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PHYSICAL AND TECHNICAL ENERGY PROBLEMS

THE POTENTIAL OF RENEWABLE ENERGY SOURCES IN LATVIA

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The article discusses some aspects of the use of renewable energy sources in the climatic conditions prevailing in most of the territory of Latvia, with relatively low wind speeds and a small number of sunny days a year. The paper gives a brief description of the measurement equipment and technology to determine the parameters of the outer air; the results of the measurements are also analysed. On the basis of the data obtained during the last two years at the meteorological station at the Botanical Garden of the University of Latvia, the energy potential of solar radiation and wind was estimated. The values of the possible and the actual amount of produced energy were determined.

Keywords: *Betz-Zhukovsky criterion, intensity of solar radiation, potential, renewable energy resources, wind speed.*

1. INTRODUCTION

Currently, the technology for production of heat and electricity using renewable energy sources (RES) has become increasingly relevant. This owes to a continuous increase in the rate of energy consumption, rising prices for traditional energy sources, and environmental degradation. At present, the greatest interest is attracted to the technology using wind energy and solar radiation energy [1]–[4].

The modern level of technology using a variety of mono- and polycrystalline photo cells or polymer converters provides solar collectors of high efficiency [5]–[7]. There are examples of successful projects on the use of renewable energy sources in Latvia. For example, in the complex Sun Republic in the town of Saulkrasti solar collectors and photo batteries are installed, which minimise energy consumption for water heating and contribute to the reduction of CO_2 emissions into the atmosphere [8]. Furthermore, the use of solar collectors affects favourably utility bills, which can reduce by 30 %. According to [9], the operational practice of Saulessukni EKTOS heating system, using vacuum solar collectors TS400, can save up to 85 % of the energy consumed for heating and hot water.

Owing to its geographical location and climate, the Baltic coast area is in a favourable condition to site wind farms in Latvia, as the wind speed here is relatively high. Many papers are published that consider the study of parameters of the wind in coastal areas, and analysis of physical and technical characteristics and economic performance of existing wind farms. In [10], the authors show the results of the study of seasonal variations of wind speed on the coast of the Baltic Sea in Latvia. Using approximating functions, the authors assess the energy potential of wind by processing statistical weather data of wind speed and density fluctuations at altitudes from 10 m to 160 m, obtained from long-term observations (2004–2013). In [11], the authors show that "power generation at offshore wind farms is by 25–40% greater than on land, in case they are placed at a distance of 3–5 km far from the coast where the weaker onshore wind transforms into a stronger sea wind, but not farther than 40 km." The profitability of surface wind farms also depends on the distance from the coastline, which is confirmed by the results of operation of two wind farms in Latvia: Uzhava (500 meters far from the sea) and Alsunga (13.5 km far from the sea) [12]. Wind turbines of 1 MW with a 60 m high tower are mounted at both farms. The analysis of parameters of wind and wind farm economic performance has shown that Uzhava WF, where the wind speed is greater by about 25 %, produces 2 times more electric power; its cost is 2 times lower than that in Alsunga.

Indeed, the wind power potential is strongly dependent on the speed, and as a rule, the wind speed of 3 m/s is not considered a possible energy source. However, the greatest part of the territory of Latvia as well as large cities with tall buildings are blown by a low-speed wind. In this article, the wind speed measurement data and that of intensity of solar radiation obtained in an urban environment of Riga are quoted. Their possible potential to use for the independent power supply of a small building or a house is estimated. The solution to this problem is challenging in many regions of Latvia where there are rural buildings or in small villages, the population of which, unfortunately, is decreasing and centralised electricity supply becomes unprofitable.

2. THE TECHNIQUE OF MEASURING THE PARAMETERS OF OUTER AIR AND SOLAR RADIATION LEVEL

Since April 2013 at the VTPMML Laboratory parameters of outer air in Riga have been monitored [13]. Gill instruments MetPak Pro weather station for measuring outer air parameters was erected at a height of 4.5 meters in the Botanical Garden of the University of Latvia. Compact multi-sensor weather station instrumentation makes it possible every moment to obtain basic parameters of the outer air: wind speed and its direction, temperature and relative humidity, atmospheric pressure, etc. on-line. The specifications and the accuracy of their measurements are given in Table 1.

