Sustainable Energy Workshop

Palestine Polytechnic University

May 10-13 2010
Hebron, Palestine

Day One Agenda

Monday, 10/05/2010	
09:00 - 09:30	Registration
09:30 - 10:00	Welcome Session
10:00 - 11:00	Presentation: Sustainable Energy Sources
11:00 - 11:15	Coffee Break
11:15 - 11:30	Discussion: Sustainable Energy Sources
11:30 - 13:00	Panel Discussion: "Energy Sustainability by 2015"
13:00 - 14:00	Lunch Break
14:00 - 15:30	Solar Energy Presentation and Discussion
15:30 - 17:00	Solar Energy "Hands on" Training

Workshop Trainer: Professor Akram Ahmad Abu-aisheh
University of Hartford, West Hartford, CT, USA
abuaisheh@hartford.edu

Welcome Session

Monday, 10/05/2010: 09:30-10:00am	
Mr. Ahmad S. Tamimi	President of UGU and Palestine Polytechnic University Board of Trustees
Mr. Daniel Rubinstein	US Consul General / Jerusalem
Dr. Ibraheem Al-Masri	Palestine Polytechnic University President
Dr. Raed Amro	Electrical and computer Engineering Department Chair and Executive Chair of PESPRU

Presentation:
Sustainable Energy Sources

Energy Resources are classified into two main categories:

1- Fossil Fuels-based sources (unsustainable sources). This category includes Coal, Oil, and Natural Gas energy

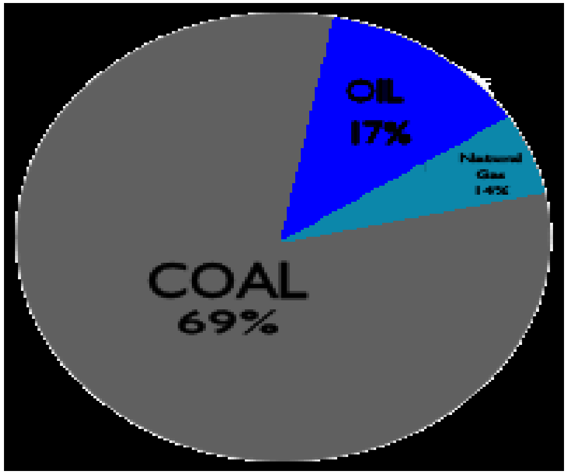
2- Sustainable energy sources. This category includes Solar and Wind energy

Fossil Fuels based Sources

Petroleum

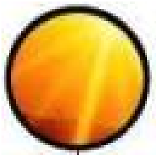
Coal

Natural Gas



The main polluter to our Planet is the extraction of Coal and another fossil resources.

Sustainable Energy Sources



Solar

Wind

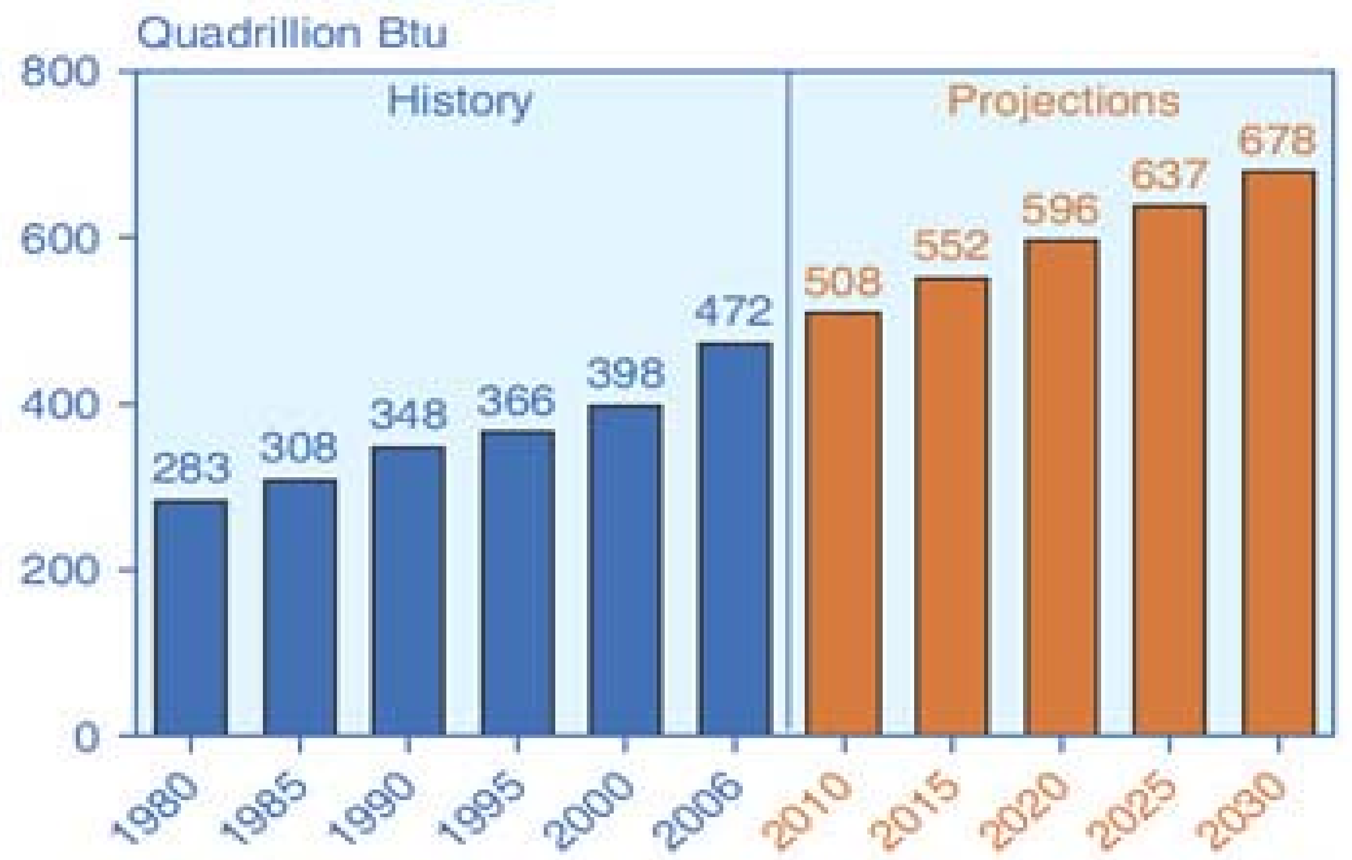
Hydroelectric

Biomass and Waste

The total electrical energy generated by renewable resources by 2008 was: 3472.70261 Billion kW/hr

6

World Energy Consumption



- Source: International Energy Outlook 2009

Top Oil Producers in 2008

- **Saudi Arabia 10.8 mbd**
- **Russia 9.8 mbd**
- **United States 8.5 mbd**
- **Iran 4.2 mbd**
- **China 4.0 mbd**
- **Mbd Million Barrels a day**
  - Source: International Energy Outlook 2009

Top Coal Producers in 2008

China	2761 Mt
USA	1007 Mt
India	490 Mt
Australia	325 Mt
Russia	247 Mt

- **Mt** **Million Ton**

- Source: International Energy Outlook 2009

Top Natural Gas Producers in 2008

- **Rusia** **662 bcum**
- **USA** **582 bcum**
- **European Union** **202 bcum**
- **Canada** **171 bcum**
- **Iran** **116 bcum**

- **bcum** **Billion Cubic Meter**

- Source: International Energy Outlook 2009

Sustainable Energy

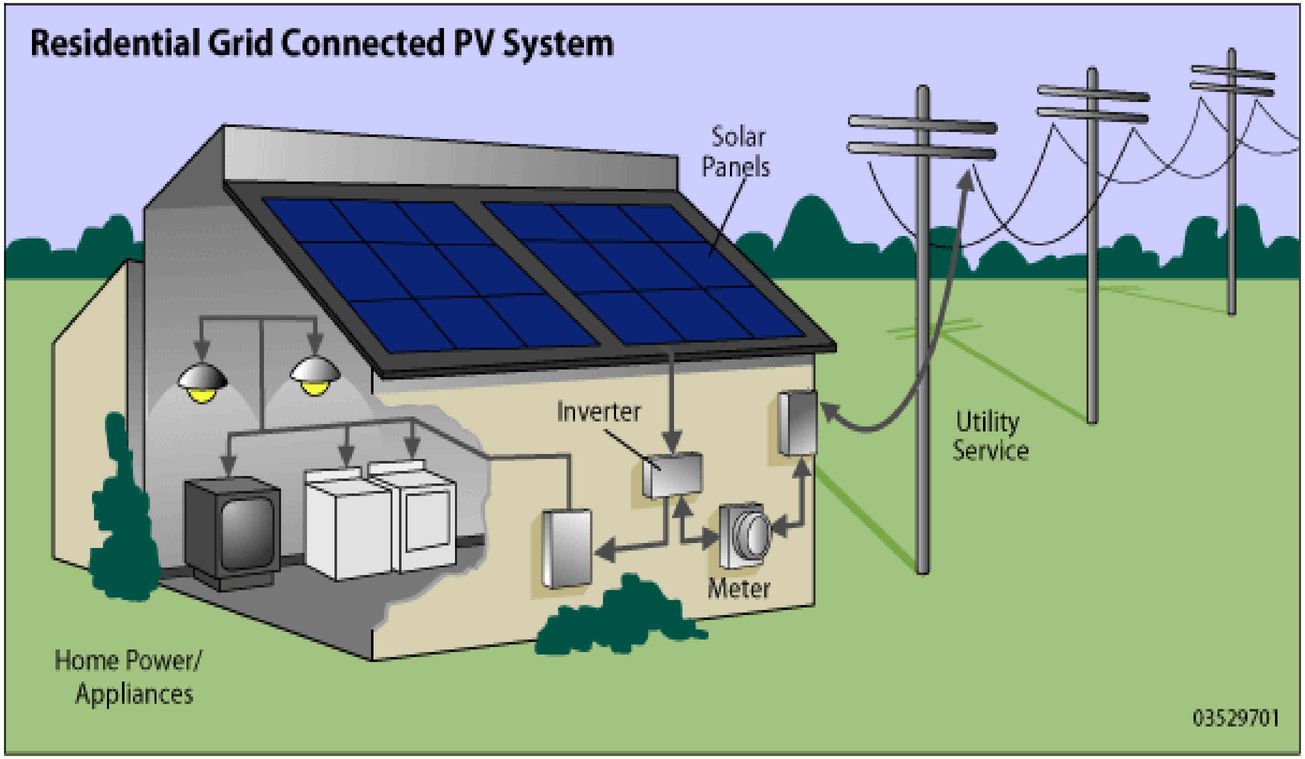
Sustainable Energy refers to energy use that ***meets the energy needs of the present without compromising the ability of future generations to meet their own energy needs and without degrading the natural environment.***

