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ENERGETIC AND ENGINEERING MUNICIPAL INFRASTRUCTURE IN FORMING THE DEVELOPMENT QUALITY OF THE POLISH CARPATHIANS

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Summary

The reduction of the disproportions between municipal infrastructure between rural and urban areas is one of crucial aspects of equalization of standards of life in mountainous area. Paper describes specific problems related to construction and operation of water supply and sewage systems in Polish Carpathian region, where on the one hand, the infrastructure expenses per capita, especially in case of water supply and sewage, are much higher in rural areas than in cities, and on the other hand the infrastructure investments in mountain areas prove to be much more effective than in the case of lowland regions of the same voivodeship. Similar investigations were made with respect to the energy infrastructure. The energy infrastructure problems identified in Carpathian area cannot be solved without strong restrictions in terms of air protection. Paper presents special solutions, dedicated to these specific regions, for hot water heating, district heating systems and ventilation with lower demand for primary energy (fossil fuels). The general idea assumes that the system would consist of a local heating network conveying heat to the buildings which would not have to be equipped with heating boilers. Such a concept could be a model solution for a large part of the Polish Carpathians, considering the large potential of available biomass as well as the mastered technologies of biogas production.

Keywords

water supply • energy infrastructure • municipal infrastructure

1. Specifics of the municipal infrastructure and the conditions for its development

The accession of Poland to the EU structures has resulted in Poland being covered by the regional policy, which focuses on equalizing the disproportion development by supporting (financially) the structural transformations in so-called problematic areas. The current EU policy for the areas with disadvantageous economic conditions (DEC) focuses mainly on: complying with the environmental protection requirements, equalizing the disproportions in municipal infrastructure, maintaining the landscape qualities, tourism development and stimulation of specific kinds of agricultural activities. All of these objectives are closely related [Roszkowska-Mądra 2010]. When discussing the reduction of the disproportions between rural and urban areas it should be noted that in the Carpathians (and the neighboring areas) these actions should force an increase of financial support for technical infrastructure investments, more so in rural areas than in urban ones. Such a conclusion may be drawn from a full evaluation of economic effectiveness of investing into this infrastructure. On the one hand, the infrastructure expenses per capita, especially in case of water supply and sewage are much higher in rural areas than in cities. On the other hand, the research conducted by the staff of the University of Rzeszów in Podkarpacie [Roszkowska-Mądra 2010] clearly indicated that the infrastructure investments in mountain areas prove to be much more effective than in the case of lowland regions of the same voivodeship. Therefore, a higher utilization effectiveness of municipal infrastructure in mountain areas compensates for the increased expenses and can fully justify the purpose of these more expensive investments. This is the reason why a lot more attention should be paid to the problems related to the technical actions aimed at improving infrastructure, especially water supply, sewage systems and wastewater treatment.

2. The role of water supply and sewage infrastructure in quality assurance of Carpathian regions

2.1. Hitherto development and future actions

The infrastructural investments in the last two decades have led to a significant increase in the number of households with water supply and sewage removal. In the Carpathian regions, during the period of the most intensive investment actions (1995–2007), the index of water supply availability almost doubled (from 14.4 to over 22 km $\cdot$ 100 km^{-2}) and the sewage output rose almost six times (from 4.2 to over 23.4 km $\cdot$ 100 km^{-2}) [Baran and Grzebyk 2009]. As a result the previous disproportions between access to water supply and sewage system are practically non-existent. Irrespective of its important environmental impact, this one factor has enhanced quality of life in the area. However, the percentage of population using the water supply and sewage is still lower than in urbanized areas, even in villages located outside mountain areas. The data analysis from the year 2011 [GUS 2012] for the Carpathian areas in Małopolska, Podkarpacie and Silesia has shown that still only about 58% of mountain area population has access to water supply (in contrast with 95% as average for all these voivodeships population). Likewise, about 30% of the population connected to sewage treatment plants with a sewage network is a very small number in comparison with the averages for this regions. The problem, besides its obvious economic background, is related to specific local factors, typical of mountain areas. These factors will be discussed later on.

