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# Comparison between the costs of utilization of energy efficiency reserves in thermal power plants and heating plants and the costs of construction of new energy sources☆

Waldemar Jędral*

*Warsaw University of Technology, Institute of Heat Engineering*
*21/25 Nowowiejska Street, 00-665 Warsaw, Poland*

**Abstract**

The paper presents the possibilities of decreasing electric energy consumption for auxiliary on-site needs in thermal power plants and combined heat and power plants by increasing energy efficiency of boiler feed water and cooling water pumping. Significant benefits can also be achieved by utilization of energy efficiency potential in circulating water systems in combined heat and power plants and heating plants. A comparison between energy and economic effects of modernization of pumping systems and unit costs of new energy sources is also made. It is shown that even highly expensive modernizations are twice less costly than the investment in the most economical energy source, i.e. the gas power plant. It is shown that, when considering construction costs of new energy sources, one should take into account their capacity factors by determining equivalent capital costs of the source referred to its continuous work in a year period, i.e. during 8 760 hrs. In these terms, photovoltaic and wind power plants turn out to be much more expensive than nuclear power plants.

*Keywords:* Energy efficiency, Energy sources, Modernization costs

## 1. Introduction

The systems of auxiliary on-site needs of thermal power plants (TPP) and combined heat and power plants (CHPP) consume about 7.5% of electric energy produced in these plants; two-third of it is used for transporting feed and cooling water and the condensate, as well as for pumping the circulating water network in CHHPs. In total, it amounts to approx. 7.5 TWh/a. In municipal heating plants (MHP), the predominant part of electric energy is consumed by the systems of water circulation in internal installations of the MHP and in the district heating system (DHS). One can assess that at least 9 TWh/a of electric energy is used for fluid (mainly water) transport in thermal power and heat industry.

In a number of previous publications, i.e. [1–6], the author has signaled that the energy consumed for the mentioned purposes can be substantially reduced through various, feasible modernization actions. However, nowadays such actions arouse only marginal interest and are taken only sporadically, especially in power industry.

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*Corresponding author

*Email address:* jedralw@itc.pw.edu.pl (Waldemar Jędral*)

Similarly as in many other branches of economy, also in power industry and heat industry decision-makers still underestimate the enormous energy reserve that is associated with the potential of energy efficiency increase in diverse production and exploitation processes. Prompt and reasonable utilization of these reserves can make it possible to exclude from exploitation the oldest, antiquated and less efficient power units, which would allow us to gain time for building new, highly-efficient power plants in Poland. It would also make it possible to reduce $CO_2$ emission, which—let alone very doubtful sense of fight against the global warming—will contribute to reducing, or even avoiding the charges for over-limit emissions.

## 2. Energy efficiency as important energy reserve

In work [7], the author undertook an attempt to define fundamental concepts concerning energy efficiency and the method of assessing economic effects of energy reserve utilization; the related costs were compared with the costs of construction of new energy sources.

Energy efficiency of an arbitrary process can be defined, in most simple way, as

$$E_e = \frac{E}{W} \quad (1)$$

where: $E$—effect, i.e. measurable outcome of a given process, $W$—input, i.e. amount of energy (electric, heat or metric tons of coal equivalent ) consumed to yield the effect $E$.

In this way, one can define e.g. energy efficiency of the whole national economy; in this case $E$ would be the national income, expressed e.g. as the Gross National Product (GNP).

The inverse of energy efficiency of a process, i.e. $W/E$, is its energy consumption factor.

It is most convenient to assess energy efficiency $E_e$ of a process when both E and W are expressed in energy units, or—as it happens in many practical situations—in power units. In this case, $E_e$=$\eta$ is simply energy efficiency factor of the process. For example, in the case of a pumping facility (heating pumping station, circulating water network in a heat plant or combined heat and power plant, boiler feed water system in a power plant) $E_e$ is equal to $\eta_{ft}$ of the fluid transport process in this object

$$E_e = \eta_{ft} = \frac{P_u}{\sum_i P_{el,i}} \quad (2)$$

where: $P_u = Q_s \Delta p$—usable (effective) hydraulic power imparted from the pump to the fluid, $Q_s$—fluid flow output from the pump system, $\Delta p$—pressure difference between output and input of the system, $P_{el,i}$—electric energy drawn from the mains by the drive system of the $i^{\text{th}}$ pump.

Energy efficiency of individual machines and devices, i.e. $E_e$ of a pump set, blower, fluid coupling etc., is equal to their efficiency $\eta$.