Solar Energy

Off-Grid

Off-Grid Systems

Grid Connected Homes



Photovoltaic – Grid Connected

Wind Energy

Large Wind Turbines

0.55 MW to 3.6 MW

Wind Turbine Components

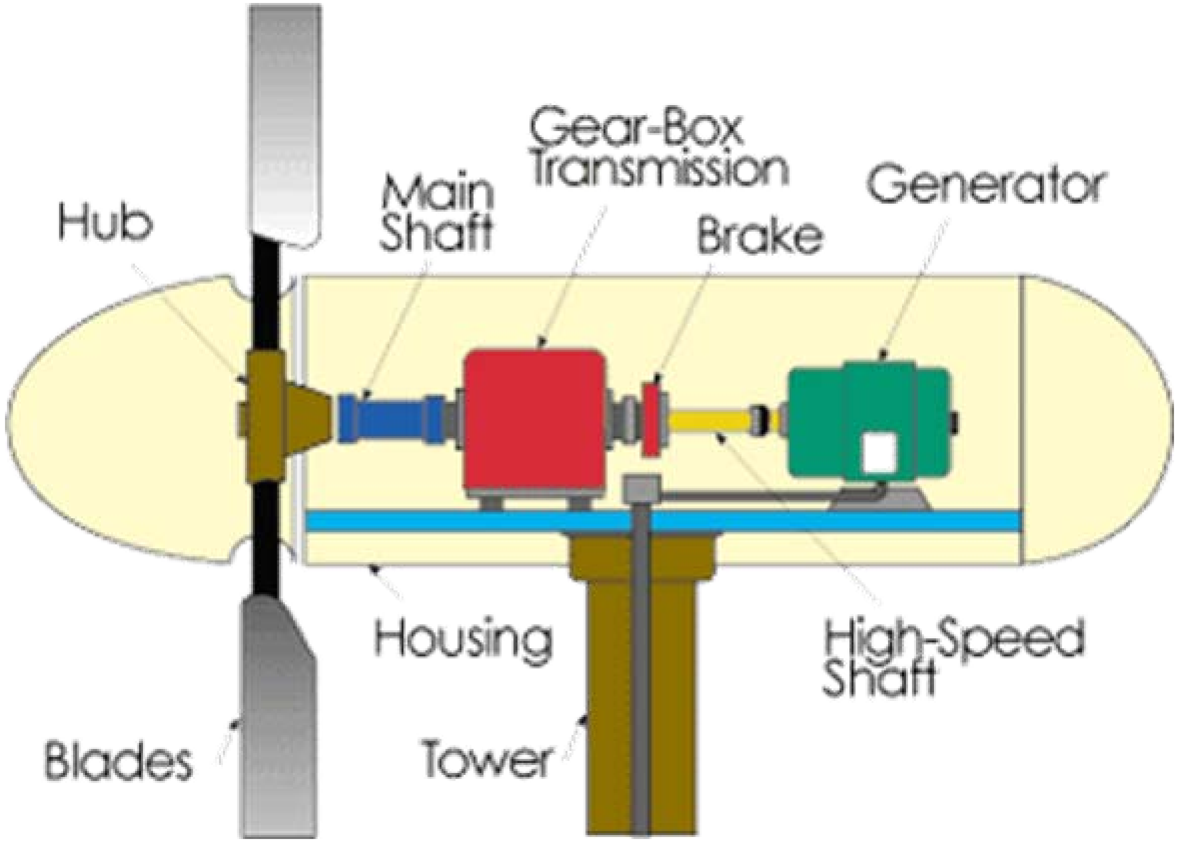
Workers

Blade
112' long

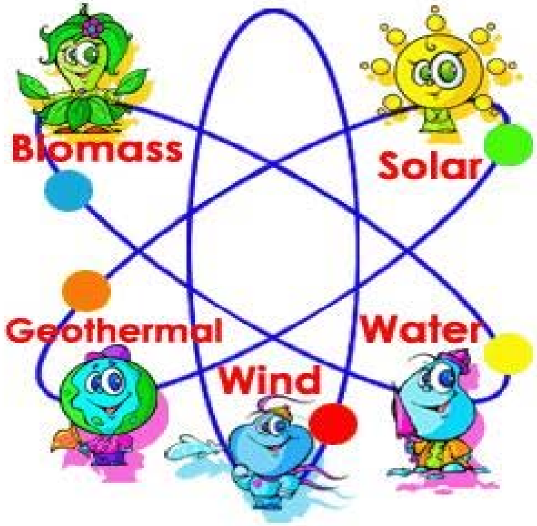
Nacelle
56 tons

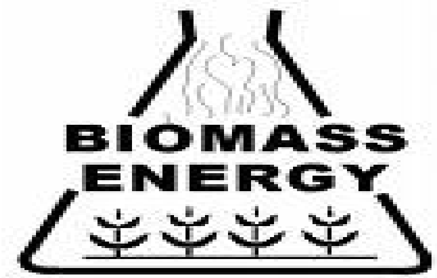
Tower
3 sections

Wind Turbine Components



Sustainable (Renewable) Energy





Why Should We Care ?

Our present actions determine what the world will be like in the future.

Discussion:
Sustainable Energy Sources

Presented By:

Professor Akram Ahmad Abu-aisheh
CEO, Sustainable Illumination Systems

Assistant Chair and Program Director
Electrical & Computer Eng. Department
College of Eng., Tech., and Architecture
University of Hartford tel.(860)768-5479
abuaisheh@hartford.edu

Panel Discussion:
Energy Sustainability by 2015

Solar Energy Presentation

Energy from the sun can be used in many ways. We are interested in directly converting the sun's rays into a usable energy source: electricity. This is accomplished through the use of "solar collectors" which are more commonly known as solar panels

There are two ways in which solar power can be converted to energy. The first, known as "solar thermal applications," involve using the energy of the sun to directly heat air or a liquid. The second, known as "photoelectric applications," involve the use of photovoltaic cells to convert solar energy directly to electricity. Learn more about them by following the links below.

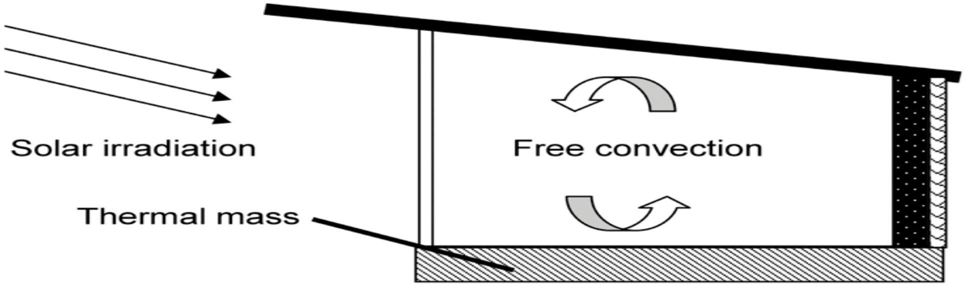
Solar Energy Presentation

Solar Energy Systems are broadly classified into two main categories:

1- Active Solar Systems
2- Passive Solar Systems

In this workshop, the hands-on training and computer simulation parts will focus on active Solar Systems.

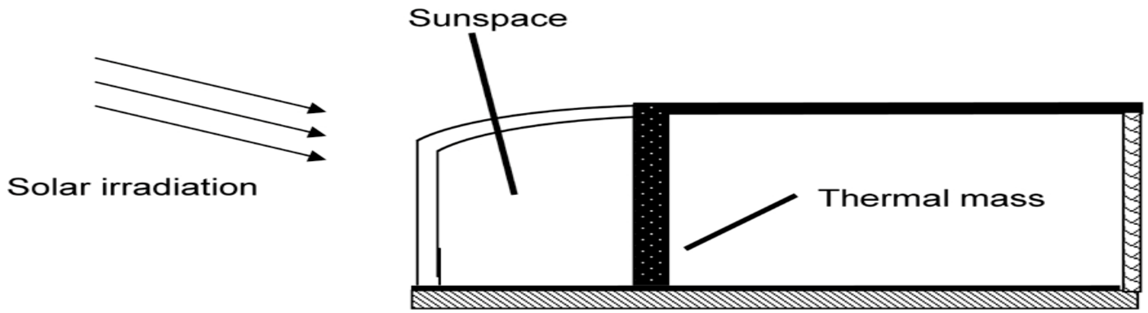
Passive Solar Systems



(a)

(b)

Passive Solar Systems

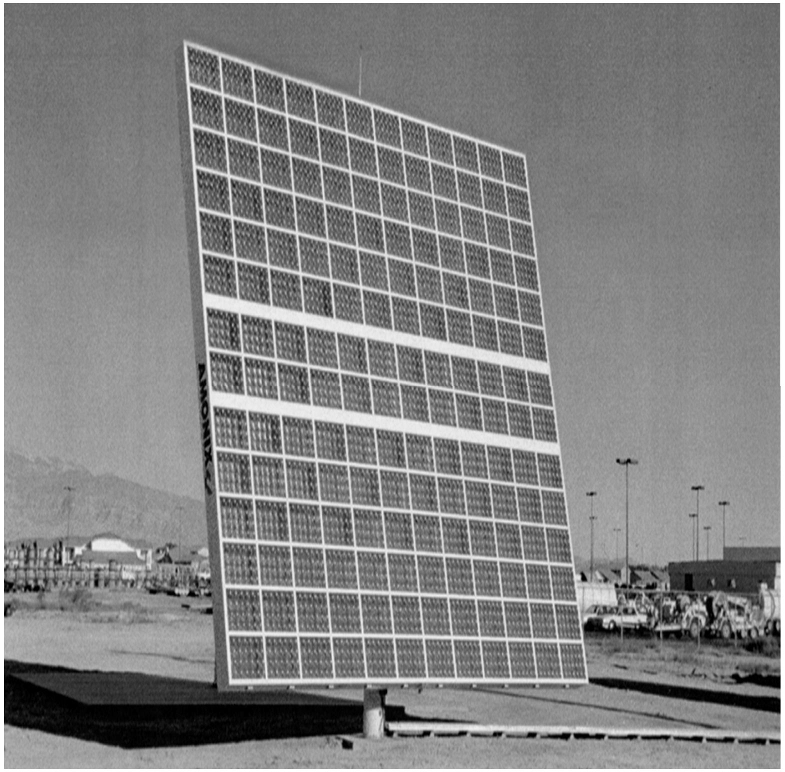


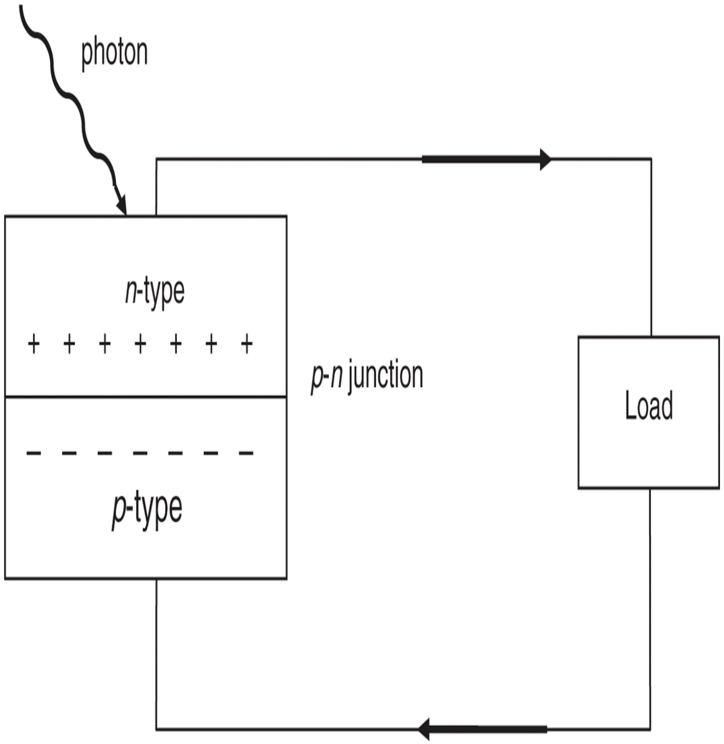
(a)


(b)

