Chapter 1

Introductory Chapter: New Trends and Recent Developments for Thermal Power Plants

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Additional information is available at the end of the chapter

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1. New trends and challenges

The largest share of sources for electricity generation still belongs to fossil fuels such as coal, natural gas, and oil. Conventional thermal power plants based on the fossil fuel combustion are currently facing new challenges. The challenges and recent activities mainly result from the development of technologies that use renewable energy sources and activities aimed at reducing the emission of harmful substances into the atmosphere.

The new challenges are a decisive impulse for introducing changes in power plants and combined heat and power plants, as well as for the implementation and continuous development of new technologies allowing for the electricity and heat production in the least harmful way to the environment. In recent years, many activities have been observed to reduce pollutant emissions and optimize the performance of thermal power plants. Ensuring a continuous supply of electricity and heat is necessary and requires a continuous monitoring of all processes and conduct of maintenance and optimization works.

Based on the data provided by International Energy Agency [1], we can observe how electricity generation during almost last 50 years is changing (**Figure 1**). Total electricity generation was increased almost 6 times, reaches in 2015 value 24,255 TWh, with the share of fossil fuel on the level around 66% (75% in 1973). The share of renewable energy sources (**Figure 1**) includes mainly geothermal, solar, wind, ocean, biofuels, and waste was increased from 0.6 to 7.1% of total electricity generation sources. Despite these changes and the intensive development of technologies based on renewable energy sources, fossil fuels still dominate. The values presented in **Figure 1** confirm current trends indicating the continuous use of coal (39.3% in 2015) as the main source and a large increase of natural gas utilization (22.9% in 2015).

The use of various sources for the electricity generation is strongly diversified and depends on the geographical location which determines the possibility of using renewable resources, as