The potential of energy efficiency increase is very high. According to many sources (i.e. [8]) energy consumption needed for producing a unit of GNP in Poland is 2.5–3 times higher that that in 15 countries of the so-called “old EU”. It is feasible to decrease this energy consumption by 25–30% [8], or—according to some other authors—even by 40%, in a relatively short time. Assuming that the losses of electric energy in various processes in national economy might be decreased only by 10% of the presently consumed amount, i.e. by approx. 15 TWh/a, we would avoid the necessity of constructing new power units of at least 2 750 MW total power (assuming average working time of a power unit 6000 h/a and transmission losses in the power grid at a level of 10%). At the same time, we would avoid $CO_2$ emission amounting to approx. 14–15 million ton a year.

Achieving such energy savings is quite real, estimations by [4, 7], show that, in pump systems only, by reasonable modernization of pumps and installations one could eliminate the losses which presently amount to 6.5–7.5 TWh/a.

More and more frequently we can encounter the thesis that the potential of effective utilization of energy is an important energy reserve, of which one can make advantage through very profitable, modernizing investments of short pay-out time [9].

It is estimated that in pump systems in thermal power industry one can obtain—without great effort and very quickly—energy savings as high as 1–1.5 TWh/a, and in heat industry 0.5–1 TWh/a.

## 3. Methods and costs of improvement of energy efficiency of pump systems in power plants, combined heat and power plants and in heating plants

In numerous publications, e.g. those mentioned in Section 2, there are described various modernizing actions concerning boiler feed pumps, cooling water and condensate pumps in TPP and CHPP, and district heating pumps in CHPP and MHP. The result of these actions is improvement of efficiency $\eta_c$ of fluid pumping in individual networks. The main modernizing actions are the following:

- changing pump system structure, e.g. feed pumps, or district heating pumps,
- improving selection of pump parameters, according to the requirements of the system,
- changing the method of pump delivery control, by replacing throttling control by a more energy-saving one,
- modernizing pumps in order to improve their internal and external seals,
- changing the place of water input from the feed pumps to control injectors of steam superheaters,
- introducing the control of axial pumps delivery in cooling water system by changing angle of inclination of impeller blades,
- introducing computer control of operation of pump groups consisting of several district heating pumps or cooling water pumps.

Example modernizing actions of above-mentioned kind and their energy and economic effects are juxtaposed in Table 1. Taking into account annual energy savings $\Delta E$ resulting from modernization, and time of work of pumps in a year $T_a$, we can calculate the “avoided losses” (saved power), $P_{av}$

$$P_{av} = \frac{\Delta E}{T_a}\varepsilon \tag{3}$$

The sum of these powers can be utilized in the national economy, thus making it possible to avoid construction of new energy sources producing such a power.

In the case of modernization performed in a thermal power plant or combined heat-power plant, one should assume $\varepsilon$=1; in modernization of other pump systems, i.e. in heating plants, it is necessary to take into account also the avoided power losses in the power grid. On the bases of statistical data published annually by the Energy Market Agency S.A., we can assume, on average, $\varepsilon$= 1.1 (however, in the case of an object located at the outskirts of an old mains, this could be even $\varepsilon \approx$1.3–1.4).

As we can see in Table 1, the money spent on modernization is paid back quickly. In the examples shown in Table 1, and in many others, the simple pay-back period usually does not exceed 1–1.5 year. Moreover, contrary to many cases of construction of new energy sources, the period of modernization realization is very short, usually 1.5 year, or 2 years at most, including the time needed for preparing the project and settling the tender. Any tedious formalities, administrative, environmental, etc., are not needed either, and many other costs can be avoided (infrastructure, ground, connection to mains, fuel, services, etc.).

*Remarks to Table 1.*

**a)** Exchanging two 50% pumps, driven through fluid coupling with multiplying gear, for one 100% pump driven by high-speed 6 kV electric motor with a stepping-up frequency converter.

**b)** In the existing pumps, according to item a), cutting back of impeller blade tips in order to decrease too high pump head by 10%.

**c)** Replacement of stages 2 and 3 of feed pump enabling a decrease of pump head by 300–350 m while maintaining the required pressure of water on superheater control injectors.

**d)** Reconstruction of malfunctioning mechanical control system of impeller blade setting angle in cooling water pump (a complicated system of toothed wheels and gears) and replacing it with a hydraulic one.

