ANALES

SOLAR ENERGY USAGE IN THE REGION OF DEBRECEN

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Résumé

La première condition de l'héliodynamique efficace est la connaissance exacte de l'énergie entrée dans un point de la superficei de la terre. Il y a un rôle fondamental des dessous technologique et du développement dans l'utilité de l'hélio-énergie. Au delà des aspects météorologique et technique c'est le système de l'encouragement et de financement qui est le troisième pilier dans l'emploi d'un porteur d'énergie. Le quatrième point de vue est l'adhésion de la société qui détermine la mesure de l'application de chacun des ressources énergétique. Ce dernier est en fonction de l'éducation, du media et de la politique.

On ne peut atteindre des profonds changement qu'avec l'aide accordée et coordinée de l'Union européenne, des politique gouvermentales et régionales de même que de la communication, de l'éducation, du développement de la recherche et du media.

Key words: Solar energy usage, meteorological aspects, social aspects

Introduction

The following study we are going to show the energy producer background, the technical-sociological aspects and the supporting-financial aspects of the North-Great Plain Region. We hope that this essay can be the starting-point for the decision makers and the users.

The climatic elements, which are directly linked to the solar energy usage, like global radiation, length of the sunny hours, cloudiness and the foggy weather should be shown shortly in our essay. After this chapter we are going to describe the radiation and energy income of the horizontal and other characteristic southern slopes.

At the same time we will give estimation about the quantity of the electricity that can make from the solar radiation in the case of different technological backgrounds. Through the technical aspects we are going to show the influences of the supporting-financial situation and the social attitude of the solar and other energy system. After these pillars we are going to give a short summary about the near and middle-distance future.

Definition of the quantity of the direct radiation in the case of various expositional and inflexional surfaces

The value of arriving solar energy on given climatic factors is the result of the geometrical characteristic of the surface. The slope property modify the radiation income due to the quantitative distribution of the direct radiation.

The radiation intensity of the horizontal surface (I)

$$\mathbf{I} = \mathbf{I_0}\, q^{Tz} \sin h \qquad (1)$$

Where I_0 – solar constant, q - transmitting coefficient of the clean atmosphere, T - dimness coefficient of Linke, z – length of the radiation's way in the atmosphere, h – height of the sun.

In the case of the determination of the potential solar energy income, its necessary to analyse the energy income of different slopes of gradient and orientations. The ratio of the solar energy income in different slopes is calculable by geometrical coherences from the values of the global radiation income on horizontal surface (Kaempfert, W. – Morgen, A., 1952, Kondratyev, K., 1954 Justyák J. - Tar K., 1973).

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In the case of the surface, which is perpendicular to the irradiation, and arriving through the atmosphere, the energy formula is (I), while the energy formula of the energy income to slope surface is (I_L):

$$\mathbf{I_L = I\,[\cos\beta\,\sin h + \sin\beta\,\cos h\,\cos(\alpha_N - \alpha_L)]} \qquad (2)$$

In this case: I – intensity of the radiation income, which is perpendicular to the surface, β – inflexion of the slope, h - height of the sun, α_N – azimuth of the slopes normality, α_L – azimuth of the sun (Kondratyev, K., 1954).

The quantity of the arriving direct radiation to the sloping surface is depends on the height of the sun, angle of incidence of the solar radiation, inflexion of the slope and the direction of the slope. In our analysis we calculate the energy income on horizontal slope and others with different characteristic, according to this we elaborated an index number (q_β) of the solar radiation income arriving to horizontal surface:

$$\mathbf{I_L = q_\beta\, I_V} \qquad (3)$$

Where I_L – quantity of radiation income, arriving to the surface of the slope, I_V – quantity of horizontally arriving measured direct radiation, q_β – index number. The method was made by Justyák J. – Tar K. (1973), which can be used only in the case of cloudless firmament, consequently it can used to determine the direct radiation income.

For the simplification of the arithmetic operation, we determined the q_β values only to the southern slopes, seeing that the southern direction has outstandingly high values of the radiation in an annual average. In the course of the year the determination of the maximum radiation acceptor angle of slope was made by Major Gy., (1985).

