Teaching wind energy in 18 hours?

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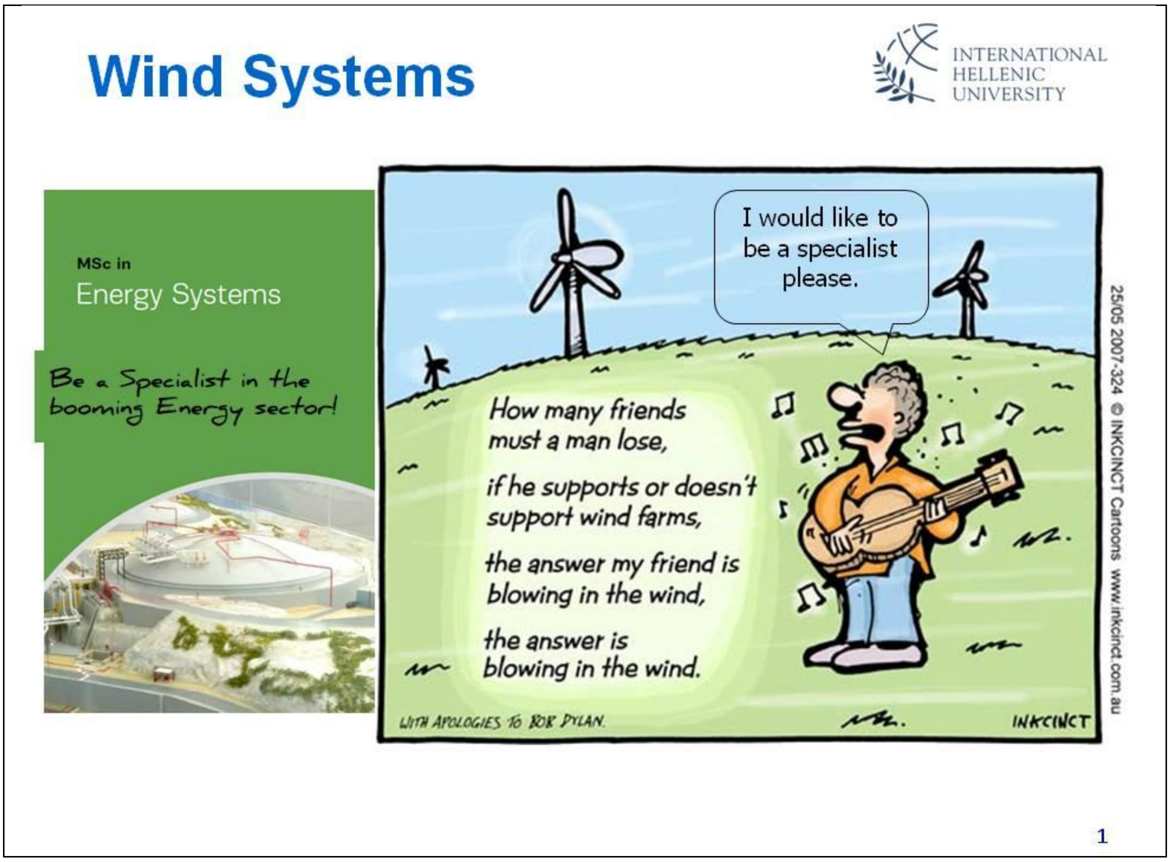
ABSTRACT

Today various universities are offering courses that vary in duration. The International Hellenic University, based in Thessaloniki in Greece, has an 18-hour course about wind energy for postgraduate students pursuing the MSc in Energy Systems degree in Greece. The course is offered in English to Greek and international students. The challenge was to develop a series of lectures that combine the time limitation with quality knowledge taking into account the students' diverse background in sciences. The paper presents the key subjects that a postgraduate needs to know about wind engineering and explains why they need to be taught in that order. References are made regarding the accredited sources from where material was taken or proposed for further reading. Major internet sources and online tools freely available today were thoroughly discussed and a multitude of links were provided. Last but not least, the use of technical video and animation presentations was proven to be a most didactic tool which was most welcome by the students.