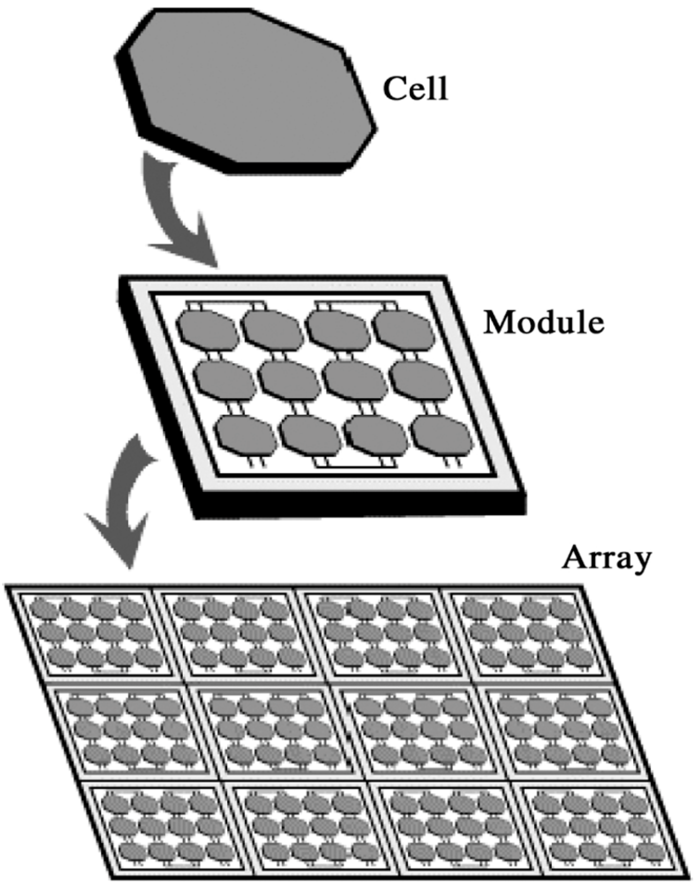
Passive Solar Systems

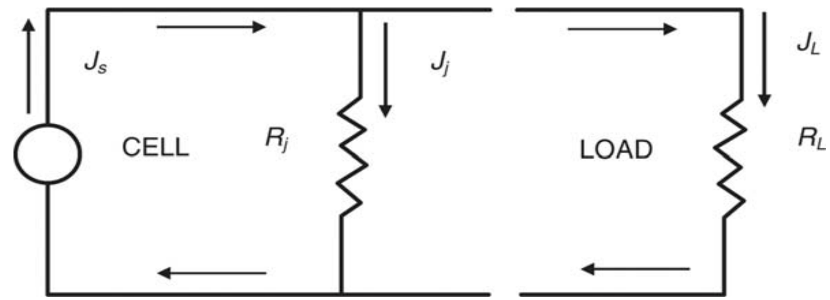
Active Solar Systems

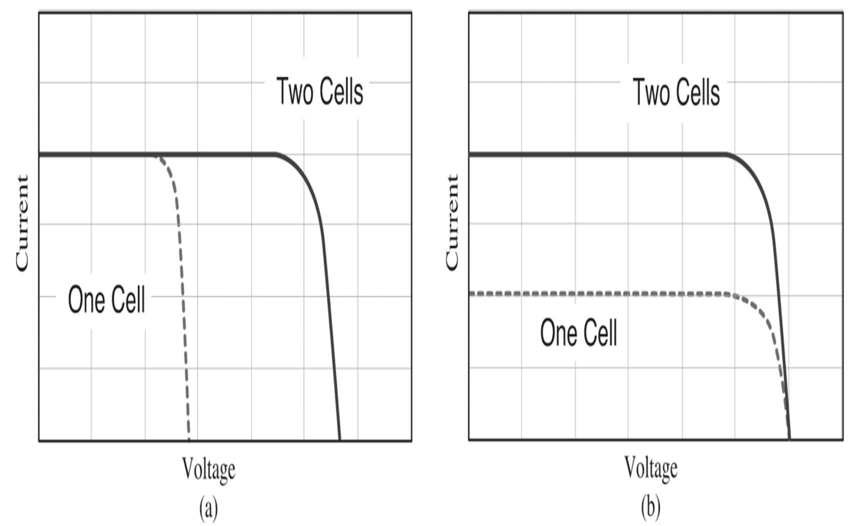




Active Solar Systems







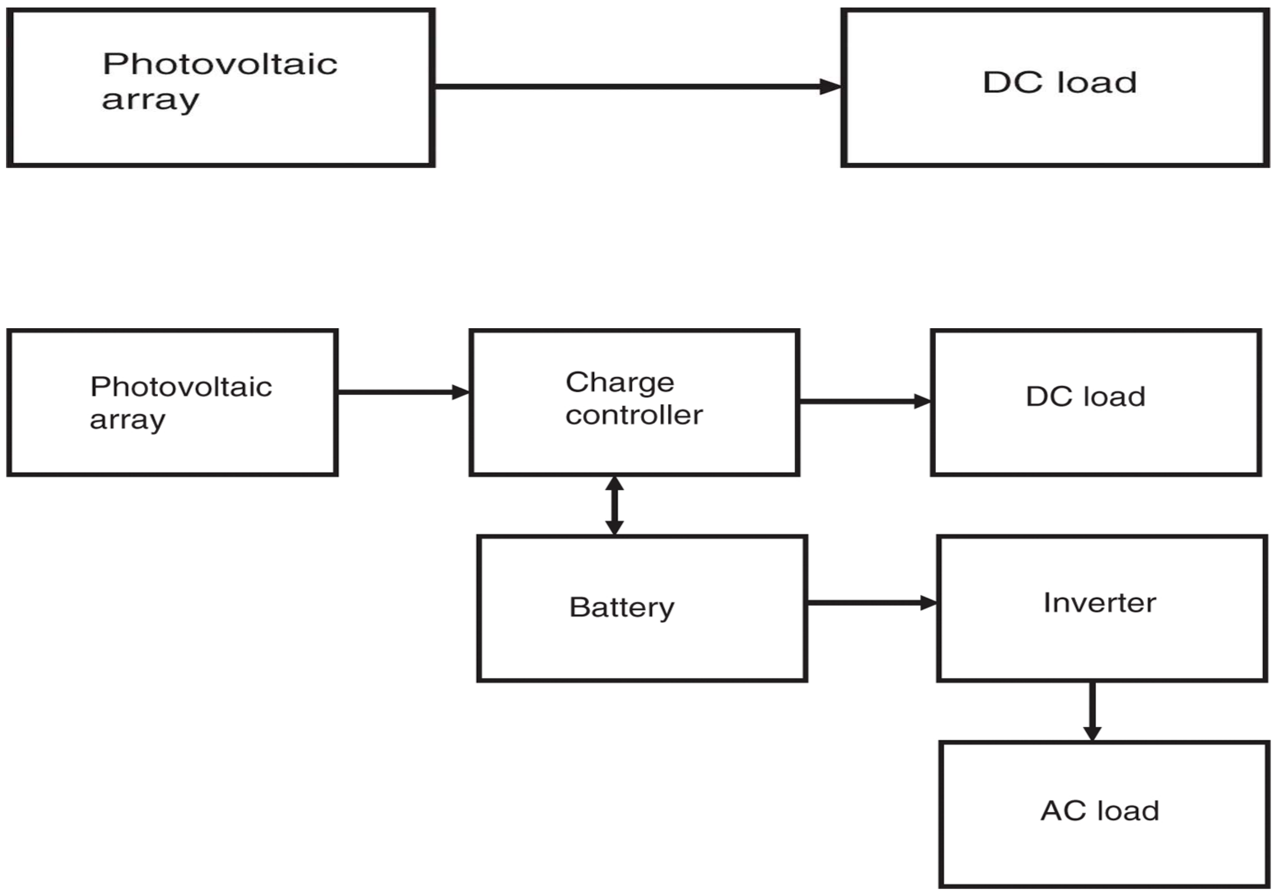
PV Systems Configurations

Photovoltaic (PV) based Solar Energy Systems are classified into the following categories:

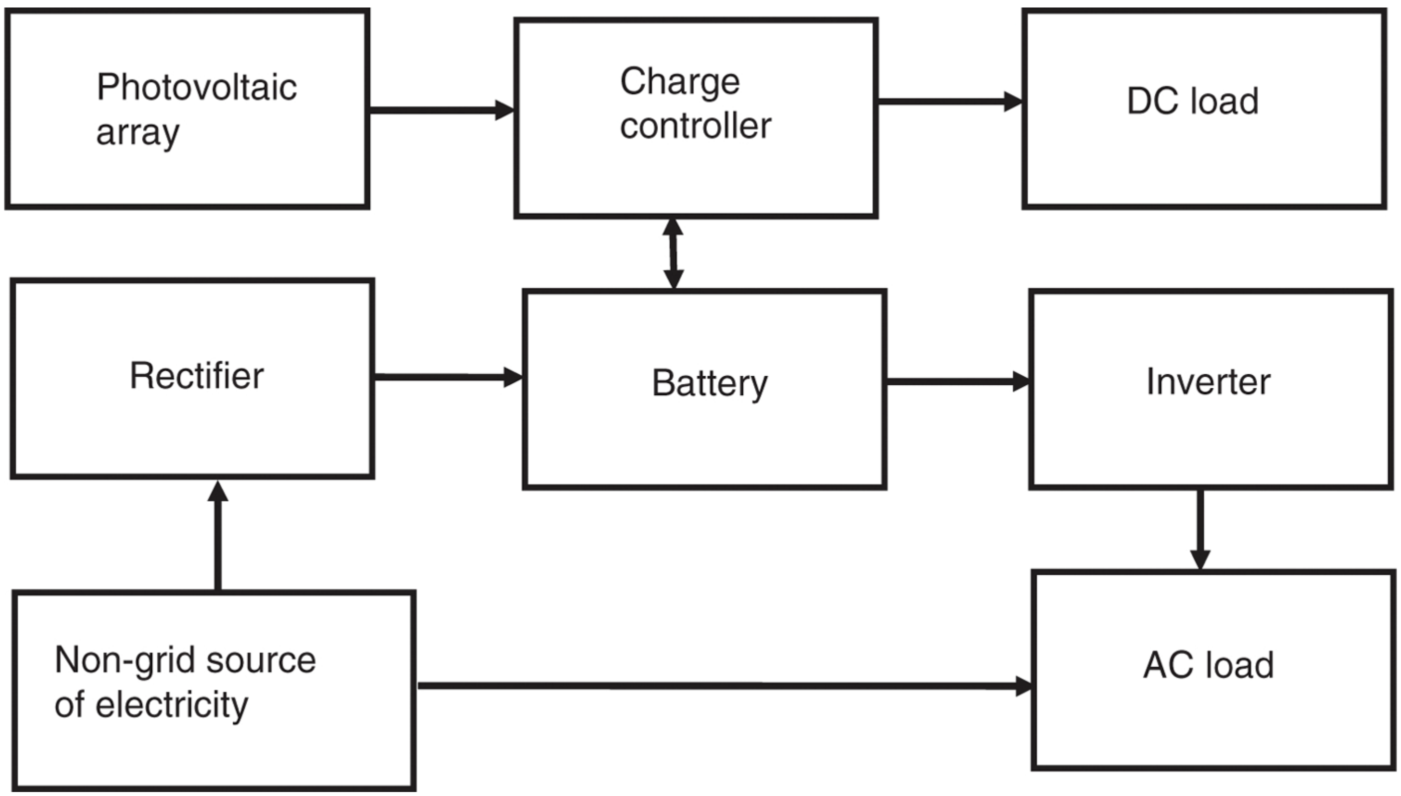
1- Off-Grid Systems with backup
2- Off-Grid Systems without backup
3- Grid Connected Systems with backup
4- Grid Connected Systems without backup

This workshop (presentation, training and simulation) will focus on the first category, Off-Grid Systems with backup.

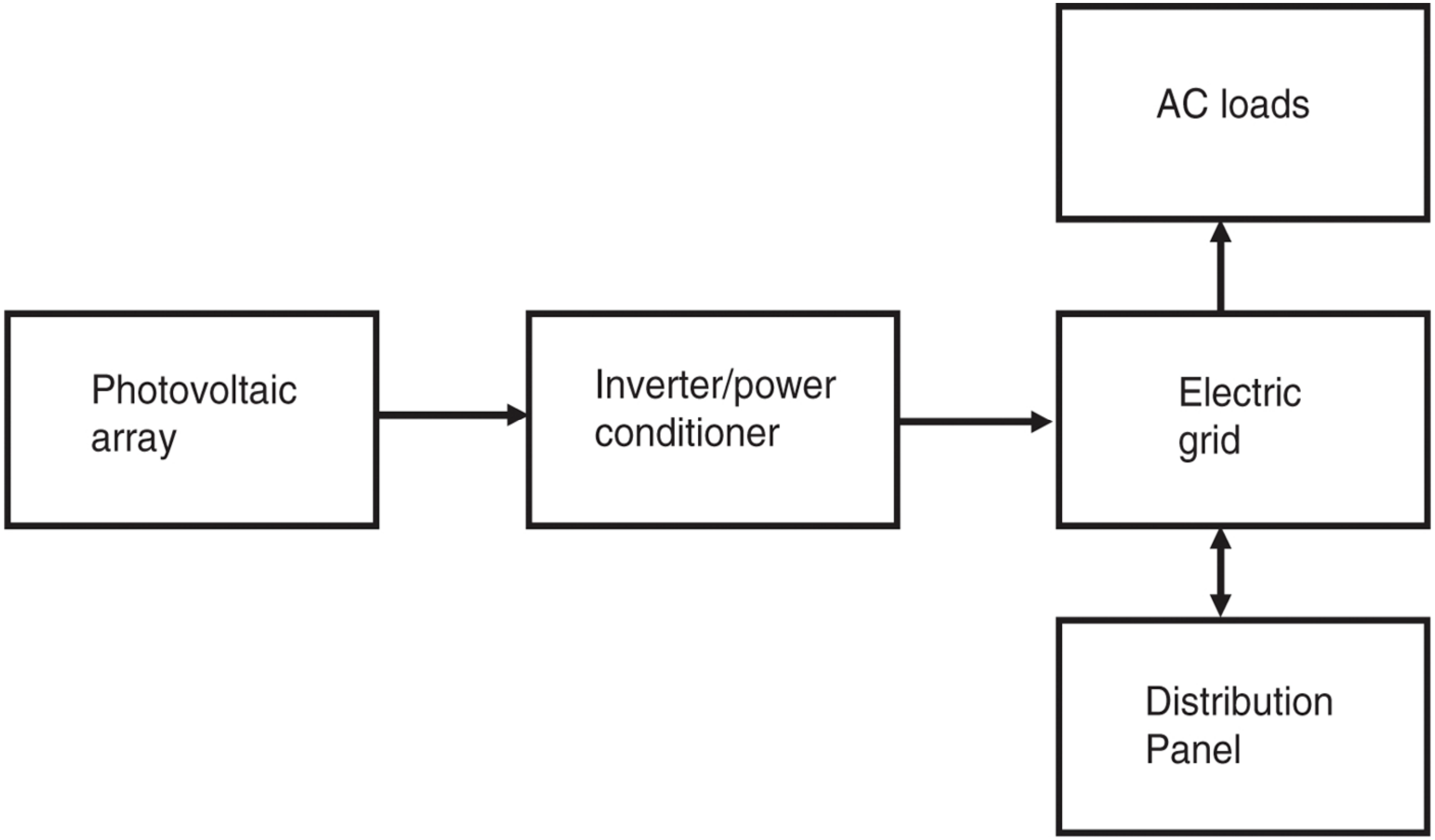
Off-Grid PV Systems



Off-Grid Hybrid Systems



Grid Connected PV Systems

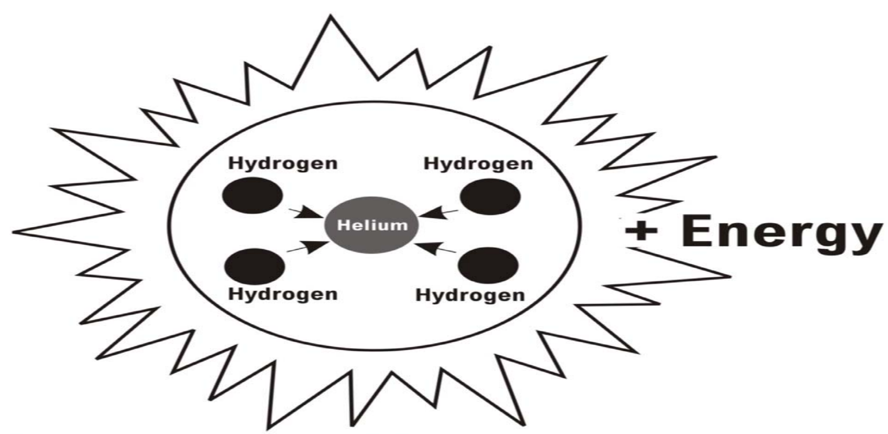


What is Solar Energy?

