Introduction to Wind Energy for Secondary Schools

March 2001

Paul T. Smulders & Jan de Jongh

ARRAKIS

The Netherlands

Curriculum
for a Module
Introduction to Wind Energy
for Secondary Schools

Name of the training activity: INTRODUCTION TO WIND ENERGY

Introduction:
Since renewable energy is one of the fast growing industries nowadays, experts are required in increasing numbers. Presently there is a lack of these experts, while education is not providing specific knowledge to this subject. E.g. in Spain the wind energy industry is growing very fast, but there are no Spanish technicians which have been trained in wind industry, nor at school nor in the industry itself, since the industry is very young. Education at all levels is required to evoke interest among students to enter the field of renewable energy and to provide them with the required knowledge and skills.

General objectives:
- To provide a curriculum on a general ***introduction to wind energy*** for secondary school level students, that can be used to develop a training module.

Requirements of the target group:
- Students from Secondary schools, age 16;

Subjects in which part of the module can be treated:
The module includes topics that can be treated on its own within the relevant subject, without the other topics being treated within the other subjects

<u>Topics of the modules to be treated within the subject:</u>
1, 2 power in the wind & wind energy resources, within physics
3,4 and 8 within geo-physics
4 history of windmills, within history
5,6,7,8 within Technology,
3 windmills and 10 environment within human science and environment
All subjects within National Language

Alternative: Integral treatment in one project.
The school can decide to have one project on wind energy that is treating the complete module, be it within a certain subject, eg Technology , by one teacher, or the module is split up in treatment within all the other subjects, given by the respective teachers of those subjects.
The project may be concluded with an exhibition, a forum discussion etc.

Length of module:
Approx. 10 pages written text, tables, figures and pictures come in addition to the text. Approx. 3 hours treatment by teacher of the module itself. An additional project on wind energy could be included inside the options given to the students (eg the manufacture of a small wind generator) . Duration of this project depends very much on the contents.

Method of study and length of lectures: will be indicated per subject.
Generally, reading and exercises, including preparing essays and site visits, interviews, Web search

Style of the description and contents of the module:
In order to capture the attention of the students as well as to learn them some sound basics of wind energy, the style can best be described as:
It should be FUN, SOUND & SOLID.

Contents description of the module:
The contents can best be developed by providing answers to a number of questions, which have been mentioned below. These questions can in most cases also be posed to the students, either as an exercise or as a focussing question in the classroom, before answering of the question by the teacher.

1 Power in the wind
How much power is there in wind?
How much can be captured by a wind turbine?

2 Wind energy resources:
How does wind develop?
How many % of solar energy reaching the earth becomes wind energy?
How does this relate to the total energy demand in the world?
What are the effects of WE in nature? Clouds, seeds, etc.
What manmade technologies using wind energy do you know? (sailboats, kites, windmills)

3 Windmills:
Where are windmills used for?
What are the main characteristics of a windmill? How is the size indicated? (rotordiam, hubheight, power)
Mention all the applications you know where windmills are used for.
Have you ever visited one?

4 History of wind mills:
Where does the oldest mills come from and how long ago?
What type could you call it?
What was its application?
For the past: Mention the countries which used wind mills most and for what purposes, in which time?
Dutch type (NL+UK)+ multiblades in USA + Australia and South Africa.
What are presently the leading countries in modern wind energy?
What is the application mostly used?
5 How does a wind mill work?
An old Dutch type; wherefore did they use removable sails?

How in great lines works a modern electricity producing wind mill?
How were windmills directed in the wind? In the past and presently?

6 Aerodynamics:

Explain the difference between lift and drag.
Do you know other applications of lift? (swimming, kites, airplanes, birdwings)
Applications of drag driven devices? Ventilators, Savonius rotor, resistance while cycling, etc.
Explain the physics of the lift phenomenon (difference in pressures)
Two different methods of reducing forces with high windspeeds (feathering and stalling)

7 Electrotechnics:

Generators. Explain the working of a bicycle dynamo. A wind turbine generator works the same.