Keywords: wind energy, wind systems, teaching



1. The design parameters-course preparation

In collaboration with the International Hellenic University course organizers, CVs of the postgraduate students were studied. The class of 2016 had a mixture of environmental specialists, electrical engineers, geologists, mathematicians and chemical engineers. A very diverse group of sciences.
This fact was taken into account in the mathematical content of the lecture notes, the physics behind the engineering to be presented and the extra material to be suggested for further reading in order to satisfy a student that needed to go the extra mile. This may sound evident, but the material targeting mechanical or electrical engineering graduates only, can be incomprehensible for other sciences.

The lectures took place on Friday evenings and Saturday mornings in order to accommodate working students. They lasted for 3 hours each time. The course was completed after 6 days. An exam followed in June 2016. All the lecture material was uploaded in a university portal prior to the lectures. This was essential because the students had time to look at it and prepare questions.

For each teaching day additional material was uploaded well in advance. This included reports from EWEA (WindEurope) [1], GWEC [2], IEA [3], World Bank [4], IMF [5], books and papers. References were made to these during the lectures. Links to international research centers such as DTU (RISØ) [6], NREL [7] and MEASNET [8], were presented with commentary about their usefulness. Emphasis was given to publications within the past 3-4 years in order for the students to be updated in all aspects of wind energy applications. For this course it was decided that a careful selection of videos and animations related to wind would be beneficial compared to a powerpoint presentation. This meant spending a lot of time viewing and selecting short but very informative material.

2. Course curriculum

The course curriculum and the content in number of slides and videos are presented in table 1.

Wind turbine technology today and future trends onshore & offshore, wt certification, IEC 61400 standard	45 slides, 6 videos, (31 minutes)
Wind resource evaluation (instruments-measurements-modeling), meteorological parameters	121 slides, 2 videos (6 minutes)
Atmospheric Boundary Layer, wind speed profiles, analysis of measurements, wind atlases onshore & offshore	54 slides
Selection methodology of most suitable locations, site surveys	58 slides, 1 video (2 minutes)
Energy yield (measurements-modelling-state of the art tools), wake losses, CFD codes	76 slides
Environmental constrains & social acceptability	79 slides, 3 videos (6 minutes)
Detailed methodology on how to design wind farms in areas of complex terrain, plains or the sea	45 slides + working example with students
A full example of a technical and economic evaluation of a big wind farm	22 slides

Table 1: The main subjects taught, number of presenting slides, no of videos and duration.

In total, 500 slides and 45 minutes of videos comprised the material presented in 18 hours.

Quantity wise the number of slides was proven to be more than sufficient in covering the time available and without going through pictures or graphs in a speedy manner.

3. Order of presentations

3.1 The element of surprise on the 1st lecture

This was an idea that sprung into mind in order to win the students' attention from the first 15 minutes of the first lecture. A case study was presented to them for a large wind farm, like they were already trained on matters of wind energy and they had to research and provide answers in order to evaluate if the project was bankable or not.