2.2. Characteristics of water supply in Carpathian areas

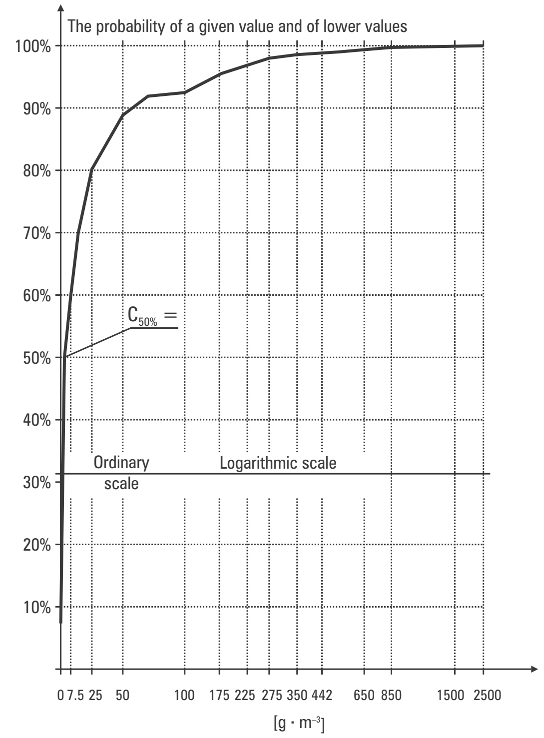
The problems related to water supply in mountainous areas, which occur in the Carpathians, include in particular:

- very dynamic variability of water quality in the surface water intakes,
- big pressure differences resulting from the lie of the land,
- significant variability of the number of people using the water from water-pipe network,
- low-density housing.

The Polish Carpathians may seem to be a region where the supply of good water quality should not be a technical or organizational problem. However this popular belief that the region has easy access to plentitude of water supply sources (such as many clear brooks and mountain rivers), which do not require any technical treatment, is not quite true. The main problem with using these water resources for water supply purposes is the very disadvantageous, large variability of water quality in mountain rivers and creeks. This is an incomparably greater problem than in lowlands. Typical problem is the sudden increase in the turbidity of the surface waters resulting from weather changes, especially intensive rains. The increased turbidity (over 25 NTU) occurs relatively rarely, less than 10% of the year [Pawełek 1993]. However, with the water turbidity that can increase over a thousand times during a single day water supply provider must deliver water of a required quality. This problem is illustrated in Figure 1, which shows the statistical turbidity distribution with a significant difference between the maximal and minimal value. This phenomenon significantly complicates the structure of the technological systems and water treatment plants and increases their investment cost. There is no simple solution of this issue, as ensuring proper water quality has to be based either on expanding the technology with an advanced processes of coagulation, sedimentation and filtration (these are unnecessary during 90% of operating time) or on building clear/treated water reservoirs, which not only increases investment costs but also causes operational problems (water taste, biological stability, etc.). The simplest solution is to use underground waters aquifers of good quality, but this is not always possible.

Specific topography of mountain areas is connected with the next technical problem, namely the great difference in water pressure supplied between the lowest and highest areas. The high pressures can often exceed the durability of the pipeline materials. In case of the network in Zakopane the elevation difference is 300 m, which exceeds the durability of standard pipelines by a level of magnitude.

This is a problem of water supply companies. In some areas they have to divide the water supply network into zones and install devices lowering the pressure and in other zones (usually those located higher) they have to pump water and build auxiliary reservoirs. A certain benefit is the potential to recuperate excess energy from the water flowing through the pipelines. This partially compensates for the additional expenses for the network construction. The significant variability of the number of water supply system users is a major problem for the Carpathian areas, which thanks to their tourist attractiveness are visited by large number of visitors. Mountain tourism, the growth of sport centers and "Wellness & Spa" facilities significantly increase the number of water supply network users in certain periods of the year. The scale of change can be illustrated by the average annual water use per person in Zakopane in 2012 [GUS 2012] (44.5 $m^3 \cdot cap^{-1}\ year^{-1}$). This was greater, almost by half, than the average for all the Polish cities. Intensive water usage is typical of the tourist season but for the remaining part of the year water usage drops to smaller values accordingly to the drop of the users number. This change is not favorable to the water treatment plants. Moreover, it means that water supply systems must have higher efficiency, which is unprofitable for the water supply companies. The problems of low-density housing and the resulting costs of the construction and maintenance of the water supply network are characteristic to the whole country, but in mountain areas their scale is much greater, due to higher water supply construction costs.



