CONCEPT OF A SMALL WIND TURBINE SYSTEM (SWT) FOR THE FIELD OF AGRICULTURE, AS A ISLAND SOLUTION FOR SELF-SUFFICIENT OPERATION IN EMERGING COUNTRIES

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ABSRTRACT
The paper shows how energy – self sufficient, sustainable farming, using wind energy is economically also in countries with weak wind such as Slovakia.

KEY WORDS: sustainable, self-sufficient farming, wind energy, climate protection

INTRODUCTION

Especially in emerging countries, far away from public electricity networks, small wind turbines (SWT) for the production of electrical energy are interesting, because they require no fuel as opposed to diesel generators. This is an important factor for the overall profitability of a farm at ever-increasing prices for crude oil.
Although not always the wind blows, but for this he writes no invoice. Climate-friendly energy is generated with wind turbines in particular without emissions of climate-relevant gases. The damages of climate change in nature and agriculture will be reduced.
A pan-European destination has become so against the background of global climate change the need to increase the proportion of renewable energy to generate electricity, therefore also for wind power. For Germany this has been associated with the adoption of the law on renewable energies (EEG) expressed 1. April 2000. (Ref. 1)
At the beginning of the 7^{th} European framework programme (2007-2013), 2,35 billion Euroswere made available, including more than 50% for projects in research and development of renewable energy sources (Ref. 2)
By 2010 wind turbines, to produce ~ 180 TW of electric energy, were created, 5.3% of the total demand of the European Union. While the annual increase was ~ 18% (REF. 3).
Though the use of wind energy has become also an important economic factor in Europe with well over 100 000 jobs (REF. 4). The major part of the energy generated is provided by large wind turbines. These are plants with a capacity > 100kW up to now built those with 3MW (Enercon 101,138 m hub height and 100 m rotor diameter) and offshore installations with 6.15 MW in wind park Thornton Bank, Belgium (REF. 5).
Such facilities are subject to large investment projects, usually through capital funds, because the investment to the tune of over Euro 10 million per plant, and therefore several 100 million Euros per wind farm, only from those can be provided.
Subject of considered wind turbines here, are small wind turbine systems (SWT, 0-100kW) and especially such so-called mini wind turbine systems for the energy sector 5-30kW, how they can be used even in the field of agriculture. In Germany meanwhile, 10 000 of such SWT are installed. (Ref.6).
Such plants need little planning, permits, wind measurements and planning tasks. Also construction and maintenance can be performed single-handedly by the future owner and operator, par example the farmer.

PLANNING A SYSTEM WITH SMALL WIND TURBINES (SWT)