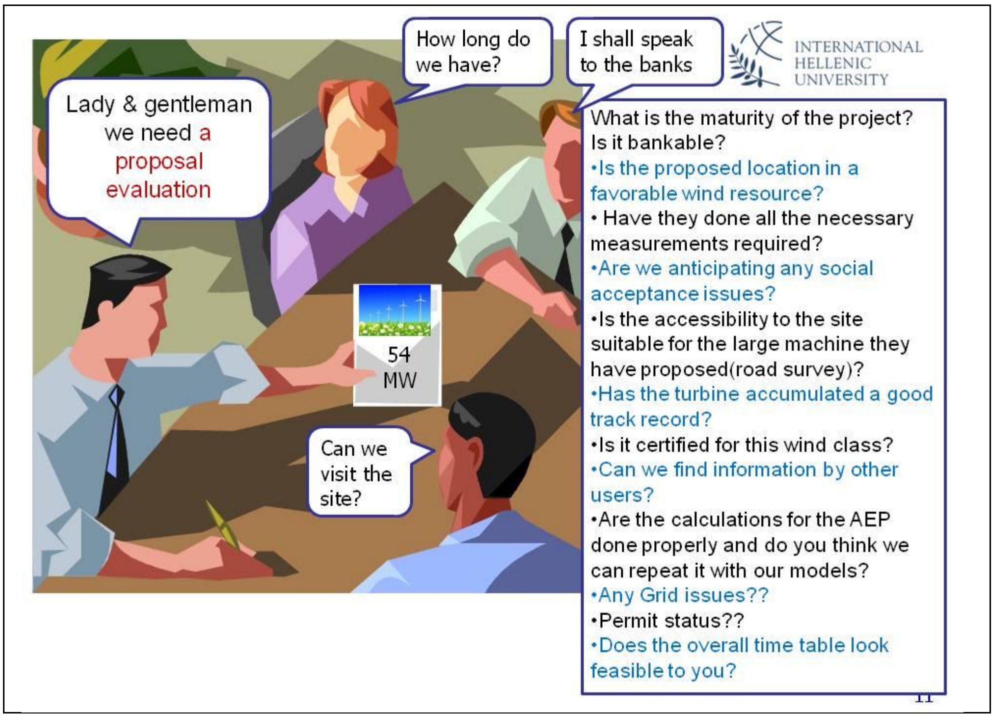


Figure 1: The questions asked by the team leader in an evaluation situation.

The element of surprise worked well with almost all of the students that of course could not answer. They were told that after they have studied this course with the curriculum presented to them as shown in table1, this would be possible.

3.2 Wind turbines

Many courses start lectures explaining about the wind resource and introduce technology much later. The problem with this approach is that the technology terminology is needed in order to describe how wind variability affects the performance of a wind turbine. Familiarization of the students with terminology and features of the geared and direct drive wind turbines was considered important. This is why the first lecture was about turbines and their technical caracteristics. Wind turbine certification according to IEC 61400 standard, and choice depending upon extreme conditions was an issue discussed in detail for wind turbines classes, I-II-III and S.

Within the first 3 hours on the first day it was considered important to explain the basic aerodynamic principles, mode of operation, transportation and construction of large wind farms onshore and offshore globally, with the use of videos. This is why 6 videos of a total duration of 31 minutes were presented. This was approximately 70% of the total video time designed for the course. It is very easy to get carried away and provide more videos and spend more time but we must keep in mind to provoke interest, make them ask questions so to engage on a didactic dialogue. Discussion followed after each video presentation. All video material was given to students and the links related to that.