Table 1

Specifications of MetPak Pro Weather Station Measurements

Denomination	Specifications	
Wind speed	Range:	0.01 to 60 m/s
	Accuracy:	± 2 % @ 12m/s
	Resolution:	0.01 m/s
	Threshold:	0.01 m/s
Wind direction	Range:	0 to 360º (no dead band)
	Accuracy:	± 3º @ 12 m/s
	Resolution:	1º
	Response time:	0.25 sec
Air temperature	Range:	-35ºC to +70ºC
	Accuracy:	± 0.1ºC
	Resolution:	0.1ºC

To determine the wind speed and its direction, the WindSonic ultrasound technology is used. The values of temperature, relative humidity and dew point are determined by the Rotronic HC2-S3 HygroClip sensor, which is protected from all forms of radiation by a case with a special coating. The sensor (piranometre) of the brand mark Hukseflux LP02 [15] measures the intensity of incident solar radiation and the associated thermal energy; characteristics are given in Table 2. The sensor measures the intensity of solar radiation, covering the entire visible range on a horizontal plane (the angle of 180°). This sensor can measure the intensity of the direct and reflected solar radiation, both indoors and outdoors.

Table 2

The Main Characteristics of the Solar Radiation Sensor

Parameter	Value
Response time for 95 % response	18 s
Sensitivity	10–40 $\mu V/Wm^{-2}$
Non-linearity	< +/- 2.5%
Directional response for beam radiation	within +/- 25 W/m^2
Spectral selectivity	+/- 5% (305 to 2000 nm)
Tilt response	within +/- 2%
Expected voltage output	0.1 to + 50 mV in natural sunlight
Sensor resistance	Between 40 and 60 Ohms

In addition to the outer air characteristics shown in the table, in [13], [14] detailed data on the measurement of other parameters such as atmospheric pressure, relative humidity of the air, etc. are given.

3. EXPERIMENTAL RESULTS

In general, during the year the climate in Latvia, and particularly, in Riga is characterised by variable clouds and high humidity. The amplitude of diurnal temperature changes is the interval from 10 °C to 17 °C; during the month the average temperature varies within the range of (15÷22) °C (Fig. 1).

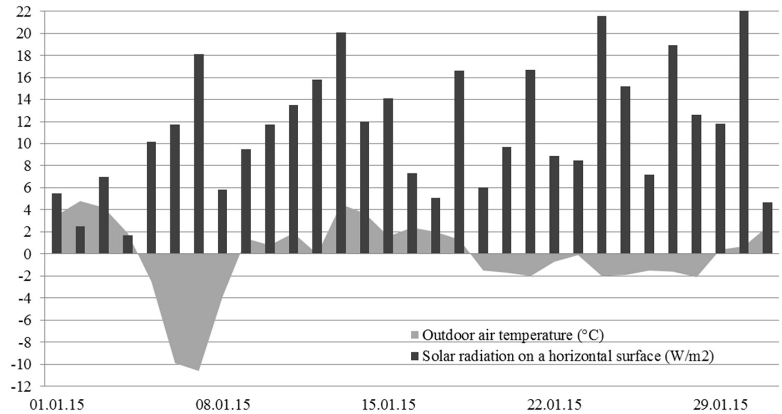
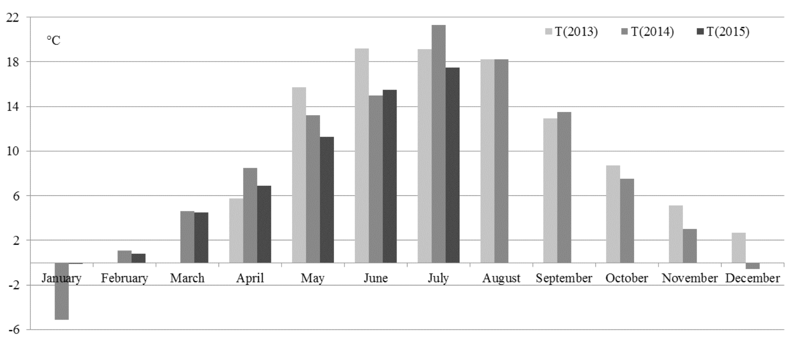
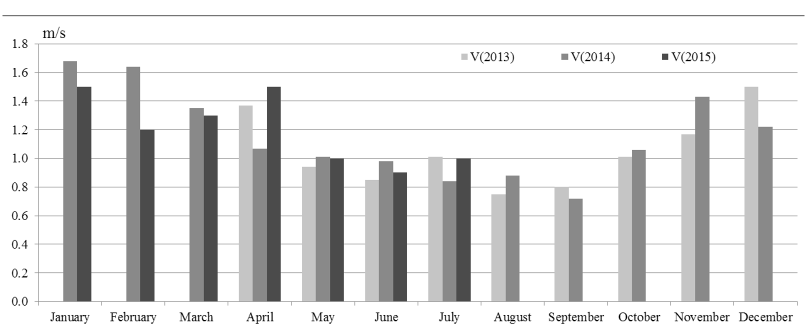


