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Quo Vadis Power Engineering? A Slow Transition from Centralised Power Generation to Distributed Power Generation And what about Poland?

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Is the world's power engineering at a crossroads? Does the rapid development of new emerging fields such as the Internet of Things, smart city or e-mobility make us take a completely different point of view on the world's energy future? What are our visions and development forecasts related to this? Who is right, Exxon Mobil Corporation or the visionary investor Elon Musk? The author of this article is trying to find answers to these and many other questions. In the long-term perspective, a transition from centralised power generation to distributed power generation seems to be inevitable, and that is the central message of this article.
The article also presents the situation of the Polish power engineering against the background of global trends, as well as proposals for solving the smog problem using anti-smog technologies developed at the Institute of Fluid-Flow Machinery of the Polish Academy of Sciences in Gdańsk and by launching a pilot project that will cover 1,000 households equipped with these technologies. The author and his closest co-workers recommend equipping boilers, including both older and newer ones, with low-power electrostatic precipitators. In this way, one can burn low-quality fuels while keeping the emission of airborne dust at a low level. It is a quick and not pricey solution to the smog problem.

Keywords: world's power engineering, development forecasts, distributed power generation, anti-smog technologies.

1. A few thoughts about the world we live in

If we are asking ourselves the question given in the title of this article, I think the real question is "Where are we today?". Are we really justified in our fears of the world being at a crossroads? [1–7].

Firstly: Let us note that what we witnessed was **the most important demographic event in the world**: population more than doubled over a lifetime of a single generation (from 3 billion in 1960 to 6.5 billion in 2005). It will never happen again! The world's population will reach about 9 billion over the next 50 years and, what is worse, the population growth will be uneven. On average all over the world, it will be +40% (including -25% from Eastern Europe, +33% from the USA and +175% from Africa!). It means increased needs, including the increased demand for electricity, and if it is not possible to meet them, a rising tide of social unrest. It is estimated that the poverty area will disappear – there will be no more people living on one dollar a day – but drastic differences in the living standards of people from different parts of the world will remain. This will cause enormous social and political problems and unprecedented challenges for the world's power engineering.

Secondly: **The efficiency of the world's power engineering is dramatically low**. Figure 1 makes this fact clear. **We are able to produce only 9.5 units of effective energy** per 100 units of energy contained in the primary fuel (coal, oil or natural gas). The rest is lost in the form of power plants' losses, starting from pipelines, valves, through pumps, motors to transmission losses in power grids and local losses (see Fig. 1). Will new technologies that allow reducing energy losses emerge? We will see. NEGAWATTS (watts we save by conserving energy) are always cheaper than MEGAWATTS (generated watts). It gives an incentive for many countries to allocate huge financial resources for the broadly understood energy efficiency.

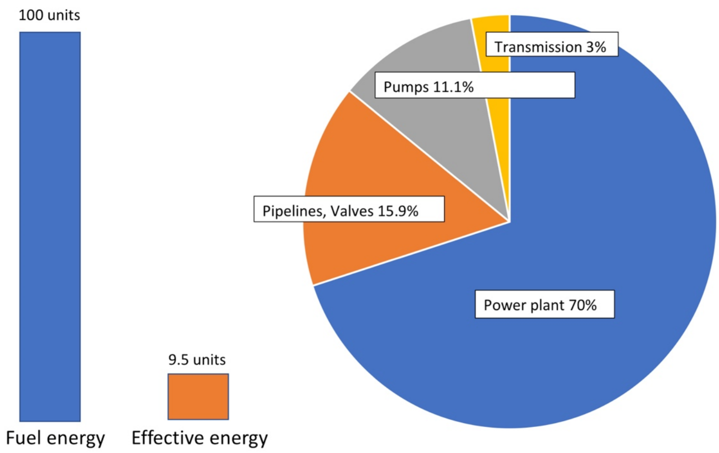

Figure 1 Low power conversion efficiency on a global scale – we are able to use only 9.5 energy units out of 100 energy units contained in primary fuels. On the right-hand side: accumulated energy losses, ranging from those at the power plant, through pipelines and valves, up to transmission losses

Thirdly: Of course, we are very much aware that **global reserves of fossil fuels are limited**. If we look at these reserves in more detail, assuming average global forecasts of their consumption, it turns out that **there could be as little as 50 *years of oil and gas* left and about 100 years of coal and uranium left** (Fig. 2). From the point of view of human civilization, these are relatively short periods of time!