- Every day, the sun radiates an enormous amount of energy- called **solar energy.**
- The sun radiates more energy in one second than the world has used since time began. This energy comes from within the sun itself.
- Like most stars, the sun is a big gas ball made up mostly of hydrogen and helium gas. The sun makes energy in its inner core in a process called **nuclear fusion.**
- Only a small part of the solar energy that the sun radiates into space ever reaches the earth, but that is more than enough to supply all our energy needs.

What is Solar Energy?

- It takes the sun's energy just a little over eight minutes to travel the 93 million miles to earth.
- Solar energy travels at a speed of 186,000 miles per second, the speed of light. storage of solar energy.



During a process called FUSION, four hydrogen atoms combine to form one helium atom, with a loss of matter. This matter is emitted as radiant energy.

Solar Technology

- Solar technologies are broadly categorized as either passive or active, depending on how they capture, convert, and distribute sunlight. Passive solar technologies involve selection of materials with favorable thermal properties, designing spaces that naturally circulate air, and referencing the position of building the sun. These technologies reduce the need for alternate resources and are generally considered demand side technologies. Active solar technologies make use of photovoltaic panels, pumps, and fans to convert sunlight into useful outputs, and are considered supply side technologies.

- For low cost solar panels, try this link: http://www.smarter.com/se--qq-Cheap+Solar+Panel.html?subid=d722bc81246175bf91c9b0dbc08034df

Discussion: Solar Energy

Presented By:

Professor Akram Ahmad Abu-aisheh

CEO, Sustainable Illumination Systems

Assistant Chair and Program Director

Electrical & Computer Eng. Department

College of Eng., Tech., and Architecture

University of Hartford tel.(860)768-5479

abuaisheh@hartford.edu

Discussion:
Solar Energy

"Photovoltaic Cell"

Of all the renewable energy technologies, Photovoltaic (PV) cells show the greatest promise for worldwide acceptance and application. The universal appeal of PV cells lies in the fact that they generate electricity from the sun with no moving parts, and they are relatively simple in design, need very little maintenance, and are environmentally friendly. PV cells produce electricity whenever they are exposed to light.

P.E.S.P.R.U

Discussion: Solar Energy

"Photovoltaic Cell"

Over the past several years, many world governments have directed the largest portion of their solar energy research budget to PV projects; that trend continues even now. With further research and projected advances in this solar technology, PV cells will play a big role in renewable energy future. The following information helps answer the most frequently asked general questions about Photovoltaic cells. For more detailed treatments of the subject, you may wish to consult the publications in the list of selected references.

Discussion: Solar Energy

Q1: What are photovoltaic?

Photovoltaic are solar cells that produce electricity directly from sunlight. They are usually made of silicon -- the same material that makes up the common sand. The cells are wafer-thin circles or rectangles, about three to four inches across. Solar cells operate according to what is called the photovoltaic effect ("photo" -- light, "voltaic" -- electricity). In the photovoltaic effect, "bullets" of sunlight -- photons -- striking the surface of semiconductor material, such as silicon, liberate electrons from the material's atoms. Certain chemicals added to the material's composition help establish a path for the freed electrons. This creates an electrical current. Through the photovoltaic effect, a typical four-inch silicon solar cell produces about one watt of direct current electricity.

Discussion: Solar Energy

Q2: How are photovoltaic cells made?

In the most common cell production process, very pure silicon is reduced to its molten form. Through a painstaking and time-consuming process, the silicon is re-formed into a solid, single-crystal cylinder called an ingot. Extremely thin slices cut from the ingot are chemically treated to form photovoltaic cells -- sometimes referred to as solar batteries. Wires attached to the negative and positive surfaces of the cell complete the electrical circuit. Direct current electricity flows through the circuit when the cell is exposed to light. For efficiency and practicality, multiple cells are wired together in a series/parallel fashion and placed in a glass-covered housing called a module. The modules themselves can then be wired together into arrays. PV arrays can produce as much direct current electricity as desired through the addition of more modules.

Discussion:
Solar Energy

Q3: What research is being conducted on photovoltaic technology?

Presently, photovoltaic research is focused on two areas -- manufacturing and applications. Within the area of manufacturing, both methods and materials are being explored. Semiconductor materials other than silicon also are receiving attention. Manufacturing methods being researched include new ways of purifying silicon to "solar grade," better methods of slicing cell wafers from silicon ingots, and more efficient production of cell material by casting it into blocks, or depositing a thin film of the material on an inert base. Research on photovoltaic applications is both regional and national in scope. The U.S. Department of Energy has funded research centers in the Northeast, Southwest, and Southeast to study the application of photovoltaic systems in these very different regions.

Discussion: Solar Energy

Q4: What are the current uses of photovoltaics?

Many remote uses of photovoltaics are cost-effective and practical now. Photovoltaics are generating power for traffic control systems, irrigation systems, bridge corrosion inhibitors, and radio relay stations. They are also providing electricity to remote villages, medical centers, and other isolated sites where the cost of photovoltaics is less than the expense of extending cables from utility power grids or producing diesel-generated electricity.

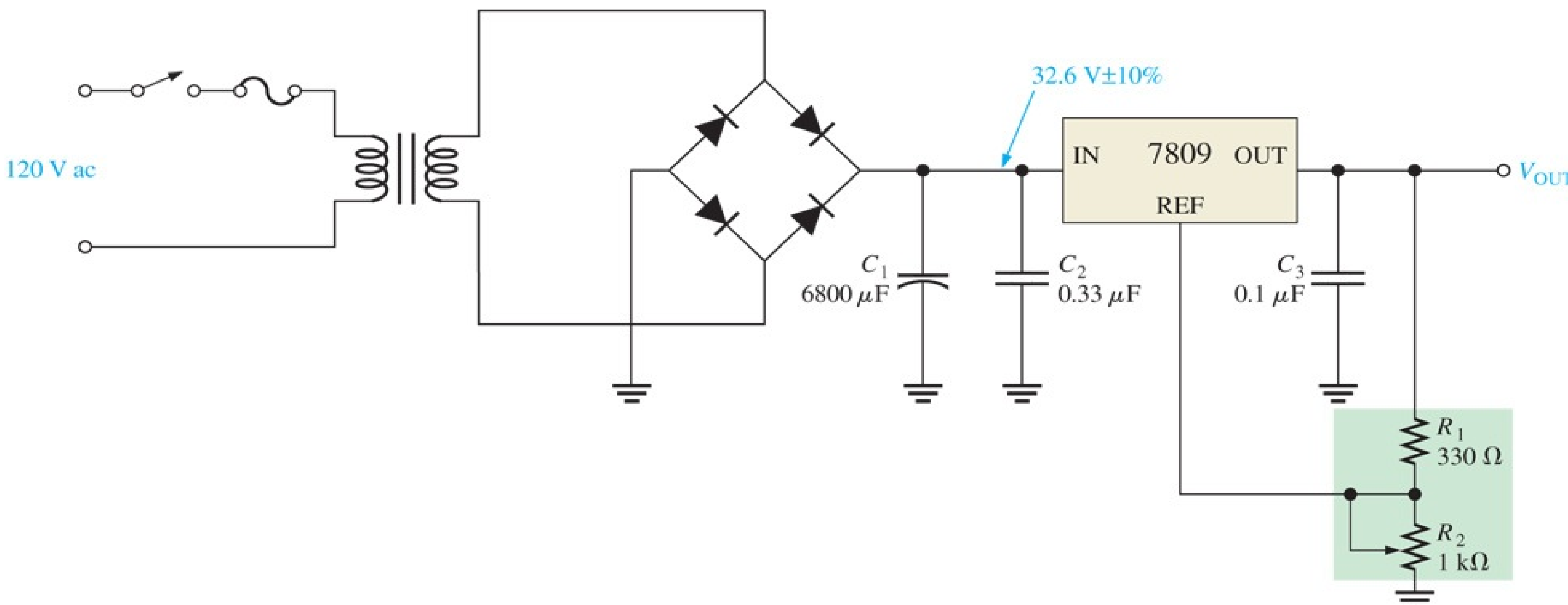
Discussion: Solar Energy

Q5: Can PV modules power regular appliances?

Because most appliances and equipment are designed to be powered by alternating current (AC), PV-produced electricity must be converted. This is accomplished by an inverter. Most of these solid state devices convert DC current to an AC current compatible with that sent over utility grids. As a result, PV installations may be interconnected with a utility grid, sending power onto the grid whenever there is excess and drawing electricity from the utility when sunlight is not available. Most inverters have a fail-safe relay that disconnects the PV system from the utility grid whenever the grid fails, ensuring the safety of utility repair personnel.

Discussion: Solar Energy

Q5 follow up: Can PV modules power regular appliances? Why not? It should.



Discussion: Solar Energy

Q6: Why aren't PV modules in widespread use?

Photovoltaic modules are currently too expensive to be cost-competitive with readily available utility power. However, PV costs are decreasing. When the first photovoltaic systems were used by NASA to power orbiting space satellites, the costs were as high as $1,000 per peak watt. (Peak watt is the amount of electricity produced by a PV cell when bright sunlight is available.) An individual can now purchase modules for $7 to $12 per peak watt. When photovoltaic module costs are reduced to about $1 per peak watt, they will be competitive for electricity production in residential settings. At that price, an installed PV system large enough to provide substantial amounts of residential power would cost about $10,000 -- a great deal of money, but not too much to pay for a power system with at least a 20-year life span and a probable payback time of about 10 years.

Discussion: Solar Energy

Q7: Why is PV cells so expensive and how can the cost be reduced?

Material and manufacturing costs are the two major factors that influence the price of photovoltaic cells. Even though silicon is the second most abundant material on earth, the silicon used for PV cells must be very pure; refining high-grade silicon to remove most of its impurities is an expensive process. In addition, the manufacture of PV cells at present is labor and capital intensive, although methods of automation have been undertaken. More efficient cells also will help to lower the costs somewhat. The limit of efficiency for silicon PV cells is estimated to be about 25 percent. As they currently are manufactured, most PV cells operate at about 10 percent efficiency. When the cells and systems can be made to operate at higher efficiency levels, the cost of a system may be lower .

Discussion: Solar Energy

REFERENCES:

1. Consumer Guide to Solar Energy. By Scott Sklar and Ken Sheinkopf. Bonus Books. 2002.
2. Designing with Solar Power: A Sourcebook for Building Integrated Photovoltaics. Edited by Deo Prasad and Mark Snow. Earthscan. 2005.
3. The Easy Guide to Solar Electric, Part 1 and Part 2. 2nd Edition. By Pieper Adi. 2001.
4. Photovoltaics: Design and Installation Manual. By Solar Energy International. 2004.
5. Planning and Installing Photovoltaic Systems: A Guide for Installers, Architects and Engineers. By the German Solar Energy Society. Earthscan. 2005.
6. Power with Nature: Solar and Wind Energy Demystified. By Rex A. Ewing. Pixyjack Press. 2003.
7. Practical Photovoltaics: Electricity for Solar Cells. By Richard J. Komp. Aatec Publications. 1995.
8. The Solar Electric House: Energy for the Environmentally Responsive, Energy-Independent Home. By Steven J. Strong with William G. Scheller. Sustainability Press. 1993.
9. Solar Electricity. Edited by Tomas Markvart. Wiley. 2000.

