passenger and freight EVs (Box "*Electric Vehicle Industry in Ukraine*").

### ELECTRIC VEHICLE INDUSTRY IN UKRAINE

Electric vehicles in Ukraine have become increasingly popular in recent years. The most popular EVs in the market are *Nissan Leaf*, *Renault Fluence* and *Tesla Model S*. Electric public transport was also introduced in Ukraine, as in January 2016 the Lviv-based Electron factory manufactured the first electric bus. The Cabinet of Ministers, the National Police, Ukrposhta, NEC *Ukrenergo*, DTEK and many others also plan to adopt zero-emission vehicles.

In general, the global EV market can grow significantly. J.P. Morgan[1] estimates that electric cars would account for 35% of the global market by 2025, and at least 48% (about half!) of the motor vehicle market by 2030. Given adequate development of relevant service infrastructure, Ukraine is expected to follow the global EV expansion trends, yet with a potential lag of 5-10% in relevant years.

Starting from 2013, Ukraine demonstrates consistent growth in EV sales. The Q2 2017 electric car sales topped the previous quarter by 27% and soared by 187% compared to Q2 2016. In general, for the first 6 months of 2017 as many as 1,668 EVs were registered – a 165% growth compared with the same period of 2017. By mid-2017, the total number of registered electric cars in Ukraine reached 3,818. By EV sales growth Ukrainein 2016 outperformed such developed automobile nations as the United States and Japan. However, Ukraine remains a "basement dweller" by the number of electric cars per person compared to the EU (one EV per 92 thousand in Ukraine, compared to 1,400 in France, 2,700 in Germany, and 13,000 in Italy).

Due to a widespread poverty and poor infrastructure, the EV expansion in Ukraine faces additional challenges. Because of limited driving range, potential EV owners are often unsure whether they will be able to charge car battery outside large cities. By the number of charging stations to the territory ratio, Ukraine is not far behind other Eastern European countries. As of March 2017, Ukraine had about 600 charging stations – just 8.5% of more than 7,000 petrol stations operating at the beginning of the year. These figures fall far behind Denmark – the global leader in EV infrastructure, where the number of EV charging stations is equal to the number of petrol stations. One should also consider the uneven use of EV, as the vast majority of 4,000 electric cars currently registered in Ukraine run in the largest cities – Kyiv, Odesa, Kharkiv and Dnipro.

Various government solutions are being elaborated in Ukraine to support citizens who are ready to replace their petrol cars with environmentally friendly vehicles. Important incentives in this context are the introduction in 2018 of zero customs duty and zero VAT on electric cars imports as well as postponed accounting of VAT on innovative vehicles to bolster the development of EV infrastructure.

**The innovative transition to a low-carbon economy is expected to open up broad opportunities for economic growth and job creation. The EU's technological leadership in this area will also encourage Ukraine to follow the EU standards. This move goes hand in hand with deployment of new technologies in the domestic energy sector and related industries.**

[1] *Source*: Available at: *https://www.cnbc.com/2017/08/22/jpmorgan-thinks-the-electric-vehicle-revolution-will-create-a-lot-of-losers.html*.