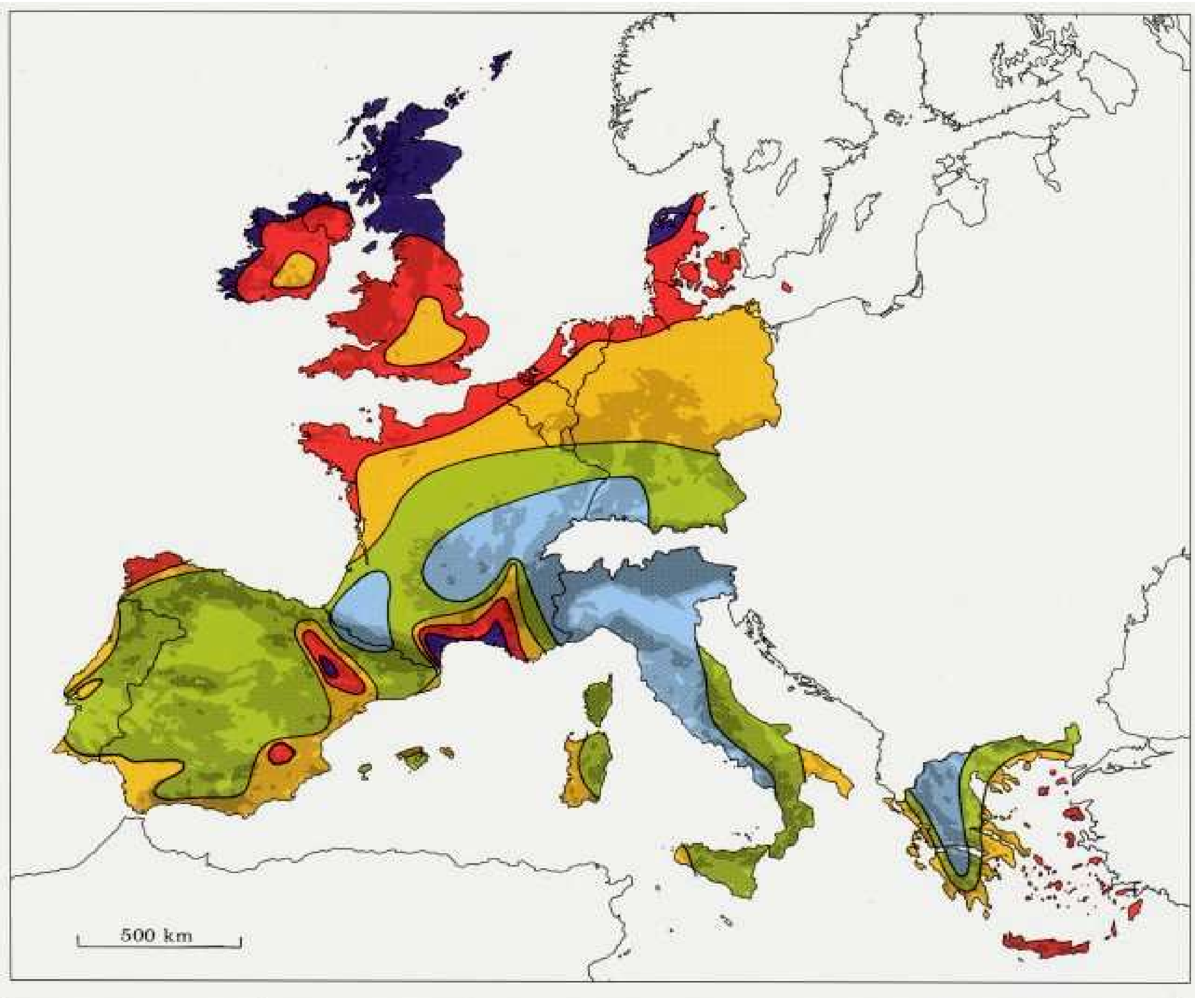
There are 3 parameters of crucial importance when planning such systems.

1) How much wind is blowing at the site (usually near the farm buildings)? Makes the middle wind speed, measured over the year,the installation of a system useful?
2) How large is the energy consumption? and
3) How much are the invest- and operating costs?

So, how interesting is the plant economically compared to the purchase of electric power from the public network, if one exists?

To answer the first question, the most reliable answer is given by a 1-year, simple wind measurement. Because here already costs are produced (wind instruments, etc.) , a first indication can be, the experience statement 4 m / sec wind speed. (REF. 6).

This can be validated with the help of a Wind Atlas, as he is created in all countries by weather stations. (e.g. in the Slovakia, here the wind forecast for the February 2013 for