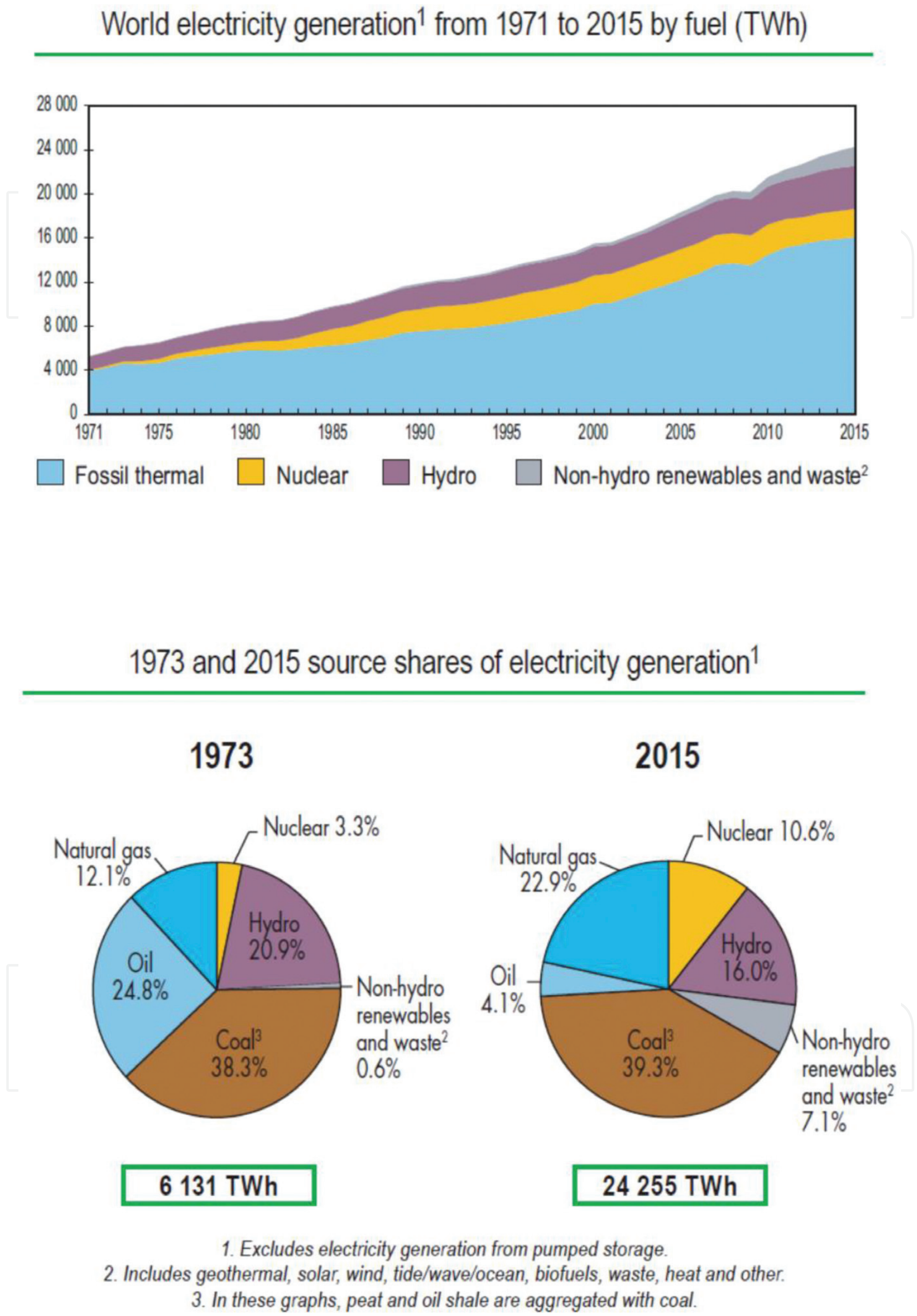

Figure 1. World electricity generation by fuel between 1971 and 2015 [1].

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well as on the availability of fossil fuels (coal, gas). The next very important factor is the change in the demand for electricity, which is conditioned by the development dynamics of individual regions of the world. **Figure 2** presents data illustrating changes in the quantities of electricity produced in particular regions of the world. It is noticeable that in recent years, the increase in electricity generation has changed in many regions of the world with different rates. Organization for Economic Co-operation and Development (OECD) countries have the largest share all the time (44.7% in 2015), but for some time the rate of growth has decreased and this level is almost constant.

Coal-fired power plants currently face a big challenge to reduce the level of gaseous pollutants and to adopt new flue-gases treatment methods and devices. Regulations for reducing NO_x, So_x, and dust emissions become more strict [2], and the required limits of gas emission levels are different for old and for new units. In case of old units, with the fuel power above 300 MW, permitted emission levels have been changed during last year's [2]. The upper limits of the average annual values for pulverized coal-fired boilers and for sources above 300 MWt are presented in **Figure 3**. In addition to these values, the future regulations can also include limits of emission levels for HCl, HF, Hg, and NH_3, as well as CO indicator levels. Emission limit values are developed every few years based on the best available techniques (BATs) that exist or will be available in the future.

Due to mandatory environmental regulations, coal-fired power stations in many countries need to install denitrification plants ($DeNO_x$) for nitrogen oxide (NO_x) and desulphurization plants ($DeSO_x$) for sulfur oxide (SO_x) removal from the flue gases. The most popular methods for removing sulfur oxides from exhaust gases are calcium methods. There are several types of this calcium method such as dry, semi-dry, but the Wet Flue Gas Desulfurization (WFGD) method is the most common technology for SO_x control. The reduction of NO_x emission levels is currently possible using primary and secondary measures. Primary measures are used inside the combustion chamber including methods as proper selection of the excess air ratio and temperature, modification of combustion techniques (re-burning, exhaust gas recirculation, air staging, cooling the flame and burners re-design). The use of primary measures allows to reduce NO_x emission with an efficiency about 35%, so in many cases is not enough to meet the environmental concerns. The other solution is to use secondary measures of NO_x reduction, such as Selective Non-Catalytic Reduction (SNCR) and Selective Catalytic Reduction (SCR). These techniques based on the auxiliary installations are located behind the boiler combustion zone. Secondary measures are more effective than primary methods and NO_x reduction efficiency can reach about 50 and 95% for SNCR and SCR techniques, respectively. Many research activities are currently focused on the developed methodology of prediction and assessment [3–6], optimization [7–10], and improving the efficiency of NO_x reduction using primary as well as secondary measures.

