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# POSSIBLE APPLICATIONS FOR THE WIND ENERGY IN THE HEATING AND AIR CONDITIONING SYSTEM

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**Abstract**. *For centuries wind energy is the only natural energy at man's disposal, and then for nearly a hundred years almost forgotten. One of the reasons is the wind fluctuation over time with impossible exact prognosis, in addition to small energy concentration to take into consideration for big investments. Besides, The wind energy hardly accumulates. Basically, the wind is a part of the solar energy, but in a consequential form, which directly gives mechanical work. From the total sun radiant energy on planet, around 2% transfers to wind energy, of which theoretically 59% can be used. Based on the analyses that are done for our conditions, the total effective energy that we can be obtained from the wind is defined for each month. On the basis of these analyses and calculations of the windwheel power as well as on the basis of the heat needed for heating and air conditioning, a functional diagram is defined for wind energy application in the heating and air conditioning system. The possibilities of our planet on this ground are surely many, but they are not examined enough yet.*

**Key words**: *Wind Energy, Windwheel, Heating, Air-conditioning*

## 1. INTRODUCTION

The total kinetic energy of the wind flow in the atmosphere is estimated around $3\times10^{15}$ *KWh* per year, which approximately corresponds to 0,2% of solar radiation that reaches the earth. The use of huge energy has a very long tradition and has been really important for agriculture, cattle breeding and tourism development in remote regions. Aero-generators demonstrate an efficient and economical source of energy especially in costal and mountain districts, where there is enough wind. All in all, the speed and change of the airflow, in time and space, depend on geographical situation and topographic conditions; that is why the potential wind energy in technical usage is not higher than $3\times10^{15}$ *KWh* per year. Small windwheels, powered from 10KW to 30KW, come into consideration only in districts with the wind speed higher than 4(*m*/*s*). They can be put anywhere (on open hills or on taller buildings) for mechanical energy production: there is an immediate start for water pumps, air compressors, and electrical generators. Watering soil is very important in many developing countries, and the need of windwheel can be solved in an economical way. If they give electrical energy, a system for foraging the energy might be needed.

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## 2. WINDWHEEL POWER

On the whole, energy availability of air mass in flow can be represented in this form:

$$N_{sr} = 0,5 m_v c_0^2 \quad (1)$$

In an ideal case (if there is no loss of friction) the windwheel's energy will equal the difference of kinetic energy in front of and behind the screw (vane) of the air mass in flow. If we suppose that the speed of the flow behind of the vane does not have marginal components, then, the energy is:

$$N_t = 0,5 m_v (c_0^2 - c_2^2) \quad (2)$$

The air mass flowing through the surface of the vane can be shown like:

$$m = G/g = V/vg = Ac'/vg = d^2 \pi c'/4vg \quad (3)$$

When:

$$c' = 0,5(c_0 + c_2) \quad (4)$$

To get maximum energy the windwheel's speed $c_2$ has to be optimal, and that would be:

$$c_{2opt} = 1/3\ c_0 \quad (5)$$

The flow speed through the vane, then, is:

$$c'_{opt} = 0,5(c_0 + 1/3 c_0) = 2/3 c_0 \quad (6)$$

Swiftest (maximum) energy is:

$$N_t = \frac{1}{2}\frac{d^2\pi}{4vg}\frac{2}{3}c_0\left(c_0^2 - \frac{1}{9}c_0^2\right) = \frac{d^2\pi}{8vg}\frac{16}{27}c_0^3 \quad (7)$$

If we take into account the corresponding value, we get a term for maximum theoretic energy:

$$N_t = \frac{16\pi}{8 \cdot 0.79 \cdot 9.81 \cdot 27 \cdot 102} \cdot d^2 c_0^3 = 0.00029 d^2 c_0^3 \quad (8)$$

To get the real energy, in the upper value, we need to put in the utilized form of vane ($\eta_p$):

$$N_t = 0.00029 \eta_p d^2 c_0^3 \quad (9)$$

The dependence of windwheel energy on the rotor diameter and the wind flow speed are shown in Figure 1