Day Two Agenda

Tuesday, 11/05/2010 (For Trainees)	
09:30 - 10:45	Computer Simulation Tools for Solar Energy System Design
10:45 - 11:00	Coffee Break
11:00 – 12:00	Presentation: Wind Energy Systems
12:00 - 13:00	Mathematical Analysis of Wind Energy Systems
13:00 - 14:00	Lunch Break
14:00 - 15:15	Discussion: Wind Energy Systems
15:15 - 15:30	Coffee Break
15:30 - 17:00	Wind Energy "Hands on" Training
14:00 – 14:30	Panel Discussion: "AC vs. DC"
14:30 - 15:30	Closing Session

Workshop Trainer: Professor Akram Ahmad Abu-aisheh
University of Hartford, West Hartford, CT, USA
abuaisheh@hartford.edu

Computer Simulation Tools for Solar Energy Systems

- For this workshop, I plan to use the internet as a as a resource. For example, to present solar energy, including the use of PV cells, I would refer you to www.photowatt.com and www.pvsquared.com. then, discuss the websites contents.
- for high brightness LEDs for building illuminations, visit www.diconlighting.com, and compare and contrast the system there with the other available systems, see www.powerpod.com.
- For Solar energy simulation visit the website: http://www.mathworks.com/company/events/webinars/wbnr41354.html?id=41354&p1=697801410&p2=697801422

Computer Simulation Tools for Solar Energy Systems

The following webinars will be very helpful to evaluate the tools that MathWorks provide for Energy Production. http://www.mathworks.com/energy-production/

- Solar energy simulation:
- http://www.mathworks.com/company/events/webinars/wbnr41354.html?id=41354&p1=697801410&p2=697801422

- To find more about the toolboxes that would be mentioned in those webinars, please refer to the following page for a comprehensive list:
- http://www.mathworks.com/products/product_listing/index.html

Presentation:
Wind Energy Systems

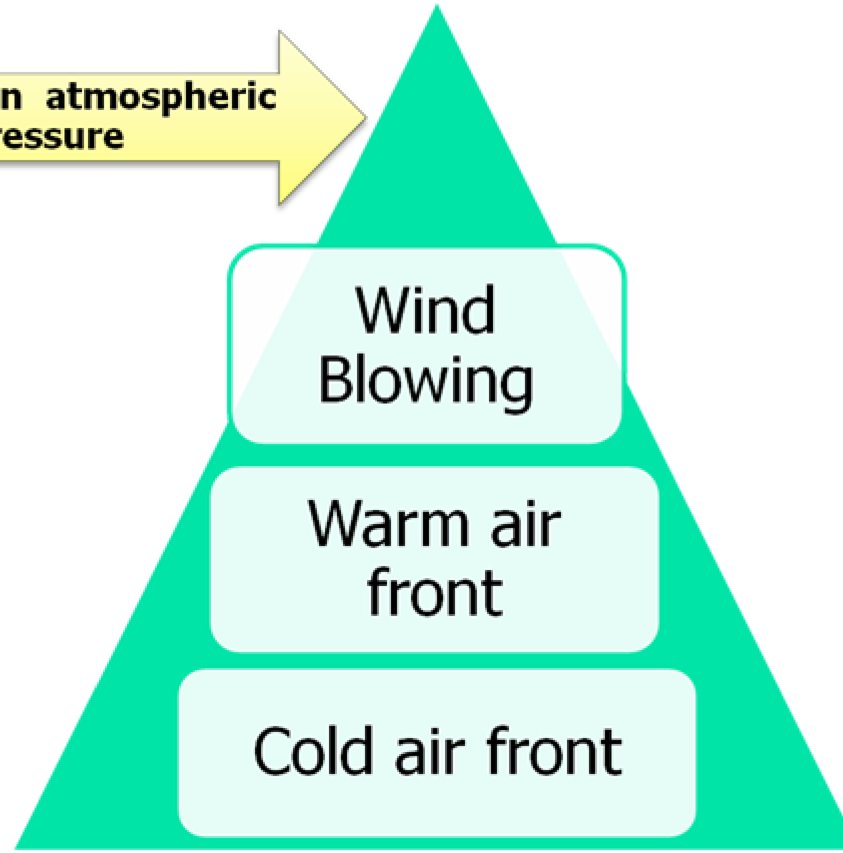
Wind Turbines, Power for a House or City




INTRODUCTION: WIND ENERGY

CAUSE :

Different in temperatures → **Different in atmospheric pressure** →



Eventually tornados

When air fronts of different temperatures come in contact, resulting different air pressure,…. Wind blowing

Wind Turbine
TYPES AND CLASSIFICATIONS

Turbines can be categorized into two overarching classes based on the orientation of the rotor

Vertical Axis

Horizontal Axis

Wind Turbine
TYPES AND CLASSIFICATIONS

- Vertical axis wind turbines

  - have their axis of rotation vertical to the ground and almost perpendicular to the wind direction.
  - can receive wind from any direction; therefore complicated yaw device can be eliminated.
  - have generator and the gearbox are housed at the ground, which make the tower design simple and more economical.
  - have ground level maintenance.
  - have no need of pitch control when used for synchronous applications.

- Also there are a lot of disadvantages:

  - They are not self-starting, additional mechanism may be required to push and start the turbine.
  - Guy wipes are required to support the tower structure which may pose some practical difficulties.

Wind Turbine
TYPES AND CLASSIFICATIONS

- Horizontal axis wind turbines

  - have their axis of rotation horizontal to the ground and almost parallel to the wind stream .

  - most of the commercial wind turbines fall under this category.

- This type machines has some distinct advantages

  - low cut-in wind speed
  - easy furling (rotating) and manufacturing.
  - they have high power coefficient, which make them good advantage in design of large power plants.

- Also there are a lot of disadvantages:

  - they have complicated and expensive design because of the generator and the gearbox are placed over the tower in the nacelle.
  - the need for tail (yaw) drive to orient the turbine towards turbine.

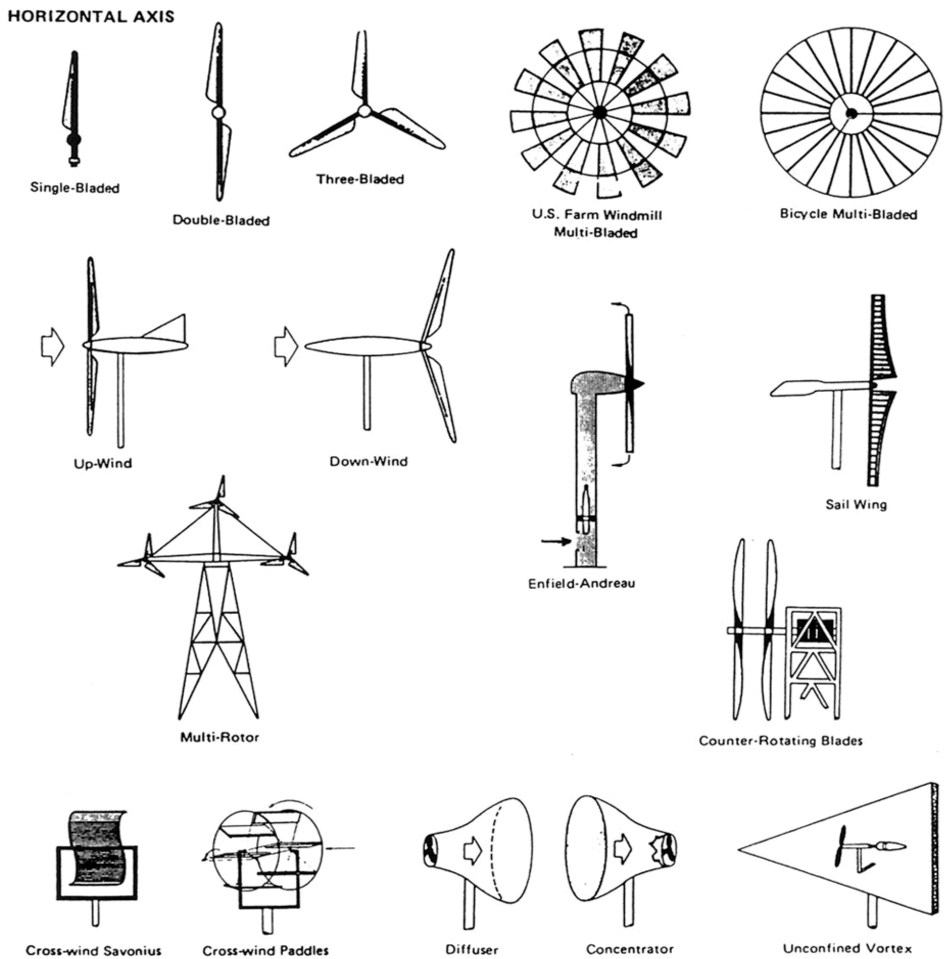
Wind Turbine
TYPES AND CLASSIFICATIONS

Horizontal WT can be classified into three types :

- Single blade;
- Two blades
- Three blades
- Multi blades

These turbines are characterized with high power coefficient and extended extracted power range, but needs high advanced ratio (high wind speed).

Single and two-blades are rarely used due to the need of counter weight. Three-blades turbine are mostly used and commercially available.