8 Siting and power output of a wind turbine:

Why are wind turbines placed in open areas and not in cities?
Why are there more wind turbines at the coast than inland?
Why are modern wind turbines much higher than the old (Dutch) types?
Explain to solve these questions:
The main variables of a site that influence the electricity production of a wind turbine:
Average site wind-speed, surroundings(obstacles etc), and height (hub height and site height)
How many households can be served with certain wind turbines?

9 Economics

Since the wind is for free, are there any costs to wind energy?
What are the economic benefits of wind energy?
Is there a link to the oil-price?

10 Environment:

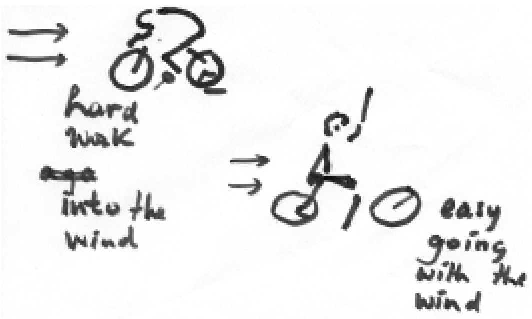
Wind energy is called clean energy, why?
Why are people objecting against wind energy?
Mention the various reasons, horizon pollution, sound, shadow hindrance, birds, etc.

Sample section, for a Module
Introduction to Wind Energy
for Secondary Schools

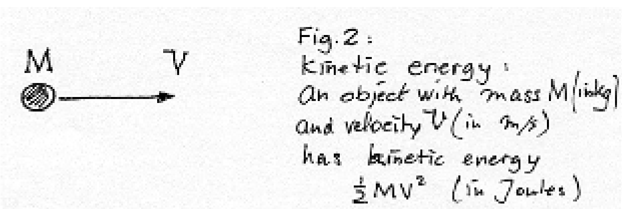
Introduction:
In order to find out what we would like to develop finally as a complete module (not part of this AEOLUS project, we restrict ourselves to the Curriculum only), a first topic on Power in the wind has been written, the sample section. This is done in order to get an impression of how the module should look like.

Power in the Wind

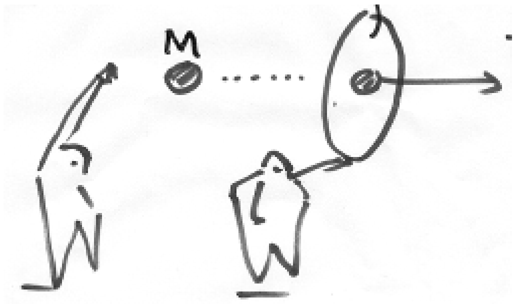
W e all know the **force** of the wind. Anybody who rides a bicycle prefers to have the wind in his back rather than having to ride headlong into the wind in which case he experiences a larger resistance force by the wind. But **energy** in the wind is not straightforward.



What is wind?
Wind is air in motion. It is air with a certain mass and moving with a certain speed. From our lessons in physics we know that an object with a mass M, e.g. a tennis ball, which is moving with a velocity V has a kinetic energy, equal to: $1/2 \times M \times V^2$ (expressed in Joules).

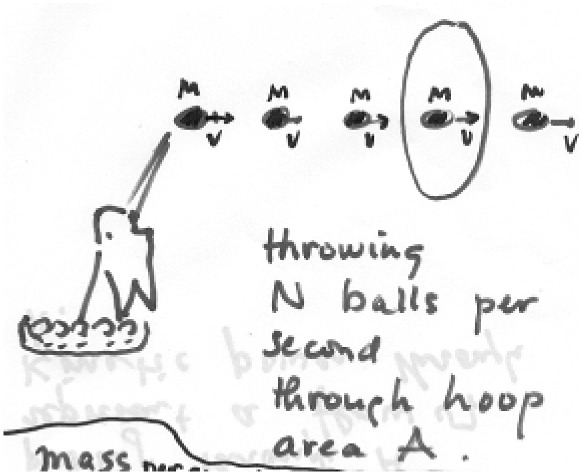


In the same way **wind is kinetic energy;** it has mass and it is moving. How can we make good use of this energy ? Let us first try and get an idea of how much energy (or power) there is in the wind.
Let us play the following game.