Fig. 1. Variation of the average outer temperature and intensity of solar radiation in January 2015 in Riga.

Mean monthly values of air temperature, wind speed and solar radiation intensity according to measurements in April 2013 are shown in Fig. 2. Analysis of the parameters of outer air in Riga shows that over the past two years, in Latvia the average yearly temperature has increased, and it is +8.04 °C. In the summer months the average air temperature is +17 °C, the average maximum is + 25.4 °C. The coldest months are January and February, when the average minimum temperature is -13.7 °C (Fig. 2a).



a)



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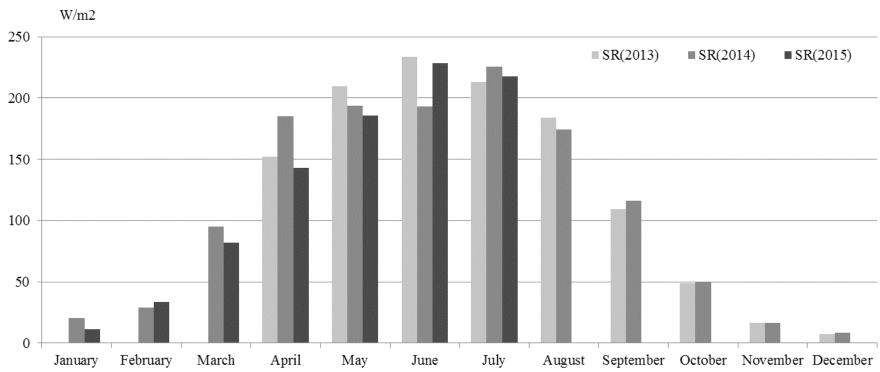

c)

Fig. 2. Average monthly values of the outer air parameters in Riga:
a) temperature; b) wind speed; c) intensity of solar radiation.

According to the results of the measurements, the average wind speed in Riga is 1.13 m/s (Fig. 2b). In the day-time and in the evening, the wind increases, low wind speed is observed mostly at night and in the early morning hours. The maximum speed of 5 m/s and greater is observed in the winter and autumn months, but this wind speed keeps not more than 2 % of the time.

As for intensity of solar radiation SR (Fig. 2c), its annual average level during 2 years is $SR_{av} = 123\ W/m^2$. The reliability of the measurement results (Figs. 1, 2) is confirmed by the fact that in general they are consistent with on-line data of the operative information of the Latvian Centre for Environment, Geology and Meteorology [15]. Figure 3 shows the average monthly temperature of the outer air in Riga by different data.