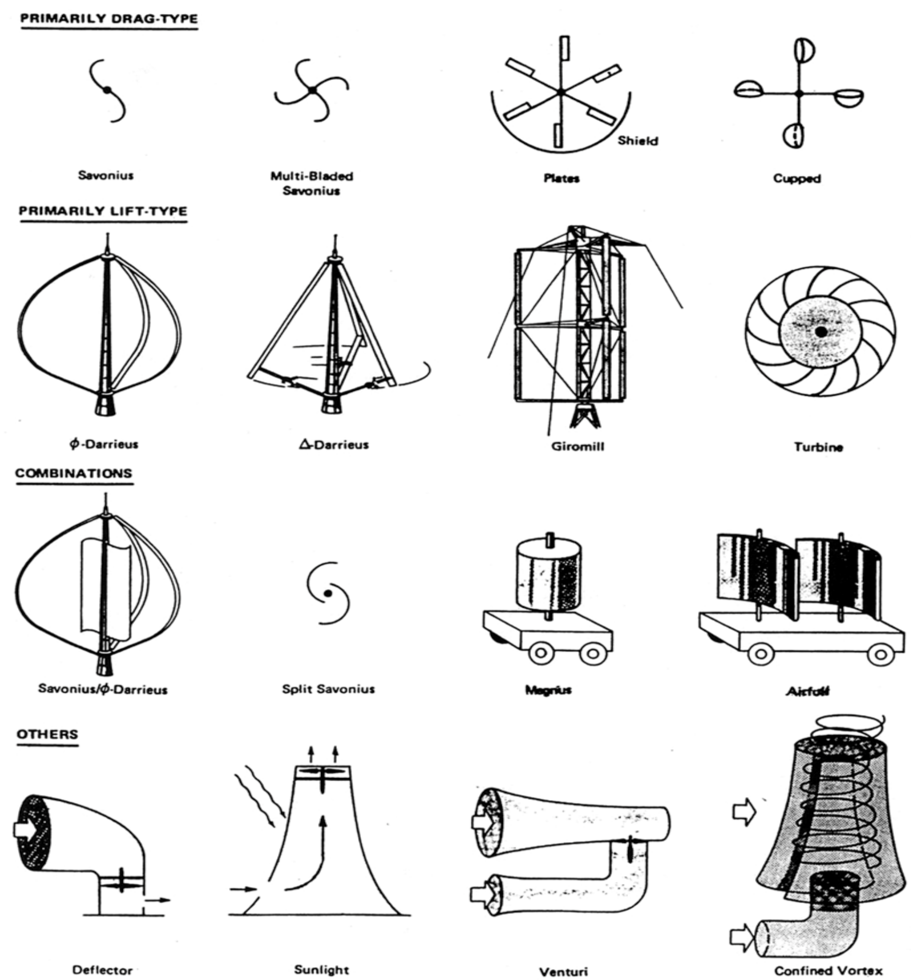


Wind Turbine
TYPES AND CLASSIFICATIONS

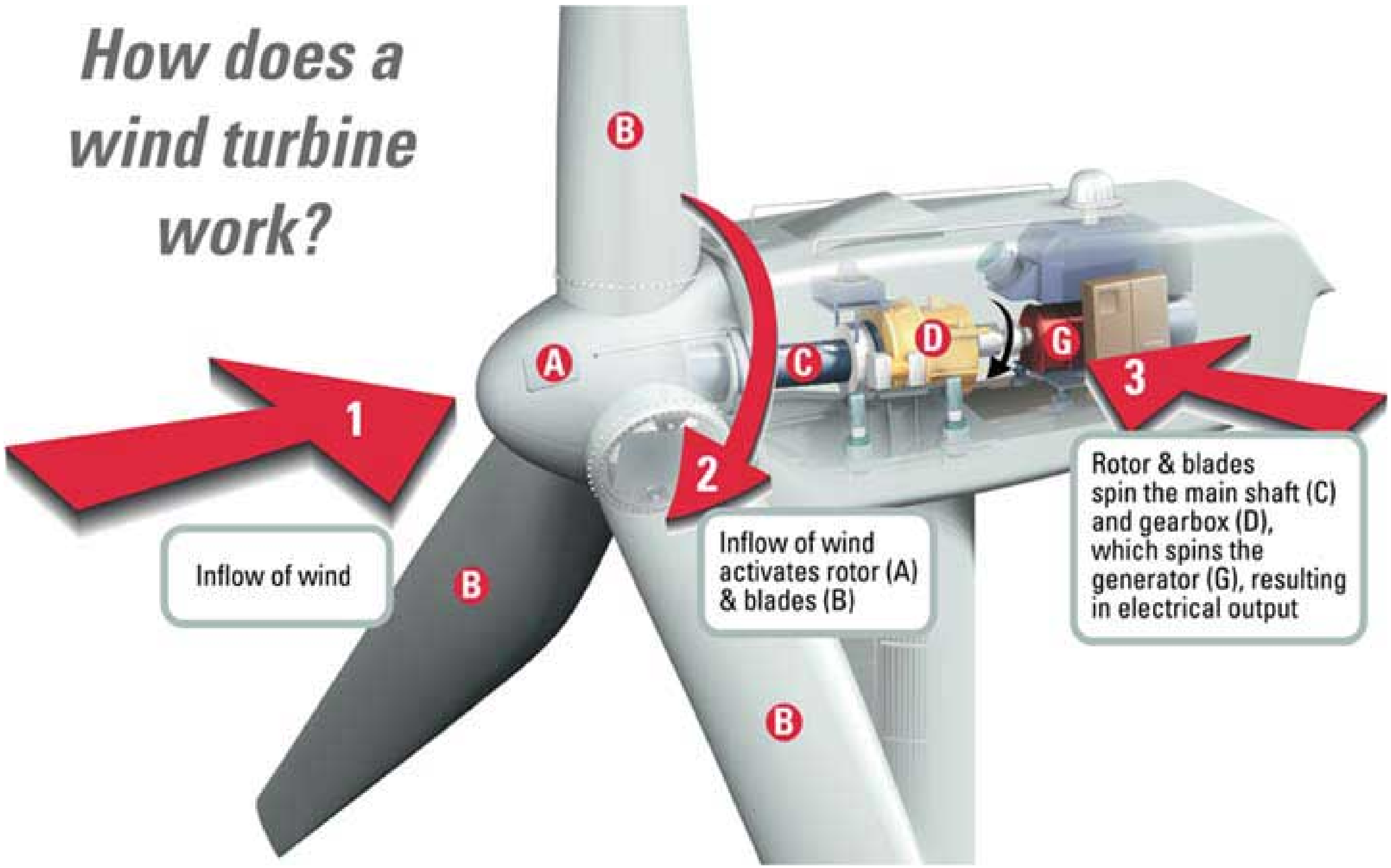
Vertical WT can be classified into three types :

- Darrieus
- Savonius
- Musgrove

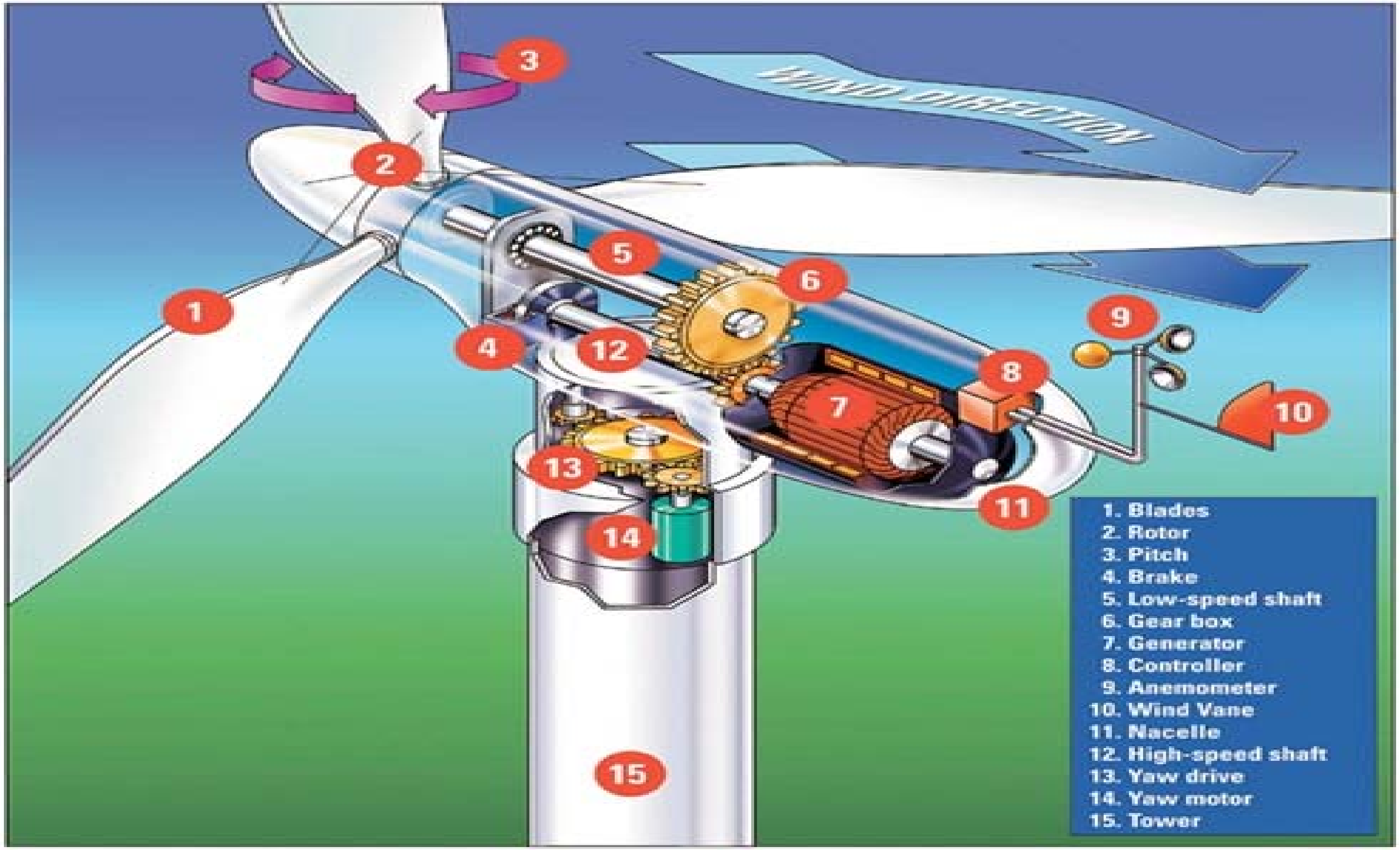
These turbines are characterized with low Power coefficient and limited extracted power, but in the mean time have with low advanced ratio (low wind speed), which is good indicator.



Wind Turbine (WT) Description



Wind Turbine Construction



WT PARTS FUNCTIONS

The Nacelle: this is the machine corpus mounted on the tower, and contains all the machine elements.

Rotor: this is, three-blades (more or less) diameter that swept in the air.

Blades; are made from light material with pitch angle. The pitch mechanism on the blades adjusts the angle of the blades to be in the wind direction and to maximize the extracted power.

Low- speed shaft: this is a steel shaft connected with the plate, rotates at low speed with high torque, and transmit the speed to the next stage (high speed stage).

Gear box: change the speed form low rate to the high rate values (high speed) suitable for the electrical generator operation.

High-speed shaft: used to rotate the generator at high speed with purpose to generate the required voltage and electrical frequency.

WT PARTS FUNCTIONS

Generator: This either DC or AC generator that converts the input mechanical power in terms of torque and speed into output electrical power in terms of voltage and current (electrical energy).

Brake: this an electromechanical system that acts on the low-speed shaft with purpose braking the turbine in emergency case or when the speed falls below the cut-in value or raised up above the cut-out value.

Yaw drive and Yaw motor: are used to keep the plane of the blades oriented into the wind.

Anemometer: wind measurement device used to measure the speed value and direction.
Wind vane: used to direct the nacelle toward the wind direction.

Tower: this a cement construction used to carry on all the equipments

Wind Turbine CONSTUCTION MATERIALS

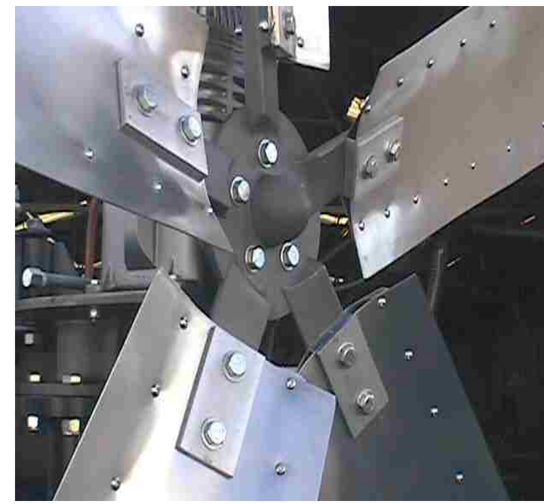
Wood

- Strong, light weight, cheap, abundant, flexible
- Popular on do-it yourself turbines

- Solid plank
- Laminates
- Veneers
- Composites

Blade Composition Metal

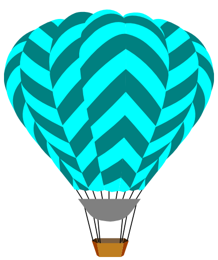
- Steel
  - Heavy & expensive
- Aluminum
  - Lighter-weight and easy to work with
  - Expensive
  - Subject to metal fatigue



POWER IN THE WIND MODELING

Power= 1/2 x air density x swept rotor area x (wind speed)^3

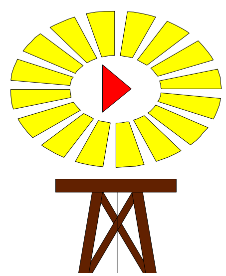
ρ | **A** | **V^3**



Densityρ = P/(RxT)

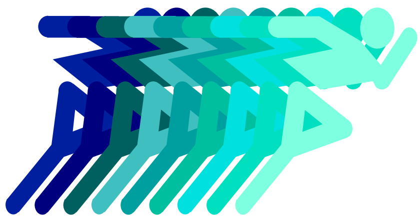
P - pressure (Pa)
R - specific gas constant (287 J/kgK)
T - air temperature (K)

kg/m^3



Area = π r^2

m^2



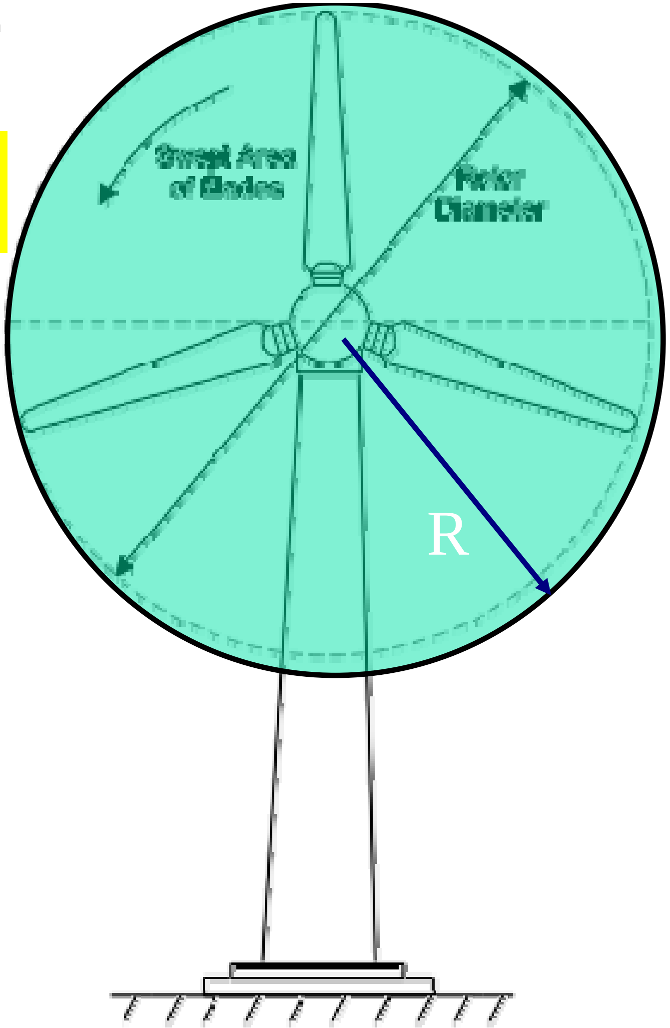
Instantaneous Speed (not mean speed)

m/s

Where : Swept Area: A = πR^2 Area of the circle swept by the rotor (m^2).

POWER IN THE WIND MODELING

Power in the Wind=½ρAV^3



This power depends on :

- The swept area, A
- Wind speed, V
  (cube of this speed)
- Air density, ρ

POWER IN THE WIND MODELING

- Wind Speed
  - Wind energy increases with **the cube** of the wind speed
  - 10% increase in wind speed translates into 30% more electricity
  - Twice time increase in the wind speed translates into eight time increase in the generated electricity

- Height
  - Wind energy increases with height to the 1/7 power
  - Twice time the height translates into 10.4% more electricity, because as the tower high increases the cold air has high density, and it help in moving the blades.

