DOI: 10.15199/17.2023.3.5

The financial aspect of local rainwater management on a wind farm

Finansowy aspekt lokalnego zagospodarowania wód opadowych na farmie wiatrowej

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Keywords: *local rainwater management, profitability analysis, wind power plant, infiltration boxes, absorbing well*

Abstract
Nowadays, due to the progressing water deficit, increasing attention is paid to the possibility of retaining rainwater at the place where precipitation occurs. In terms of selecting the method for local rainwater management, the financial profitability of the investment is a very important issue for an investor. In the article, the profitability of two methods of drainage the selected facilities of the wind power plant is analyzed. The solutions with an absorbing well and infiltration boxes were taken into account. The indicators of financial profitability classified as discount methods were used in the analysis. The investigation made it possible to determine the relationship between investment costs and profits in terms of achieving investment viability. The analysis concerns the specific object, so its results are not universal. However, they can be helpful in the case of similar investments, which is especially important because of the fact that draining rainwater from selected wind plant facilities is necessary.

Słowa kluczowe: *lokalne zagospodarowanie wód opadowych, analiza opłacalności, elektrownia wiatrowa, skrzynki rozsączające, studnia chłonna*

Streszczenie
W związku z postępującym deficytem wody, coraz większą uwagę zwraca się obecnie na możliwość zatrzymywania wód opadowych w miejscu występowania opadów. W przypadku wyboru sposobu lokalnego zagospodarowania wód opadowych bardzo ważną kwestią dla inwestora jest opłacalność finansowa inwestycji. W artykule przeanalizowano opłacalność 2 metod odwodnienia wybranych obiektów farmy wiatrowej. Uwzględniono rozwiązanie ze studnią chłonną oraz rozwiązanie ze skrzynkami rozsączającymi. W analizie wykorzystano wskaźniki oceny efektywności finansowej inwestycji zaliczane do metod dyskontowych. Badania pozwoliły określić powiazanie między kosztami inwestycyjnymi a zyskami w aspekcie osiągnięcia opłacalności inwestycji. Przeprowadzone analizy dotyczą konkretnego obiektu, więc uzyskanych wyników nie można traktować jako uniwersalne. Mogą być one jednak pomocne w przypadku innych podobnych inwestycji. Jest to szczególnie ważne ze względu na konieczność odprowadzenia wód opadowych z obiektów farm wiatrowych.

1. Introduction

The climatic changes observed in recent decades have resulted in a change in the nature of precipitation. Snowless winters are more common, while in summer there are torrential rains preceded by long rainless periods [1,2]. As a result, the level of groundwater lowers and the risk of desertification occurs. Thus, due to the progressing water deficit, increasing attention is paid to the possibility of retaining rainwater at the place where precipitation occurs. Local rainwater management not only reduces the amount of water introduced into an often overloaded stormwater system, but also has environmental and hydrological advantages – supports raising the groundwater level, has a positive effect on the microclimate by providing water to plants, pre-treats rainwater, supports the prevention of urban floods [3]. Simultaneously, the increasing deficit of drinking water necessitates its rational management, e.g. by replacing drinking water with water of inferior quality, if the use of drinking water is not necessary – as in the case of flushing toilets, watering plants or cleaning works [4]. In such cases, filtered rainwater can be used, especially since the rainwater is characterized by a low content of calcium and magnesium ions, and therefore by a low hardness [5].

In this context, there is clearly a need for the widest possible use of Low Impact Development (LID) solutions for rainwater management. The LID facilities are decentralized and microscale methods of rainwater management at the source, analogously to the nature. The concept of LID as well as analogous concepts (e.g. sustainable urban drainage systems – SuDS in the UK, water sensitive urban design – WSUD in Australia) are gaining popularity around the world as an effective means of inhibiting the negative effects of urbanization on hydrological processes [6–8].

The attention paid to the rational and environmentally safe manage of rainwater is imposed by the law regulations. The objectives of the EU Water Framework Directive include promoting sustainable water use, protecting and improving the aquatic environment, and mitigating the effects of floods and droughts [9]. The 2030 Agenda for Sustainable Development (Goal 6) requires the sustainable management of water

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resources so that all people have access to water and sanitation [10]. Including the problem of water management in legal regulations emphasizes the importance of this issue in the broadly understood social interest.