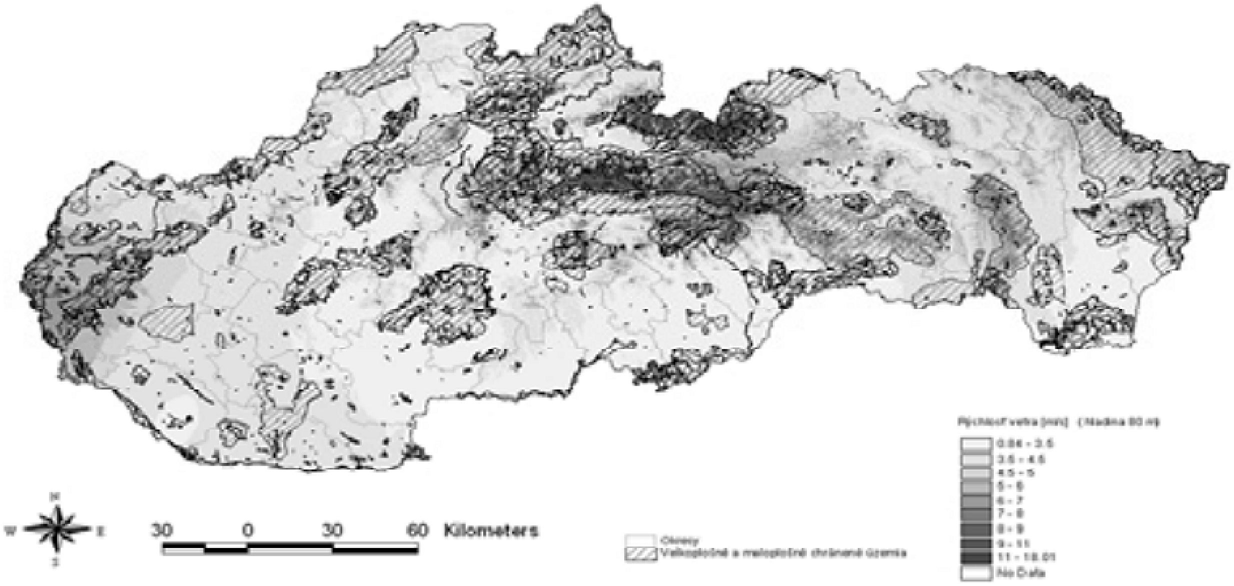
Wind resources[1] at 50 metres above ground level for five different topographic conditions

	Sheltered terrain[2]		Open plain[3]		At a sea coast[4]		Open sea[5]		Hills and ridges[6]	
	m s^{-1}	Wm^{-2}	m s^{-1}	Wm^{-2}	m s^{-1}	Wm^{-2}	m s^{-1}	Wm^{-2}	m s^{-1}	Wm^{-2}
(dark blue)	> 6.0	> 250	> 7.5	> 500	> 8.5	> 700	> 9.0	> 800	> 11.5	> 1800
(red)	5.0-6.0	150-250	6.5-7.5	300-500	7.0-8.5	400-700	8.0-9.0	600-800	10.0-11.5	1200-1800
(orange)	4.5-5.0	100-150	5.5-6.5	200-300	6.0-7.0	250-400	7.0-8.0	400-600	8.5-10.0	700-1200
(green)	3.5-4.5	50-100	4.5-5.5	100-200	5.0-6.0	150-250	5.5-7.0	200-400	7.0- 8.5	400- 700
(light blue)	< 3.5	< 50	< 4.5	< 100	< 5.0	< 150	< 5.5	< 200	< 7.0	< 400

Bratislava resulted in 4 m / sec) (REF. 7) (REF. 8).

Examples of such wind atlases show the figures 1(Ref.9), 2(Ref.10) and 3(Ref.10).

Figure 1: Wind – Atlas , wind resources at 50 m above ground level for different topographic



conditions in Europe. Ref.9)

Figures 2 and 3: Wind potential in Slovakia, measured 1961-1980, (Ref.10,8)

To get a precise statement of the volume of wind, it is useful after the first iterative statement about the wind Atlas, for measurements, as mentioned above, to use

an anemometer (s.Abb. 4, ref. 6), which is mounted on a mast in height of the rotor hub height of the wind power plant to be built.