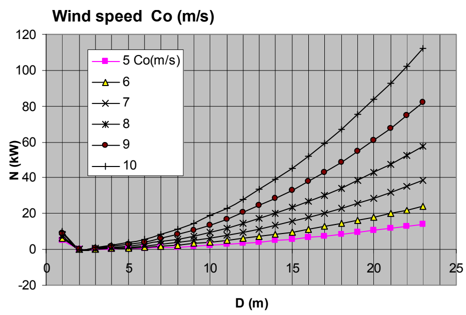


**Fig. 1** Dependence of the Windwheel on Rotor Diameter and Wind Flow Speed

## 3. WIND ENERGY

### 3.1 Dependence of the Wind Parameter on Height

Wind speed is different on different heights. The effect of the wind on the impeller is different as can be found on different heights. Figure 2 gives a typical wind speed diversity per height $h$ is shown from the ground up to 100 metres. On the ground $h = 0$ the wind speed is always equal to zero. With the height increase, the speed is increasing, too. Dependence of wind speed on height is shown as:

$$h - d = h_0 \exp(u_2 / V) \quad (10)$$

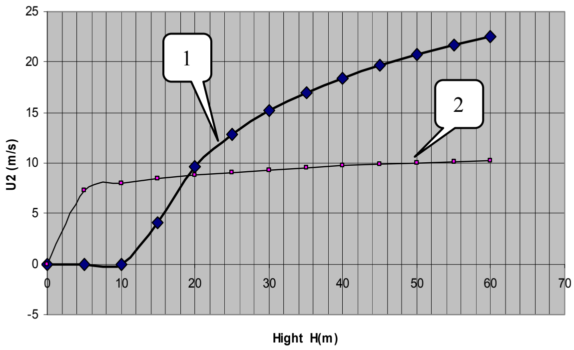


**Fig. 2** Dependence of the Wind on Height above the Ground (1-log dependence; 2-by formula (12)

Or:

$$u_2 = V \ln((h - d) / h_0) \quad (11)$$

Correctly, windwheel impeller is on the height from 5 to 50 meters. To define speed $u_2$ on these heights we often use approximate formulas, in which the standard wind speed $u_s$ is measured on the height of 10 meters, and the formula is:

$$u_2 = u_s (h / 10)^{b'} \quad (12)$$

For open places, parameter $b' = 1/7 = 0,14$. The lower the parameter $b'$, the lower the difference load. Parameter value $b'$ is different in different times of the year, it's even different in a day. Formula (12) is to be carefully used, especially on heights over 50 meters.

### 3. 2 Wind Parameter Change in Time

With many practical windwheel problems it is very important to know the overall energy value that the wind can make, for example, in a year. We also need to know for how long the energy can be constant. With strong winds, on higher speed, for instance 12(*m/s*), the wind-wheel produces huge amounts of electrical energy, but flashily the speed can drop or the wind-wheel can stop working. It is harder when we have a long period of no wind or weak wind. By the windwheel rules, when the windspeed is less than 5(*m/s*) we regard it as too low to move the windwheel, but speed from 8(*m/s*) is considered to be really good for moving the windwheel.

Independently, in all these cases we need to carefully choose the windwheel parameters that can be used in local weather conditions. Before we move to further theoretical analysis, let's see the necessity for this, the method of analysis wind parameters, in the next example. Here is an analysis of the wind taken from weather station in Prizren, Dragas, and Brezovica in 1998. The basic statistical analysis is done with the data and shown in Table T1. From the results in Table T1 and Figures 3, 4, 5 and 6, some dependance is shown.