The daily proportion aggregate of the solar radiation of the different inclinational and horizontal surface can be determine by the following formula (Justyák J. - Tar K.,1973):

$$q_\beta = \frac{\omega_1' \sin\delta \sin(\varphi - \beta) + \cos(\varphi - \beta)\cos\delta \sin\omega_1'}{\omega_1 \sin\varphi \sin\delta + \cos\varphi \cos\delta \sin\omega_1} \qquad (5)$$

where q_β – index number of direct radiation between the horizontal and southern slope, δ – declension of the Sun, φ – geographic longitudinal circle of the given place, ω_1 – angle of the sunrise on horizontal surface, ω_1' – angle of the sunrise on southern slope.

On a given place the angle of the sunrise (ω_1) on horizontal surface is definable by the following formula:

$$\mathbf{\cos\omega_1 = -\,tg\varphi\; tg\delta} \qquad (6)$$

where ω_1 – angle of sunrise in radian, φ – latitude of the geographic place, δ – declension of the Sun. The counted values should be corrected by the given longitude of the geographic point, as a result of this the ω value were counted by the following:

$$\mathbf{t = 12 + \omega/15} \qquad (7)$$

The given place is Debrecen ($\varphi = 47{,}3^0$, $\lambda = 21{,}3^0$).

The exact moment or the angle of the slope-sunrise and the slope- sunset should be known on different slope inflexions to determine the deviation of the radiation income from the horizontal slope. This can determine by the following formula in the case of the southern slopes (Justyák J. - Tar K.,1973):

$$\cos \omega'_{1,2} = \frac{\mathrm{tg}(\varphi - \beta)}{\mathrm{tg}\,\varphi} \cos \omega_{1,2} \qquad (8)$$

where $\omega'_{1,2}$ - is the angle of the slope sunrise and slope sunset in radians. φ – geographic latitude. β – angle of slope inclination. In the case of the zero and negative declinations the $\omega'_{1,2} = \omega_{1,2}$.

The index number calculated by this method is valid for the direct radiation income, otherwise it is only usable in the case of the cloudless days. The q_β is calculated during the year, on the 21st of every month in Debrecen, which gives us the relation between the horizontal surface and other different inclinating slopes (on southern slopes).

1st table: Deklination of the Sun in the 21st day of every month (δ), and the horizontal and southern 30° slopes radiation on the given day, with respect to the β_{max} – which is the maximum radiation income, and their relation ($\varphi = 47{,}3^0$)

Date	21-jan	21-feb	21mar	21-apr	21-may	21-jun	21-jul	21-aug	21sept	21-okt	21-nov	21-dec
δ	-19.58	-10.41	0.05	11.37	20.06	23.26	20.32	12.13	0.5	-10.34	-19.49	-23.26
$B_{30}{}^0$	2,47	1,83	1,43	1,15	1,00	0,94	0,99	1,13	1,42	1,86	2,68	3,02
$\beta_{max}{}^0$	3,32	2,17	1,49	1,15	1,03	1,00	1,02	1,13	1,45	2,21	3,69	4,32

In the case of the usage of the solar power the optimal angle of slope is 30°. We determined the deviation between radiation income of the horizontal and optimal surfaces during the year. On the 47^0 30' geographic latitude during the summer term the optimal angle of slope is 25°, while on winter term this value is 59°.

1st Figure: Angle of inclination of the maximum radiation incomes during a year in Debrecen (Suri, 2005)

As a function of the duration of the usage the solar modules angular offset can be changed. The maximum energy income can be reach by the usage of 42° angle of slope. During the following sentences the results of the calculation of the radiation income will be acquainted.

The differences of the direct radiation income on horizontal and inclined surface can be determined on every day with the usage of our applied method. In our analysis we calculated the q_{β} index number on the 21st of every month, and multiplied this by the average monthly direct radiation a good approach is calculable about the radiation on given inflexion surface. Due to the method is only refer to the cloudless periods, a maximal possible monthly energy income is calculated on given surface, in the case of the following astronomically possible maximal incomes.