Source: Rybicki and Rybicki 2005

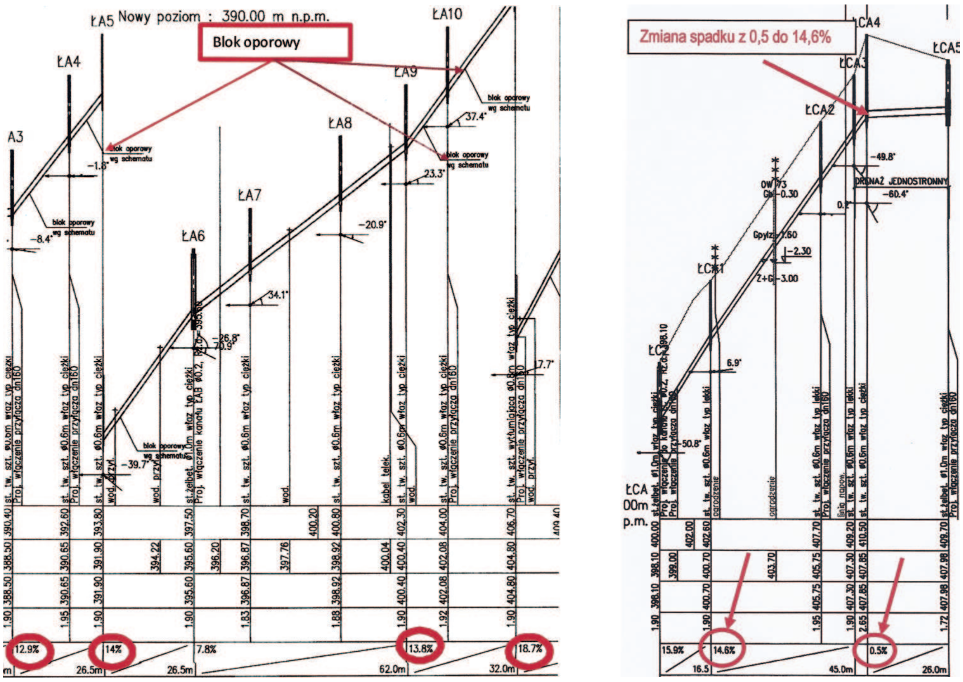
Fig. 1. The duration curve of suspensions concentrations in the raw water in Carpathian river

2.3. Characteristics of construction and use of sewage network and sewage treatment plants in the Carpathian mountain areas

The disproportion between the availability of water supply and sewage systems has recently led to intensive design and construction of new sewage networks. The specificity of the discussed area is the reason why the unit cost of elements of this infrastructure is much higher than in other regions of the country. Similarly to water supply system, the sewage and sewage treatment systems in tourist cities and villages are irregularly and unfavorably loaded by the sewage. Again, Zakopane serves as the example. The city has an official population of 27.000 but the sewage network is designed for more than 100.000 of so called "equivalent inhabitants". It means additional costs for Zakopane outside the season, when water use is lower.

The dynamics of sewage network development is impaired by the morphological (lie of the land) and geological characteristics of the region that make planning and construction stages of sewage networks more difficult. That is why the investments in the Carpathians are different than the ones in other regions of Poland. These special qualities include:

- very diverse terrain elevations mean that the pipelines must run at highly variable angles (ranging from values close to the minimum to very high values, which locally exceed the maximum), which leads to higher axial loads and to additional adverse tensile stresses in pipe joints,
- the pipelines connected at very variable slopes, from those close to the minimum (around 0.5%) to the very high slopes, forced by terrain shape (exceeding 20%).



Source: Rybicki 2011

Fig. 2. Exemplary solutions for sewerage networks in mountain areas

Figure 2 presents an exemplary solution of this problem, as proposed by the designer of the sewage network in Beskid Żywiecki. It involves additional elements (resistance blocks) and changing of the terrain gradient as required by the lie of the land.

The attempts to use local systems (wastewater soil infiltration, small adjacent treatment plants) are not always applicable, because the geological conditions usually limit the application of wastewater soil infiltration and similar systems.

2.4. Conclusions regarding water supply and sewage infrastructure

1. The Carpathian regions which developed very quickly in comparison with other regions require investments in sewage and water supply infrastructure. The present level of investment is not sufficient and is proportionally lower than in other regions of the voivodeships in Polish Carpathian.
2. Investments in the networks and their operations in the Carpathian regions is much more difficult than in other Polish regions, due to two factors:
   - lie of the land,
   - variable number of users.
3. The above qualities mean the increased investment expenses and operating costs of installations, as well as water supply and sewage infrastructure.