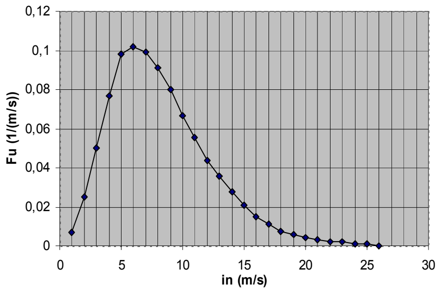


**Fig. 3** Wind Speed Dividing Function (Probability Density Schedule)

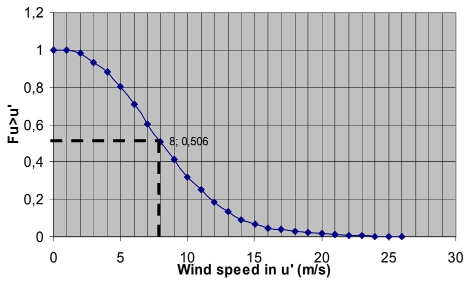


**Fig. 4** Wind Speed Probability Function, Higher than *u'* (for Density Probability, Calculated by Fig. 3)

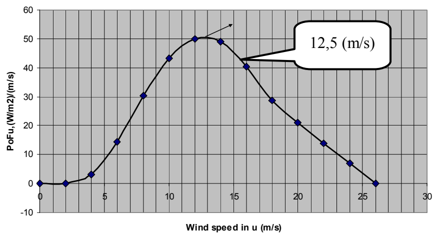


**Fig. 5** Wind Energy Dividing Function (by Fig. 3)

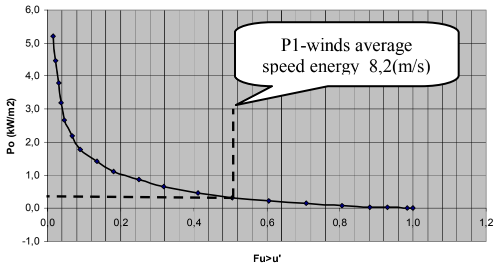


**Fig. 6** Dependence of Specific Wind Flow Energy from Probability $F_{u>u'}$

## 4. The Necessary Heat Energy for Heating and Air Conditioning

For analysis of energy consumption for heating, we will use a smaller motel in Brezovica, dimensions $20 \times 20 \times 2 = 800(m^2)$, the height is around 7 meters (two storey), total area cover $A_{OM} = 1360(m^2)$ with average coefficient of heat flow $K = 1{,}8(W/m^2K)$ Overall analysis is shown in Table T2.

The windwheel energy in summer can be directly used for air conditioning through the refrigerating machines. But when it is windy in the summer the air temperature is lower, so the need for cooling energy is lower. The reason why plant with absorption – type refrigerating machine would be better is that it would be working with the hot water from the accumulation. To ensure enough energy, in the summer for cooling, in winter for heating , and when there is not wind on the heat accumulator a brine heater can be attached. This auxiliary heat will be of great use where there is no possibility for the windwheel to be connected to electric network. As we can see from the diagram shown in Figure 7, it is necessary that extra produced electric energy from October and November is accumulated with heat accumulator, with necessary isolation thickness. In this way the accumulated heat would be used in December and January, when we have less energy. Around 11000(*KWh/year*) energy is less in these two months. Heat accumulator density in this case would be:

$$V_{RE} = Q_{AK}/cdtp = 11000/(4,2 \cdot 988 \cdot 90/3,6 \cdot 1000) = 106(m^3 / year)$$

**Table 1** Statistical Result Analysis for Measuring the Wind Speed

| $u'$ $\left(\frac{m}{s}\right)$ | $dN/du$ $\left(\frac{m}{s}\right)^{-1}$ | $F_u$ $\left(\frac{m}{s}\right)^{-1}$ | $F_{u>u'}$ | $F_u\,u$ | $u^3$ $\left(\frac{m}{s}\right)^{-3}$ | $F_u\,u^3$ | $P_u$ $\frac{KW}{m^2}$ | $P_u\,F_u$ |
|---|---|---|---|---|---|---|---|---|
| 26 | 1 | 0,000 | 0,000 | 0,000 | 17576 | 0,00 | 11,42 | 0,0 |
| 25 | 1 | 0,001 | 0,001 | 0,025 | 15625 | 15,63 | 10,16 | 10,2 |
| 24 | 1 | 0,001 | 0,002 | 0,024 | 13824 | 13,82 | 8,99 | 9,0 |
| 23 | 2 | 0,002 | 0,004 | 0,046 | 12167 | 24,33 | 7,91 | 15,8 |
| 22 | 4 | 0,002 | 0,006 | 0,044 | 10648 | 21,30 | 6,92 | 13,8 |
| 21 | 8 | 0,003 | 0,011 | 0,068 | 9261 | 30,10 | 6,02 | 19,6 |
| 20 | 12 | 0,005 | 0,015 | 0,090 | 8000 | 36,00 | 5,20 | 23,4 |
| 19 | 14 | 0,006 | 0,023 | 0,114 | 6859 | 41,15 | 4,46 | 26,8 |
| 18 | 19 | 0,008 | 0,030 | 0,136 | 5832 | 44,18 | 3,79 | 28,7 |
| 17 | 25 | 0,011 | 0,038 | 0,193 | 4913 | 55,84 | 3,19 | 36,3 |
| 16 | 35 | 0,016 | 0,046 | 0,249 | 4096 | 63,69 | 2,66 | 41,4 |
| 15 | 45 | 0,022 | 0,068 | 0,330 | 3375 | 74,25 | 2,19 | 48,3 |
| 14 | 75 | 0,030 | 0,091 | 0,420 | 2744 | 82,32 | 1,78 | 53,5 |
| 13 | 70 | 0,040 | 0,136 | 0,522 | 2197 | 88,25 | 1,43 | 57,4 |
| 12 | 82 | 0,045 | 0,182 | 0,545 | 1728 | 78,43 | 1,12 | 51,0 |
| 11 | 97 | 0,066 | 0,250 | 0,721 | 1331 | 87,22 | 0,87 | 56,7 |
| 10 | 117 | 0,070 | 0,318 | 0,697 | 1000 | 69,67 | 0,65 | 45,3 |
| 9 | 137 | 0,093 | 0,412 | 0,837 | 729 | 67,80 | 0,47 | 44,1 |
| 8 | 160 | 0,096 | 0,506 | 0,768 | 512 | 49,15 | 0,33 | 31,9 |
| 7 | 175 | 0,099 | 0,605 | 0,693 | 343 | 33,96 | 0,22 | 22,1 |
| 6 | 179 | 0,115 | 0,707 | 0,690 | 216 | 24,84 | 0,14 | 16,1 |
| 5 | 172 | 0,098 | 0,805 | 0,490 | 125 | 12,25 | 0,08 | 8,0 |
| 4 | 136 | 0,075 | 0,882 | 0,300 | 64 | 4,80 | 0,04 | 3,1 |
| 3 | 106 | 0,058 | 0,930 | 0,174 | 27 | 1,57 | 0,02 | 1,0 |
| 2 | 48 | 0,028 | 0,985 | 0,056 | 8 | 0,22 | 0,01 | 0,1 |
| 1 | 30 | 0,004 | 0,999 | 0,004 | 1 | 0,00 | 0,00 | 0,0 |
| 0 | 12 | 0,007 | 1,000 | 0,000 | 0 | 0,00 | 0,00 | 0,0 |
| Total | 1763 | 1,000 | | 8,236 | | 1020,7 | | |

