From Nuisance to Technological Specialty

Can the fight against smog be won? Can new technologies become our allies in this struggle?

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The modern-day approach to the natural environment – in particular to the power industry and the issue of clean air – has been changing of late, due to a whole range of important factors. Firstly, we are currently witnessing the rapid development of IT technology, the Internet and mobile applications. The ***Internet of Things*** (IoT), which refers to the use of a smart network to connect up self-organizing objects, is an exciting new development at the forefront of this wave. Both the IT revolution and Internet of Things have laid the foundations for a new, rapidly evolving concept known as the fourth industrial revolution – or ***Industry 4.0*** for short. One of the aspects of Industry 4.0 involves applying new IT technologies in distributed, prosumer-based power generation and intelligent power management.

Another important factor is ***e-mobility***, which in fact means a more than just electric cars. It also – and perhaps above all – encompasses:

- the planning, modeling and managing of local power systems (including electric cars) as specific receivers/generators and energy storage devices,
- a system of technical, organizational and legal solutions enabling the development of ecological transport.

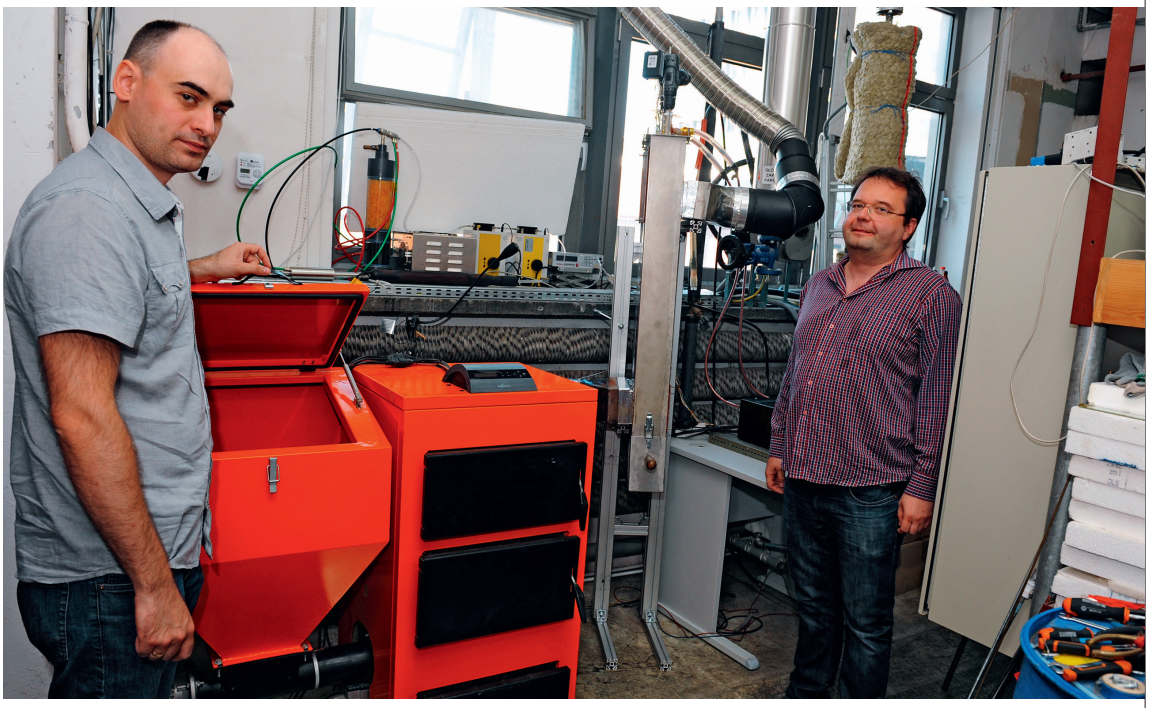
This leads us to the important conclusion that electric vehicles are just part of a broader, distributed power management system, and that hybrid systems, synergy effects, energy storage, and electric vehicles themselves all together in fact comprise what can be seen as a ***Smart Energy System***.