Table 1: Juxtaposition of modernization effects of pump systems and other technological installations

| Example | Kind of object | Subject (range) of modernization | Annual loading $T_a$, h | Modernization cost $K_m$, PLN | Energy saving per year $\Delta E$, kWh | Avoided power* $P_{av}$, kW | Simple pay-back period SPB**, year | Avoided cost*** $k_{av}$, $\frac{PLN/kW}{€/kW}$ | Reference |
|---|---|---|---|---|---|---|---|---|---|
| a | 200 MW power unit of a fossil fuel plant | Exchange of boiler feed pumps (high-cost investment) | 6000 | $5.5 \cdot 10^6$ | $6.88 \cdot 10^6$ | 1147.0 | 6.0 (DPB) | $\frac{4800}{1220}$ | [3] |
| b | as above | Adjustment of boiler feed pump parameters (low-cost investment) | 6000 | $0.15 \cdot 10^6$ | $1 \cdot 10^6$ | 166.7 | 1.0 | $\frac{900}{230}$ | [3] |
| c | 200 MW power unit in another fossil fuel plant | Changing water input place to control injectors | 6000 | $0.25 \cdot 10^6$ | $4 \cdot 10^6$ | 666.7 | 0.3 | $\frac{375}{95}$ | [7] |
| d | 200 MW power unit in any fossil fuel plant | Introducing control of axial pumps by adjustment of impeller blade setting angle | 6000 | $0.13 \cdot 10^6$ | $1.6 \cdot 10^6$ | 266.7 | 0.4 | $\frac{490}{125}$ | [10] and author's private inform. |
| e | Heat plant in a city with 80 000 inhabitants | Installing 3 frequency converters | 5100 | $0.096 \cdot 10^6$ | $0.361 \cdot 10^6$ | 77.9 | 0.7 heating season | $\frac{1230}{310}$ | [11] |
| f | Heat plant in a city with 50 000 inhabitants | Change of installation concept of circulating water network | 5100 | $0.35 \cdot 10^6$ | $2.2 \cdot 10^6$ | 474.5 | 0.4 heating season | $\frac{740}{190}$ | [11] |
| g | as above | Installing cool-mixing pump | 5100 | $0.046 \cdot 10^6$ | $0.11 \cdot 10^6$ | 23.7 | 0.9 heating season | $\frac{1940}{490}$ | author's private inform. |
| h | High-power combined heat-power plant ($Q_s$=11000 $m^3$/h) | Rewinding electric motors + buying new pumps | 5100 | $0.5 \cdot 10^6$ | $2.8 \cdot 10^6$ | 549.0 | 0.9 heating season | $\frac{910}{230}$ | Unpublished report ITC PW |
| i | Combined heat-power station in a big industrial plant | Exchange of flow elements in circulating water pumps | 5000 | $0.18 \cdot 10^6$ | $0.825 \cdot 10^6$ | 165.0 | 0.55 heating season | $\frac{1090}{280}$ | [12] |
| j1 | CHPP supplying a part of big regional town | Exchange of flow elements in circulating water pumps + frequency converters | 5200 | $0.44 \cdot 10^6$ | $1.32 \cdot 10^6$ | 253.8 | 1.7 heating season | $\frac{1730}{440}$ | author's private inform. |
| j2 | as above | New, big pomp set with frequency converter | 5200 | $1.26 \cdot 10^6$ | $1.97 \cdot 10^6$ | 378.8 | 3.2 heating season | $\frac{3320}{845}$ | author's private inform. |

*Avoided power $P_{av}$–according to formula 3

**$SPB = k_e \Delta E / K_m$–Simple Pay-back Period, DBP–Discounted Pay-back Period; $k_e$=0.20 PLN/kWh was assumed for power plants and $k_e$=0.20 PLN/kWh for other objects

***Avoided cost $k_{av}$ – according to formula 4

**e)** Replacing throttling control by speed control—installing frequency converters for all three pumps cooperating in parallel.

**f)** Cold mixing circulation without throttling; instead, applying a separate mixing pump and carrying out modernization of the set of district heating pumps, consisting in adjusting pump parameters to the new concept.

**g)** Installing a separate cold mixing pump with speed control.

**h)** Twofold decrease in too-high height of head of booster district heating pumps by decreasing rotational speed of driving motors from 1485 rpm to 987 rpm (through rewinding), and purchasing and applying a new pump of lower delivery.

**i)** Replacing flow elements in two multistage district heating pumps (improvement of operating parameter selection, and significant increase in efficiency).