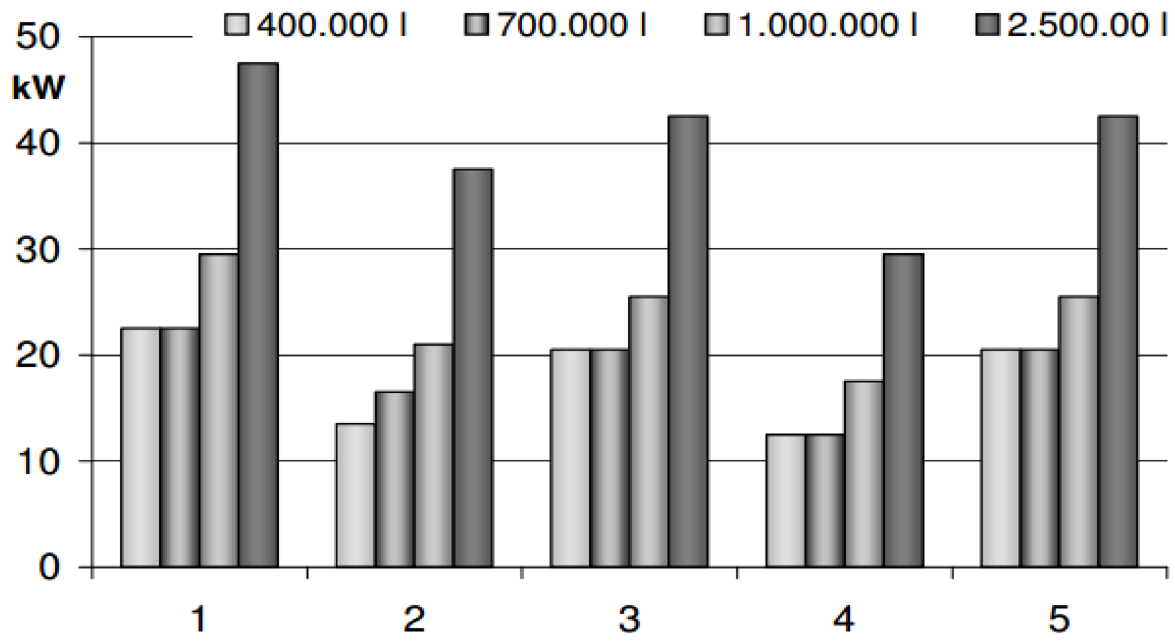
Figure 4: Anemometer for measuring wind speed (Ref.6)

The more wind power, the more electrical power is produced, the more electricity is generated, the lower are the costs of per generated **k**ilo**W**att**h**our.
Conclusion: The more wind, the more economical is the **S**mall **W**ind **T**urbine (SWT).

THE REQUIREMENT OF POWER AND ANNUAL ENERGY CONSUMPTION

If establishing a SWT makes sense according to the measured data, now the energy consumption is to determine. This should be determined already parallel to the wind measurement, using a energy counter holding the chronological sequence of the energy demand. For farms to get reference values but also from literature

Figure 5 and table 1 (REF. 11) show the power requirement for the dairy farming of various large companies. Table 2 shows the annual energy consumption.



1	2	3	4	5
Circulation cleaning + direct evaporator cooling	Boiling cleaning + direct evaporator cooling	Circulation cleaning + ice water cooling	Boiling cleaning + ice water cooling	Circulation cleaning + Milk pre-cooling + direct evaporator cooling

Figure 5 :Power demand in the dairy industry, for different company sizes and procedures (Ref.11)

Procedure Nr.	Size of the dairy operation or production volume number of animals (units); annual milk quantity (kg)			
	60 cows 400.000	**100 cows 700.000**	**150 cows 1.000.000**	**400 cows 2.500.000**
1	20-25 kW	20-25 kW	27-32 kW	45-50 kW
2	12-15 kW	15-18 kW	18-24 kW	35-40 kW
3	18-23 kW	18-23 kW	23-28 kW	40-45 kW
4	10-15 kW	10-15 kW	15-20 kW	27-32 kW
5	18-23 kW	18-23 kW	23-28 kW	40-45 kW

Table 1: Size ranges of measured power of typical production processes in dairy farming as a function of the volume of milk production (Re. 11)

Production volume				
Number of cows (units)	**60**	**100**	**150**	**400**
Annual milk quantity (1.000 kg/a)	**400**	**700**	**1.000**	**2.500**
Energy consumption per year (kWh/a)	**20.000**	**35.000**	**50.000**	**115.000**

Table 2: Annual energy consumption in typical production processes in dairy farming. (Ref.11)

For the here performed example calculation we consider a small farm with 60 dairy cows (dairy industry) and some 400 000 ltr. milk production each year, or alternatively a fattening farm with 600 pigs. Both have roughly the same energy (REF. 11)
A specific energy consumption 5kWh/per 100 kg of milk per year in dairy farming and 40kWh per fattening place per year in pig fattening shall apply for the calculation (REF. 11).
Both companies have daily peak loads by ca. 1 hour in height of ~ 12 kW at dairy farm at the time of milking and cooling of the milk and of ~ 5 kW, at the time of cleaning.at fattening farm(REF.11) For both companies resulting in additional energy consumption for pumps, fans and heating (s. table3, Ref. 11) an annual energy consumption of approximately 24 000 kWh/year is needed.
This energy can surely be produced with a small wind turbine, also in a weak wind country (for example, Slovakia, figure. 2u.3) with an annual average wind speed between 4 and 6 m/sec.