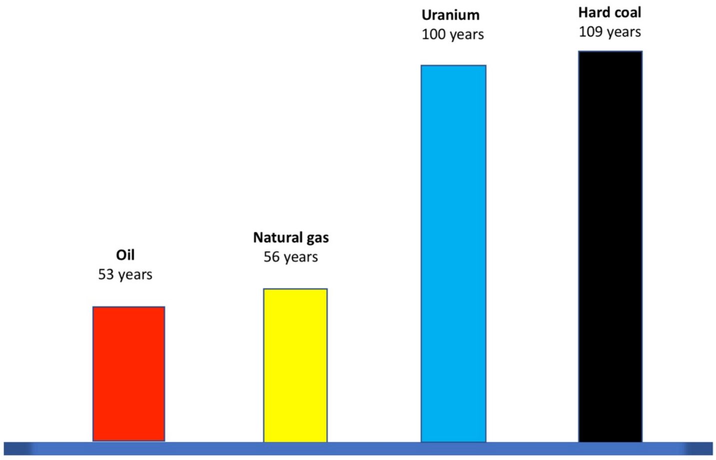

Figure 2 Average global reserves of fossil fuels

Considering the three above-mentioned facts (the demographic event, power conversion efficiency and scarce energy resources), there is an extremely urgent need for the world's power engineering to review previously determined paths of development and re-evaluate priorities. The only alternative in my view is **a large-scale energy crisis**. Pessimists announce: Don't ask **whether** a crisis will happen. Ask **when** a crisis will take place.

2. Visions, forecasts

When I am making predictions about what the future will bring I am thinking about how to solve one of the main problems of our civilization, that is, how to provide energy security for the generations to come. This is an extremely important need. Although there is a lot of publications on this topic, quite often they are contridictory to each other [1–7, 8–12], and there is no way to synthesise all these pieces of information into ideas.

Nevertheless, it may be worth quoting some opinions that may illustrate the complexity of this situation. These opinions were publicly expressed by individuals or institutions that could exert a strong influence on global energy markets. The author of this article has chosen only two extreme opinions, namely:

- **Exxon Mobil Corporation's** opinion, i.e. the opinion of the company that has a long history of leadership in the petroleum and petrochemical industries (it is said that this company is endowed with John D. Rockefeller's heritage [8]).
- **Elon Musk's** opinion, i.e. the opinion of a visionary investor, founder of PayPal, SpaceX and Tesla Motors, the man of whom there is a lot of talk about lately [9].

These two opinions, trying to reach forward to what lies ahead (up to 2040), can be summarised in several points as follows:
Exxon Mobil Corporation:

- Fossil fuels will not be depleted so soon (new reserves).
- In 30 years' time, people will continue to obtain roughly 80% of all energy from fossil fuels.
- Renewable energy source (RES) will constitute only a small fraction of global energy supply.
- There is no future for electric cars (there will be only 5% of them), the future lies in hybrid vehicles (every second car will be a hybrid vehicle).

Elon Musk:

- Future: distributed power engineering, energy production for own needs, production of integrated domestic systems – PV panels – energy storage – electric cars.
- Widespread electric transportation (elimination of pollution, drop in oil prices).
- Autonomous and self-driving vehicles.
- Sharing of vehicles.

It is easy to see that these two opinions are extremely different. Elon Musk outlined his future plans, among others, in a blog post entitled "*Master Plan, Part Deux*". With this, he gained both supporters and opponents.

On the basis of the above, it is concluded that when on is forecasting the development of power engineering – even when one is looking into not too distant future – **each opinion should be viewed as a subjective opinion** which in addition comes with a certain degree of uncertainty. This is confirmed by the fact that most of previous energy forecasts did not worked well, hence many experts negate the purposefulness of their elaboration.

All opinions expressed by the author in the following part of the article are also subjective in nature.

3. We need a new perception of the future of power engineering

There are some important aspects and circumstances underpinning a change in the way of thinking about power engineering and its future development. We must start with the fact that we are currently witnessing the rapid development of IT technologies, the Internet and mobile applications. The Internet of Things (IoT) is developing at a very fast pace. It is the network of various items, e.g. such as physical devices, vehicles, home appliances, etc., which can also include items connected to a *smart* and self-organising network. The Information and Communication Technology (ICT) revolution and the Internet of Things created conditions for the development of **Industry 4.0** (commonly referred to as the fourth industrial revolution). This is the new trend of automation and data exchange in manufacturing technologies. One of the tasks of the *Industry 4.0* concept covers the implementation of IT technologies for distributed and prosumer power engineering energy and *smart* energy management.

The second important aspect is electromobility (**e-mobility**) in a broad sense. The term electromobility includes not only fully electric vehicles, hybrid electric vehicles and those using hydrogen fuel cell technology but also, and maybe most of all:

- planning, modelling and management of local energy systems including electric vehicles as specific receivers/generators/storage of energy,
- a system of technical, organisational and legal solutions that enable the development of the ecological transportation.

This leads us to the important conclusions: (1) an electric vehicle is only a part of the energy management system in distributed power generation, (2) hybrid systems, synergy effects, energy storage and of course the electric vehicle itself could, in fact, form a ***Smart Energy System***, and thus the system with a bright future.

The term *Smart Energy System* can refer to both a single building and a housing estate. In the first case, the subject of analyzes is a technological solution such as a hybrid/modular system of energy sources for a single building. In the second case, considerations and implementations concern **energy clusters**, including especially monitoring of the local electricity and heating grids as well as the creation of various operational scenarios for specific real or virtual system solutions. In both of these cases, a *Smart Energy System* is a fine example how the Elon Musk's vision can become reality and, at the same time, an example of the distributed power generation.

And lastly, a mention can be made of the ***Smart City*** concept. In recent years, it has not only been a publication and conference hit, but also an example of the most spectacular results of activities undertaken by many cities, companies and organisations from around the world.