The notion of a Smart Energy System can apply to the scale of a single building, with hybrid/modular systems of power supply as the subject of analysis, or to the scale of a whole housing estate, taking **energy clusters** as the subject of consideration, with a particular emphasis on monitoring the local power grid and heating network and devising various types of operational scenarios for given real or virtual solutions. The Smart Energy System idea can also be applied on the urban level, leading us to the concept of a ***Smart City***. This latter notion has not only made a big splash in the research literature and at conferences in recent years, but is has also given rise to some quite spectacular initiatives on the part of many cities, companies and organizations around the world.

Will all these new phenomena – the Internet of Things, Industry 4.0, e-mobility, Human Smart Cities and Smart Energy Systems – impact the future development of the energy industry, contributing to the further evolution of traditional notions of environmental protection and power generation in general? Certainly, yes. The rapid improvement of IT technology (the Internet of Things, Industry 4.0, Human Smart Cities), as well as the forecast growth of e-mobility will increasingly demand the development of Smart Energy Systems – entailing a switch from a large-scale power industry towards distributed power generation. What is more, this also entails a different, more comprehensive view on the issues of clean air, including smog.

The question of loss

The scale of the problem is as follows. There are approximately 13.4 million households in Poland. Most of them (55.5%) live in multi-family buildings, with 44.5% in single-family buildings. Around 5-6 million households burn coal and biomass in or-



JAKUB OSTAŁOWSKI

Lab at the PAS Fluid-Flow Machinery Institute – an electrostatic filter and its creators: M. Lackowski (right) and T. Przybyliński (pictured here), M. Dors and J. Podliński.

der to generate heat and supply themselves with domestic hot water. They mainly use older-generation, low-efficiency boilers with high emissions. The old appliances include solid fuel stoves, whose average age exceeds 24 years, and boilers that are 10 years old on average. These solid fuel boilers, used by just one portion of households, are nevertheless estimated to be responsible for **more than 90%** of emissions leading to ambient air pollution.

Smog therefore has its source in a kind of energy poverty: we burn everything that has an energy value, predominantly solid fuels, which are cheap and they do not require any extensive transmission or storage infrastructure. There are, however, certain solutions that can improve the current state of affairs; these include the expansion of thermal distribution systems, the development of the natural gas network and replacement of old boilers with new, gas-fired boilers that meet the emission standards applicable to class 5 boilers.

When it comes to the expansion of thermal distribution systems, there are obvious and quite significant limitations due to the high investment costs (often unbearable for individual recipients) and technical restrictions related to substantial modification of existing thermal distribution infrastructure (the construction of heat-feeding nodes is itself relatively expensive, whereas the construction of the interconnecting transmission network, consisting mainly of pumping systems, is quite a large-scale and complex investment). There must, of course, also be a heat source, usually in the form of a combined heat-and-power plant with sufficient capacity and situated within at an acceptable distance. Another important factor in terms of energy poverty is the price of such heat, comparable to the price typical of an individual gas-fired source but higher than that of a source fired with solid fuel.

The expansion of the natural gas network and the replacement of old boilers with gas-fired ones is another possible way to reduce emission levels. In Poland, 52.5% of the population have access to the existing gas infrastructure. Further expansion of the network and increasing the availability of natural gas generates huge investment costs, stemming from the development not only of the low-pressure networks that deliver the fuel to individual customers, but also the backbone and storage infrastructure. Investments of such scale are essentially a generational issue. What is more, merely installing a gas boiler does not eliminate the basic and most important problem: the material status of the user, who may not be able to afford the expense of the fuel itself. The installation of class 5 boilers with relatively low emission levels also entails significant costs: a boiler with a heating capacity of approximately 25kW may cost more than 10,000 PLN. Another important factor in this respect, from the user's point of view, involves restrictive limitations (imposed by producers) on the quality of fuels, which also has an impact on the end cost.