With reduction average coefficient of heat flow $K$ to reduction and impassable quantity of heat for heating. With value coefficient of heat transfer smaller from $K = 1,07$ ($W/m^2K$) to follow to not have for heat accumulator. For this reason necessary to order optimum thickness heat insulating material for building. This analysis to accompany with windweels diameter of impeller D=20 (m).

Is summer and in months when we produce extra electric energy, we can transfer it to electro-energetic system. In this way we will make a possibility of selling the extra electric energy that is produced in the windwheel, and a financial growth. Functional chart is shown in Figure 8.

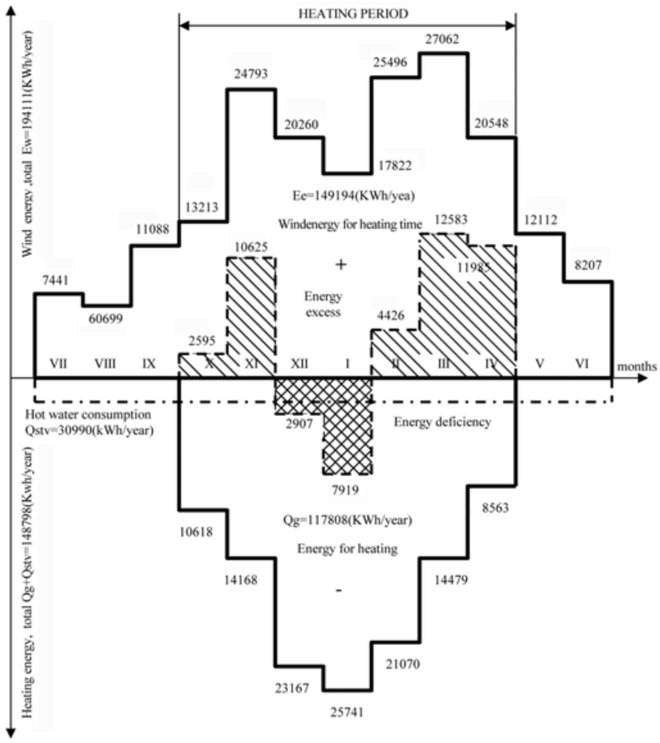


**Fig. 7** Distribution Chart of Produced and Spent (used) Energy

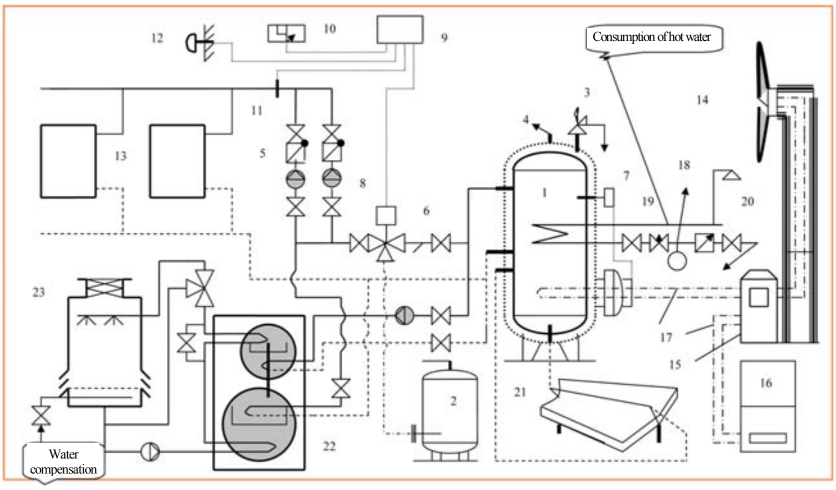


**Fig. 8** Functional chart (1-accumulation bin with electric heaters; 2-expansion bin; 3-safe valve; 4-antiradition valve; 5-circulation pump; 6-dirt separator; 7-electric heater; 8-three-way motor valve; 9-amplifier regulation; 10-room thermometer;11-starting water whisker; 12-outer leverage whisker ;13-fan-coil ; 14-windwheel; 15-control panel; 16-storeheater; 17-electrical cables; 18-manometer; 19-safe valve; 20-hot water consumers; 21-radiant parabolic heater; 22-absorbic cooling machine; 23-cooling tower;

**Table 2** Calculation Table of Necessary Heat Quantity for Heating a Place Data of Produced Electric Energy with the Windwheel

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Heat quantity for heating and preparing sanitary hot water in months | | | | | | | | | | | | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 3 | 14 | 15 |
| | | K*Aom | 2448 | | | | | | | | | | | |
| | | | | | | | | | | | | | | Total |
| | Months | January | February | March | April | May | June | July | August | September | October | Novem | December | Average |
| | Number of days | 31 | 28 | 31 | 30 | 31 | 30 | 31 | 31 | 30 | 31 | 30 | 31 | 30 |
| | Tun | 19 | 19 | 19 | 19 | | | | | | 19 | 19 | 19 | 11 |
| | Tsp.sr | -1 | 1,5 | 4 | 8 | | | | | | 8 | 6 | 1 | 2 |
| | Dt© | 20 | 17,5 | 15 | 11 | | | | | | 11 | 13 | 18 | 9 |
| | K*Aom(W/K) | 2448 | 2448 | 2448 | 2448 | 2448 | 2448 | 2448 | 2448 | 2448 | 2448 | 2448 | 2448 | 2448 |