**j1)** Actions as in item i) concerning the set of three district heating pumps, and purchasing one frequency converter.

**j2)** Buying a new, high-efficiency pump set of delivery threefold greater than that in existing pumps, with a frequency converter accommodated to cooperation with one existing pump after overhaul.

There are other possible actions, also very promising, especially those related to introduction of delivery control through rotational speed control in diagonal cooling water pumps, as well as in condensate pumps, in 360 MW power units [13]. Another interesting possibility consists in applying self-regulation in condensate pumps in the condition of partial cavitation [2]. Both mentioned solutions require detailed energy and economic analysis, which is worth performing.

## 4. Comparison between costs of utilization of energy efficiency potential and costs of construction of new energy sources

Considerable decrease in auxiliary power consumption in TPPs and CHPPs, along with reduction of energy used by district heating pumps in CHPPs and MHPs, supported by similar actions in other branches if economy, can make construction of new energy sources unnecessary.

In order to assess cost-effectiveness of investments in utilization of energy efficiency potential, the author [7] proposed comparing the investment costs related to1 kW in various, newly constructed energy sources, with the relative avoided costs $k_{av}$, PLN/kW expended on modernization aimed at increasing energy efficiency. Avoided cost is then an equivalent of investment cost of the new energy source which we don't need to create. It can be defined as

$$k_{av} = \frac{K_m}{P_{av}} \; [PLN/kW] \tag{4}$$

where: $K_m$—cost of modernization, PLN; $P_{av}$—avoided power,kW; defined by formula 3.

Table 2 shows juxtaposition of unit investment costs, known from literature, $k_{inv}$, PLN/kW, €/kW, pertaining to construction of new energy sources, and the avoided costs $k_{av}$. Because different sources give various values of capacity factor $T_a$ (time of work in a year with full installed power), so that one should compare equivalent costs $k_{eq}$ increased in relation to investment costs $k_{inv}$

$$\alpha = \frac{8760}{T_a} \tag{5}$$

times.

The costs that must be expended to build a source of a greater power

$$P_{eq} = \frac{8760}{T_a} P = \alpha P \,, \tag{6}$$

such that would be capable of producing, in the period Ta, the same amount of energy as a given source of installed power $P$ working with full capacity during the whole year, i.e. 8760 h, are then the following

$$k_{eq} = \alpha \, k_{inv} \tag{7}$$

The value of $\alpha$ changes within a wide range, from $\alpha$=1.095 for nuclear power plants ($T_a$=8 000 h) up to for wind power plants ($T_a$=2 200–2 000 h)[1] [16]. It significantly influences equivalent cost $k_{eq}$ of producing 1 kW of power.

In the case of wind power plants one needs to add some other costs, of no small importance. Because, especially in summer, there could appear very long windless periods, one must construct, next to the wind farm, an emergency power plant—preferably a gas-fuel one—of installed power equal to at least 30–50% of that of the wind farm. In order to equalize the effects of variable wind velocity within 24 hrs, one must install an accumulator battery with DC/AC converters next to the wind farm. Its power should be equal to approx. two-third of installed power of the wind farm [17, 18]. According to [17], the cost of installing such a battery amounts presently to 3.0–3.5 million € per 1 MW (private information from the author [17]). In sporadic, favorable cases it is possible, instead of installing an accumulator battery with converters, to build a pumped-storage power station of comparable construction costs.

In these conditions, wind power plants have very high equivalent cost $k'_{eq}$—that includes all above-mentioned additional costs (among all types of power plants contained in Table 2, only solar (photovoltaic) power plants have even higher equivalent cost $k_{eq}$), but their enthusiasts, quite tactfully, prefer to remain silent about this fact.

An apparently surprising conclusion is that the cost of construction of one 1 000 MW nuclear power unit would be lower, even much lower, than the total cost of a wind farm consisting of 2 000 windmills of installed power 2 MW each.

It should be mentioned that the costs of connecting 2000 windmills to the high-voltage power grid would be probably much higher than the cost of connecting one unit of a nuclear power plant. The maintenance cost would undoubtedly be higher, as well, compensating, to some extent, for the costs of fuel in nuclear power plant. The area of ground occupied by a wind farm would also be greater, which would generate additional costs, not taken into account in Table 2.