3. The role of energy infrastructure in quality assurance of the Carpathian regions

3.1. Requirements, development and research directions on self-sufficient systems

Energy infrastructure, as well as municipal infrastructure, apart from its basic function of providing certain services for the population, should also enable maintaining the environment and limit the environmental related hazards. To accomplish these tasks system and technological solutions should be applied. These will serve to reverse not only future hazards but also the effects of the previous, often improper use of valuable mountain areas. The energy infrastructure located in such areas should be placed under tight restrictions in terms of air protection. This especially applies to the Carpathian Europe regions with their high-density of natural protected areas of high environmental values. Therefore, it is necessary to adopt special solutions like using environment friendly energy sources for hot water heating, heating systems and ventilation with lower demand for primary (fossil) fuels. The ongoing discussion about the so-called zero-energy buildings, passive buildings and buildings with low energy demands, and generally about the need to reduce the energy demand of buildings, is not leading to desired solutions. An energetically self-sufficient town or village is very rarely mentioned and seems easy to accomplish in practice. In literature, a bioenergetic village was defined by Karpenstein-Machan [2009] as: "village, whose energetic demands (electricity, heating) are fulfilled with the use of local, renewable energy source". According to this concept, created by a group of German scientists, electricity and heat is produced by the use of biogas and additionally during the winter heat is generated by boilers burning wood chips or straw. The idea assumes that the system would consist of a local heating network conveying heat to the buildings which would not have to be equipped with heating boilers. Such a concept could be a model solution for a large part of the Polish Carpathians, considering the large potential of available biomass as well as the mastered technologies of biogas production. Today it is not difficult to construct local biogas works equipped with a sufficiently large fermentation chamber, devices for gas purification and its storage. These objects can produce biogas from agricultural waste (grass silages, crop waste or corn) cultivated just for this purpose. In Poland a special technology has been patented [Zgłoszenie w Urzędzie…] which covers the methane production method and the system production of electricity and heat. This multi-energetic system is used for gas fuel production (methane or a standardized mixture of methane and carbon dioxide) and simultaneously provides mechanical energy, electricity and heat. It is characterized by a high electrical energy production efficiency (even exceeding 40%) by a generator and heat production efficiency, up to 70% with the use of a thermo regenerative cell. It is easy to lead the produced biogas to the gas fuel standard meeting all the requirements for power generators fuels. The commonly available CHP (Combined Heat and Power) plants [De Paepe et al. 2006] can be used for supplying the buildings with heat and electricity. Figure 3 presents a device made by the Capstone Company, based on a micro-turbine. It burns high-methane gas and delivers heating power of about 90 kW and electric power of about 60 kW. Analogical devices, based on a combustion engine, can directly burn purified biogas that does not have to be previously enriched. The heat produced during power generation can be partially used for heating of the fermentation chamber. The rest can be used for water and building heating or wood chip drying. Electricity on the other hand can go to the energy system or be utilized for its own purposes. For many years The Baltic Renewable Energy Centre BREC/IBMER in Warsaw has been promoting construction of small biomethane power plants (SBPP) using biogas produced from agricultural waste and of electric power of about 5 MW.

The aforementioned possibilities were applied to a solution that meets the requirements of an energetically self-sufficient village and implemented in practice as a pilot project in Germany. For a few years data was collected during each project stage in the village of Effelter, which was used as the research site. This village, located in Bavaria (Kronach commune), had a population of 280 people and covered 68 households [Żukowski 2013], at the time. According to the website of the German Ministry of Agriculture[1], the information and experience gained from this project stimulated 136 similar investments (already realized or under implementation). Also, similar projects on much smaller scale are being implemented in other countries. Local energy systems, which connect infra-structurally large number of objects and meet their needs by using renewable energy sources, not only comply with environmental impact limits requirements (with the constantly growing energy demand) but also are rational because of their economic effectiveness.

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[1] http://www.wege-zum-bioenergiedorf.de/bioenergiedorfer/ (accessed 19.06.2013).

Source: Capstone Microturbine Corporation offer leaflet (www.capstoneturbine.com/prodsol/products)

Fig. 3. CHP unit of Capstone Microturbines Corporation

Obviously, the buildings located in mountainous areas should also use the energy supplied to them in a highly efficient way. It is necessary to gradually adjust the existing buildings to new architectural standards and energy efficiency requirements. Apart from thermal insulation and ensuring wind tightness the internal heating systems and hot water supply systems should be modernized. In the case of heat input from a local heating network via a substation it is necessary to select the proper regulation devices.