In terms of selecting the method for local rainwater management, the financial profitability of the investment is a very important issue for an investor. While the environmental benefits of local rainwater management are not in doubt, the financial benefits are much more debatable [11,12]. Thus, the aim of the article was to assess the financial profitability of two methods for drainage of oil basins of power and earthing transformers on the premises of a selected wind farm, and to identify opportunities to increase this profitability.

2. Materials and methods

In order to achieve the aim of the work, it was necessary to develop 2 variants for drainage of the oil basins of the power and earthing transformers, estimate the investment and exploitation costs as well as benefits of each variant, and then calculate selected indicators of financial profitability of the investment.

2.1. Object

The object under consideration is a power station receiving energy from 13 windmills and converting direct current into alternating current, adapted to the operating conditions of the low-voltage network supplying the nearby town. The station is located in central Poland.

The objects needing drainage are the basins of 2 transformers: the power transformer and the earthing transformer. Both transformers are placed on the reinforced concrete basins with granite crushed stone on a steel truss in the upper part. The task of the basins is to collect both rainwater falling onto the transformer stations and possible leakages of transformer cooling oil. Thus, the basins must be drained with safely separating the oily substances.

2.2. Variants of drainage

Two variants of draining rainwater from the transformer basins have been proposed:

– variant 1: a system with an absorbing well,

– variant 2: a system with infiltration boxes.

Both variants 1 and 2 are classified as LID methods because they enable the natural management of rainwater at the source – in the place where rainfall occurs. Rainwater with possible oily substances is drained in cast iron pipes to a coalescing oil separator and then, depending on the variant, in PVC pipes to an absorbing well or to infiltration boxes. The basic materials used in the individual variants are summarized in Table 1.

Table 1. Basic materials used in variants 1 and 2

Tabela 1. Podstawowe materiały wykorzystane w koncepcjach 1 i 2

Material	Amount	
	Variant 1	Variant 2
Concrete manhole DN 800	2 pcs.	2 pcs.
Concrete manhole DN 1200	1 pc.	1 pc.
Coalescing oil separator	1 pc.	1 pc.
Cast iron pipes DN 150	35 m	35 m
PVC pipes DN 160	24 m	24 m
Absorbing well DN 1200, H = 5 m	1 pc.	–
Infiltration box 0.43 m^3/pc.	–	12 pcs.

The total area requiring drainage, including the power transformer and earthing transformer basins, equals 73 m^2.

2.3. Financial efficiency analysis

The first stage of the financial efficiency analysis was an estimation of investment and exploitation costs, as well as financial benefits for the both variants. All prices necessary to estimate cash flows were assumed at the level of July 2022. The investment costs were calculated as a sum of materials' costs and working costs (man-hours and machine-hours). The exploitation costs included costs of checking the patency of the system elements, costs of on-going repairs and the coalescing oil separator service.

Calculations of investment and exploitation costs were carried out for 2 cases. The first case covered the entire investment for each of the variants, i.e. all pipes, sewage chambers, oil separator and local rainwater management device. In the second case, the costs calculations omitted the shared part – these elements of the investment that must be built regardless of the variant. Thus, the second case covered investment and exploitation costs of rainwater management device (an absorbing well or infiltration boxes, depending on the variant) and required connections only.

The benefits result from the fact that an alternative to the proposed variants of local rainwater management is disposal of rainwater into the stormwater system. Thus, the benefits will be financial savings from not having to pay fees to the municipal company for draining rainwater through the system. The fee in the town near which the wind farm is located equals 1.42 €/m^3. The value of the benefits does not depend on whether the entire investment is considered or the shared part is omitted. The value is the same in both cases.