The *Smart City* concept has undergone an evolution marked by periods of its development. It is worth listing them.

Smart City 1.0 – early phase of the creation of smart cities – kind of like forcing it:

- creation of ICTs by large companies,
- no one asked mayors and residents whether it was necessary,
- result: ghost-towns like Masdar (UAE) and Songdo (South Korea).

Smart City 2.0 – local authorities are the initiators, selective use of ICTs, mobile applications:

- attempt to include the city into the *Internet of Things*,
- public WiFi networks, traffic control, big data, energy meters,
- drawbacks: excessive technocracy of cities, citizens fade into the background.

Smart City 3.0 – ***Human Smart Cities*** – active attitude of residents:

- solutions proposed by residents (open data),
- ecological and social issues, quality of life,
- sharing economy.

As can be seen from the above overview, it is necessary to ensure that the Internet of Things and ICTs (Information and Communication Technologies) do not become more important than the needs of residents. These technologies were developed to serve residents and not to be a testing ground for interested corporations, and the cities of Masdar and Songdo are eloquent examples of this manner of experimentation.

Of course, *Human Smart Cities* is a beautiful vision of the development of cities and a concrete target for inhabitants of the Earth to reach. It would be the implementation of the perennial human yearning for an improvement of living standards and thus the quality of life.

In the above considerations, we have omitted the role of traditional centralised power engineering. It is obvious that this way of energy generation will continue exerting a dominant influence on the energy security of our civilization for many years to come. Although it will be based on fossil fuels, changes in technologies will be necessary. According to many experts, the future lies in modern gas-fired power blocks, highly efficient coal-fired power blocks based on clean coal technologies (CCT) and gas-turbine/steam-turbine combined systems [13–16].

Let us formulate a rhetorical question: Are all these issues that we have just mentioned here, namely *Internet of Things*, *Industry 4.0*, *e-mobility*, *Human Smart Cities* and *Smart Energy System*, have an impact on the future development of power engineering and can they change our way of thinking about it? Yes, of course. It is demonstrated quite clearly in Fig. 3.

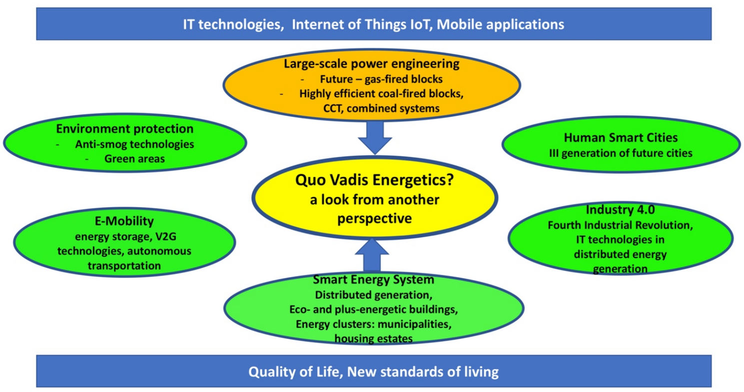

Figure 3 A new perception of the future of power engineering. Its development will be influenced not only by classical centralised power generation but also by new, rapidly developing fields that can completely change the traditional understanding of the role and meaning of the power engineering

The rapid development of IT technologies (Internet of Things, Industry 4.0, Human Smart Cities), as well as the anticipated development of electromobility, will contribute to the development of the ***Smart Energy Systems*** concept, thus a transition of the centralised power generation on a large scale **towards distributed power generation**.

This trend was confirmed by long-term forecasts of the consumption of primary energy sources. Having analysed a lot of information found on the Internet and having studied many articles, publications and books [1–16], it can be said that some final conclusions are contradictory to each other. It seems reasonable to assume that the proportion of each type of primary fuel in the global consumption of energy resources will change significantly (Fig. 4), but only after a very long period of time (e.g. after 2050). In the next century, the Sun will become the most important source of energy for humanity. Are we then heading to **the era of the Sun**? If so, technologies related to distributed power generation should become dominant and the transition from centralised to distributed power engineering is inevitable.

The nearest future (e.g. up to 2040) may look a little different. Changes in the power engineering could be a compromise, for instance, between the Exxon Mobil Corporation's concept (fossil fuels will be dominant) and the Elon Musk's vision (dispersed, domestic energy systems will be dominant). Of course, no one knows in what proportion and pace such a compromise (if any) will take place. Regardless of where you stand on that issue, though, you can probably agree that in the longer term, the centralised energy production based on fossil fuels is very unlikely.

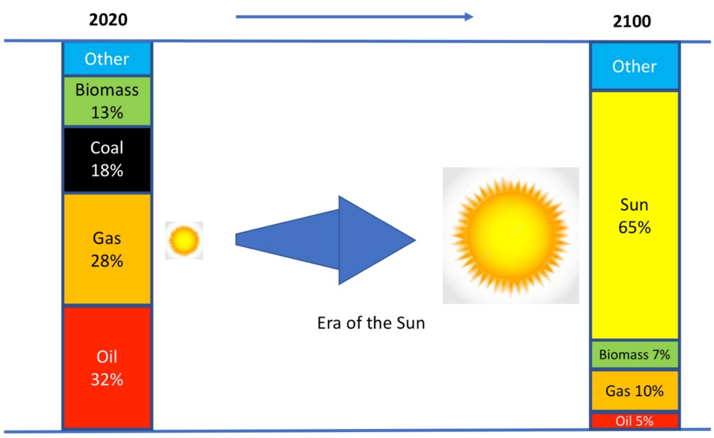

Figure 4 Forecast of the consumption of primary energy sources in 2020 and 2100. Will the next age be the era of the Sun for mankind?