3.2. Factors conditioning energy infrastructure modernization and development in mountains areas

To create a modern energy infrastructure that meets the sustainable development requirements it is necessary to raise consciousness of both building owners and local governments, so that they become informed energy consumers (of electricity, fuel). Such conscious *prosumers* will not only use renewable energy but also produce it and transform it into heat or electricity. That kind of energy can be generated in the so-called micro-installations described in the new Energy Law as a part of a household's equipment or in large installations requiring concession for energy production and delivering it to their consumers via internal networks and for sale. It is possible to implement in Polish mountain areas the solutions presented above. However, to get a whole picture it is necessary to consider which factors will favour the implementation of these solutions and which would stand in its way. The success of the pilot project in the energy self-sufficient village in Germany and the fulfilment of their related hopes does not mean that the experiment would lead to a similar success in Poland. In our country there is no equivalent of the very effective German government policy of supporting and financing the development of renewable energy sources as well as innovative solutions. Pilot projects, such as Effelter, require significant financial support from the state and engagement of the local government or even private companies acting as ownership companies brought into being to perform the original investment task. The projects, when they are completed, are sources of important data and evaluations that are essential to make an informed decision about implementing or rejecting the pilot projects as a model solution. Without this knowledge attempts at similar investment opportunities are likely to give rise to the protests of Polish local communities more willing to see only the disadvantages and hazards, if there is no convincing data regarding the expected benefits. Moreover in Poland there is a series of additional objective reasons which make the development of an energy infrastructure much more difficult:

- significant density of protected areas in mountain regions (national parks, landscape parks and 'Natura 2000' areas) which impose special requirements on the neighbouring infrastructure,
- low-density housing and many buildings located in rugged and difficult areas, which means increased costs of heating networks construction and of linear infrastructure that connects objects,
- since many years there is growing urbanization pressure than can hinder terrain acquisition for purposes of the aforementioned investments,
- insufficient amount of biomass for methane fermentation can limit the production capabilities of biogas works.

There is also a series of favourable factors, which include:

- legal regulations and documents on the energy policy, such as: the revised energy law, the new act on renewable energy sources, Energy Policy of Poland until 2030 [Polityka energetyczna… 2009], Strategy for Energy Security and Environment [Strategia Bezpieczeństwo… 2013],
- financial support for pilot projects that use renewable energy, from the National Fund for Environmental Protection and Water Management (340 million zloty available by the year 2016),
- large availability of technological equipment for: biogas works, small fast pyrolysis systems, biomass burning boilers, etc.,
- development of consulting companies offering cooperation and support with renewable energy resources evaluation, drawing up of planning documents and with public consultations regarding the location of RES installations.

If the proposed energy solutions can meet the minimal economic effectiveness requirements in Poland, then they should be implemented. The solutions are perfectly aligned with the regulations of Strategy for Energy Security and Environment [Strategia Bezpieczeństwo… 2013] aimed at improving the state of environment. They include the rational waste use for energy purposes and air protection by limiting the impact of energy (point 3.3 of the Strategy). The proposed solutions fully meet the detailed objectives of the Strategy, especially by increasing the number of decentralized, renewable energy sources (point 2.6) and development of energy, in suburban and rural areas [Strategia Bezpieczeństwo… 2013].

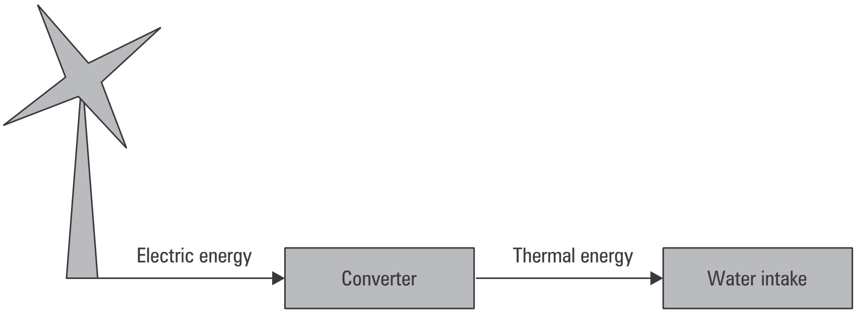
3.3. An example of purposefulness evaluation of renewable energy use and application of CHP (Combined Heat and Power) in supplying buildings with heat and electricity

The current thought is that the buildings should use renewable energy and if possible export any additional energy produced onto the outside market. Also, CHP is promoted as more efficient in the production of heat and additional electricity than traditional fuels. The study [Hopkowicz and Maludziński 2012] was aimed at evaluating the efficiency range of renewable energy harvesting in a standard house with a low energy demand and assessing the effects of CHP application in supplying a multi-family residential building with electricity and heat. The impact of these technologies on the energy quality of the objects was determined.