The figures shown in Table 2 confirm that utilization of energy efficiency potential is economically more advantageous than construction of new energy sources, especially renewable ones. As we can see, the cost of 1 kW of avoided power is—even in the case of high-expenditure modernization—almost twice lower than the cost of 1 kW from the cheapest source—the gas power plant without CCS installation. In the case of low-expenditure modernization, i.e. when complete replacement of all facilities is not required, this cost could be more than tenfold lower.

Practical possibility of generating high power in solar power plants in Poland, especially with photovoltaic generators, is also questionable. As it is known, the solar constant equals 1 368 W/m$^2$. Let us imagine a solar power plant orbiting around Earth. Let us assume very high efficiency of future photovoltaic generators and highly-efficient system of electric energy transmission to Earth—together up to 73%. From 1 m$^2$ of such a power plant one could get 1 kW. Obtaining 1000 MW of electric power, like from a nuclear power unit or a great unit of carbon power plant of super-critical parameters, would require an area of the solar panel equal to $10^6$ m$^2$=1 km$^2$. Besides, the question of transmitting such a power to Earth is still unresolved. Then, construction of high-power orbiting solar power station today seems absolutely unrealistic. Construction of such a power station on Earth would require much greater ground area[2].

It is worth noticing that large-scale burning of biomass, in the form of co-burning in boilers of power units, has already caused disturbances on the timber market. It is planned that in the new 100–190 MW biomass-fired power units healthy wood will be used as a fuel, instead of cones, sawdust, bark or straw. Such an energy source should never be numbered among renewable ones, and subsidizing the “green energy” should be abolished.

It should be emphasized that, in the case of power acquired from the reserves of energy efficiency, there

[1]According to [14], $T_a$ value for wind power plants in Poland is even smaller, approx. 1 630–1 740 h/a; this values are consistent with the data from [15], which relate $T_a$ to annual average of wind velocity.

[2]The areas occupied by solar power plants presently constructed are even 20–40 times greater, which limits the possibility of constructing them on a greater scale.

Table 2: Juxtaposition of unitary, equivalent investment costs for new power plants, and unitary avoided costs associated with utilization of energy efficiency potential in existing plants

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| No | Source of electric energy | Capacity factor $T_a$, h (acc. to [19], [20]) | Unitary investment cost $k_{inv}$, €/kW | | Equivalent cost factor $\alpha$ | Equivalent investment cost $k_{eq}$, €/kW | | (acc. to Table 1) $k_{av}$, $\frac{PLN/kW}{€/kW}$ |
| | | | according to [19] | according to [20] | | concerning data from column 4 | concerning data from column 3 | |
| 1 | Hard coal power plant (without CCS) | 5500 | 1500 | 1300 | 1.592 | 2390 | 2070 | - |
| 2 | Brown coal power plant (without CCS) | 6000 | 1500 | - | 1.460 | 2190 | - | - |
| 3 | „On shore" wind power plant | 2000<br>2200 | 1700<br>1700 | –<br>– | 4.38<br>3.982 | 7450<br>6770 | –<br>– | –<br>– |
| 4 | as above, including costs of gas PP and accumulator battery | 2000<br>2200 | - | - | 4.38<br>3.982 | $k'_{eq}$ = 17780[I]<br>$k'_{eq}$ = 16170[I] | | –<br>– |
| 5 | Nuclear power plant I[II] | 8000 | 3000 | 1500 ($3^{rd}$ *generation*) | 1.095 | 3285 | 1640 | - |
| 6 | Nuclear power plant II[III] | 8000 | 4500 | - | 1.095 | 4930 | - | - |
| 7 | Geothermal power plant | 8000 | - | 1500 | 1.095 | - | 1640 | - |
| 8 | Small hydroelectric plant (below 5 MW) | 5500 | - | 2000 | 1.592 | - | 3180 | - |
| 9 | Concentration-based solar power plant (CSP) | 5000<br>6000 | –<br>– | 3300<br>4500 | 1.752<br>1.460 | –<br>– | 5780<br>6570 | –<br>– |
| 10 | Photovoltaic solar power plant | 1600<br>1600 | - | 4000<br>5000 | 5.475<br>5.475 | - | 21900<br>27400 | –<br>– |
| 11 | Biomass power plant | 5500<br>5500 | –<br>– | 1900<br>3000<br>(*incogeneration*) | 1.592<br>1.592 | - | 3025<br>4780 | –<br>– |
| 12 | Gas power plant (without CCS) | 4000 | 900 | - | 2.19 | 1970 | - | - |
| 13 | Avoided cost acc. to Table 1 (high-expenditure modernization)[IV] | - | - | - | - | - | - | $\frac{4020}{1020}$ |
| 14 | Avoided cost acc. to Table 1 (low-expenditure modernization)[V] | - | - | - | - | - | - | $\frac{700}{180}$ |