The financial analysis was carried out using discounting methods for assessing the efficiency of an investment project, taking into account changes in the value of money over time. Four indicators were adopted as criteria of investment profitability evaluation: Net Present Value – *NPV*, Benefits-Costs Ratio – *BCR*, Discounted Payback Period – *DPP*, and Dynamic Generation Cost – *DGC*. The indicators were calculated according to the formulae [13–15]:

$$NPV = \sum_{t=1}^{n} \frac{CF_t}{(1+r)^t} \tag{1}$$

$$BCR = \frac{\sum_{t=0}^{t=n} \frac{B_t}{(1+r)^t}}{\sum_{t=0}^{t=n} \frac{C_t}{(1+r)^t}} \tag{2}$$

$$DPP = min\left\{s \middle| \sum_{t=1}^{s} \frac{CF_t}{(1+r)^t} \geq 0\right\} \tag{3}$$

$$DGC = \frac{\sum_{t=0}^{t=n} \frac{C_t}{(1+r)^t}}{\sum_{t=0}^{t=n} \frac{EE_t}{(1+r)^t}} \tag{4}$$

where: t – time period (usually a year) in the investment time duration, n – total number of time periods during an investment operation (30 in this study), s – the number of time periods ($s < n$ for a profitable investment and $s > n$ for a non-profitable investment), CF_t – net cash flow at time t [€/year], r – discount rate per period [%], r_0 – discount rate per period for which $NPV = 0$ [%], B_t – benefit at time t [€], C_t – investment and exploitation costs at time t [€], EE_t – ecological effect in time period, expressed in this study by volume of drained rainwater [m^3].

The *NPV* indicator shows what net profits the investment will generate after the assumed investment period. The higher the *NPV* value, the more profitable the investment is. Negative *NPV* values mean that the investment generates financial losses. The *BCR* indicates what profit corresponds to the unit of money spent (e.g. 1 € spent). The relation $BCR > 1$ means a profitable investment, while $BCR < 1$ is characteristic for a non--profitable investment. The period *DPP* means the time when benefits equal expenses. The *DGC* indicator means the cost-effectiveness of the investment understood as the cost of obtaining the environmental effect of the investment – in this article, the environmental effect is the volume of rainwater disposed. A lower *DGC* value means a more profitable investment.

The next stage of the analysis was to check how much changes in investment costs *IC* and benefits *B* values improve the financial efficiency of the investment on the example of the *NPV* indicator. For this purpose, the values of *IC* for the case not considering shared part of the investment, were gradually reduced from 100% to 10% of their actual value, using the multiplier P_{IC} ($P_{IC} \in \langle 10\%,100\% \rangle$) and the *NPV* indicator were calculated for each reduced *IC*. Similarly, the benefits *B* were gradually increased (using the multiplier $MB \geq 1$) until $NPV \geq 0$. This allowed to determine the values of *IC* and *B* (both parameters independently) for which the investment became profitable. The last stage of the analysis was to find the relationship between the values of *IC* and *B* for which $NPV = 0$.

3. Result and discussion

The results of the calculations summarized in Table 2 indicate that none of the variants is a financially viable investment. Despite the fact that the sum of investment and operating costs of the entire investment in variant I is much lower than in variant II, all the calculated indicators of financial efficiency prove high unprofitability not only of variant II, but also of variant I. Negative *NPV* values indicate that after the assumed 30 years of operation, the proposed solutions would generate a financial loss of 17,608.5 € for variant I and 23,705.31 € for variant II. The indicator $BCR < 1$ means that the financial benefits will not balance out the expenses. The investment will not return even after the time exceeding 3-times the period of operation ($DPP > 90$). The costs of the environmental effect exceed almost 10 times and 13 times (respectively variants I and II) the fee for the possible disposal of rainwater to a stormwater system.

Table 2. The results of calculating financial efficiency indicators for the entire investment

Tabela 2. Zestawienie wyników obliczeń wskaźników opłacalności finansowej dla całej inwestycji

Parameter	Symbol, unit	Variant 1: absorbing well	Variant 2: infiltration boxes
CASH FLOWS FOR ENTIRE INVESTMENT			
Investment costs	*IC*, €	16107.5	22036.5
Exploitation costs	*EC*, €/year	227.07	237.99
Benefits – variant I	*BI*, €/year	129.43	129.43
FINANCIAL EFFICIENCY INDICATORS			
Net Present Value	*NPV*, €	-17608.5	-23705.31
Benefits-Costs Ratio	*BCR*, –	0.101524	0.077435
Discounted Payback Period	*DPP*, years	>90	>90
Dynamic Generation Cost	*DGC*, €/m^3	13.98	18.33