In the analysis the following objects were used: a single-family building and a multi-family building consisting of 50 apartments. The single-family building was a two-floor building with no basement, a functional attic and the functional area of 268 m^2. The external walls and ceiling were characterized by a very advantageous heat transfer coefficient of $U = 0.1\ W \cdot (m^{-2}\ K^{-1})$ and the windows coefficient equalled $0.8\ W \cdot (m^{-2}\ K^{-1})$. The object was assumed to be equipped with gravity assisted ventilation, not allowing for the recovery of heat loss from the air ventilated to the outside. The usable energy demand for the heating and domestic hot water use was calculated and then the annual demand for fuel and the electrical energy necessary for the operation of the building were rated in both variants: with renewable energy and without it. The calculations were performed by means of the procedures used to prepare energy efficiency certificates of buildings, according to the regulations [Rozporządzenie Ministra… 2008]. The annual utility energy demand for heating and ventilation for this building equalled $16172\ kWh \cdot year^{-1}$ and for hot water heating (for 4 people) equalled $2409\ kWh \cdot year^{-1}$.

The multi-family building with a functional area of 2690 m^2 was a four story building, with four staircases and a basement. The external walls and the ceiling were characterized by a heat transfer of coefficient $U = 0.1\ W \cdot (m^{-2}\ K^{-1})$ and the windows had a coefficient $U = 0.8\ W \cdot (m^{-2}\ K^{-1})$. The building was equipped with mechanical ventilation with heat recovery from the ventilation air removed outside. The usable energy demand for the heating and ventilation of the space equalled $152\,500\ kWh \cdot year^{-1}$ and $165\,557\ kWh \cdot year^{-1}$ for hot water heating.

It was assumed that the single-family building, apart from the gas boiler for hot water heating, will also make use of solar collectors, a wind turbine and a photovoltaic cell. The chosen turbine was a WS–30 made by Windside, with a vertical rotational axis and a starting speed of $2\ m \cdot s^{-1}$. The relatively high nominal electric power of the wind turbine (2 kW) is achieved at the wind speed of $10\ m \cdot s^{-1}$. The study assumed that the electricity harvested in this way would be applied to hot water heating. It was also assumed that some (small) part of this energy will power auxiliary devices (controllers, circulation pumps) in the hot water heating system. As the hot water demand is variable and the wind energy supply is unpredictable, it was assumed that systems for energy accumulation and storage will be used.



Source: authors' study

Fig. 4. A scheme of the wind turbine energy transformation

As shown in Figure 4, energy accumulation is possible in two locations: between the turbine and electricity to the heat converter and after the converter. In the first case the electric energy is accumulated and in the second case it is heat energy. Directing most of the turbine generated electricity directly to the heater in order to heat water allows removal of batteries and expensive DC/AC converters from the system. Accumulation of energy as heat, in a classic hot water reservoir, brings many benefits. The electricity supply from photovoltaic cells for a single-family building was assessed too. It was assumed that polycrystalline modules of 5 m^2 in size will generate DC electricity with the use of solar energy, with the efficiency of 17%. The photovoltaic system was supposed to work in parallel with the supply from the electrical network. The energy from the cells can provide power for auxiliary devices (pumps, controllers) in the house and the hot water heating system. Batteries are not necessary, as the network can fully take over supplying these devices with electricity.

In the case of the multi-family building the heating energy demand (152 500 kWh $\cdot$ year^{-1}) was assumed to be covered in 70% by the CHP generator (107 121 kWh $\cdot$ year^{-1}) and the remaining heat would be provided by a gas condensation boiler. It was also assumed that the complete heat necessary for heating hot water (165 557 kWh $\cdot$ year^{-1}) will be delivered by the CHP generation unit. CHP unit C 60, made by Capstone Microturbine Coraporation, was selected with the nominal electric power requirement of 60 kW and a nominal heating power of 89.3 kW, working at 57.6% heating efficiency and 34.1% electric efficiency. The analysis proved that the generator working, in heating mode will generate annually 163 320 kWh of electric power. This will cover power supply demand of the auxiliary devices (pumps, fans, controllers) in the heating system, the mechanical ventilation and the hot water heating system at 16 633 kWh $\cdot$ year^{-1}, in total. The remaining electricity of 146 690 kWh $\cdot$ year^{-1} can be "exported" outside. Although this energy could completely cover the power demand of the apartments (lights, appliances, etc. estimated at 45 000 kWh $\cdot$ year^{-1}), the apartments were assumed to be powered from the electric network, and the excess energy will be sold to the outside, as CHP energy.