# UKRAINE'S ENERGY SECTOR TRANSITION: CONCLUSIONS AND RECOMMENDATIONS

1. In 2016, the global primary energy consumption reached 13.28 billion toe, which is 2 billion toe (or 18%) more than in 2006. The largest energy consumers are China, the United States, India, Russia and Japan. Altogether they accounted for 54.1% of the total energy use in 2016. China and India are the main drivers of increasing global energy consumption. Meanwhile, Ukraine's share was 0.7%. Over the past decade, most of the growth in energy consumption (3.7%) comes from developing economies. By contrast, the developed nations (OECD countries) have steadily reduced the annual use of energy resources by an average of 0.3%.
2. The -36% rate makes Ukraine a global leader in reducing the energy use in 2006-2016. However, this decline was due to the dramatic drop in GDP rather than increased energy efficiency measures. Another reason for such a decline in consumption is the annexation of Crimea and Russian-backed conflict in eastern Ukraine (2014-2017).
3. In 2006-2016, the global energy industry was marked by a growing potential of renewable energy. The share of renewables in final energy consumption over this period increased significantly, reaching an average annual growth rate of 16%. Renewable energy consumption has increased from 93.2 to 419.6 mtoe, or by 4.5 times. This clearly demonstrates competitive advantages of RES over traditional energy sources.
4. Despite the growth of renewable energy, fossil fuels continued to dominate the global primary energy consumption sector. Their share in total energy consumption in 2016 reached 85.7%, decreasing by only 1.7% compared to 2006. Specifically, the share of natural gas increased from 22.9% to 24.1%, while the shares of oil fell from 35.2% to 33.3% and that of coal – from 29.4% to 28.1%.
5. Among all fossil fuels, only natural gas has good chances of improving its position in the global energy mix owing to its environmentally friendly benefits.
6. Over the past two years, global demand for coal has dropped from 3.89 to 3.73 billion toe, or by 4%, although it grew steadily by an average of 2% annually during 8 years before that. This may suggest the emergence of a growing trend towards reduced global demand for coal, linked to measures aimed at combating climate change globally.
7. The primary energy mix in Ukraine in 2006-2016 has changed substantially. First of all, there was a dramatic reduction in the share of natural gas – from 60.3% to 30%. The same is true for oil, which share in global energy consumption fell from 14.2% to 10.5%. By contrast, the share of nuclear energy has increased from 14.8% to 21.1%, which is mainly due to a general decrease in primary energy consumption, rather than the improved efficiency of nuclear power use. If we compare the consumption of low carbon fuels in Ukraine with global data, we will see that Ukraine has a significant advantage in this respect, as the share of low carbon energy in Ukraine is 53% vs 38.6% globally.
8. The Ukrainian energy sector as an integral part of the global energy industry cannot stand aside and ignore the global energy transformations underway. Ukraine should focus not only on present-day priorities but also on meeting challenges that will shape its future transition, taking into account global energy trends.
9. The European market may soon welcome another strong player, as the President Trump's Administration actively promotes the idea of increasing LNG supplies from the US to world markets, and particularly to Europe. The "shale revolution" has enabled the United States to export up to 50 bcm of LNG to Europe over the next 5-7 years. The realisation of this potential, however, will depend on two key factors – commercial competitiveness of American LNG and the ability of the EU's leading political forces to recognise that reducing gas supplies from Russia is central to ensuring the energy security.
10. It will be difficult for American exporters to oust *Gazprom* from the EU market because Russia will do its best to prevent this from happening by dumping and employing previously established corrupt schemes with some representatives of the European political and business elites. Intensified support of the *Nord Stream 2* gas pipeline project by Germany, France, Austria and the Netherlands is a vivid example of such actions.

11. In 2006-2016, Ukraine demonstrated the highest reduction in gas consumption in the world. During this period, it has dropped from 67 bcm to 29 bcm, or by 2.3 times.[1] The main reason for that was not energy efficiency but rather the decline in industrial production. A significant rise in gas prices also resulted in reduced consumption.

12. 2016-2017 was the first period ever when Ukraine ceased importing natural gas from Russia. This was achieved thanks to a continued and effective diversification of supplies from the EU. Ukraine's access to Polish LNG terminal *Swinoujscie* in the Baltic Sea by 2020 would be another effective step to diversification.

13. Ukraine owns 0.6 trillion cubic meters of proved gas reserves, and if compared with the EU countries, it is second only to the Netherlands in this regard. Ukraine's projected resources amount to 3.5 trillion cubic meters allowing the country – given favourable investment climate – to increase production to 30-32 bcm/y by 2025 and almost fully meet the domestic demand for natural gas with own production.

14. In the past 10 years, Ukraine also demonstrated a downward trend in coal consumption, as it fell from 39.8 mtoe in 2006 to 31.5 mtoe in 2016 – a 20.8% reduction. This decline in consumption was particularly noticeable in 2014-2015 as a result of hostilities in Donbas that led to a damage and in some cases – loss of mining assets. Ukraine suffered serious damages following the unlawful seizure of the DTEK property by militants in non-government-controlled areas in March-April 2017.

15. The deficit of coal, especially anthracites, causes shortages at TPP, which in turn threatens the stability of the Unified Energy System of Ukraine (UES). All these factors force Ukraine to increase coal imports. In 2016, Ukraine imported this fuel in the total amount of $1.47 billion – mostly from the Russian Federation, the United States, South Africa and Canada. To reduce import dependency, DTEK increases investment in extraction of gas coal and in TPP retrofitting to be able to use gas coal instead of anthracite. PJSC *Centrenergo* also invests heavily in TPP modernisation.

16. Until 2016, the formation of coal prices in Ukraine was based on the "cost plus" approach, rather than on market principles. This approach negated any incentives for coal mining companies to reduce their costs, while industry revenues were not distributed efficiently. In 2015 NEURC proposed a pseudo-market pricing model, where the cost of coal was tied to the "Rotterdam+" price formula.

17. The idea of introducing domestic market prices based on the price parity with the European stock exchange - until fully functioning stock exchange is established in Ukraine – can be considered correct, as evidenced by a rather effective similar model developed for the gas sector. However, the Rotterdam+ formula, due to certain methodological errors, does not reflect current market situation and causes waves of criticism from the expert community, thus it needs to be upgraded based on the expert consensus.