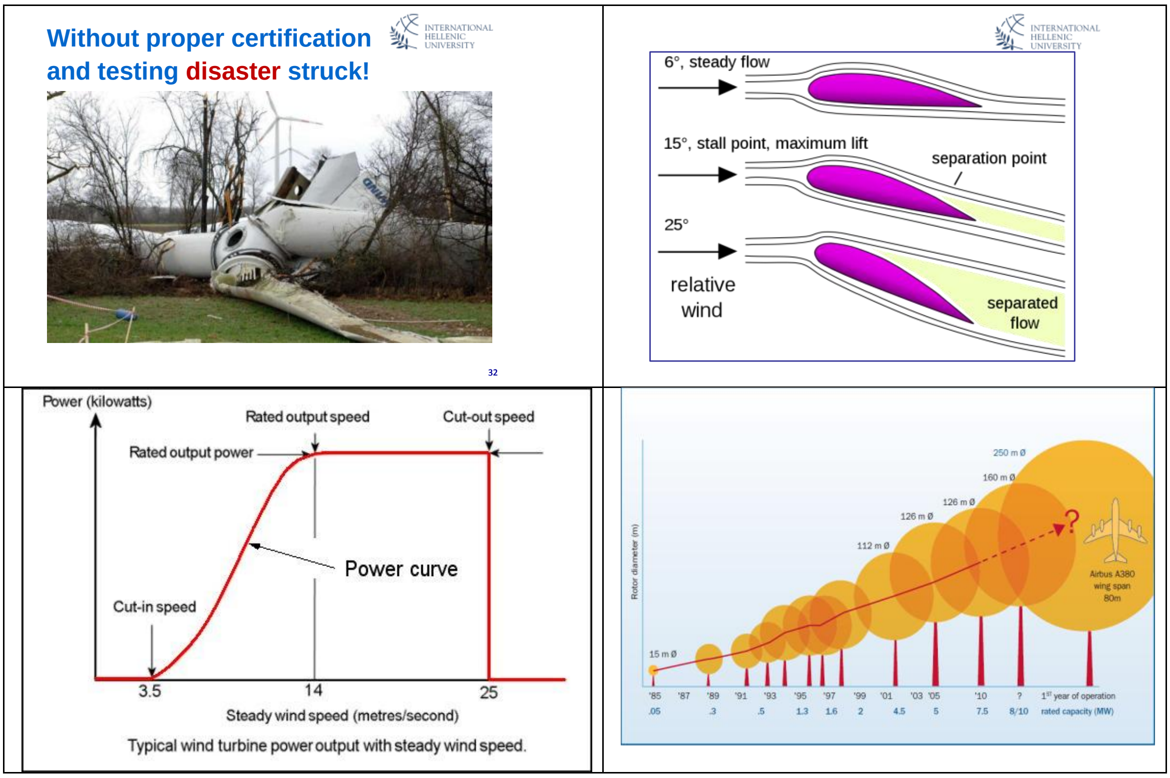


Figure 2: Four slides from the module on turbine technology

3.3 Wind resource

This fundamental part of wind energy took 24 % of the slide content. Instrumentation and state-of-the art LIDAR and SODAR technologies were introduced.