3.4. Variants and calculation results for a single-family building

The analysis for a single-family building was performed with the following variants of sources:

- WJ1 – gas boiler with open burner chamber and hot water reservoir,
- WJ2 – condensation boiler and hot water reservoir,
- WJ3 – condensation boiler, hot water reservoir, photovoltaic cell,
- WJ4 – condensation boiler, hot water reservoir, photovoltaic cell, wind turbine,
- WJ5 – gas boiler with open chamber + solar collectors + solar reservoir,
- WJ6 – gas boiler with open chamber, solar collectors + solar reservoir and wind turbine,
- WJ7 – condensation gas boiler + solar collectors + solar reservoir + wind turbine,
- WJ8 – condensation gas boiler + hot water reservoir + wind turbine + photovoltaic cell.

The calculation results for the final energy demand, sufficient for heating of a building and hot water, for a single-family building is presented in Table 1. They were used to estimate the final energy consumption QK and primary energy factor EP, as an evaluation of energetic quality of the building. Figure 5 presents the values of these primary energy factors for heating the building EP_H, for heating hot water EP_W and the total primary energy factor EP of the considered single family object.

Table 1. Calculation results of final energy consumption: for heating Q_{KH}, of hot water Q_{KW}, and for electricity needs for the considered variants of single-family building energy supply in kWh · year^{-1}

Variant	Q_{KH}	Q_{KW1}	Q_{KW2}	$E_{el,\ pom\ H}$	$E_{el,\ pom\ W}$	$E_{el,\ pom\ sol}$
WJ1	19 454	3610	0	249	351	0
WJ2	17 360	3936	0	249	351	0
WJ3	17 360	3936	0	100	0	0
WJ4	17 360	783	3154	100	0	0
WJ5	19 454	1804	2461	249	351	88
WJ6	19 454	1967	2461	0	0	0
WJ7	17 360	1967	2461	0	0	0
WJ8	17 360	3936	0	100	0	0

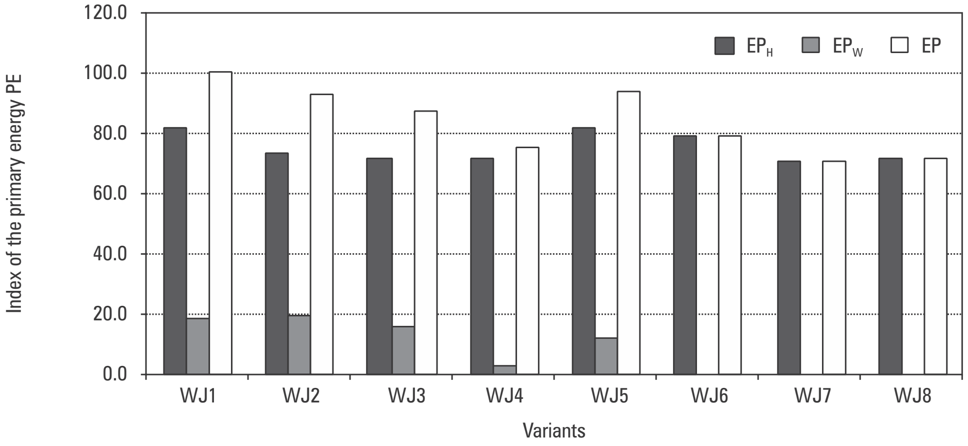


Fig. 5. Calculation results for the primary energy factors for building heating purposes EP_H and hot water heating EP_W for the considered variants $EP = EP_H + EP_W$

3.5. Variants and calculation results for the multi-family building

To cover the heat demand for heating water and the building the practical aforementioned solution was used. CHP was chosen to supply the building with energy and to lower the EP factor when compared to the alternate solution of supplying the building with a gas boiler and supplying electricity from the outside network.

The analysis was performed for the following variants:

- WW1 – CHP system for heat and electricity supply,
- WW2 – separate supply of heat from the gas boiler and electricity from the outside network.

As mentioned earlier, the CHP system WW1 provided 272 678 kWh · year^{-1} of heat energy and 163 323 kWh · year^{-1} of electricity. It was assumed that the remaining heat for heating purposes would be supplied from a peak condensation boiler. The production capabilities of the selected CHP generator are 72% greater than the building's total electricity demand. The calculated primary energy factor EP equals 142 kWh · m^{-2} per year.