Contrary to expectations, a significant reduction in expenses by omitting in the analysis the shared part of the investment, which must be built regardless of the variant, did not improve the profitability sufficiently (Table 3). Although the values of the indicators improved (e.g. the financial loss indicated by the *NPV* decreased 4.7 times for variant I and 2.4 times for variant II, the cost of achieving the environmental effect decreased by almost 3.5 times and more than 2 times, respectively), both variants still remained clearly unprofitable investments. Analyzing cash flows for a case without a shared part (Table 3), it can be seen that exploitation costs are definitely the slightest importance due to zero or low value (according to producers' information, absorbing wells for rainwater do not require operating costs). Therefore, in the next stage of the analysis, to determine the conditions that must be met, so that the investment becomes profitable, we focused on the investment costs *IC* and benefits *B*. The financial efficiency of the investment at this stage was assessed on the basis of the value of the *NPV* indicator.

Table 3. The results of calculating financial efficiency indicators for the investment without the shared part

Tabela 3. Zestawienie wyników obliczeń wskaźników opłacalności finansowej dla inwestycji bez uwzględniania części wspólnej

Parameter	Symbol, unit	Variant 1: absorbing well	Variant 2: infiltration boxes
CASH FLOWS FOR INVESTMENT WITHOUT SHARED PART			
Investment costs	*IC*, €	5728.059	11657.05
Exploitation costs	*EC*, €/year	0.00	10.92
Benefits – variant I	*BI*, €/year	129.43	129.43
FINANCIAL EFFICIENCY INDICATORS			
Net Present Value	*NPV*, €	-3738.367	-9835.18
Benefits-Costs Ratio	*BCR*, –	0.347359	0.168263
Discounted Payback Period	*DPP*, years	>90	>90
Dynamic Generation Cost	*DGC*, €/m^3	4.09	8.43

Figure 1 illustrates how much the reduction of investment costs increases the value of the *NPV* indicator, and thus improves the profitability of the investment. In the case of the solution with an absorbing well (variant I) to achieve profitability expressed as $NPV \geq 0$, without changing potential benefits ($M_B = 1$), the actual IC would be reduced by as much as 65.3% ($P_{IC} = 34.7\%$). In the case of a more expensive solution – infiltration boxes (variant II), this value is of course greater – 84.4% ($P_{IC} = 15.6\%$). The variant II turned out to be more sensitive to changes in the value of investment costs.

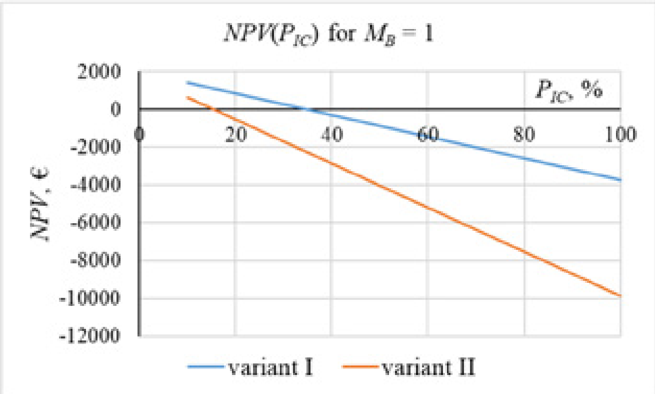

Fig. 1. The impact of the change in the value of investment costs IC on the value of the NPV indicator (P_{IC} – percentage of actual investment costs, M_B – financial benefits multiplier)

Rys. 1. Wpływ zmiany wielkości kosztów inwestycyjnych IC na wartość wskaźnika NPV (P_{IC} – odsetek rzeczywistej wartości kosztów inwestycyjnych, M_B – mnożnik korzyści finansowych)

In turn, to achieve financial profitability ($NPV \geq 0$) without reducing investment costs ($P_{IC} = 100\%$), it is necessary to increase the benefits (Fig. 2). Both variants showed the same sensitivity to a change in the value of the benefits. For variant I, the *NPV* indicator reached the value of 0 after an almost 3-fold increase in benefits ($M_B = 2.88$), while in the case of variant II it was necessary to increase B almost 6 times ($M_B = 5.95$).