| | Qgh(W) | 48960 | 42840 | 36720 | 26928 | | | | | | 26928 | 31824 | 44064 | |
| | Number of heating hours (h/year) | 16 | 16 | 12 | 10 | | | | | | 12 | 14 | 16 | |
| | Qgd(kWh) | 783,36 | 685,44 | 440,64 | 269,28 | | | | | | 323,14 | 445,54 | 705,02 | |
| | Qm(kWh) | 24284 | 19192 | 13660 | 8078,4 | | | | | | 10017 | 13366 | 21856 | |
| | Coef. Infiltration | 0,06 | 0,06 | 0,06 | 0,06 | 0,06 | 0,06 | 0,06 | 0,06 | 0,06 | 0,06 | 0,06 | 0,06 | |
| | Qgukm(kWh) | 25741 | 20344 | 14479 | 8563,1 | 0 | 0 | 0 | 0 | 0 | 10618 | 14168 | 23167 | 117081 |
| Special heat quantity for preparing the sanitary hot water on the number of guests | | | | | | | | | | | | | | |
| | Qstv1(kWh) | N1 | V | Cp | Ro | T2 | T1 | | | | | | | |
| | | (gos/dan) | m3/dan | kJ/kgK | kg/m3 | C | C | | | | | | | |
| | 2,8224 | 1 | 0,05 | 4,2 | 960 | 60 | 10 | | | | | | | |
| | Number of guests | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | |
| | Qstvd(kWh/days) | 84,672 | 84,672 | 84,672 | 84,672 | 84,672 | 84,672 | 84,672 | 84,672 | 84,672 | 84,672 | 84,672 | 84,672 | |
| | Qstvm(kWh/months) | 2624,8 | 2370,8 | 2624,8 | 2540,2 | 2624,8 | 2540,2 | 2624,8 | 2624,8 | 2540,2 | 2624,8 | 2540,2 | 2624,8 | 30905 |
| | Quk(kWh/months) | 28366 | 22715 | 17104 | 11103 | 2624,8 | 2540,2 | 2624,8 | 2624,8 | 2540,2 | 13243 | 16708 | 25792 | |
| | Quk(kWh/year ) | | | | | | | | | | | | | 147986 |
| | Quk(KJ/year) | | | | | | | | | | | | 532750556,2 | |
| Data of produced electric energy in months with windwheels diameter of impeller D=20(m) | | | | | | | | | | | | | | |
| | N1(kW) | 0,0003 | ETAp | D(m) | C(m/s) | | | | | | | | | |
| | 0,0928 | | 0,8 | 20 | 1 | | | | | | | | | |
| Average speed | Csr(m/s) | 7,22 | 7,83 | 7,74 | 7,52 | 6,73 | 6,38 | 6,03 | 5,76 | 6,42 | 6,51 | 7,74 | 7,22 | 6,93 |
| Frequency | Pm(%) | 68,70 | 85,10 | 84,40 | 72,20 | 57,50 | 47,30 | 49,20 | 45,90 | 62,60 | 69,30 | 79,90 | 80,70 | 66,90 |
| Power | N(kW) | 34,93 | 44,55 | 43,03 | 39,46 | 28,29 | 24,10 | 20,35 | 17,73 | 24,56 | 25,60 | 43,03 | 34,93 | 30,82 |
| Windhour | VS(h) | 511,13 | 571,87 | 627,94 | 519,84 | 427,80 | 340,56 | 366,05 | 341,50 | 450,72 | 515,59 | 575,28 | 600,41 | 5848,68 |
| Energy | Em(kWh/months) | 17852 | 25476 | 27020 | 20515 | 12101 | 8207 | 7448 | 6056 | 11068 | 13201 | 24754 | 20970 | |
| | Eg(kWh/year) | | | | | | | | | | | | | 194669 |