Device technology	Power (kW)	Annual running time (hours/year)	Annual Energy consumption (kWh/a)
Pumps	6 bis 24	80 bis 120	480 bis 3.000
Fan	0,2 bis 0,6	6.000	1.200 bis 3.600
Heating / Cooling	2-3	500	1.000 bis 1.500

Table 3 : Energy consumers (Ref.11)

SELECTION OF A SUITABLE WIND TURBINE

A small wind turbine is now to select, the final section of the plan. With their specific data, the cost-effectiveness of the required investment is expected to check, whether the demand for energy from the public network (if one exists) is not favourable.
To be examined now is a stand- alone- plant, that means a small wind turbine (SWT), with lead-acid batteries for storage and buffering the energy peaks for autonome and self-sufficient operation.
For the above mentioned data a mini wind turbine with a capacity of 5 to 30 kW can be considered which is designed for low wind with v ~ 5, 5 m/sec. Here is to be expected (at a cost of 2,000-10,000 euros per kW. (Ref.6)
To determine the size of such a plant, the rotor diameter of the turbine can be obtained from the following equation.
The equation applies to the performance of a wind turbine is:
$P = C_p \times C_t \times 3{,}14 \times D^2/4 \times 1{,}225\ kg/m^3 \times V^3$ (Ref.13)

with:

P = Power in W

Cp = Aerodynamic efficiency of plant (0,4- 0,5)

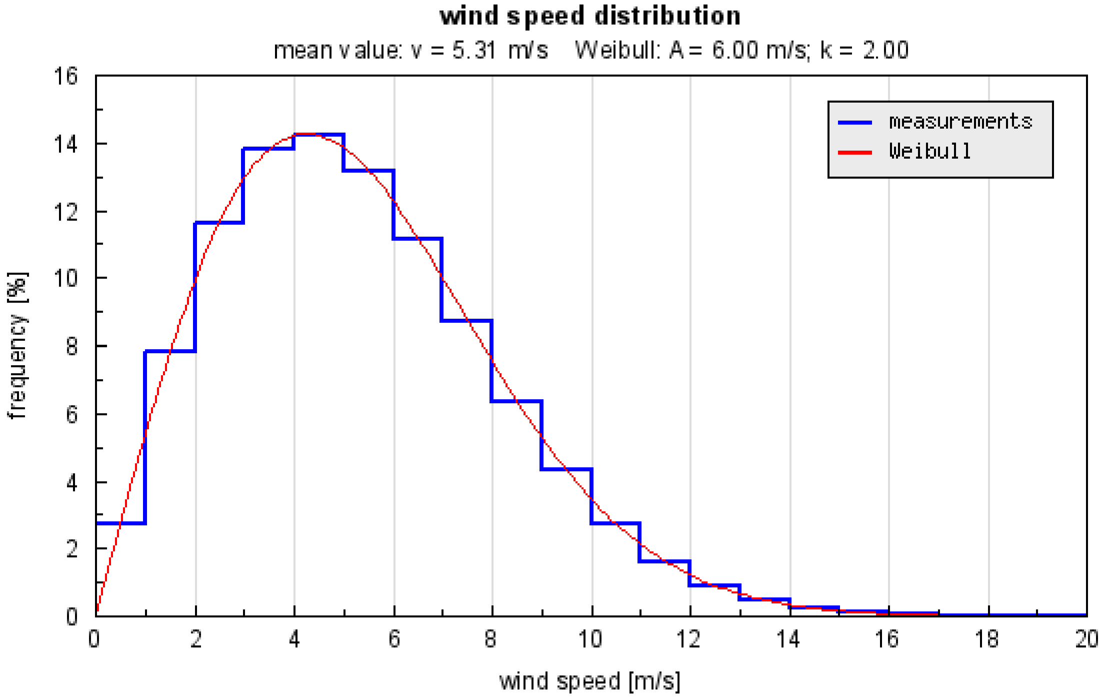
Ct = Efficiency of the turbine (0,8 – 0,97)

D = Rotordiameter in m

1,225 kg/m³ = Luftdichte in Meereshöhe

V = Windspeed in m/s

The yield so one can be influenced with the the rotor diameter. On the other hand, as seen from the equation, it is dependent on to the 3rd power of the wind speed, this can be influenced indirectly by the hub height at the chosen location.