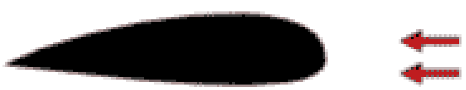
POWER IN THE WIND MODELING

- Air density
  - Wind energy increases proportionally with air density
  - Humid climates have greater air density than dry climates
  - Lower elevations have greater air density than higher elevations

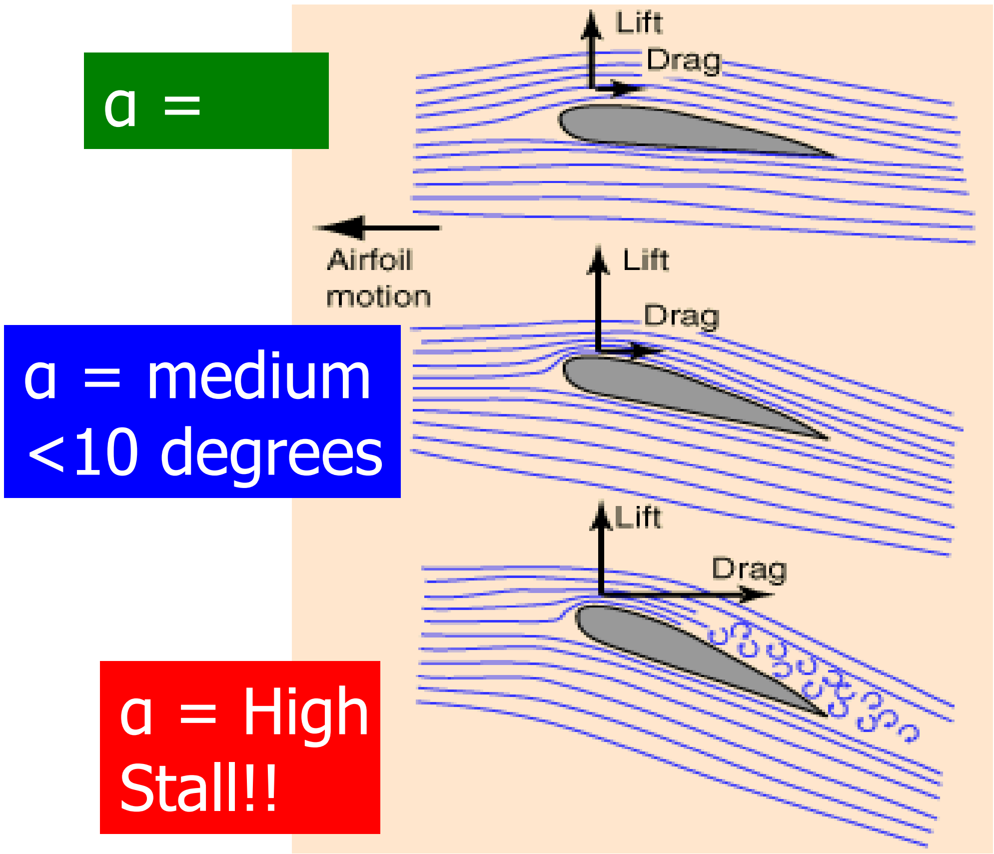
- Blade swept area
  - Wind energy increases proportionally with swept area of the blades
    - Blades are shaped like airplane wings
  - 10% increase in swept diameter translates into 21% greater swept area
  - Longest blades up to 413 feet in diameter
    - Resulting in 600 foot (200m) total height

POWER IN THE WIND MODELING

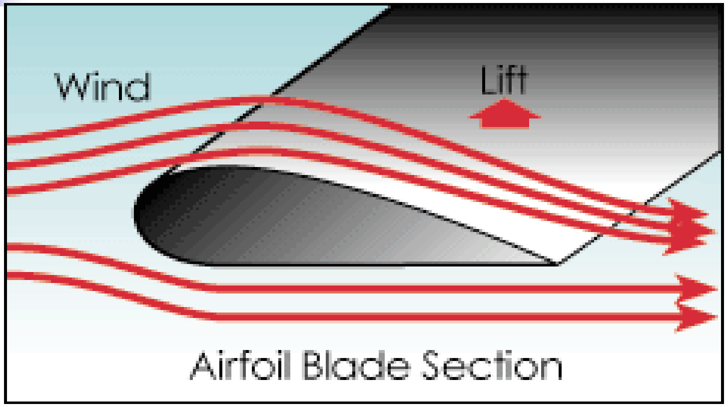
- The *Lift Force* is perpendicular to the direction of motion. We want to make this force BIG.



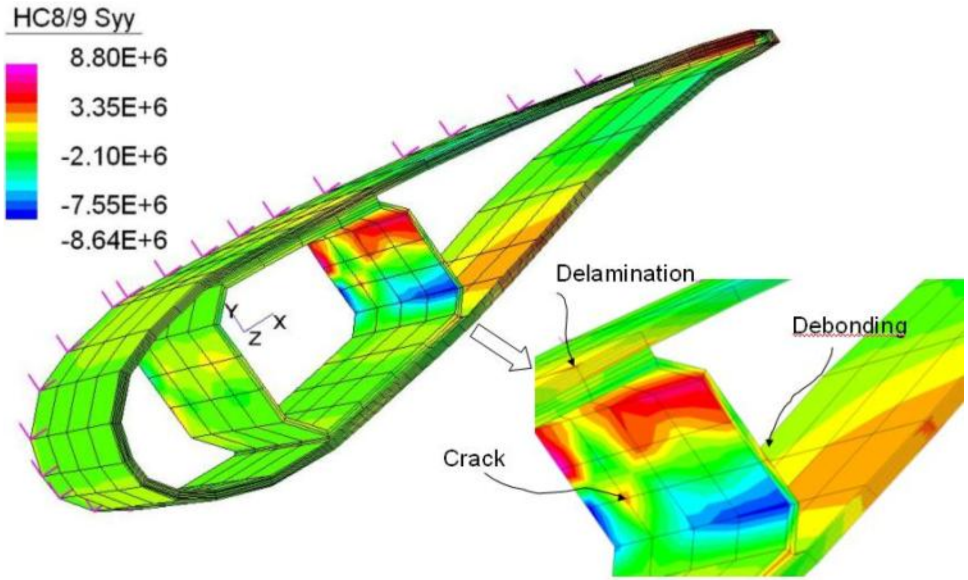
- The *Drag Force* is parallel to the direction of motion. We want to make this force small.



Airfoil Shape

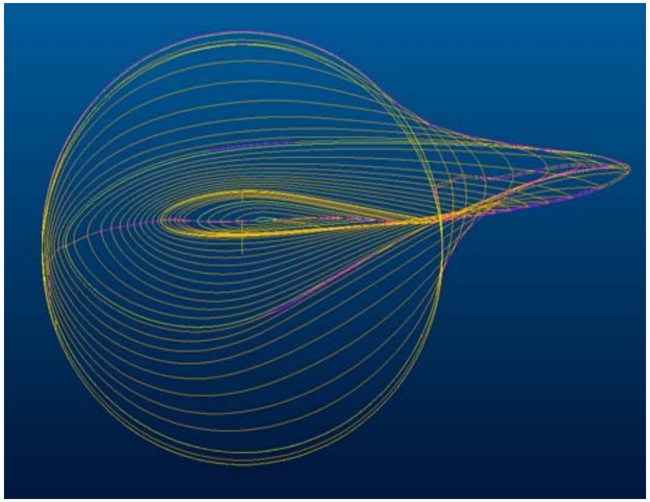


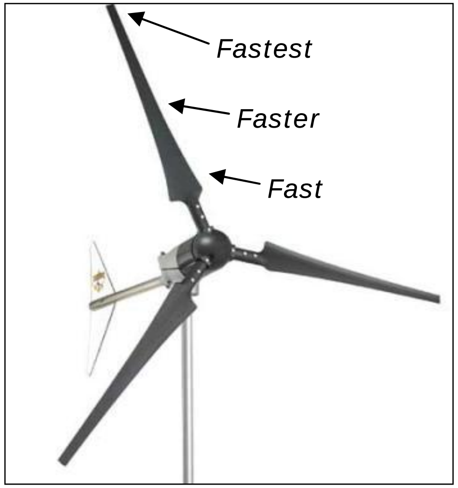
Just like the wings of an airplane, wind turbine blades use the airfoil shape to create lift and maximize efficiency.

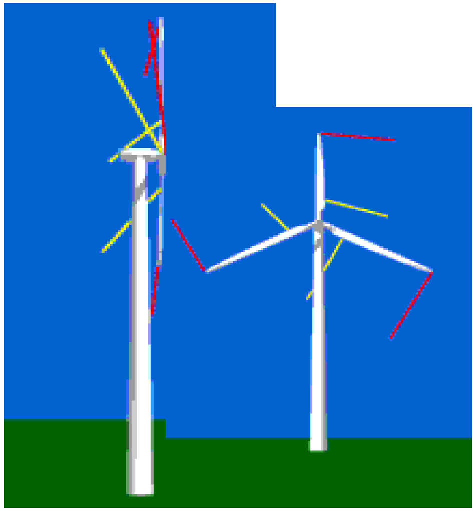


Twist & Taper

- Speed through the air of a point on the blade changes with distance from hub
- Therefore, tip speed ratio varies as well
- To optimize angle of attack all along blade, it must twist from root to tip







Tip-Speed Ratio

- Tip-speed ratio is the ratio of the speed of the rotating blade tip to the speed of the free stream wind.
- There is an optimum angle of attack which creates the highest lift to drag ratio.
- Because angle of attack is dependant on wind speed, there is an optimum tip-speed ratio

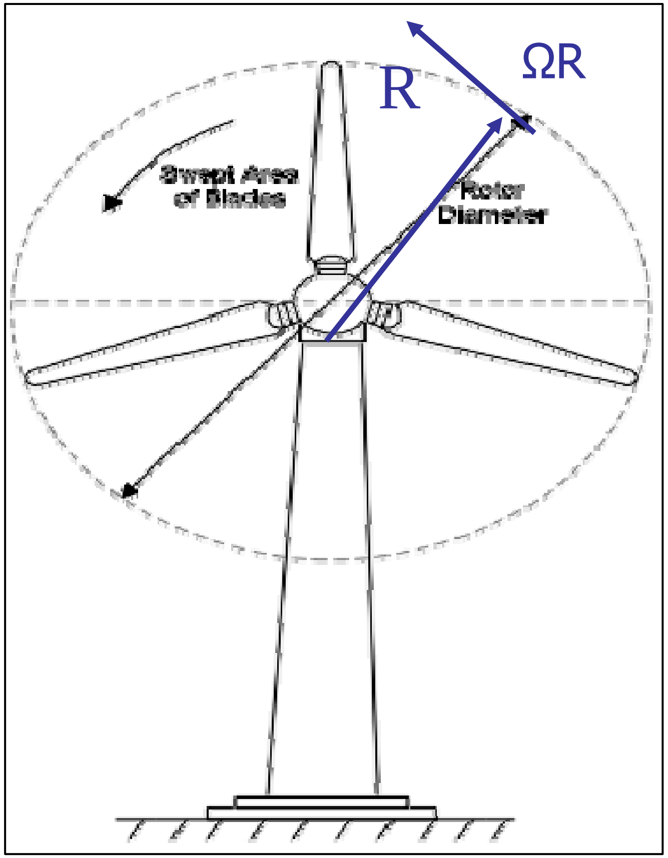
$$TSR = \frac{\Omega R}{V}$$

Where,

Ω = rotational speed in radians /sec

R = Rotor Radius

V = Wind "Free Stream" Velocity



Betz Theory:

According to Albert Betz / German Scientist,1928 theorem, the question is :

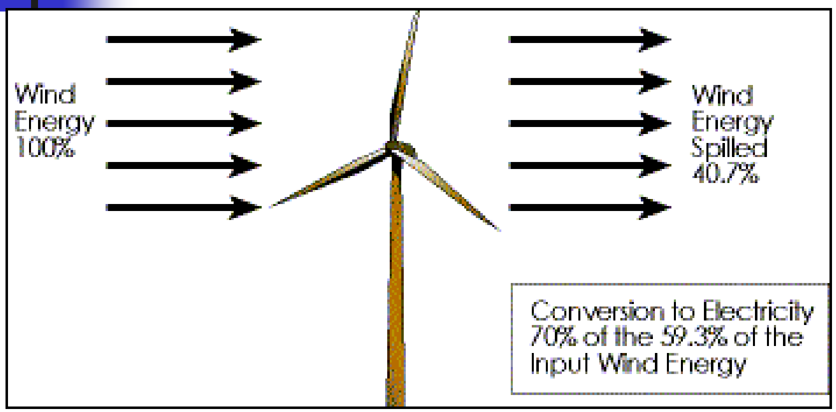
How much available and reasonable power can be extract from wind turbine with concrete design ?.