The question of approach

The PAS Institute of Fluid-Flow Machinery in Gdańsk has proposed a solution based on our own

proprietary technologies generating a significant decrease in pollutant emissions, involving the distributed generation of electricity in combination with heat. The following four stages of implementation of this solution have been proposed:

- equipping older household boilers with a **low power electrostatic filter** (patent IMP PAN P.422507), which is a fast and relatively cheap solution;
- developing technologically advanced **solid fuel boilers with ultra-low emission**, equipped additionally with an electric filter;
- launching **micro-scale power plants** generating heat and electricity, to replace the existing central heating boilers;
- launching a series of **mini cogeneration power plants**, for the needs of small companies, public utility buildings, multi-family municipal buildings.

Each of these four aspects will now be described in turn.

The use of **low power electrostatic filters** for older boilers in household installations has many advantages: at the current stage, a fast implementation path is possible due to the high degree of technological readiness (with laboratory tests and piloting plant operation tests completed, larger scale testing by individual customers NOW underway). Low power electrostatic filters are highly effective in removal of particulates (over 90%) and their serial production price is relatively low (up to PLN 2,500). An important advantage of this solution is that such filters can be used with various kinds of boilers in existing household boiler rooms.

The next proposed solution involves **ultra-low emission solid fuel boilers** (a special type of high efficiency boiler with an electrostatic filter), using a highly efficient combustion process at elevated temperature, with a two-stage heat removal and equipped with an electrostatic separator of solid material. In addition to increased energy efficiency, this solution allows for the use of solid fuels of inferior quality, namely fine-grain types of coal that contain a higher percentage of minerals, which will decrease the overall operating costs. There is no such product currently available on either the Polish or the broader European market. Our boiler design has been constructed to meet the requirement of very low level of particulate matter emissions despite the combustion of low quality fuels.

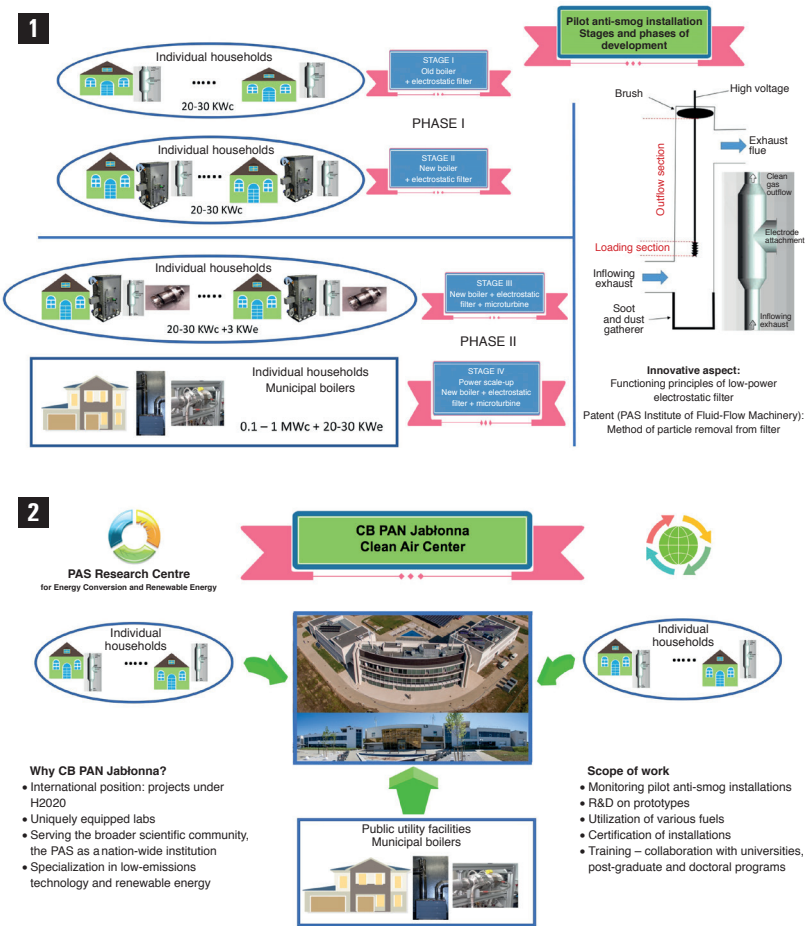
The total cost of producing this proposed ultra-low emission coal boiler has been estimated at 10,600 PLN. This price is competitive already at the purchase stage, compared to the prices of other currently produced boilers with the capacity of approximately 25 kW (class 5 according to PN EN 303-5:2012) ranging from 11,600 (Draco Versa Tekla) to 12,600 PLN (ERGO PLUS Witkowski). In addition, economic analysis indicates that owing to the use of lower quality fuels, investing in the proposed 25 kW ultra-low emission boiler will pay off after 5 years, and while using it over 10 years will yield profits in excess of 20,000 PLN.