However, to avoid efficiency reduction of the production process by applying these methods, the thermal efficiency of the boiler needs to be constantly at a high level. It is necessary to perform optimization work of combustion process using dedicated and novel measurement techniques, optimization algorithms, consequently developed by many researchers and boilers

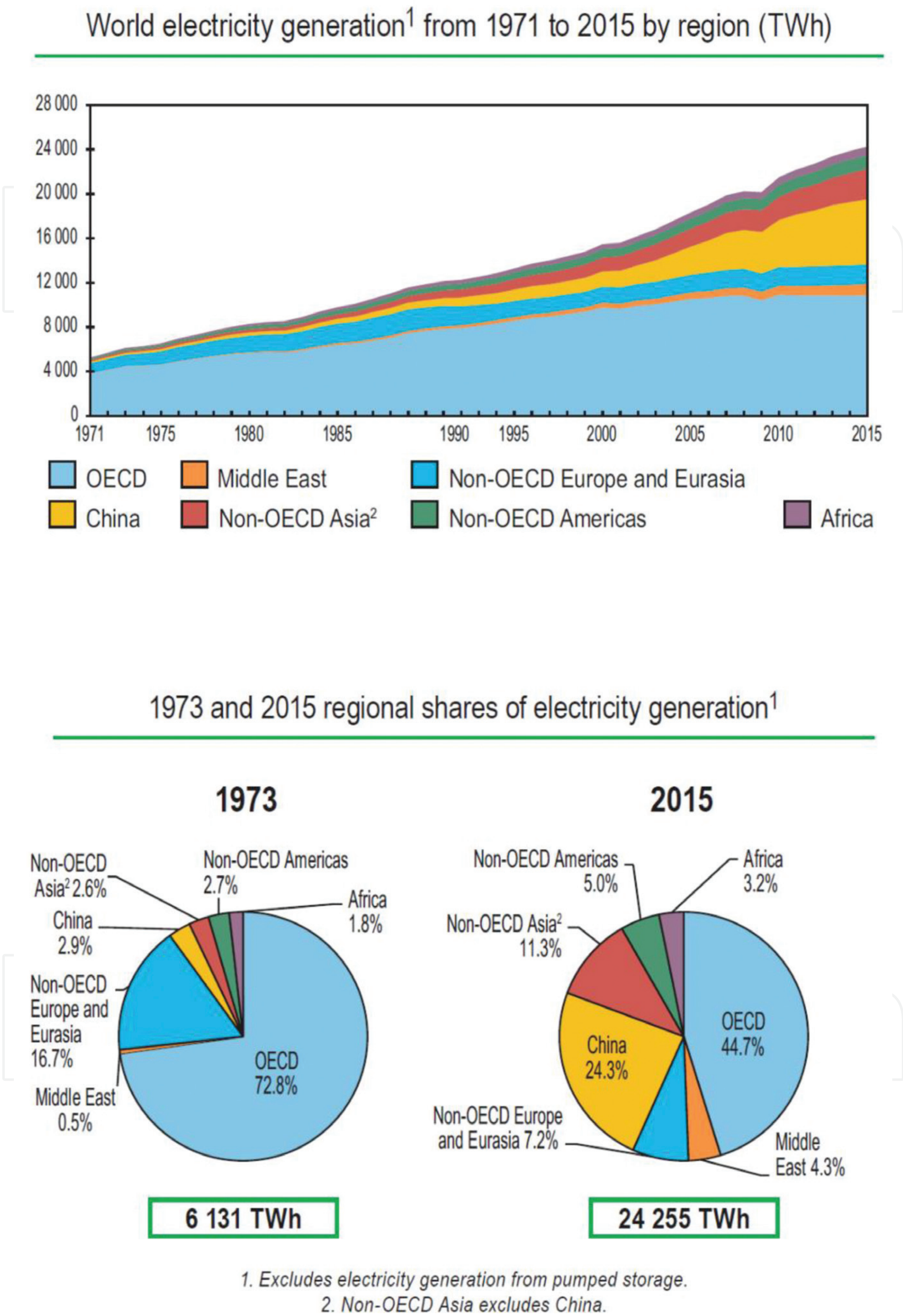

Figure 2. World electricity generation by region between 1971 and 2015 [1].

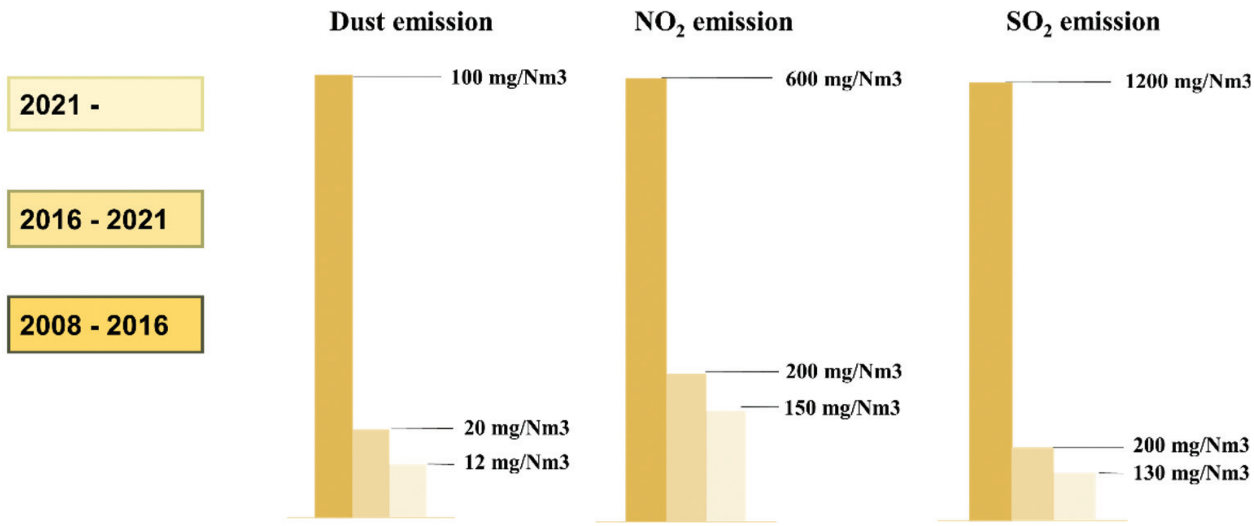

Figure 3. Emission limit values (mg/Nm^3) for SO_2, NO_2, and dust for fossil fuel-fired power plants using solid or liquid fuels with the exception of gas turbines and gas engines, and for the total nominal power delivered in fuel >300 MW.

manufacturers [11–18]. Introduction of primary and secondary measures for NO_x reduction can result in a higher level of carbon in fly ash. Many research activities are observed regarding the quality of fly ash [19, 20] and its potential utilization [21, 22] as well as ash monitoring and optimization of cleaning methods of ash deposits formation inside the boilers [23–30].

Currently, one of the big challenges is to assess the possibilities of CO_2 capture and to develop a technology that allows limiting the emission of this greenhouse gas. For this reason, many theoretical studies, as well as experimental work, have been carried out, among others in order to evaluate the possibilities of CO_2 capture, and the impact of applying technology on production efficiency in both old production units and newly built [31–35].