4. Something about the Earth's climate and CO_2

The issue of environment protection and related climate changes caused by human activity has been the subject of hot disputes between scientists and publicists for many years. Of course, the goal is to reduce emissions of greenhouse gases and other pollutants. Currently, *we find ourselves witnesses to* a gradual warming of the Earth's atmosphere – global warming. This seems to be an undisputed fact. The issue of disputes, however, is whether this warming is caused by human activity. In the geological history of Earth, many times there were significant changes in the mean surface temperatures and the amount of CO_2 in the atmosphere (Fig. 5). And what is more, plant and animal life flourished when there was much more CO_2 in the Earth's atmosphere than there is now. This gives an argument for some publicists (e.g. people from the MATRIX 3000 group) that the increase in the global mean temperature and the amount of CO_2 is a natural geological cycle of Earth caused by, among others, increases in the dynamic pressure of the solar wind. Additional arguments – mentioned on the same occasion – are as follows:

- there is only 0.3% of carbon dioxide in the atmosphere and this amount has a negligible effect on the global warming (water vapour has a far greater effect),
- most of CO_2 is released into the atmosphere by plants and not by human activity,
- the temperature also increases on Mars (there are no people on this planet).

On the other hand, many scientists highlight a dramatically fast increase in the amount of CO_2 in the Earth's atmosphere. A famous report by Al Gore and Hillary Clinton, in which it was pointed out that for 650,000 years, the CO_2 content in the atmosphere has never been as high as it is now, can be worrying. **Therefore, it can be assumed that it is not the increase in the average temperature on Earth (and thus the increase in the amount of CO_2) is caused by human activity, but the PACE of this increase**.

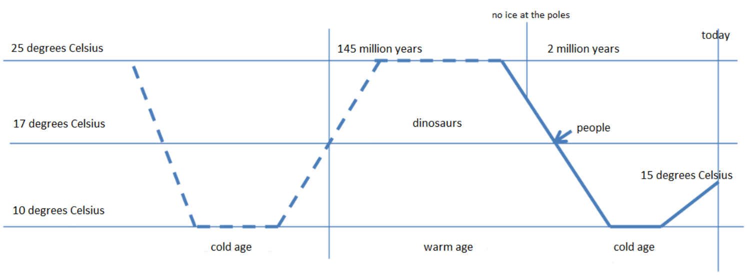

Figure 5 Geological cycles of Earth. In the geological history of Earth, there were already higher global mean temperatures (and higher amounts of CO_2) but the current rate of temperature rise is dramatically high and caused by human activity

Even though most people would agree that an increase in the amount of CO_2 in the atmosphere (within certain limits) will not have a great impact on the human body, surely not all of them would agree that the same increase can have catastrophic effects on climate (tornadoes, droughts, floods, rise in ocean levels, etc.). This raises the legitimate question: will our civilization cope with global climate changes? It is much better *to prevent those changes from happening than to fight their effects.* Therefore, not only the majority of scientists but also the governments of many countries strongly opt for introducing low-emission technologies in the power engineering and promoting RES. Such initiatives are strongly backed by the European Union. The world's power engineering must adapt to these new trends and the philosophy of changes.

5. And what about Poland?

The situation of Poland is specific from the point of view of its energy potential. We have a national treasure in the form of coal deposits, which are mined and provide us with energy security. We also have ***green coal*** in the form of biomass and other renewable energy sources that are used to a much smaller extent than they could.

Renewable energy sources (RES) have a bright future, but there is still neither good legislation nor a vision for the development of Polish power engineering [17, 26]. The use of renewable energy sources to a large extent, smart energy meters and smart houses – this is a vision that we should promote in parallel to the development of highly efficient energy generation on a large scale.

The amendment of the Renewable Energy Sources Act prepared by the Ministry of Energy, after eight months of governmental work and after being approved by the Standing Committee at the meeting of 15 February 2018, is awaiting decisions of the Council of Ministers before its direction to the Polish Parliament.

The main reason for the low effectiveness of the proposed solution is the preparation of financial instruments only for selected technologies and the exclusion of the right to the use of technologies that could be used more widely (e.g. photovoltaics, micro-cogeneration systems that use biomass and small windmills). Despite the preparation of a complex set of legislative instruments for small RES installations, the increase in energy production using RES will be insignificant in 2020 (the deadline of *Poland's obligations* assumed in the result of arrangements made at EU level) [26].

Activities undertaken in 2018 are crucial for increasing the chances of Poland's fulfillment of RES obligations and for obtaining a number of other economic benefits from this. This requires a rapid mobilisation of the Polish RES energy sector and the exploitation of its investment potential.