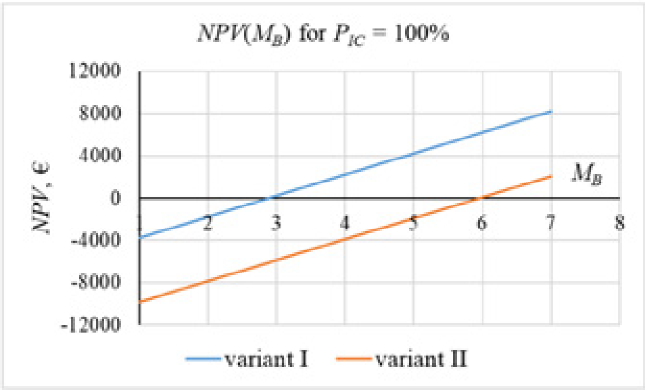

Fig. 2. The impact of the change in the value of benefits B on the value of the NPV indicator (P_{IC}, M_B – like in Fig. 1)

Rys. 2. Wpływ zmiany wielkości zysków B na wartość wskaźnika NPV (P_{IC}, M_B – jak na Rys. 1)

Considering changes in the *IC* and *B* values independently of each other, to achieve the return on investment, resulted in low values of the P_{IC} percentage and high values of the M_B multiplier – not useful from a practical point of view. Therefore, in further analysis, both *IC* and *B* were changed simultaneously. Doubling the benefits ($M_B = 2$) caused that in order to achieve profitability of the investment, IC must be reduced by 30.5% (P_{IC} = 69.5%) for option I and by 67.3% (P_{IC} = 32.7%) for variant II (Fig. 3). In turn, the 3-fold increase in benefits ($M_B = 3$) resulted in the fact that variant I was profitable without reducing *IC* (because the multiplier M_B exceeded the limit value of 2.88, designated as the zero point in the graph in Fig. 2), and to achieve profitability for variant II, it was necessary to reduce the IC by half (P_{IC} = 50%) (Fig. 4).

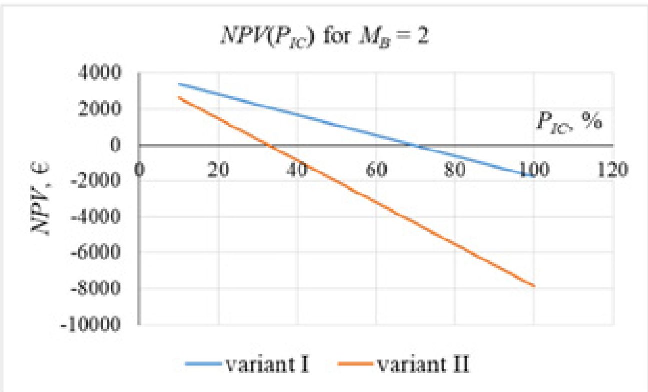

Fig. 3. The impact of the change in the value of IC on the value of the NPV indicator with a 2 fold increase in B (P_{IC}, M_B – like in Fig. 1)

Rys. 3. Wpływ zmiany wielkości IC na wartość wskaźnika NPV przy 2-krotnym zwiększeniu korzyści B (P_{IC}, M_B – jak na Rys. 1)

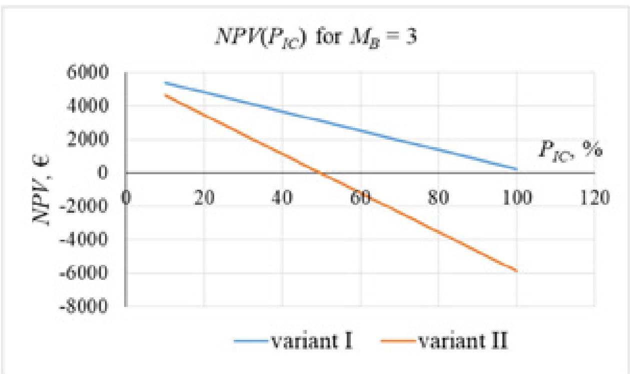

Fig. 4. The impact of the change in the value of IC on the value of the NPV indicator with a 3 fold increase in B (P_{IC}, M_B – like in Fig. 1)