The increased share of electricity produced from renewable energy sources [36] requires from coal-fired power plants more flexible operation to balance power grids and compensate the variable electricity demand [37]. Coal-fired power plants need to adopt these requirements and to operate in the flexible regime. Flexibility in the power plants operation is characterized by the necessity of frequent load changes, the need to work outside the nominal operating conditions, and the need of more frequent power units start-ups as well as shortening the time of start-up, shutdown or changing a partial load. The necessary flexibility can be achieved with acceptable impacts on component life, efficiency, and emissions but it needs continuous monitoring and controlling of basic operating parameters [38–47]. In **Figure 4**, the forecasted electricity generation (2012–2040) based on renewable energy sources is presented.

In recent years, an intense increase in the use of gas-fired systems can be observed. Gas-fired plants are characterized by high efficiency and the ability to provide fast response to variable electricity demand. Production of electricity and heat using gas technology is widely used in the power industry, and from year to year more and more units start the operation [48–50]. The efficiency of the gas turbine is mainly responsible for the high efficiency of the system, as well as the ability to quickly change the load and operate under high flexible regime [51, 52]. Ensuring

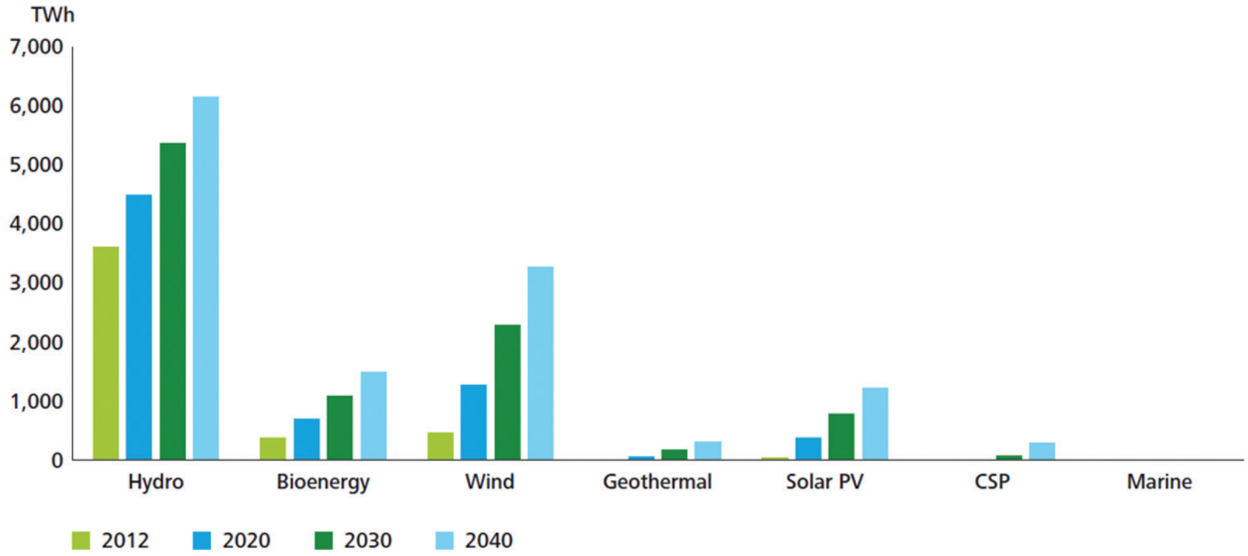

Figure 4. Electricity generation by sources (2012–2040) [36].