What about the Polish power engineering then?

A classic plan to build new coal-fired power blocks (forced by the pressure of the mining sector) will be difficult to uphold in the longer term. Therefore, it will be necessary to **restructure the national energy mix (coal-gas-RES)**:

- outsourcing of IT specialists,

  adapting to new customer trends: smart buildings and energy systems,

- adapting to a rapidly growing electric transportation sector.

The research on alternative energy sources (e.g. **hydrogen power engineering**) will be up-to-date for many years to come. In this respect, the leading position in the country is occupied by the Silesian University of Technology and the research team of Prof. **T. Chmielniak** [15]. Also, the research works concerned the low-emission processing of coal carried out, among others, at the AGH University of Science and Technology by the team of Prof. **W. Nowak** [14] are very important.

One can, therefore, formulate a to-do list for today as follows:

- rapid development of the power engineering based on gas, RES or other alternative energy sources,
- development of anti-smog and low-emission technologies,
- construction of new cross-border power grids,
- abandoning the construction of a nuclear power plant,
- energy saving has the highest priority.

Poland is not one of the richest countries in the world, hence the opinions about the resignation from the construction of a nuclear power plant are quite common. With this money, one could build several highly efficient conventional power plants that can provide much more jobs for Polish specialists and workers. For similar reasons, technologies ensuring higher energy efficiency are important. Currently, the issue of energy saving should have the highest priority.

Finally, it is worth quoting the Elon Musk's opinion on the perspectives of the development of the Polish power engineering:

"Polish power engineering is already doomed to struggling between limitations and being under the pressure of technological changes and EU restrictions, and technological advances will only exacerbate this struggle" [9].

6. Scientific potential

Does this Elon Musk's opinion (not a very flattering one) find its justification in facts? Even though our country is not a leader in technological advances compared to the leading countries in the world, recently, in Poland, a number of activities aiming at modernising the power industry sector have been observed, both at central government and local government levels. What is especially positive is that such activities also concern such fields as e-mobility and smart city, i.e. fields that will have an increasing impact on the traditional understanding of the role and importance of power engineering.

The author of this article does not claim the right to view and evaluate these activities. It would not be possible due to the limitation in the length of the text, nor is it the purpose of this work. Nevertheless, it is worth noting a few facts, including the tendencies to consolidate the national scientific potential in the fields such as e-mobility, smart city and Industry 4.0. However, let us come back to the issues to which a solution has to be found in the not so distant future. The issues such as the revolution in IT technologies, climate changes and greenhouse gas emissions are global in nature, whereas the solutions can be found at the country level. However, currently, Poland has an even more pressing problem, namely the smog.

7. Smog – Poland's pressing problem. Anti-smog technologies

Scale of the problem. There are about 13.4 million households in Poland. Most of them (55.5%) are located in multi-family houses, and 44.5% in single-family houses. Currently, approximately 5-6 million households utilise coal and biomass for heating buildings and utility water. The vast majority of them use older generation boilers, which have low-efficiency ratings and high emission levels of pollutants. The oldest devices include solid fuel stoves (whose average age exceeds 24 years) and boilers (the average age of which is 10 years). On the other hand, the share of boilers and solid fuel stoves as sources of pollution to the atmosphere in Poland is estimated at **over 90%**.

Smog originates from energy poverty, we burn everything that has a calorific value! So far, the fight for clean air was one of the central and local government's priorities, the examples of which are the Ordinance of Ministry of Development and Finance dated August 1, 2017, on the requirements for solid-fuel boilers as well as resolutions of local assemblies on restrictions and prohibitions regarding the operation of boilers. Activities of the National Fund for Environmental Protection and of the Voivodship Funds for Environmental Protection (e.g. under the Jackdaw programme) provide the financial support for farms. Legal actions are aimed at banning the sale of low-class boilers and coal with a high share of culm. This method essentially aims to reduce dust emissions but does not address one of the basic causes of smog, namely the energy poverty [19-25]. So, how to solve the problem of smog? Do we have anti-smog technologies suitable for rapid implementation in our country?

An example of anti-smog technologies with a high degree level of technological readiness are the installations developed at the Institute of Fluid Flow Machinery of the Polish Academy of Sciences in Gdańsk. At this point, it is worth mentioning the results of the works of research teams managed by Prof. **D. Kardaś** (low-emission boilers [19, 20]), Prof. **M. Dors**, Dr. **J. Podliński**, Prof. **A. Jaworek** (electrostatic precipitators [21-25]), Prof. **J. Kiciński** and Dr. **G. Żywica** (micro power plants [18]), Dr. **M. Lackowski** (energy storage) as well as Prof. **A. Cenian** and Prof. **P. Lampart** (gasifiers, biogas power plants and ORC systems [27]). The work of these teams led to the development of technologies which Poland so desperately needs.

There were proposed four stages of the implementation of these innovative technologies:

1. equipping older generation domestic boilers with low-power electrostatic precipitators (IMP PAN patent No. P. 422507). Fast and relatively cheap implementation,

2. development of technologically advanced coal-fired boilers with very low levels of dust emissions, equipped with electrostatic precipitators,

3. introduction into the market of domestic micro power plants that enable the production of heat and electricity and can replace central heating boilers,

4. introduction into the market of a series of micro-cogeneration power plants

that can meet the energy needs of small companies, public buildings and multi-family houses.