The next, more advanced solution is to involve a **home cogeneration power plant** (consisting of a low level emission boiler, a microturbine, and an electric filter), generating electricity and heat in combination for an individual household. The PAS Institute of Fluid-Flow Machinery has for years been conducting research on the construction of such a microturbine, exchanger system and boiler itself. This is the most forward-looking solution, which ensures efficient heat and electricity generation for households and keeps emissions on a low level at the same time. A pilot installation is currently under construction.

The last proposal is a future-proof solution in the form of a **home micro-scale power plant**, coal- or wood-fired, which could be a valuable complement to the power generation system through its potential wide-scale utilization. This could give the homeowner the feeling of being a real participant in the overall system, which might contribute to the

Fig. 1. Stages in implementing the concept for fighting smog – the PAS Fluid-Flow Machinery Institute's proposal.

Rys. 2. Graphic representation of the potential role of the Jabłonna Research Center in antismog policy.



rationalization of his/her power choices in a wider perspective. It is estimated that a micro-scale power plant with a thermal power capacity of 30kW and power output of 4.5kWe could bring in 1000 PLN of monthly revenue by generating electricity.

The question of scaling

The solutions listed above relate to installations for small households, which are one of the main sources of low-level emissions. However, there are also municipal boilers, boiler rooms in public utility buildings, etc., which also generate a significant share of ambient air pollution. For this segment of the market, anti-smog technologies need to be developed offering a wider range of thermal power, on the order of several hundred kWc and electric power equal to 20–30 kWe. The recipients of power plants with power output of over 20 kWe will be mainly larger agricultural farms. The number of such individual farms with an area above 50ha is estimated at over 30,000 and these are potential recipients of medium-sized power plants. Another very important group of purchasers of medium-sized power plants consists of municipal enterprises from small towns, where the main source of thermal energy is hard coal. Out of 2478 communes in Poland in total, 1563 are rural communes. If we assume that each rural commune has a school and a public utility building (for instance, a commune office) that consume heat and electricity, the number of possible future system users exceeds 3000.

Moreover, there are at least 50,000 potential recipients of gas turbine systems for burning solid fuel with a capacity of approximately 30kWe – and this group consists of large agricultural farms, small and medium-sized production and service enterprises from the agricultural and forestry sector, and municipal utility companies managed by local governments.

The question of specialty

One concept that can definitely facilitate our struggle against smog is the use of low power electrostatic filters for both older and newer generation boilers. Above, I presented the assumptions of the proposed solutions. The rationale behind the sale of such filters is based on calculations including current prices of coal and on the assumption that in serial production the filters will cost no more than PLN 2,500 apiece, which is a reasonable price. The "eco-pea" coal assortment, with a minimal calorific value of 24 MJ/kg, costs 775 PLN per ton, while small-grain coal from the Wujek Mine, with the same calorific value, costs 509 PLN per ton. Such differences between these types of coal assortments are noticeable elsewhere as well: the "Carbon" warehouse in Kielce sells the cheapest variety of pea coal for 787 PLN per ton, whereas fine-grain coal costs 537 PLN per ton, and a similar price difference of approximately 250 PLN for a ton of pea vs. fine coals is evident at other wholesalers. As we can see, an older boiler with an electric filter can use cheaper coal, and the emission of pollutants will be the same as for grade 5 boilers!

Jabłonna Research Center – demo version of an electrostatic filter together with a boiler.

During the piloting stage, a certain social problem came to light: there is a certain reluctance on the part of Polish society to invest in solutions that reduce emissions. Therefore, educational activities that we intend to undertake at the Jabłonna research center are an important element of the proposed strategy.

In conclusion, we can try to turn the fight against troublesome smog into a Polish technological specialty.

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