2nd Table: Theoretically possible global radiation on horizontal surface ($G_{possible}$), regarding 30° slope, southern slope (G_{max} 30°) Debrecen, MJ/m^2 (Justyák J. - Tar K., 1994)

	Jan.	Feb.	Mar.	Ápr.	May.	Jun.	Jul.	Aug.	Sept.	Okt.	Nov.	Dec.
$G_{possible}$	197	285	481	678	883	959	971	837	607	431	247	176
G30^0	457	487	649	753	865	892	961	921	850	819	655	495
Gmax	655	619	718	780	906	960	994	948	878	951	912	760

The higher difference in the energy income between the horizontal surface and southern slope is in the winter season, during this period the energy income is twice as much on 30° slope as it is on horizontal surface. The maximum energy income can be reached at 66° slope, which is three times as much as it is on horizontal surface. Due to this result the influential part of the slope inflexion has the highest effect on low Sun declination.

The global radiation income on horizontal were multiplied by the index number of the 21st day of every month. The calculated number is valid for 1 m^2 in the case of southern surface (30°) and the maximal energy income (Gmax). The value is in MJ.

3rd Table: Net global radiation on horizontal surface (G), and the southern 30° slope and maximal energy income slope with the usage of the Justyák-Tar index number MJ/m^2

Month	**δ**	**G**	**G 30^0**	**Gmax**
Jan	-19.6	108	266.83	358,9
Feb	-10.4	174	319.24	378,1
Mar	0.1	324	461.72	484,0
Ápr	11.4	460	529.37	528,9
May	20.1	595	592.12	610,3
Jun	23.3	622	584.73	622,9
Jul	20.3	662	654.03	677,5
Aug	12.1	557	630.52	630,8
Sept	0.5	410	582.24	593,3
Okt	-10.3	273	507.73	602,5
Nov	-19.5	120	321.86	442,8
Dec	-23.3	80	241.93	345,4

The presented calculation contains unreliability, because the global radiation database include the diffuse radiation, while the method is good for the direct radiation. The diffuse radiation arrives uniformly through the molecule of the air, water stream and polluter material, and not hang on the inflexion of the slope (Justyák-Martonné, 1979). The annual diffuse radiation income is the half of the total energy income in Hungary, due to this the function of the diffuse radiation is not negligible (Major Gy., 1985). The effects of the geometrical characteristic of the surface has different influence on the global radiations two components, therefore the processing of a new algorithm is necessary, which makes possible the separate survey of the two components.

Determination of the diffuse radiations relation

To analyze the relation of the direct and diffuse component of the global radiation on cloudy period, with the lack of calculation we used theoretical method. First of all we have to determine the ratio of the cloudiness (B) on the function of the sunny hours:

$$B = \frac{N_0 - N}{N_0} * 100 \qquad (9)$$

Where N_0 – is the astronomically possible term of sunlight, N- is the real sunlight. Assume that in the cloudy period only diffuse radiation income appears on the surface, so the relation of B is the same between the diffuse ($G_{diffuse}$) and the direct (G_{dir}) radiation.

$$G_{diffuse} = \frac{G * B}{100} \qquad (10)$$

Where G – is the global radiation

The following: $$G_{dir} = G - G_{diffuse} \qquad (11)$$

If the angle of the slope is small, the diffuse radiation till the given inflexion ($\beta \leq 40^0$) is independent from the characteristic of the slope (Muhenberg, V., 1965). Since the different inflexions on slope have effect on the direct radiation income the index number of the global radiation can be calculate with the following method:

$$G_{slope} = (G_{dir} * q\beta) + G_{diffuse} \qquad (12)$$

Similar calculation can be found in the study of Justyák-Martonné (1979).

With the usage of the method 12 we can say that the energy income on southern slopes is higher in compare with the horizontal surface. During the summer period the slope with 30°inflexion get fewer energy than the horizontal surface, as a result of the optimal inflexion is less than this. The difference is insignificant, while in winter period the energy income of the southern slope is 140 % and 164 % in the case of the maximal inflexion.