1. **Low-power electrostatic precipitator for use in older generation boilers operating in domestic installations** (IMP PAN patent No. P. 422507) – Fig.6.

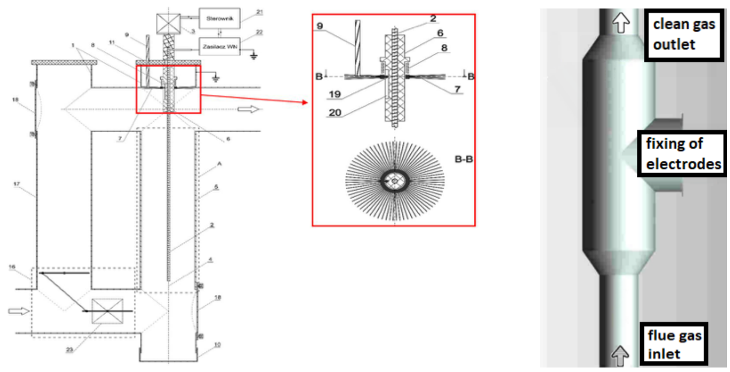

Figure 6 Low-power electrostatic precipitator and its schematic diagram (for use in domestic boilers with thermal power capacities ranging from 20 kW to 30 kW) [19–25]

Device characteristics:

- Quick implementation is possible, high degree of technological readiness (the device already passed laboratory tests and operational tests of the pilot installation).
- Dust removal efficiency reached 90%.
- The price of one electrostatic precipitator would not be higher than PLN 2,000 (assuming the mass production).

Remark: Even though it is fast and cheap, it is not the ultimate solution to the problem.

2. **Ultra-low emission coal boiler** (highly efficient device plus an electrostatic precipitator) -Fig.7.

The boiler enables combustion of various types of low-quality fuels (e.g. coal-mine waste that is much cheaper than eco-pea coal), and thanks to the use of the electrostatic precipitator the concentration of airborne dust can be kept at a low level. This is a very attractive solution.

Characteristics of the installation:

- The electrostatic precipitator for a lower class boiler is a temporary solution. An ultra-low emission coal boiler equipped with an electrostatic precipitator is a more forward-thinking solution.

- The total manufacturing cost of an ultra-low emission coal boiler is PLN **10,600**. Having analysed the market of central heating boilers, it can be said that the selling prices of coal boilers with a capacity of approx. 25 kW (class V according to the PN EN 303-5:2012 standard) range from PLN 11,600 (Draco Versa Tekla) to PLN 12,600 (EGRO PLUS Witkowski).
- The cost of an ultra-low emission boiler with a capacity of 20 kW will be paid back after 2.5 years, and the profit from its use will exceed PLN 40,000 within 10 years.
- High degree of technological readiness (after laboratory tests).

An ultra-low emission domestic boiler will be an original solution based on a highly efficient combustion process at elevated temperatures, with a two-stage heating and will be equipped with an electrostatic separator of solid particles. In addition to increased energy efficiency, this solution will enable the use of low-quality solid fuels, i.e. coal dust containing a higher percentage of minerals, which will significantly reduce exploitation expenses. A product of this kind is not available either on the Polish or European market.

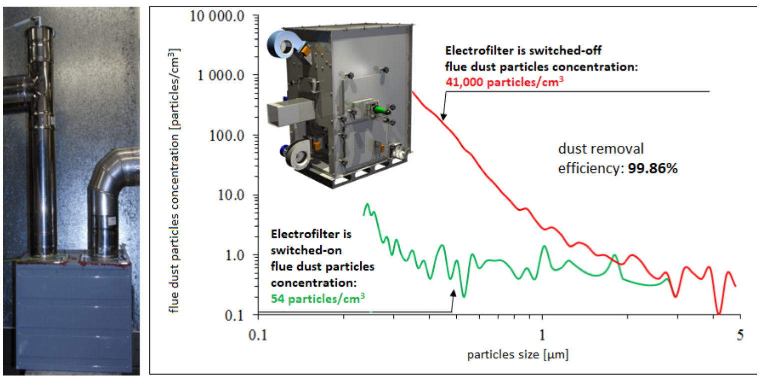

Figure 7 Electrostatic precipitator behind the flue and the graph that shows the dust emission reduction. The dust removal efficiency is 99.86% [19-25]

3. **Domestic cogeneration power plant** (low-emission boiler, microturbine, electrostatic precipitator) – Fig.8.

   Characteristics of the installation:

   - It is the most forward-thinking solution that allows producing heat and electricity in households while, at the same time, providing low emission levels of pollutants.
   - The installation passed laboratory tests, a pilot installation is currently under construction.

- A coal-fired or wood-fired domestic micro power plant will be profitable mainly due to the synergy between the production of heat and electricity (cogeneration). Achieving profits from the production and sale of electricity can lead to a situation in which the technology demonstrated herein will become a technology of the future from the point of view of civic power engineering.
- It is estimated that a micro power plant with a thermal power capacity of 30 kW and an electric power capacity of 4.5kW can give an income of PLN 1,000 a month.