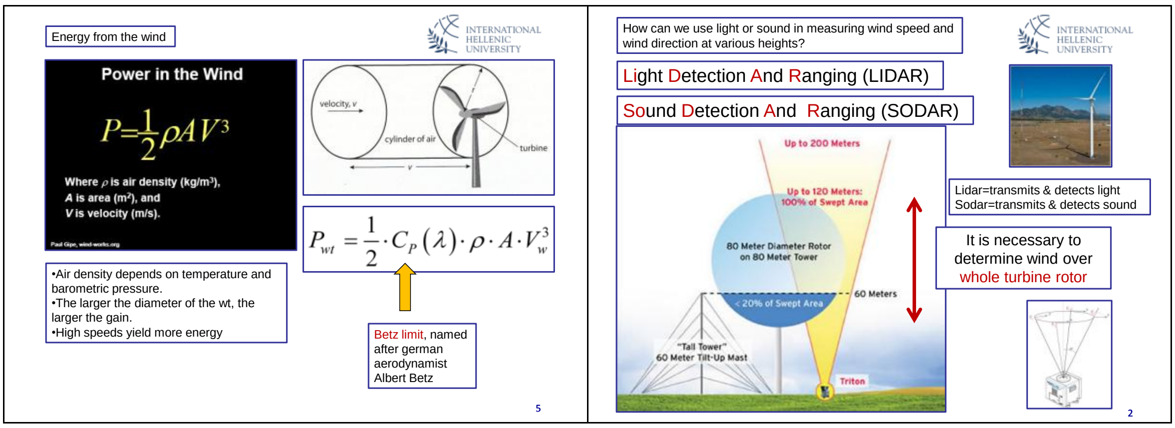


Figure 3: Energy content of wind, LIDAR & SODAR technology

The content included global surface winds and how they change with latitude, energy content in the wind and why it is so important to measure speed accurately emphasizing that the energy is proportional to the wind speed in the power 3. Many examples were discussed from measuring station with data from one year to twenty years. Recommendations about duration were provided in compliance with country permitting rules. All the instruments available today for measuring wind speed and direction were presented with the advantages and disadvantages that this entails. Examples of erecting a met tower were given accompanied by two short video presentations lasting six minutes. As instruments such as SODAR and LIDAR are becoming the state of the art for more accurate readings, with the advantage of covering heights up to 300 m AGL, the two technologies were introduced and many vertical profiles were presented. Comparisons were made with these two technologies and a standard mast equipped with anemometers and wind vanes.

The **M**easure **C**orrelate **P**redict (MCP) methodology was presented by examples. The Modern-Era Retrospective analysis for Research and Applications by NASA [9], MERRA was presented with examples and comparisons for Greece. This is a most useful freely available database needed for MCP.

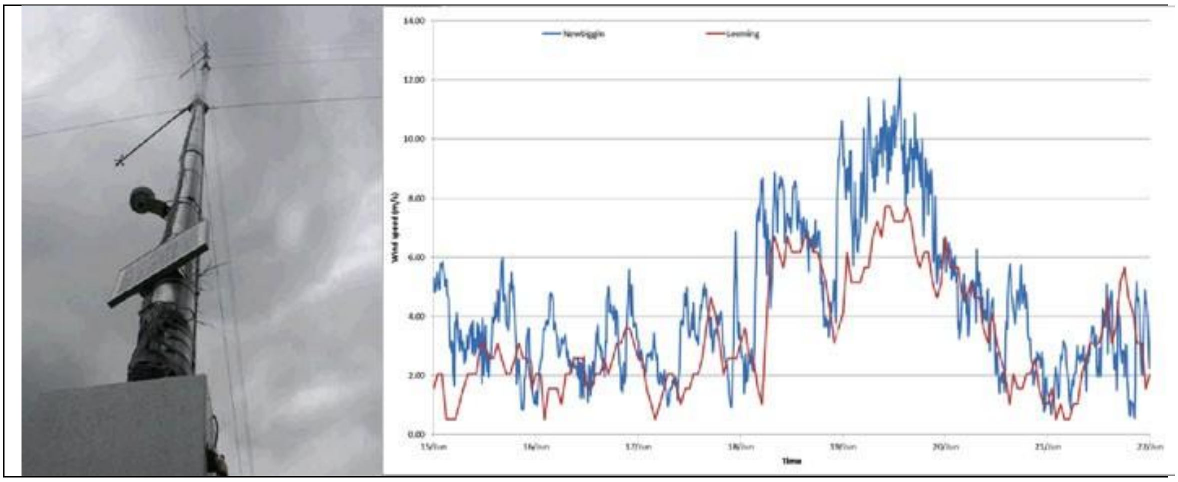


Figure 4: An MCP example

As we see more and more offshore development many examples were provided where to acquire data such as the NOAA, Nationals Environmental Satellite, Data and Information Service. The 4C Offshore atlas is such an example [10]. They have combined their extensive offshore wind expertise with a reliable high resolution global satellite dataset to develop a 23 year wind speed database used by the offshore developers. The British offshore wind atlas, a result of modeling and satellite measurements was also presented [11].

The students became aware of many possibilities a developer has in order to quantify the resource and use it in order to predict long term energy estimations.

3.4 Siting is exiting!

Developing a new site can and should be creative and fun. The documentation needed (maps, satellite photos), preliminary road surveys, foreseeing environmental and other technical constraints, which are crucial parts to wind resource evaluation, were discussed. The advantages of using the speed up effects of hilly or mountainous areas were presented. Wake effects produced by existing buildings or forests were shown.