18. OECD countries have been in the process of liberalising their electricity markets for over 15 years. The development in electricity exchanges designed to improve competition and transparency for the benefit of consumers was one of the most important elements in this process. Europe's leading energy exchanges – *EEX* (Germany), *EXAA* (Austria), and *POLPX* (TGE) (Poland) reveal gradual decrease in electricity prices in 2011-2016 from €63/MWh to €17/MWh (in the first half of 2016).

19. Eliminating price imbalances and moving towards liberal electricity market based on the Third Energy Package will depend on how effectively the country will implement the Law of Ukraine "On the Electricity Market" adopted in April 2017. In particular, this law provides for the launch of all segments of the electricity market, including the day-ahead market, the intraday market, the balancing market, the market of bilateral contracts, and the market of ancillary services.

20. Approximately 1.2 billion people (about 16% of the global population) still live without electricity. The vast majority of them are in sub-Saharan Africa and Oceania. Renewable energy sources are the most effective means to overcome energy poverty, since they can be effectively applied at the regional and local level using local preferences, primarily solar, wind and biofuel energy without the need to build additional high-voltage power networks.

21. The Paris Agreement, which objective is to limit the increase in global average temperatures to well below 2 °C, was a milestone in accelerating the renewable energy industry. Through climate commitments (*Intended Nationally Determined Contributions*), more than 150 countries worldwide have formulated their policies to catalyse clean energy investment. The concept "Transforming Our World: The 2030 Agenda for Sustainable Development" adopted at the 70th Session of the UN General Assembly in September 2015 is another event that deserves attention, as it calls to substantially increase the share of renewable energy in the global energy mix.

22. If compared to 2015, the global renewable energy generation capacity increased by 161 gigawatts (GW) (or by almost 9%) in 2016. It was the largest growth ever, in absolute terms. Inclusive of hydropower,

[1] This does not include process gas used by the Ukrainian GTS.

renewable energy accounted for over 30% of the total global installed power generation capacity and reached 2,017 GW. The amount of solar power added worldwide soared by 47% in 2016, while wind and hydropower accounted for 34.5% and 15% of new capacity.

23. Despite the enormous potential of renewable sources estimated at 68 mtoe, Ukraine currently uses it at 5%. According to the Energy Strategy (and in line with the Energy Community Treaty, and the National Renewable Energy Action Plan until 2020) the share of renewables in final energy consumption should reach 11%. It is clear, however, that this task was rather politically motivated with no prior assessment of realistic investment opportunities. In other words, Ukraine is unlikely to reach this target.

24. Ukraine's tariff policy for renewables currently has serious defects, as it does not reflect the global trend towards rapidly falling renewable power generation costs. The share of RES in UEM revenues, which is derived from the WEP structure, more than 3.5 times exceeds the share of electricity produced under the "green tariff". Introduction of tariff auctions for investors could be an effective mechanism to promote a competitive tariff model for renewables.

25. Key global energy trends promoting innovation until 2035 include:

    - decarbonisation of the power industry through accelerated development of energy generation from renewables and reduced energy intensity of production;
    - reduced cost of energy accumulation and increasing storage volumes;
    - transition towards mass manufacturing of electric vehicles;
    - decentralisation of energy supply, particularly by managing energy consumption;
    - deeper penetration by new generation digital technologies into the energy production and distribution (digitalisation), including cloud computing, Big Data processing and analysis, Blockchain, the Internet of Things; smart grids.

26. The world energy investment by 2035 is expected to increase by 1.72 times compared to the period of 2000-2013. This amounts to $48 trillion of total investment, including over $39 trillion going to the power sector, and over $8 trillion spent on energy efficiency.

27. In the period until 2035, global primary energy consumption will increase from 13.15 billion toe in 2015 to 17.16 billion toe, or by 31%. The share of oil in global energy consumption in 2015-2035 will drop from 32% to 27%, and that of coal – from 29% to 22%. Instead, the share of renewables will increase substantially from 3% to 14%. Therefore, it is projected that the total share of fossil fuels in global energy use will decrease from 85% in 2015 to 74% in 2035, making a significant contribution to the global community's action on climate change.

28. The cost of building new solar and wind power plants is expected to continue to fall in 2015-2035. The cost of solar power projects will reduce at a much slower pace compared with wind power generation, because the innovative potential of wind turbines are currently thought to be higher than that of solar PV modules. The onshore wind turbines are particularly competitive in this regard.

29. In pursuance of the objective of the Paris Agreement, in September 2015, Ukraine has updated the UNFCCC Secretariat on its INDC, setting the target not to exceed 60% of 1990 greenhouse gas emissions level by 2030. It should be noted that the Paris Agreement calls on the parties to periodically review their emission reduction targets, and for this purpose introduces a cyclical mechanism for them to update their benchmarks. This means that each Party shall communicate a Nationally Determined Contribution (NDC) every five years to the UNFCCC Secretariat to replace the Intended Nationally Determined Contribution reported in 2015.