With the established values is therefore:

$P \sim 0{,}39 \times D^2 \times V^3$ (W)

Figure 6 : Wind Speed Distribution (Ref.14) over the year

As the wind speed, according to a frequency distribution (measured see.p.3 and fig. 6) over the year varies, the output of a wind turbine but only at a given wind speed Vnom is reached, arises under the assumption that the estimated percentage of the year hours (8760Std/a), which reach this speed Vnom, is about 25% (REF. 15), for the annual yield:

$$E \sim 0{,}25 \times 0{,}39 \times D^2 \times V^3 \times 8760 \text{ Std} \quad (\text{Wh})$$

This yield should be achieved with a mean wind speed of 5, 5 m/sec (average wind speed in the example of Slovakia (REF. 8.10) throughout the year) and this yield should cover the energy-consumption of 24000kWh, as identified on page 7.

So therefore arises for the diameter

$$D = \sqrt{\frac{24000 \times 10^3}{0{,}25 \times 0{,}39 \times 5{,}5^3 \times 8760}} \quad (\text{m})$$

So the Diameter: D= 13m.

Specifically, an SWT among various providers, e.g. over the Internet, can be selected now. (REF. 12)
From the listed plants underRef.12, one from the Swiss firm Aventa AG, Type AV-7 ,(see fig.7), is selected for further investigation.
The system is specifically designed for weak and in strength and direction variable winds, how those inland that usually prevail. (Ref. 16) According to the manufacturer, it is easy to install.
The embodied energy (grey energy) that is the energy used for the manufacture, transport, storage, sale and eventual disposal of the SWT (REF. 17), is, according to the manufacturer, in 2-4 years by the wind turbine generated.
The system is very quiet (noise levels in 50 m distance < 30dBA), so that it can safely be built near the farm. The lifetime is specified by the manufacturer at age of 20 years. The system costs about 19,000 euros. It is produced in series since 2002 and sold around the world.

Figure 7 : SmallWindTurbine (SWT), Aventa AV-7

Table 4 : **Technical Data AV-7**

Maindata	
Hubheight	18,0 m
Rotordiameter	12,9 m
Nominal Power AC	6,5 kW
Onset-Windspeed	2,0 m/s
Nominal Windspeed	6,0 m/s
Cut – Out Windspeed	14,0 m/s
Noise Level in 50 m Distance	< 30 dBA
Rotor	
Diameter	12,9 m
Rotorarea	129 m2

Power Design (Nominal power: Rotorarea) 50 W/m2

Speed variabel 20 – 66 R/min

Wing Tip Speed max. 44 m/s

Fields of application: For sites with maximum average wind speed of 4.5 m/s

With the indication of the rotor diameter D (12. 9 m) can now be examined , based on the data for the energy content of the wind in the vast majority of the Slovakia of 50 W / m² (see fig. 3) ,if the rated power Pn of the AV-7 and therefore the SWT is suitable for the site.

P = A x Pw with : A=Rotorarea = 3,14 x D (m²)/ 4 ; Pw =50 W/m² Windpower

Therefore : Pn ~ 6,5 kW and so fit.