Rys. 4. Wpływ zmiany wielkości IC na wartość wskaźnika NPV przy 3-krotnym zwiększeniu korzyści B (P_{IC}, M_B – jak na Rys. 1)

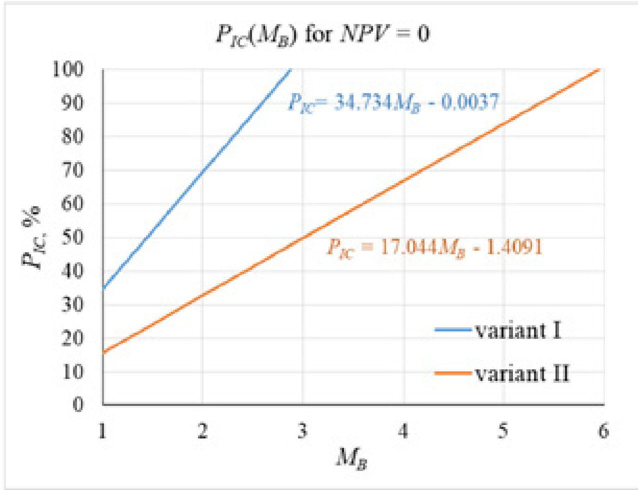

Fig. 5. Relationship between percentage P_{IC} and multiplier M_B for NPV = 0

Rys. 5. Związek między wartościami procentu P_{IC} i mnożnika M_B dla NPV = 0

Assuming different values of M_B, it was made a graph of the dependence of those values of percentage P_{IC} on the M_B multiplier, for which $NPV = 0$ (Fig. 5). All points located on the chart (on the blue line for variant I and on the orange line for variant II) mean the limit of the investment profitability, while the points located below the chart indicate profitability. The points of intersection of the graphs with the vertical axis correspond to the zero points of the graphs in Fig. 1. The points of intersection of the graphs with the line P_{IC} = 100% correspond to the zero points of the graphs in Fig. 2. The intersection points of the graphs with the lines $M_B = 2$ and $M_B = 3$ correspond to the zero points of the graphs shown in Fig. 3 and 4, respectively. Using the basic mathematical relationships, the equations of the functions (lines) presented in Fig. 5 were determined as:

– for variant I

P_{IC}=34.734·M_B-0.0037,% (5)

– for variant II

P_{IC}=17.044·M_B-1.4091,% (6)

Equations (5) and (6) refer to specific investment solutions and are not universal. However, they can be helpful in making investment decisions, especially in terms of applying for external funding. It is also important that the fees for the disposal of rainwater into a stormwater system vary greatly across the country, which means that the profitability of even the same investment in different locations varies.

4. SUMMARY AND CONCLUSIONS

Two concepts for draining rainwater from power and earthing transformers' basins on the premises of a wind farm were proposed and assessed in financial terms in the article – a system with an absorbing well (variant 1) and a system with infiltration boxes (variant 2). None of the variants turned out to be financially viable, regardless of whether the entire investment was considered or only its part, for which alternative solutions could be used. Variant I was less unprofitable because it required both lower investment expenditures and generated lower operating costs. The potential profit was the same for both variants. Regardless of the lack of profitability of the proposed solutions and the costs incurred by an investor, transformer basins must be drained of water for environmental and technological reasons. Nevertheless, financial issues are always very important for the investor, which is why the investor often looks for the possibility of external funding (government funding, sponsorship, etc.).

The conducted analyzes showed that with the current fees for rainwater discharge into the sewage system, the solution proposed in option I would be profitable only with external funding of at least 65.3% of investment costs, while option II would require funding in the amount of as much as 84.4%. For variant I, if the investment was located in a town where the fees for the use of the stormwater system are twice as high as compared to the actual location of the wind farm, a 30.5% financial support would suffice, and with three times higher fees, the investment would be profitable without any external support. In the case of variant II, the co-financing of 30% would be sufficient to achieve profitability of the investment, if the fees for using the stormwater system were more than 4 times higher than the actual fees. It should be underlined, that the investigation concerns the specific object, so its results are not universal. However, they can be helpful in the case of similar investments located in different places of the country.

ADDITIONAL INFORMATION

This research was funded by internal projects of Lublin University of Technology, Poland, number FD-20/IS-6/015.

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