4^{th} Table: N_0 – astronomically possible sunlight term (Debrecen), N – real sunlight term (Debrecen 1927-1991), G – global radiation (Debrecen, 1961-1990), B – cloudiness N_0-N, B % percentage of cloudiness in compare with the N_0 , $G_{diffuse}$ – diffuse radiation, G_{direct} – direct radiation

	Jan.	Feb.	Marc.	Apr.	May.	Jun.	Jul.	Aug.	Sept.	Okt.	Nov.	Dec.
N_0 (hour)	275	285	367	407	466	475	480	440	377	336	279	262
N (hour)	57	85	149	192	249	268	296	273	206	156	67	47
G (MJ/m^2)	108	174	324	460	595	622	662	557	410	273	120	80
B (hour)	218	200	218	215	217	207	184	167	171	180	212	215
B %	79.3	70.2	59.4	52.8	46.6	43.6	38.3	38.0	45.4	53.6	76.0	82.1
$G_{diffuse}$ (MJ/m^2)	**85.6**	**122.1**	**192.5**	**243.0**	**277.1**	**271.1**	**253.8**	**211.4**	**186.0**	**146.3**	**91.2**	**65.6**
G_{direct} (MJ/m^2)	**22.4**	**51.9**	**131.5**	**217.0**	**317.9**	**350.9**	**408.2**	**345.6**	**224.0**	**126.8**	**28.8**	**14.4**

Technical background

The technical usability is hang on the ratio of the cost and value. The biggest problem of the solar technologies is the low efficiency and high investment cost. We can distinguish three different system: the solar cells, which makes electricity, the solar collector, which makes hot water, and the solar air conditioning, which makes hot air.

In the case of the solar cells, the efficiency of the transformation of the solar radiation to electricity is hang on the technical fundamentals. The first generation of the solar cells were made of amorphous crystal system, which efficiency is 6-10 %. The second generation is made by polycrystalline siliceous system, and their efficiency is between 10 and 14 %. The third (newest) generation is monocrystalline system with the efficiency of 16-18 %.

With the usage of one 150 wp solar module (8 % efficiency) , under the given meteorological situation on horizontal surface it will give 182,7 kWh in a year, while on a southern slope of 30° this value is 202,0 kWh. The maximum radiation income is 209,9 kWh with the same circumstances, but this possibility is not realistic nowadays because of technical reasons.

5^{th} Table: Global radiation values, determined by Justyák-Tar, and Justyák formula (kWh/m^2) in Debrecen, on horizontal surface, southern slope 30^0, and maximal income

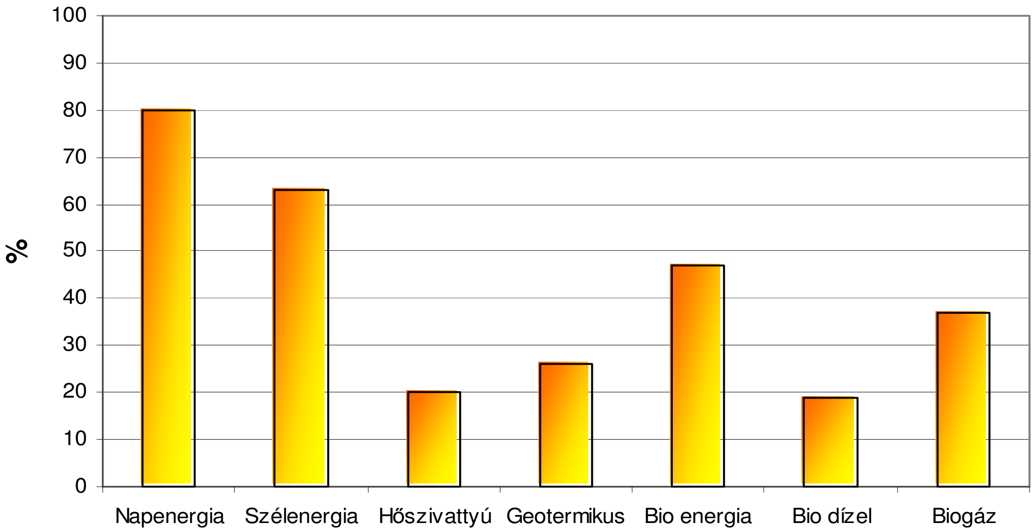
	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sept.	Okt.	Nov.	Dec.	Year
Ghorizontal	30,0	48,3	90,0	127,8	165,3	172,8	183,9	154,7	113,9	75,8	33,3	22,2	**1218,1**
G30°	39,1	60,4	105,5	136,9	164,9	166,9	182,5	167,4	140,0	106,1	46,8	30,3	**1346,8**
Gmax.	44,4	65,2	108,0	136,8	167,5	172,9	186,5	167,4	141,7	118,3	54,9	35,4	**1399,3**