Figure 8 : Performance Characteristic oft he SWT AV-7

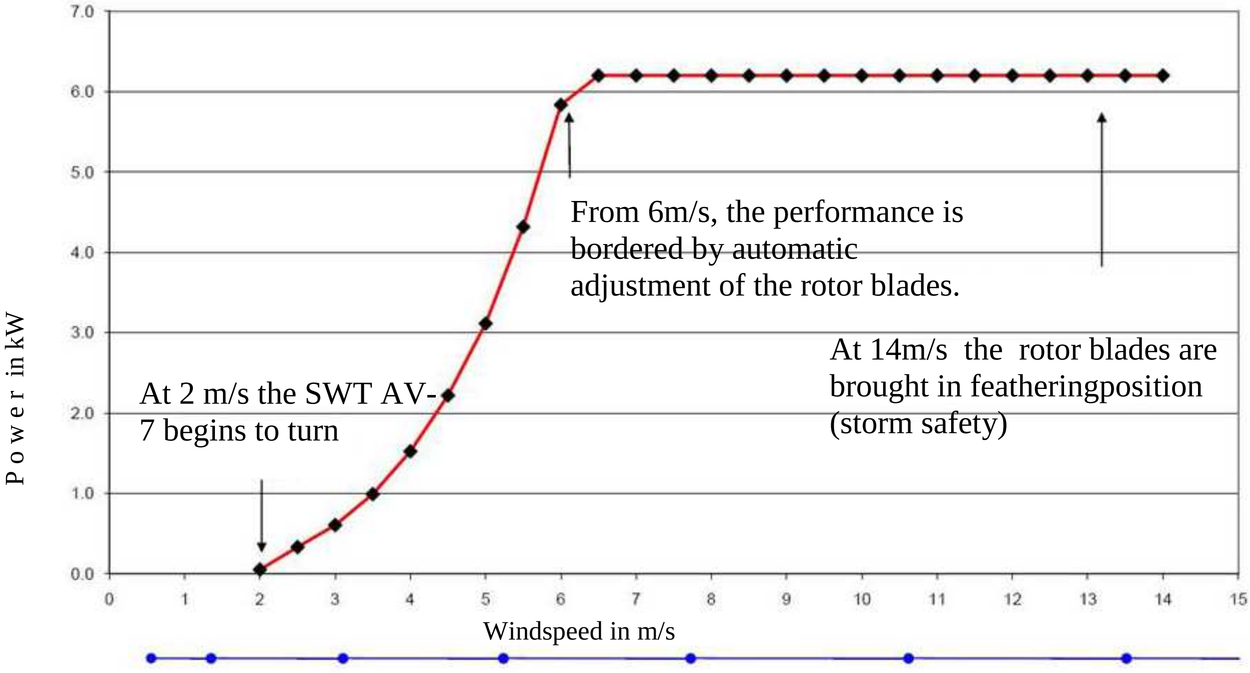


Table 5 : Yield of Energy per year at different windspeeds

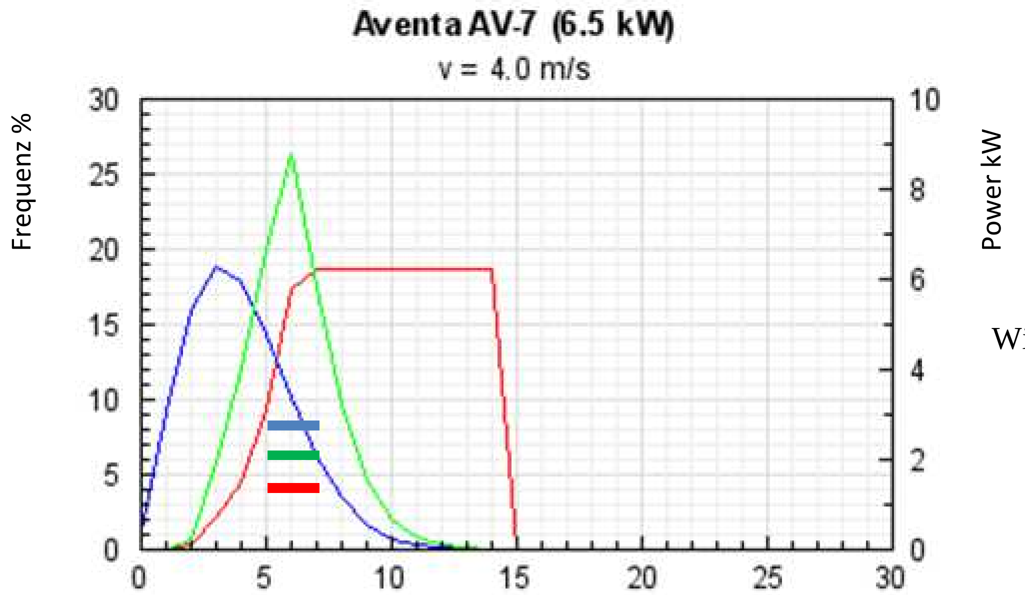
Average windspeed per year :

2,5 m/s	8'000 kWh/a
3,0 m/s	12'000 kWh/a
3,5 m/s	16'000 kWh/a
4,0 m/s	20'000 kWh/a
4,5 m/s	24'000 kWh/a

Based on the performance characteristic curve shown in Fig. 8 of the SWT and the wind data measured at the site about 1 year (s.page 5) now the annual energy yield expected can be determined, using a yield calculator, as he stands available on the Internet, (Ref. 19). Here to get for the AV-7 System, table 6 results. A nearly interruption-free operation (7844h/a) is assumed in the available year hours (8760h/a).