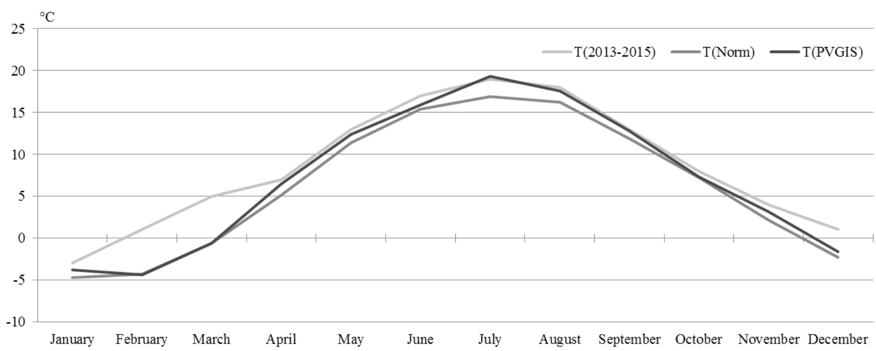

Fig. 3. Change of the average outdoor air temperature during the year in Riga.

Here T(2013–2015) represents our results of measurements [13], [14]; T(Norm) implies the data according to the site LBN 003-01 [16], which are used as regulatory standards in the calculations of the construction industry in Latvia; and T(PVGIS) is the data of the European Photovoltaic Geographical Information System [17], where the temperature values are calculated on the basis of the satellite system measurement data. It can be seen that in general the results of the outer air temperature measurements are consistent with other data, the difference is only observed in the values of temperatures in February and March. This difference can be explained by the fact that the measured values of T(2013–2015) are obtained by averaging the measurements of the outer air temperature just in the last 2 years, while the values of T(Norm) and T(PVGIS) are determined on the basis of long-term observations of more than 10 years. In addition, it is well known that in recent years the climate warming in the winter has been observed not only in Latvia, but also in some European countries [1]–[3], [7].

4. EVALUATING POSSIBLE USE OF POTENTIAL OF RENEWABLE ENERGY SOURCES

The dynamic development of renewable power generation using renewable energy sources (RES) is due to the continuous increase in the cost of energy production. The maximum increase is observed in the decentralised power supply system specific to certain areas in Latvia, far from the central power supply lines, and autonomous energy systems running on imported fuel. The advantage of using renewable energy sources is determined by the efficiency of technology compared to traditional hydrocarbon sources; and cost-effective implementation of renewable energy depends essentially on the environmental conditions. Thus, an important role is played by the determination of the energy potential of a particular type of renewable energy in a particular locality.

4.1 Evaluation of the Solar Radiation Resource

To determine the amount of incident solar energy per 1 m^2 of horizontal surface in Riga during the day, we use the averaged results of measurements of the intensity of solar radiation. As can be seen from the diagram (Fig. 4), according to the changes in it, the results of the calculation of daily solar radiation W(2013–2015) are consistent with the data of PVGIS [17], but the values are slightly smaller (Fig. 4). Probably, this difference is due to the fact that the measurements of the intensity of solar radiation in the Botanical Garden were made at 4.5 m height, and the data [17] were calculated on the basis of the measurements obtained from the satellite.

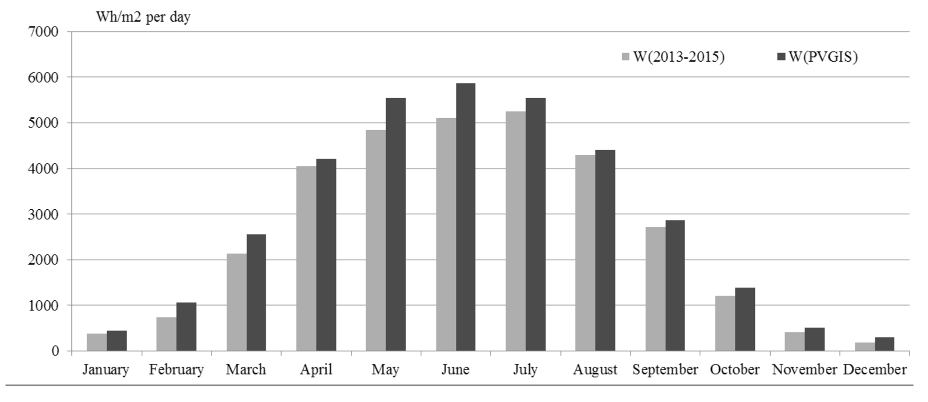

Fig. 4. Amount of energy of solar radiation per 1 m^2 of horizontal surface during the year.