30. The greatest potential for Ukraine to meet its Paris Agreement commitments is primarily linked to attaining one of ESU-2035 indicators on reducing by 2035 the energy intensity to 0.13 toe/thousand dollars (PPP) – a double reduction since 2015. It is also essential to reduce GDP per greenhouse gas emissions to the level of V4 countries.

31. Recent important changes to the national legislation are the key to strengthening environmental focus in developing Ukraine's fuel and energy complex. The most important of them are the Laws of Ukraine "On the Energy Efficiency of Buildings" and "On the Energy Efficiency Fund" (both entered into force in July 2017) as they were developed in the context of relevant directives, regulations and recommendations of the EU and the Energy Community Secretariat.

32. The list of energy sector reforms needs to be finalised in a single document outlining the government energy policy both in short- and long-term perspective. As of today, the updated Energy Strategy of Ukraine until 2035 (ESU-2035) – approved by the Cabinet of Ministers in August 2017 – represents such a systemic document.

33. Key objectives of the ESU-2035 include:
    - ensuring energy security of the state by diversifying energy supplies, increasing domestic hydrocarbon production, creating strategic oil reserves and improving the reliability and stability of the fuel and energy complex;
    - decarbonising the economy through increased energy efficiency and renewables expansion;
    - developing competitive and transparent energy markets based on the principles of the EU's Third Energy Package and creating favourable conditions for investment;
    - integrating Ukraine's power grids and energy markets in the EU.
34. The development of Ukraine's energy complex until 2035 will be based on nuclear and gas scenario plus renewables. The RES share is expected to increase by more than six times from 4% in 2015 to 25% in 2035. Meanwhile, the share of coal will reduce gradually from 30% in 2015 to 12.5% in 2035, or by 15 mtoe, which perfectly correlates with the European concept of low carbon development.
35. Following the expected economic recovery and integration of Ukrainian and EU energy systems that will bolster Ukraine's export opportunities, there will be gradual growth in electricity demand and production. In 2020-2035, the average annual growth of electricity production is expected to slightly exceed 2%.
36. To achieve the ESU-2035 goals related to integration of the national gas transmission system (GTS) in the European network, a set of measures needs to be taken to ensure maximum reliability, openness and transparency of the national GTS operator. Implementing these measures would, above all, require separating the GTS operator from the vertically integrated company, thus contributing to a non-discriminatory and transparent access for market participants. Clearly, it is also necessary to optimise the capacity and technological parameters of GTS functioning in compliance with expected utilisation scenarios and to introduce the European energy legislation, including the EU network codes and guidelines and the best business practices of the European GTS operators.
37. It is very likely that by 2019 inclusive the volume of the Russian gas transit will range within 60-90 bcm/y. At the same time, to date there is no documentary evidence confirming transit of the Russian gas through the territory of Ukraine beyond 2019. Instead, *Gazprom* together with its European partners gradually implements own projects to build alternative gas transit routes to Europe (increased transmission via the *Nord Stream*; access to the *OPAL* pipeline; construction of the *Nord Stream 2* and *Turkish Stream*).
38. It is expected that the volume of gas transmission for Ukrainian consumers will amount to 26-30 bcm/y with the share of European energy companies in gas transit through Ukraine exceeding 50%. At the same time, the share of foreign companies storing their gas in the Ukrainian UGS facilities will be no less than 20%.
39. By 2035, it is planned to complete the coal industry reform programme, including the reform of the state-owned mines:
    - privatisation of promising state-owned mines prepared during the first phase;
    - liquidation/conservation of ineffective and loss-making mines with implementation of social and environmental mitigation plans for each facility;
    - realisation of the social reconversion programmes for mine closure regions;
    - introduction of a competitive coal market.
40. Connecting the Ukrainian and Moldovan energy systems to ENTSO-E will expand the range of power exchange to 2,350 MW towards Europe and up to 2,000 MW towards Ukraine and Moldova. In the future, if appropriate measures are taken by Ukraine and relevant European system operators, the volume of mutual power exchange with ENTSO-E can increase to 4,000 MW, which means at least €1.5 billion of additional revenues from sale of both electricity and ancillary (system) services.
41. By 2035, capacities providing close to 80% of current production (20-25 GW) may be taken out of operation with no opportunity for operational period extension. Considering the time needed to design and construct new capacities to replace them (including flexible capacities) for balancing the energy system, decisions on the targeted configuration of capacities that will be operational after 2035 should be approved before 2020.
42. Efforts to improve the effectiveness of NEURC functioning in 2018-2019 by ensuring predictability of the rotation system for the Commission members, improving their professionalism and eliminating unlawful interventions by other government institutions, political parties and commercial structures are essential for creating competitive markets in Ukraine that benefit the consumers and attracting sufficient investments to modernise the country's energy infrastructure.