Producer	Aventa AG
Type	AV-7
Installed Power	7 kW
Rotordiameter	12.9 m
Yield of Energy	19'491 kWh/a
Capacityfactor	34.2%
Full-load hours	2'997 h/a
Operating hours	7'844 h/a

Table 6: Data for the SWT AV 7, calculated with yield calculator.(REF. 19)



Windspeed-Distribution

Yield-Distribution

Performance-Characteristic-Curve

Figure 9 : Yield-Distribution and Performance – Characteristic of the AV-7

The specified full-load hours 2997 h / a are by definition the quotient of annual energy yield and nominal power.

As equivalent, they specify how many hours must run the plant in nominal operation, i.e. at design speed (rated speed Vn) in achieving the annual yield, here 19491 kWh/a. A plant is, according to the German Institute for wind energy (DEWI) economically, if 2000 full-load hours are reached over the year (i.e. 23% of the year hours). (Ref. 20)

STAND-ALONE - SMALL-WIND-TURBINE - PLANT

Just for emerging countries (e.g. Slovakia) is the SWT as a "Stand alone complex" in combination with solar panels and batteries for the autonomous operation of a farm predestined, (s.Fig. 10)

Figure 10: Stand alone complex, with battery pack House

Because the wind blows not steadily, but irregularly, the SWT must be combined with buffering and storage batteries . They ensure the basic needs of electricity, but also providing peak loads by approximately 5kW at pig-fattening farms -or 12kW at dairy farming sector, as it accrues in the aforementioned farms 1-2 times a day for 1 hour (fig. 11 and 12, ref. 11).
It is possible, especially in the agricultural sector, the creation of a water reservoir in the form of a water tower, or a higher Lake. Then the accumulated wind energy will power a pump, which high pumps the water into the store and this then, on demand drives the lower generator for the generation of electrical energy.
Several such batteries can be grouped together to get sufficient storage capacity. A charge controller protects the batteries from overvoltage and deep discharge. A stand-alone inverter must be inserted for the operation of alternating-current consumers, which automatically generates a voltage (e.g. 230 V, 50 Hz) from the DC of battery and provides active and reactive power. Essentially, such a system so consists of 4 components. The small wind turbine (SWT) (possibly the additional solar generator), the charge controllers and inverters, the accumulators and consumers. The entire system must be harmoniously co-ordinated. (Ref21. 21)

A SHORT OVERVIEW OFT HE ECONOMY
Finally, the cost of such a complete system should now
set up, and the time until the payback determined (return on investment, ROI).

Small Wind Turbine Aventa AV-7, (Ref.16) :	19 000,- Euro
Installation with own contribution:	3 000,- Euro
8 Batteries (Ref.22) :	2 240,- Euro
2 Inverters,5 kW, 5 Charge Controllers (Ref.23) :	3 200.- Euro
TOTAL INVEST :	**27 740.- Euro**

For the example of Slovakia, where the cost of kWh about the utility are 14.48 cents (Ref. 24), that means, with an annual energy consumption of 24 000 kWh, savings by: 3475,-euros This means that the system amortizes itself after 8 years. The additional benefits, because of the plants calculated lifetime of 20 years, will be then for 12 years and certainly beyond, because after that time primarily only the generator and electrical components (battery, charge controller, inverter) are to renew, what will result in costs of about 10,000 Euros. But then the plant produces another 20 years energy.

CONCLUSIONS

The installation of a small wind turbine is so economical, useful in all cases, and more and more economically interesting in terms of more anticipated cost increases in the cost of electricity In combination with other plants to the production of renewable energies, such as bio-gas plants and photovoltaic systems, enormous synergies in energy generation and new business fields for the farmer can be opened.

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