Thus, due to the conversion of solar radiation in Riga it is possible to produce on average 954 кWh of energy per square meter a year. The resulted energy value was calculated without considering any loss; it is nearly four times greater than the value obtained from a 1kW system of 4 Sinergo solar batteries [18]. This is due not only to the fact that the plates of the Sinergo batteries are fixedly mounted at 15° angle to the horizon, but also that in practice it is possible to convert no more than 20 % of the energy of solar radiation [5]–[9], [18]. In reality, under the climatic conditions of Riga it is possible to obtain an average of 191 kWh of energy a year from solar radiation per $1m^2$ of horizontal surface.

The dynamics (character) of changes in the intensity of solar radiation measured in all considered cases shows that 85 % of the energy obtained by converting solar radiation is produced within 7 months (from March to September). But during the heating season from October to March, the potential of solar energy is negligible and cannot ensure even heating. Increasing the number of panels is not economical or is limited by the size of the roof. As a complement, it is possible to use the energy of the wind, the speed of which increases in autumn and winter (Fig. 2 b, c).

1.2 Evaluation of the Wind Resource

Using the results of measurements of wind speed, we evaluate the potential of the wind. The average speed is equal to 1.13 m/s, but sometimes the wind speed reaches (4÷5) m/s and more. The measurement results beginning from April 2013 showed that for almost half of the time (48 %) the wind speed was less than 1 m/s. Yearly average, 33 % of the time in Riga the value of the wind speed varies in the range of (1÷2) m/s, 12 % — (2÷3) m/s, 4 % — (3÷4) m/s, 2 % — more than 4 m/s. However, since the power of the wind turbine is proportional to the third power of the speed, even for a very short period of time it is possible to obtain a sufficient amount of energy.

It is known that the maximum available wind power is limited by C_{BZh} that is "the limit of Betz-Zhukovsky", which determines the ideal (without considering any losses) efficiency of wind turbines [19]–[20]. Ideally, it is possible to use only 59.3 % of the kinetic energy of the wind, as the maintenance of the air flow is required for any wind machine. This owes to the fact that, if the energy supplied by the wind is completely converted into useful work in the turbine, the output speed of the wind must be zero, i.e. a fresh wind flow cannot get into the turbine. For the wind to continue to move through the turbine, it is necessary for it to move inside turbine itself. Therefore, the efficiency of an ideal wind turbine of any design is defined by the limit S_{BZh}= 16/27=0.59 [19].

In [20] when deriving the formula for the calculation of the wind maximum available power it is taken into account through the wind energy use coefficient (WEUC) ξ ($\xi_{\lim} \cong 0.59$). Modern wind turbines have a power factor ξ close to this limit, but as a rule their efficiency varies in the range of $0.2 \leq \xi \leq 0.40$. In our calculations of energy W_r, which can be obtained through the conversion of wind energy, we accept ξ_r=25 %. The calculation of the wind energy converted by the wind turbine with the wind wheel of $1m^2$, depending on the wind speed is shown in Table 3.

Table 3

Dependence of the Converted Energy on the Wind Speed

Velocity, m/s	Time, %	W_t, kW*h	W_r, kW*h
(0–1) m/s	49	31	
(1–2) m/s	33	311	93
(2–3) m/s	12	491	147
(3–4) m/s	4	440	132
(4–5) m/s and more	2	464	139
Total	100	1707	512

The energy W_t = 1707 kW·h is the total estimated energy that can be obtained during a year for the perfect wind turbine, taking into account the limit of Betz-Zhukovsky. But in practice, it $W_r = \xi_r \times W_t$ = 512kW*h can only be obtained per year. The diagram (Fig. 5) shows the amount of energy that can be obtained in practice at different wind speeds.