## 5. Conclusion

The estimate of the wind energy as an energy which is being renewed is necessary in our region because of the limitation of resources that are not renewing. Measurements until now are to the height of 10 meters. The optimal height of generators for today's technology is 100 meters. Newer windwheels need to find a winder use, first for heating in winter, for heating water in pools or for air conditioning, in the tourist mountainous regions.

Windwheels can be used for lighting or starting the units on observatories, stations, cottages, buildings and agricultural ones, but for good energy accumulation the most suitable use is for heating and air conditioning.

Calculations show that the windwheel, depending on its type, size and place, built in heating or air conditioning system, would pay off in 10 to 15 years.

## 6. Denotations

$A$ – Vane area, $m^2$

$c_0$ – Flow speed, far in front of vane, $m / s$

$c_2$ – Flow speed, far behind the vane, $m$ / s

$c'$ – Flow speed through the vane, $m$ / s

$v$ – Specific air volume (=0,79$m^3/kg$) at $t_0 = 0^0C$, $p_0 = 1013{,}25$ $mbar$

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# MOGUĆNOSTI PRIMENE ENERGIJE VETRA U SISTEMIMA GREJANJA I KLIMATIZACIJE

**Šefik M. Bajmak**

*Energija vetra je vekovima jedina prirodna energija u službi čoveka, a zatim stotinjak godina skoro zanemarena. Jedan od razloga za to je vremensko kolebanje vetra sa nemogućnošću tačne prognoze, te mala koncentracija energije s obzirom na velike investicije. Osim toga energija vetra se teško akumulira. U osnovi vetar je deo sunčeve energije, ali u posledičnom obliku, koji direktno daje mehanički rad. Od sveukupne dozračene energije sunca na zemlju, oko 2% se pretvara u energiju vetra, od koje se teoretski može iskoristiti 59%. Na osnovu analiza koje su uradjene za naše uslove, za svaki mesec je odredjena ukupna efektivna energija koja se može dobiti od vetra. Na osnovu ove analize i na osnovu izvedenih proračuna snage vetrogeneratora i na osnovu analize potrebne toplote za grejanje i klimatizaciju objekata definisana je funkcionalna šema primene energije vetra u sistemima grejanja i klimatizacije. Mogućnosti naše zemlje na ovom području su sigurno znatne, ali nedovoljno istražene.*

Ključne reči: *energija vetra, vetrogenertor, grejanje, klimatizacija*