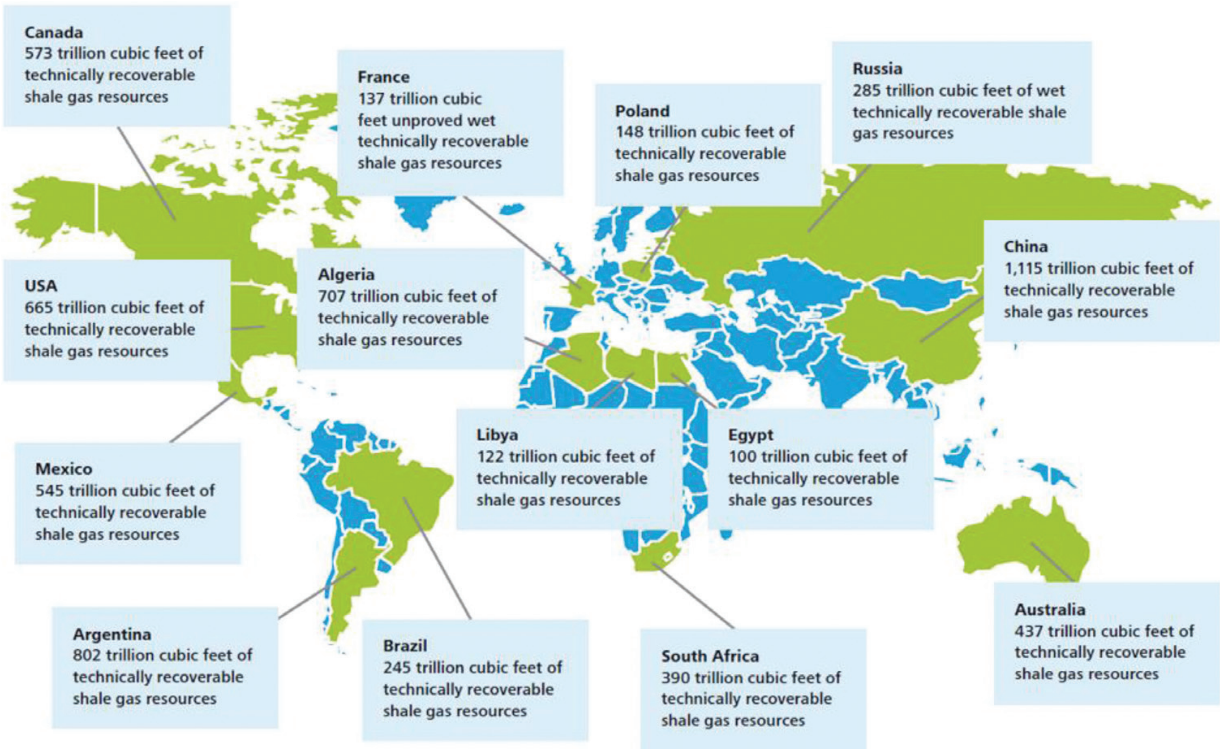

Figure 5. Shale gas resources [36].

the optimal operating conditions together with the changing demand requires the use of proper tools for monitoring and optimizing the production process.

For several years, it has been observed a great interest in the growing possibilities of obtaining gas from the unconventional gas resources. The shale gas supply can play an important role and lead to a substitution of a coal-fired plant by gas-fired plants. In **Figure 5**, the technically recoverable shale gas resources are presented.

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Shale gas deposits belong to unconventional resources (tight gas, shale gas) and are under detailed consideration as a chance for replacing fuels from conventional resources. Finding of shale formations is easier than conventional, but exploitation of hydrocarbons is more difficult [53–56]. Nevertheless, on the basis of the data presented in **Figure 5**, it can be observed that the gas resources are located in every region of the world.

2. Conclusions

Nowadays, power companies need to modify their management method and models and adapt to strongly changing requirements and regulation on the electricity generation and sale market. Development of more marketable approaches focused on high-quality services needs to be prepared in a careful way. All activities need to be scheduled taking into account upcoming requirements maintaining optimal parameters and efficiency of all processes. The demand for electricity and heat production is still largely covered by conventional Thermal Power Plants which face a big challenge to meet the environmental requirements. Constant keeping high efficiency of processes, avoiding shortening of a critical component lifetime is one of the most important tasks to accomplish. Increased share of renewable energy sources enforces more flexible operation of existing Thermal Power Plants and the necessity to provide fast response to variable electricity demand. Because of these limitations, Gas Power Plants can start to play an important role, allowing for rapid change of load and to reduce the emission of harmful gas pollutants. New environmental restrictions together with the need for operation under changing load, requires constantly introducing new solutions and technologies, as well as carrying out research and development activities to create and implement new optimal solutions.

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