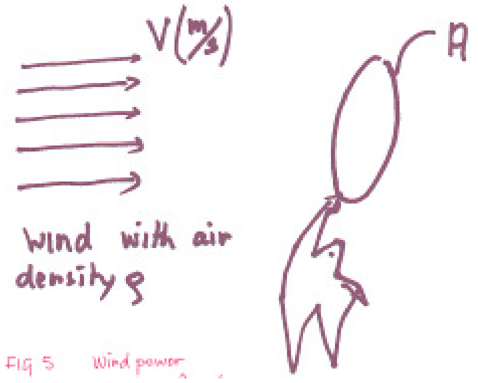


I hold a hoop above my head and you throw a tennis ball through it. Not only the ball passes the circular area of the hoop but also its kinetic energy $\frac{1}{2} \times M \times V^2$.

You now start throwing identical tennis balls through the hoop at a rate of N balls per second. That means mass is passing the surface at a rate of $N \times M$ kg per second and with it ($N \times M \times 1/2 \times V^2$) **kinetic energy** passing the surface of the hoop **per second. ENERGY PER SECOND IS POWER (in Watts).**



Let us now hold the hoop into the wind which has a wind speed *V*.



The area of the hoop with a diameter *D* is : $A_{hoop} = \Pi / 4 \times D^2$.

The **volume of air** passing through the hoop **per second** is:

$V \times A_{hoop}$ [m³/s].

We know the density of air ρ_{air} [kg/m³]. So the **mass of air** passing through the hoop **per second** is $\rho_{air} \times V \times A_{hoop}$ [kg/s]

This is comparable to $M \times N$ [kg/s] of tennis balls through the hoop.
So the kinetic energy passing **per second** through the hoop is
(mass per second) x (1/2V^2) = $\rho_{air} \times V \times A_{hoop} \times \frac{1}{2} \times V^2$ or as it is often called,
THE POWER IN THE WIND (through the area A) is:

$$P_{wind} = 1/2 \times \rho_{air} \times V^3 \times A \qquad \textbf{[watts]}$$

That tells us a lot about wind power.

- it is proportional to the cube of the windspeed. E.g., At 5m/s speed , wind power is nearly twice as large as at 4 m/s. $(5^3)/(4^3) = 125/64 = 1.9....$ So knowing the windspeed correctly is very important
- power is proportional to the area. It means that if you double the size (the diameter) of a windmill the power is 4 times larger, because the area is 4 times larger.
- air is very light; its mass is only 1.2 kg per cubic meter.

Density of air

Height above sea level [m]	Density of dry air at 20^oC
0	1.2
1000	1.1
2000	0.9
3000	0.8
4000	0.7
5000	0.6

Figure: Density of dry air at different altitudes under standard conditions.

EXERCISE
To get a feeling of the power, calculate P for a surface with a diameter of 2 meters at a wind speed of 4m/s and 10 m/s. Likewise at the same wind speeds for a windmill with a diameter of 20 meters.
The question now is: how am I going to capture the power in the wind through the area A? And can I capture it all? You can do it by having a properly designed windmill with its blades just sweeping the area A. But you cannot capture all the power. It can be shown that you can capture about 4/10 of P_{wind} and convert it to mechanical power e.g. to drive an electric generator to make electricity. How a windmill works is not our concern here. But it is necessary to have a rough idea of the power in the wind, before discussing WIND RESOURCES.