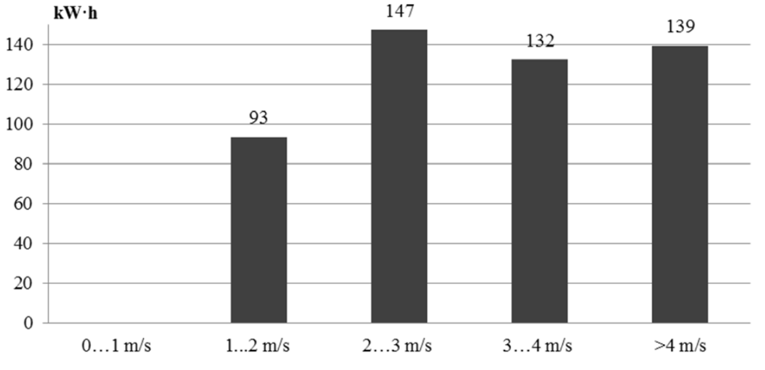

Fig. 5. The amount of converted wind energy W_r per year depending on the wind speed (see Table 3).

The calculations show that the amount of energy produced at speeds greater than 4 m/s, although the wind blows for much less time (6 times less), is comparable or even greater than the amount of energy obtained at a low speed of (1–2) m/s. It should be noted that the value of W_r per year was calculated taking into account that 49 % of the time the wind speed was less than 1 m/s (less than the start-up speed), at which even the most modern wind turbines do not run, including that of sail-type [19]–[21].

5. CONCLUSION

The analysis of the wind energy and solar radiation potential on the basis of measurements in Riga shows some promise for the development and implementation of various technologies, using these types of renewable energy sources, especially since on the market there are new technologies and combined systems for efficient conversion of renewable energy sources at low wind speeds and low levels of solar radiation to produce electricity, heating and water heating.

The potential of solar energy in Latvia is low, but it is comparable with many

European countries, where solar panels are widely used. The practice of known companies shows that for the production of electricity, solar radiation is used rather than heat. Therefore, regardless of the air temperature, solar batteries can perform their functions even in the winter sunny days when the air temperature can be -20 °C or lower.

Despite the fact that according to the results of the measurements, the average wind speed is low in Riga as well as in the ¾ part of the territory of Latvia, the calculations showed a real opportunity to obtain useful energy. In urban areas, it is possible to use small wind turbines of sail-type with a start-up speed of 1 m/s that can efficiently convert the energy of low-speed wind.

The analysis showed that during the heating season (6 months from October to March) the amount of solar radiation was 5 times less than during 6 months in summer and spring (Fig. 4). At the same time, on the contrary, increase in the wind speed during the cold season (see Fig. 2) made it possible to obtain 3.5 times greater amount of power than in the spring and summer. In general, combining devices for converting wind speed and solar radiation energy, 703 kWh of energy can be obtained per 1 m^2 of area in the climatic conditions typical of the most parts of Latvia. At the initial stage, it will require some financial investment, but in the future, it will not only reduce harmful emissions into the atmosphere, but also reduce the cost of electricity production. This is especially important for residential and commercial facilities, remote from centralised power lines, and in case of independent power supply of houses and buildings.

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ATJAUNOJAMO ENERGORESURSU POTENCIĀLS LATVIJĀ

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K o p s a v i l k u m s

Pētījumā tiek analizētas atjaunojamo enerģijas avotu izmantošanas iespējas Latvijas klimatiskajos apstākļos ar salīdzinoši zemu raksturīgo vēja ātrumu un nelielu saulaino dienu skaitu gadā. Darbā vispirms raksturotas mērierīces, ar kurām tiek veikti apkārtējās vides parametru - vēja ātruma un virziena, gaisa temperatūras un solārā starojuma mērījumi. Pamatojoties uz pēdējo divu gadu meteoroloģiskajiem datiem, tiek analizēts vēja un saules starojuma enerģijas potenciāls un ir novērtēts arī reāli saražojamās enerģijas daudzums, kas parāda, ka stabilam energonodrošinājumam šos atjaunojamos enerģijas avotus praksē nepieciešams kombinēt ar citiem.

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