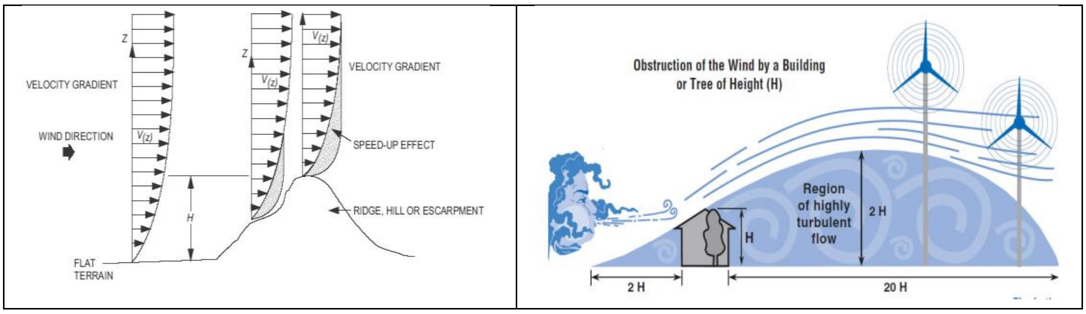


Figure 5: wind speed profiles over hills, wakes due to presence of buildings

3.5 Annual energy production

For the 20-year operational life time of a project, the margin of error should be as low as possible.

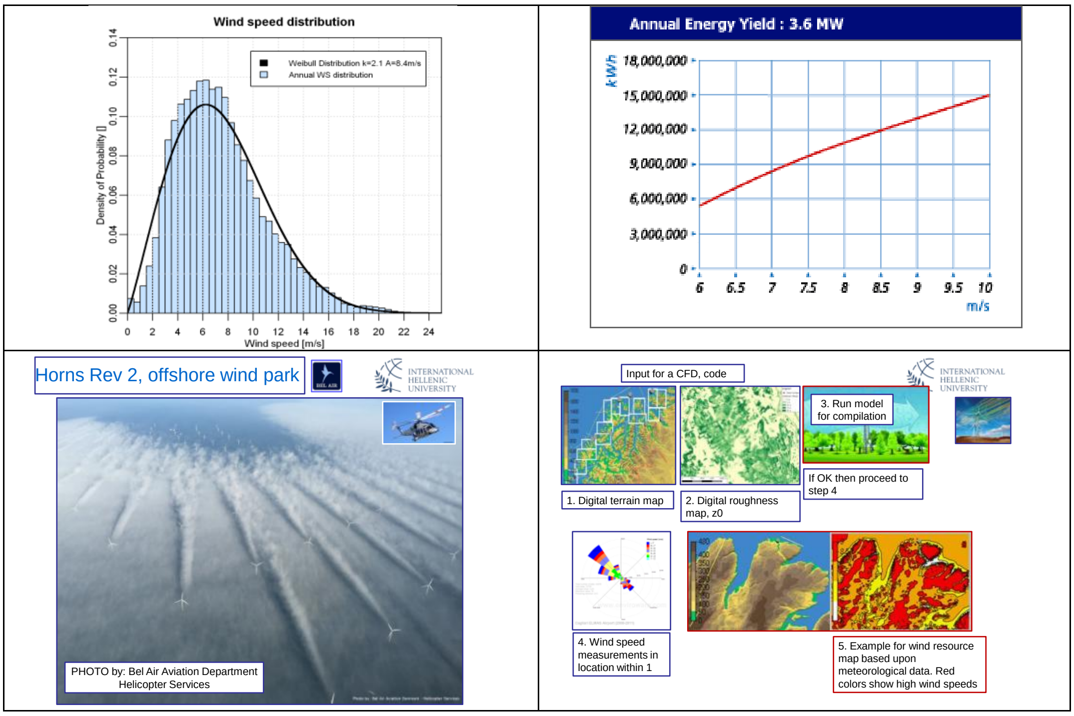


Figure 6: Top 2: Weibull distribution, Rayleigh energy estimation for a 3.6 MW turbine. Bottom 2: Wake propagation downstream, input data to a CFD code.