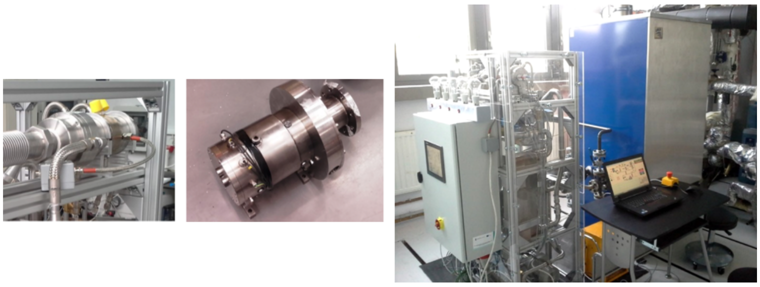

Figure 8 Micro power plant with a thermal power capacity of 25kW and an electric power capacity of 2.5 kW. On the left-hand side: microturbines operating in the ORC system [18, 19–25]

4. **Scaling. Series of power plants with higher power capacities**

The technologies listed in sections I, II and III relate to installations for use in small households, which mainly emit particulate pollutants. However, there are still municipal boiler rooms, boiler rooms for public utility buildings, etc., and all of them have a significant share in air pollution. For this market segment, it is worth developing anti-smog technologies for devices with higher thermal (several hundred kilowatts) and electric (20 – 30 kW) power capacity.

Mostly owners of large farms will be buyers of micro power plants with electric power capacities exceeding 20 kW. There are over 30,000 large farms in Poland (with an area of land above 0.5 km^2) and their owners are potential recipients of micro power plants. Another very important group of buyers of micro power plants will be municipal enterprises from small towns, which use hard coal as a basic source of thermal energy. In Poland there are 2,478 municipalities (of which 1,563 are rural municipalities). Assuming that each rural municipality has a school and a public building (e.g. a municipal office) that need heat and electricity, this gives a total of more than 3,000 potential users of the device.

In Poland, there are at least 50,000 potential buyers of solid fuel fuelled gas turbine systems with an electric power capacity of approximately 30 kW. That number covers large farms, small and medium-sized production and service enterprises from the agricultural and forestry sectors as well as municipal entities managed by local authorities.

8. What can we do now in Poland? What are our postulates?

Polish situation in terms of the content of toxic substances in the atmosphere is really tragic. In general opinion we take the last place in Europe. So the fight for clean air becomes our national priority.

8.1. *Our fight for clean air*

The most advanced and most profitable method of fighting for clean air is to completely transform the existing farm heating system in Poland into the distributed power engineering based on small installation capable of generating electricity and heat. These installations would use cheap coal and locally available biomass as fuel. A transformation of domestic boilers and local heating-generating plants into small heat and power plants will additionally result in a drastic reduction of dust emissions, which will take place due to the need to maintain high operational efficiency of all components of micro and mini power plants.

Poland has a chance to become a vast repository of knowledge about air pollution, its formation, impact on people and the environment, but also a centre for technologies for the ecologically-friendly use of solid fuels as well as prevention and elimination of smog. The goal could be to make Poland the global leader in the field of eco-friendly utilisation of solid fuels for heating households and for the cogeneration of heat and electricity.

Domestic cogeneration power plants can be perceived as the last stage of the fight for clean air. In the first stage, it is worth implementing low-power electrostatic precipitators in both older and newer generation boilers. According to Prof. D. Kardaś (IMP PAN) the stages of the fight for clean air should be the following:

Subsequent steps in the fight for clean air

1. Linking houses situated in urban areas to heat distribution networks (already underway).
2. Use of better fuels (already started, resolutions of local assemblies).
3. Use of low-emission boilers (also started).
4. Installation of electrostatic precipitators and filters (it is about time to start it).
5. Ultra-low emission boilers, very clean exhaust gas (for the years to come).
6. Micro and mini power plants that enable the production of heat and electricity for houses, small enterprises and public buildings (the best solution).

The use of low-power electrostatic precipitators for both old and new generation boilers can help a lot in this fight. According to the estimates, one electrostatic precipitator will cost no more than PLN 2,500 (assuming the mass production), which seems to be a reasonable price. The eco-pea coal, the calorific value of which is at least 24 MJ/kg, is currently sold for PLN 775 per tonne whilst the small coal from the Wujek mine with the same calorific value is sold for PLN 509 per tonne. Also in other places in the country, there are big differences in the price of these two types of coal. For example, in the Carbon company from the city of Kielce, the cheapest coal of the eco-pea type is sold for PLN 787 per tonne and the small coal is sold for PLN 537 per tonne. In other companies, the difference between the price of eco-pea coal and small coal is usually around PLN 250 per tonne. **The old generation boiler with an electrostatic precipitator can be fuelled with cheaper coal and the emission of pollutants will be the same as in modern V class boilers!**

The expense incurred to buy an electrostatic precipitator, in case of a boiler with a power capacity of 10 kW, should pay for itself within a year. The target ultra-low emission boiler developed at the Institute of Fluid Flow Machinery of the Polish Academy of Sciences (IMP PAN) is a compact, maintenance-free device that can be fuelled with cheap fuel. In IMP PAN, research is underway on an innovatory boiler (in terms of highly efficient and low emission combustion) into which the following solutions will be implemented: burner and combustion chamber will be equipped with a device that aerodynamically separates small particles, better use of thermal energy (two stages in the removal of heat), lower emission level (electrostatic separator of particulates that is equipped with a specially shaped flue that increases the efficiency of dust removal) [19–25].