The WW2 variant, in which the heat is supplied from the gas boiler and the electricity from the network, is characterized by the final energy demand (in gas) equal to 183736 kWh · year^{-1} for heating the building and 338147 kWh · year^{-1} for hot water heating purposes. The electricity demand for the auxiliary devices in the heating system, ventilation and hot water heating will be covered from the electric (AL) network. The EP factor for WW2 is 232 kWh · m^{-2} per year. Export of electricity in the CHP case (variant WW1) contributed to a decrease of EP factor by 38.7%.

3.6. Conclusions regarding energy infrastructure

To lower demand for original energy for energy services in mountain areas definitely requires an increased use of renewable energy, the application of a CHP instead of simply burning fossil fuels and advanced methods of managing the produced energy. The analysis of energy supply for selected objects of low demand shows that properly selected and adjusted systems which use renewable energy effectively improve the energy efficiency of an object and therefore decrease the fuel and energy resource demand. In the case of a single-family building the application of a small wind turbine is more effective in heating hot water than the solar collector system (by covering 40 to 50% of the heat demand). In the case of direct conversion of electricity to heat, using a heater and storing the heat in a water reservoir, a wind turbine with nominal power of 2 kW can cover the annual demand for hot water for a family of four buildings unit.

In the case of a multi-family building a careful selection of a CHP generator based on an internal combustion micro-turbine or an engine can fully cover the electricity demand of auxiliary devices and produce significant power surplus that may be sold outside. The heating power of the CHP generator, due to its high investment costs, should be dimensioned for 40% of the maximum heating power demand. Usually it corresponds to about 70% of the utility energy for this purpose. The rest of the heating power can be provided by a heating boiler or a heat exchanger using the heating network. Moreover, the generator in the heating season, as well as in other parts of the year should completely cover the hot water energy demand.

References

Baran E., Grzebyk B. 2009. Ecological infrastructure as a feature of natural environmental protection of mountain communes. Probl. Zagospod. Ziem Górs., 56, 41–48.

De Paepe, D'Herdt, Martens D. 2006. Micro-CHP systems for residential applications. Energy Conserv. Manag., 47, 3435–3446.

GUS (Główny Urząd Statystyczny). Roczniki statystyczne. 2012. Ochrona Środowiska.

Hopkowicz M., Maludziński B. 2012. Możliwości poprawienia charakterystyki energetycznej budynku o niskim zapotrzebowaniu na energię. Czasop. Techn., Budownictwo, 2-B, 3, 177–183.

http://www.wege-zum-bioenergiedorf.de/bioenergiedorfer/ (19.06.2013).

Karpenstein-Machan M. 2009. The Bioenergyvillage – Lighthouse Project for sustainable energy production in rural area. Proceedings of the International Conference on Sustainability Science, Tokyo, Japan, 5–7 Feb.

Pawełek J. 1993. Mętność wód rzek i potoków górskich w aspekcie ich oczyszczania do celów wodociągowych, Ochr. Środ., 4(51), 69–72.

Polityka energetyczna Polski do 2030 roku. 2009, http://www.mg.gov.pl/files/upload/8134/Polityka%20energetyczna%20ost.pdf.

Roszkowska-Mądra B. 2010. Obszary wiejskie o niekorzystnych warunkach gospodarowania w aspekcie ich zrównoważonego rozwoju. Wyd. Uniwersytetu w Białymstoku, Białystok.

Rozporządzenie Ministra Infrastruktury z dnia 6 listopada 2008 r. w sprawie metodologii obliczania charakterystyki energetycznej budynku lub części budynku stanowiącej samodzielną całość techniczno-użytkową oraz sposobu sporządzania i wzorów świadectw ich charakterystyki energetycznej.

Rybicki S.M. 2011. Opinia dotycząca kanalizacji miasta Gilowice. Rysunki wg projektu Scott Wilson Ltd, Kraków.

Rybicki S.M., Rybicki S.A. 2005. Koncepcja i wytyczne technologiczne dla Stacji Uzdatniania Wody w Jaśle, Kraków.

Strategia Bezpieczeństwo Energetyczne i Środowisko. 2013. Perspektywa do 2020 roku, http://bip.mg.gov.pl/files/upload/19680/2013–11–25_BEiŚ_v.4.1.pdf.

Żukowski M. 2013. Koncepcja wsi bioenergetycznej. Ciepłown. Ogrzewn. Wentyl, 8, 44, 315–318.

Zgłoszenie w Urzędzie Patentowym RP o numerze P–3486681 pt. „Sposób i układ do wytwarzania metanu, energii elektrycznej i cieplnej".

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