Examples were presented for calculating energy output, from a simple duration curve or an approximation based upon the Weibull parameters k and C or the Rayleigh distribution combined with a turbine's power curve.

Farms designed on complex terrain sites need a CFD approach. Examples documented the usefulness of the numerical codes. CFD evaluation was recommended.

3.6 Social acceptability and the environment

People working in the field of wind development sometime find it hard to defend a technology that produces clean energy. We have to keep in mind that the wind industry should play an important role in educating society in the truth of the matter. There is no way that we can convince all the people, but if the majority is in favor, then wind energy will have a future. So it is imperative for the students to know in detail the advantages and disadvantages in operation turbines in a sensitive land or marine environments. We cannot hide obstacles and conflicts with natural habitats. Detailed planning in advance, environmental studies, and early engagement of the society in an open and honest dialogue, leads to a successful wind farm operation. This part of the course was considered extremely important and the students were given extra material from actual environmental reports. With 79 slides and 3 videos this was the second largest module presented. Strong evidence in support of wind technology was presented against the NIMBY syndrome.

Figure 7: ecosystem influence, wind farms in forest, migratory issues, engaging people in an open and honest dialogue.

3.7 LAB-wind farm design in complex terrain

The students were engaged in a lab where the objective was to design a wind farm along a hill top with varied orientation. Wind turbines ranging from 300 kW to 3.45 MW were chosen with diameters from 30 to 112 m. All the students were provided with topographic maps of 1:5000 in scale and were separated in groups of 2 in order to apply simple wake theory based upon experimental data of wake propagation [12], [13]. The exercise presented a first tool for making preliminary designs in complex terrain prior to using a CFD code for final tuning and maximizing wind farm efficiency. The exercise was proven very productive, because they were able to compare different installed capacity scenarios within the restriction of the particular site. They all approached it with enthusiasm.

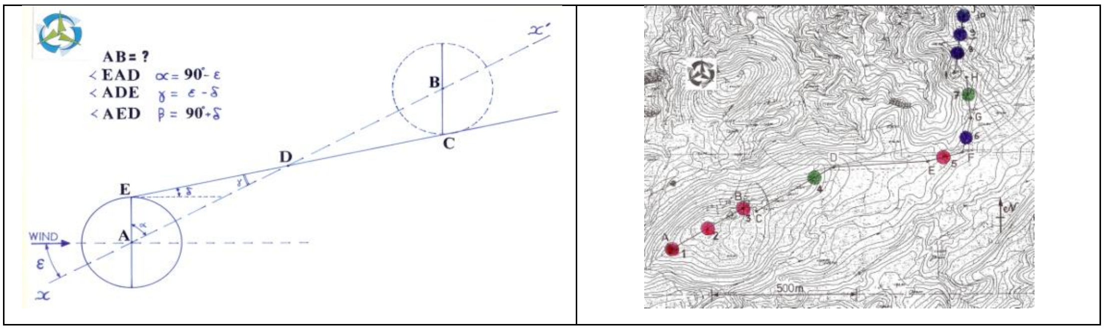


Figure 8: Estimating proximity outside the wake, wind farm layout along a hill top with prevailing winds from the WNW and NW.

3.8 A techno-economic analysis

A feasibility study was presented for a big wind farm in Crete. Experimental evaluation of the wind recourse, and CFD modelling was used, for estimating the wind potential at a 5 km by 5 km site.