Knowing of the today price level on the market it can be declared that investment is going to recover in 10-12 years (23,87 Ft/kWh electricity price). The cost returns time could be decrease by the increase of the supporting-financing system, or the increase of the delivery price of the electricity. We can mention Austia as an example, where the elecricity delivery price is 60 cent/kWh, in this case the cost returns time is 5 year.

Social background

As we can see in our previous essay (Csákberényi-Nagy G., 2005) the social background is also really important. This pillar is really important:

2nd Figure: Acceptance of different renewable energy sources (own research)



First the notoriety and the acceptance of the renewable energy sources. The high correlation is provable with data between the notoriety and the acceptance, which means the more people know about the renewable energy sources the more they accept them. The solar energy has the highest notoriety (above 90 %) and acceptance in every investigated settlement.

The wind energy has a 10 % lower notoriety ratio, but the acceptance ratio is just between 60 and 70 %. The reason must be the fear of the new source, for instance in Denmark where the sight of the wind power plants is very common the acceptation ratio is much higher.

In the case of the heat-pump and the bio diesel the main problem is the obscurity. The notoriety is between 20 % and 40 %, and the acceptance is about 10 % less in every place. I will proceed to the case of the geothermal energy, the ratios of the notoriety and acceptance are represent higher values (above 40 %). However the usability is remarkable. From among the samples only Debrecen has good usability in this field.

The last two renewable energy sources are the bio energy and the biogas. The notoriety and the acceptance of these applications are quite high (above 40 %), though the dispersion is high. In the French sample the inhabitants notoriety and acceptance are 20 % less than in the other samples.

Altogether we can say a higher ratio of notoriety produces higher acceptance, and although the common knowledge is similar, in the more developed countries the ratios are higher especially in the field in which the country has good possibilities. In this case to know the inhabitants sources of knowledge, and purchasing preferences are exceedingly important questions, because we can analyze how we can make the energy policy more effective.

In the next step I analyzed the probable reasons of the different environmental approaches. I analyzed the origin of the acquiring of knowledge about renewable energy. The most important factor is the media in every sample, but there are significant differences. The Hungarian sample is the most one-sided. In this case the media has a much higher importance (Radio/TV 46 %, press 33 %). Unfortunately education has the least function in the environmental protection in the Hungarian sample.

Summary

At the region of Debrecen the usage of the solar power can be reach a good efficiency. The optimalization is available by the usage of the high quality solar modules and the optimal southern setting of the modules. The calculated index numbers (southern 30°, horizontal,

maximum radiation incomes) have high differences between the maximum and the horizontal surfaces, for instance in the winter season it's 40%. The gates of the high spreading of the solar energy usage are among the following pillars: The technical background insures only 10-18 % of efficiency, which is very low in compare with other energy resource (for instance gas energy: 40-55 %). The other pillar, which can help of the spreading of the solar energy, is the supporting-financing system. In Hungary the national supporting system is not sufficient, but with the help of the European Union in the near future the spreading of the solar energy can reach a much higher ratio. The usage or adapting of the foreign, well functioning samples will help a lot for the Hungarian energy rationalism. The third pillar is the attitude of the population, which can be more environmental-friendly with the help of the teaching system and the media.

Serious changes will be with the coordinated policy of the European Union, the government of Hungary and the regional policy. The communication, the teaching system and the Research and Development will have central mission for the spreading of the environmental-friendly thinking.

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