The most important advantages of such boilers are the following:

- Reduction in the emission level of particulate pollutants (below 40 mg/m^3), established by the *Ordinance of Ministry of Development and Finance on the requirements for solid-fuel boilers, in force since 1 October 2017.*
- Combination of the highly efficient combustion with the low level of emission.
- Compact design ensuring small dimensions and ease of use.
- Innovative technologies ensuring low-emission combustion of fuels (original design of the burner and combustion chamber).

For potential customers, a market product is offered that will meet the required emission levels of pollutants and will have the following more favourable parameters (compared to currently sold boilers and flue gas purification installations):

- lower operating costs: low electricity consumption, low fuel consumption, compact design, the possibility of using low-quality fuels (small coal or coal containing more mineral components emitted in the form of solid particles),
- maintenance-free operation of the electrostatic separator of particulates, purchase costs comparable with devices available on the market,
- longer operating life.

8.2. *Commencement of mounting pilot anti-smog installations in households. National centre for clean air – Clean Air Centre – Fig.9.*

Financial instruments supporting state actions in the field of research and development are the Operational Programmes – Innovative Economy (POIR) and strategic programmes under which cooperation between scientific entities and the industry is realised. Funding may be granted mainly for projects submitted by both enterprises and scientific entities and their subject matter include national smart specialisations. There is no hierarchy of importance of R&D topics. From the point of view of the research and development support system, it does not matter if a given project is very important or not.

It is worth noting that:

- In the energy sector contest No. 8/1.2/2016/POIR, finished at the beginning of 2017, **none of the projects addressed the issue of smog and only one concerned distributed power engineering**.
- In the contest No. 8/1.2/2016/POIR, funding was primarily given to very large energy companies and the subject matter of projects concerned mainly issues that are important for large-scale power generation. The resolution of the contest meant that public funds in an amount of PLN 100 million were assigned mainly to support large companies.

Considering the above facts, it seems justified and urgent to **establish instruments for financing innovative anti-smog technologies** and, in particular, state funds for launching **a pilot series of electrostatic precipitators or a set of boilers with electrostatic precipitators**, e.g. in 1,000 households. Such activities seem to be a very good idea due to the reluctance of homeowners as well as local authorities to incur additional costs in the name of environmental protection. This is a task for the state. And it is feasible because the total estimated costs of such a pilot series (manufacturing and assembling electrostatic precipitators and boilers, testing of various fuels and boilers and their service) should not exceed PLN 10 million. The author of this article finds this amount acceptable, considering the importance and scale of the problem.

Activities related to the development of these technologies, including scaling, monitoring and training, could take place at the Research Centre PAN in Jabłonna. It would become a national centre for clean air technologies – ***Clean Air Centre*** (Fig. 9). This choice is not accidental. It is the most modern centre in the country and third in Europe in the field of energy conversion and renewable sources of energy (with well-equipped laboratories).

The KEZO centre is considered to be the Centre of Excellence in the field of small-scale clean energy technologies, mainly due to:

(i) membership in international organisations:

- EERA – European Energy Research Alliance (175 research entities and uni versities),
- ESEIA – European Sustainable Energy Innovation Alliance;

(ii) coordination of the Horizon 2020 project entitled "SuPREME: *Twinning for a Sustainable, Proactive Research partnership in distributed Energy systems planning, Modelling and managEment*"

Figure 9 Postulate for launching a pilot series of installations equipped with boilers and electrostatic precipitators (e.g. for 1,000 households), and the proposal of its monitoring and developing new prototypes at the Research Centre PAN in Jabłonna

9. No conclusions but simply a list of information worthwhile to remember

1. Demographic anomalies, low energy conversion efficiency, limited fossil fuel reserves ... Is an energy crisis ahead of us?

2. Radically different visions of the power engineering's future, e.g. Exxon Mobil Corporation's and Elon Musk's visions.

3. A new perception of the future of power engineering. Its development will be influenced not only by classical centralised power generation but also by new, rapidly developing fields that can completely change the traditional understanding of the role and meaning of the power engineering.

4. Will the next age be the era of the Sun for mankind?

5. In the geological history of Earth, there were already higher global mean temperatures (and higher amounts of CO_2) but the current rate of temperature rise is dramatically high and caused by human activity.

6. Smog originates from energy poverty, we burn everything that has a calorific value.

7. New technologies: a low-power electrostatic precipitator installed in the boiler that enables combustion of various types of low-quality fuels is an attractive offer for households.

8. Launching a pilot series of installations equipped with boilers and electrostatic precipitators (e.g. for 1,000 households), which would be financed by the state is a proposal that can overcome existing difficulties in implementing new anti-smog technologies.

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