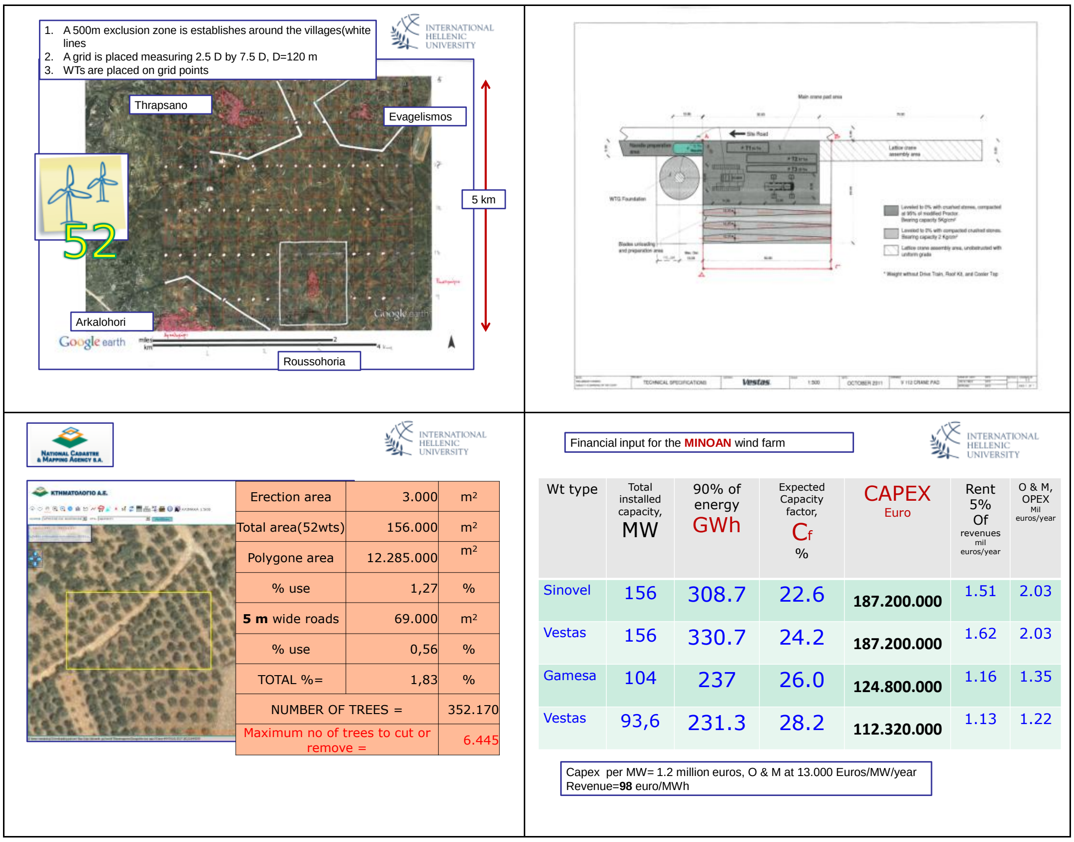


Figure 9: A 5 km by 5 km site with exclusion zones, estimating area for erecting a 3 MW turbine, estimating no of trees to be removed for 52 turbines, basic input to the economic model

Wind turbines ranging from 1.8 to 3 MW were selected. Taking into account real CAPEX and OPEX values plus financial parameters, the IRR and Pay Back Time were calculated using the free RETScreen Energy Model. This is a Clean Energy Management Software system for energy efficiency, renewable energy and cogeneration project feasibility analysis as well as ongoing energy performance analysis. [14].

This final example was designed in order to combine all the key issues learned during the course. This step-by-step approach concluded in the best possible way the methodology learned. This was the final lecture, where the students had the opportunity to ask overall questions about the material of the course. The full study presented is essential for their understanding of wind system applications.

4. Conclusions

Yes it can be done, you can teach wind energy in 18 hours. It is necessary to keep in mind that the choice of lecture material has to be understood by the majority. Anticipation of individual needs and provision of additional resources should be part of the lecture. The content can be modulated according to the students' background. Balancing slides, content of mathematics and physics explained will depend on their background. Looking for the appropriate sources of information in the internet is not an easy task and caution must be exercised in evaluating the credibility of the source. Journals and reputable conference such as those organized by EWEA (WindEurope) are offering good material.

Teaching about this marvelous renewable resource is only FUN.

Figure 10: The future looks promising for wind energy, on land, in the air or the sea! Wind is part of our future energy world

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