[I] $k'_{eq} = (1700 + 0.4 \cdot 900 + 0.667 \cdot 3000) \cdot \alpha$, €/kW

[II] Concerns investment costs from published offers, according to [13]

[III] Concerns actual contract prices, see [13]; according to up-to-date (June 2011) information from specialists, unitary cost of construction of NPP by European companies will not exceed 3500 €/kW

[IV] Weighted average of items a, g, j1, and j2 in Table 1; assumed exchange rate 1 €=3.94 PLN

[V] Weighted average of remaining items in Table 1; assumed exchange rate 1 €=3.94 PLN are not any exploitation costs associated with employment of staff[3], maintenance of devices, costs of fuel, etc. Moreover, in the case of CHP, heat pumping stations, etc., we also avoid losses in the power grid, which in Poland amount to 10% of the produced electric energy [21]. Obviously, the costs related to over-limit emission of $CO_2$ (or the costs of preventing this emission), which can appear in the case of gas of fossil fuel power plants, are also eliminated. Harmful wastes, like dusts, ashes, sulphur and nitrogen dioxides, radioactive isotopes, etc., are not produced, either. Contrary to developing new energy sources, utilization of renewable energy potential does not require any infrastructure (ground, roads, connections to network).

All these above-mentioned additional factors make the disproportion between the costs shown in Table 2 even greater, and enhance the benefits of using reserves of energy efficiency.

## 5. Conclusions

1. The reserves hidden in the possibility of increasing energy efficiency of fluid transport in PP, CHPP and CHP, and similar possibilities associated with many other technological and operation processes, must be recognized as a very serious energy reserve. Utilization of this reserve would carry with it a twofold—and in many cases even tenfold decrease in investment expenditures, compared to the construction of a cheapest, comparable source of energy.
2. Additional advantages of utilization of energy efficiency are:
   - the shortest recoupment period of realization costs,
   - the shortest time of introducing adequate modernizations,
   - lack of additional costs related to purchase of ground for the investment, construction or development of infrastructure, connecting to the power grid, costs of fuel, maintenance, etc.,
   - zero $CO_2$ emission.
3. The potential of energy efficiency, in thermal power stations and heating plants, can be assessed in Poland on the level of 1.5–2.5 TWh/a. In the scale of entire national economy, real potential of energy efficiency can be evaluated as 25–30% of presently produced electric energy, i.e. 38–48 TWh/a. Its utilization would make it possible to avoid, or rationally distribute in time, the construction of new, high-efficiency, low-emission energy sources of total power of 6.8–8.2 GW. At the same time, it would be possible to close down the plants being the worst in these categories.
4. An additional advantage of making the economy less energy-consuming is, as mentioned in item 2, the possibility of avoiding $CO_2$ emission of least 34–41 million ton yearly.
5. Utilization of the potential of energy efficiency should become a priority for the Polish state. Appropriate means of motivation must be created, much stronger than those resulting from the existing energy efficiency act. Each energy user, as well as energy producer, must be convinced of benefits resulting from decreasing energy consumption in its area of activity.
6. When we compare costs of construction of different energy sources, we must take into account their capacity factors and various additional costs that are involved. Therefore, it turns out that construction of big wind farms requires (at least) twice higher expenditures per 1 kW of power than the construction of a nuclear power plant of the same equivalent power. Moreover, big photovoltaic plants turn out to be horrendously expensive.
7. It is worth investing, on a large scale, in renewable energy sources, scattered or diffused, of relatively low powers. The highest powers must be left for high-efficiency, low-emission fossil fuel units (but without CCS), gas, and/or nuclear power plants. This would be the least expensive and the best ecologically-oriented solution.

[3] One of benefits of renewable energy sources, as one claims, will be that 3 million new jobs, associated with development of these sources, will be created in the EU by the year 2020 [18]. In Poland this number can be estimated as 350,000. It is easy to calculate that this will cause an increase in electric energy prices for end users by approx. 0.10 PLN/kWh.

Greater powers might perhaps be obtained in future by exploiting some geothermal sources.

8. The subsidies for co-burning of wood in boilers of big power units must be abolished, and construction of new, big power plants using only wood as the combustible matter must be stopped. These resources of energy can not be numbered among the renewable ones!

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