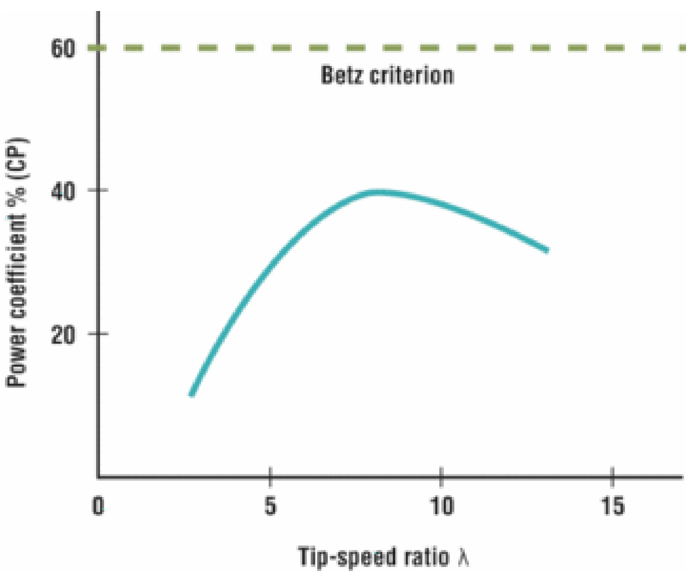
The Betz analysis uses an actuator disk approach.

The total transferred energy takes place in the plane of the actuator

And this energy transferred takes place upstream and downstream of the actuator

summary of Betz approach





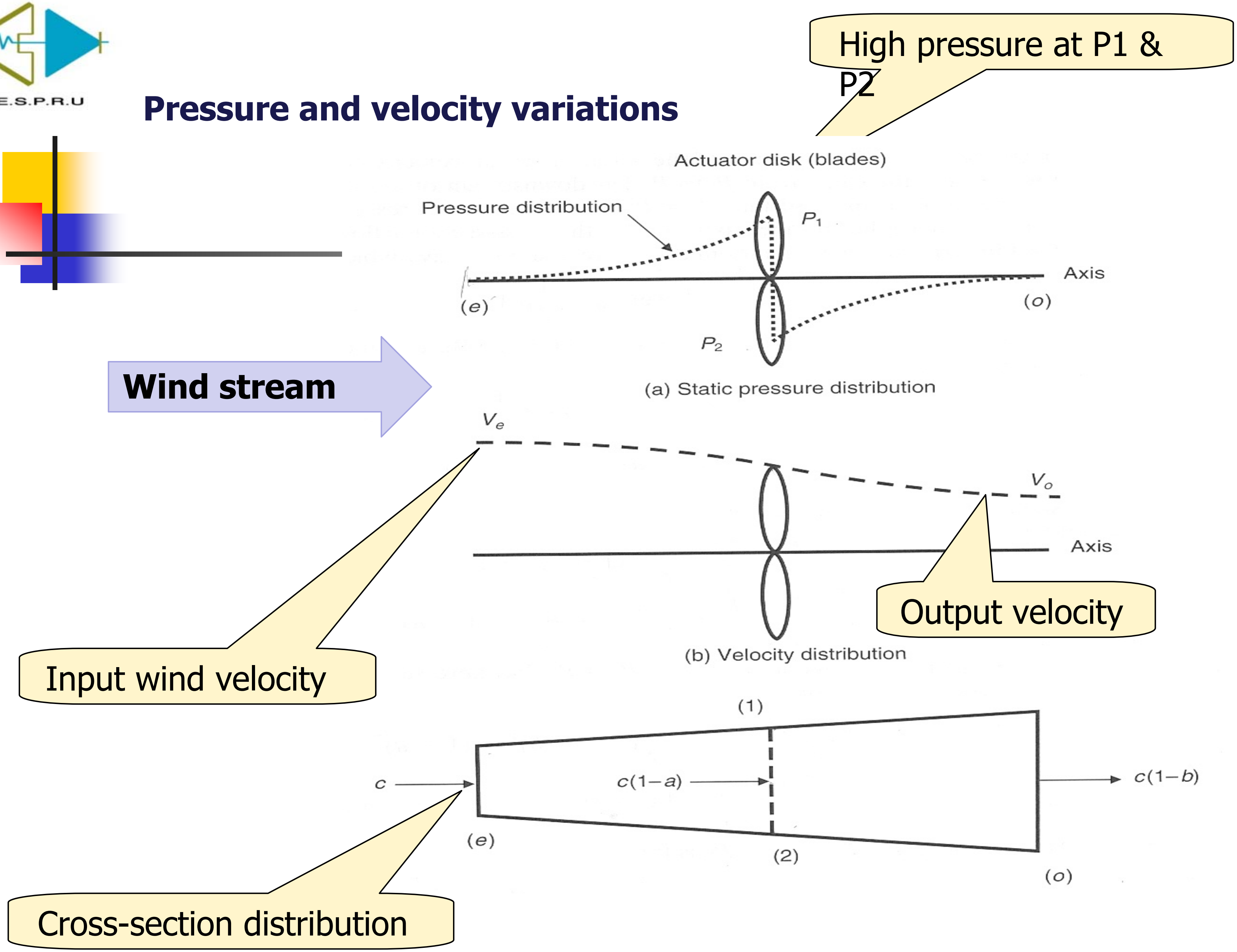
- All wind power cannot be captured by rotor or air would be completely still behind rotor and not allow more wind to pass through.
- Theoretical limit of rotor efficiency is **59%**
- Most modern wind turbines are in the **35 – 45%** range

Actuator Disk Analysis

This Analysis depicted three distributions :

- PRESURE
- VELOCITY
- CROSS-SECTION

Pressure and velocity variations



P.E.S.P.R.U

MATHEMATICAL MODELING

1. The actuator disk is represented by blades in the pressure and velocity distribution, and by a dotted line in the cross sectional area distribution.
   The actuator area is the area swept by the blades and equal to $\pi D^2/4$, where D is the blade diameter.

2. The change in the kinetic energy ΔE is :

$$\Delta E = \frac{1}{2} m V_e^{\ 2} - \frac{1}{2} m V_o^{\ 2} = \frac{1}{2} m (V_e^{\ 2} - V_o^{\ 2});$$

Where **Ve**, and **Vo** are the incoming and out-coming from the blades speed respectively.

3. The flow -rate mass of the stream air is given at ambient temperature is :

$$m = \rho_a . A_a . V = \rho_a . A_a . V_e (1 - a)$$

MATHEMATICAL MODELING

4. The output velocity(leaving the blades velocity) is :

$$V_o = V_e(1 - b) = V_e(1 - 2a)$$

According to Betz theory **a=b/2** where (a and b are integers with certain value).

5. Taking into account the up mentioned equations for the energy ca be express as follows:

$$\Delta E = \frac{1}{2}\rho_a.A_a.V_e(1-a)(V_e^{\,2} - V_e^{\,2}.(1-2a)^2)$$

Hence, the changing in kinetic energy due to moving the air from the upstream point to downstream point has a maximum value with respect to **a,** and can be found by setting the first derivative to zero.

$$\frac{d}{da}E = 0$$

MATHEMATICAL MODELING

6. We found that **E=max** at **a=1/3**, therefore the actual speed that extract energy is

$$V_{act} = V_e(1 - a) = \frac{2}{3} V_e$$

This means that the approaching (striking) to the actuator (blades) wind speed is decreased by 1/3 of its stream value (coming value).

7. The maximum available power is calculated as follows:

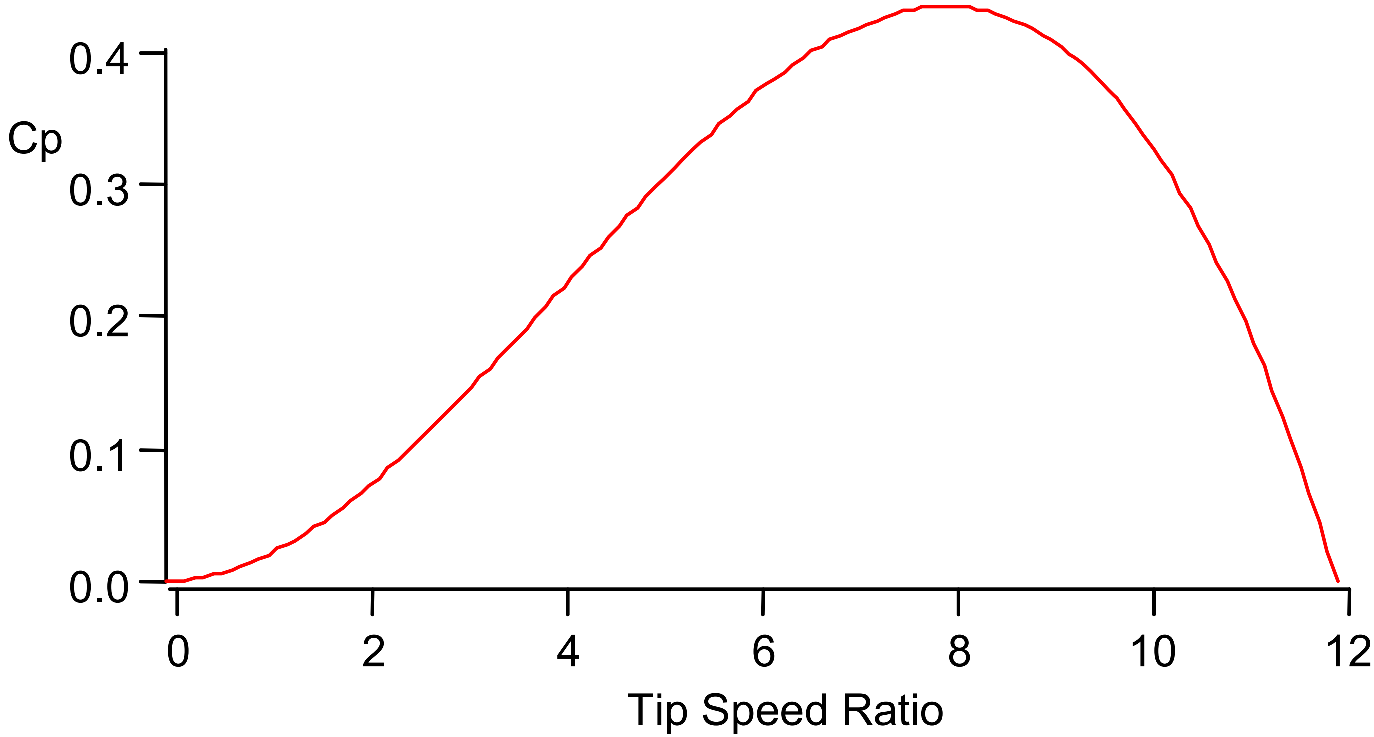
$$\Delta E_{\max} = \frac{8}{27} . \rho_a . A_a . V_e^{3} ; \Rightarrow \ at \ a = 1/3.$$

8. The maximum power coefficient can be determined as follow:

$$C_{p\ \max} = \frac{P_{extact\ \ \max}}{P_{available}} = \frac{\frac{8}{27} . \rho_a . A_a . V_e^{3}}{\frac{1}{2} \rho_a . A_a . V_e^{3}} = \frac{16}{27} = 0.5926$$

MATHEMATICAL MODELING

Which means that, the power extracted from the wind turbine theoretically according to **Bitz** approach **can not exceed 59.26%.**



MATHEMATICAL MODELING

9. The advanced or tip ratio: This is the ratio between the rotor speed and wind velocity, tip ratio can be determined as follow:

$$\lambda = TCR = \frac{Rotor\ \ speed}{Wind\ \ velocity} = \frac{r.\omega}{Ve}; \Rightarrow and \rightarrow f = \frac{\omega}{2\pi}$$

Where, ω=2.π.n/60, and n=120.f/p; p- is number of poles of the generator.

10. The rotor torque : This is the mechanical torque acting on the rotor shaft, and can be given by :

$$\tau = \frac{\Pr esonable}{\omega}, N.m$$

Depending on the rotor construction (number of blades), the TCR differs from one wind turbine to another, and according to this ratio, the wind turbine configuration can be select.

MATHEMATICAL MODELING

EXAMPLE PROBLEM :

Imagine there is a geographical location where you want to install a wind turbine with data:

Wind velocity **Ve=40km/hr** **(which is 11.11 m/s)**;

Atmosphere pressure **101.3kPa**, the wind temperature is 20°C,

Blade diameter (Rotor swept diameter **Da=10m**) .

- What is the maximum available power, $P_{available}$=?
- What can be the maximum extracted power $P_{extract}$ =?
- What is the reasonable power $P_{resonable}$=?
- What is the rotor speed ω and torque τ.

Example Problem#1

Solution: The solution will be listed in five steps as follows:

Step#1: The available power , $P_{available}$=?

$$P_{available} = \frac{1}{2} m . A_a . V_e^2 ;$$

$$m = \rho_a . A_a . V_e ; \Rightarrow \therefore \quad P_{available} = \frac{1}{2} \rho_a . A_a . V_e^3$$

$$A_a = \pi . r^2 = \pi . \frac{D^2}{4} = \pi . \frac{10^2}{4} = 78.54 \; m^2$$

The Atmosphere pressure for the temperature of 20°C is given to be around **ρ_a=1.204 kg/m³**, hence, the available power is

=➔ $P_{available}$=64.86kW.

Example Problem#1

Step#2: The available extracted power , $P_{extracted}$=?

$$P_{extracted \ \max} = Cp.P_{available} = 0.5269 * 64.84kW = 38.4kW$$

Step#3: The reasonable power, $P_{resonable}$=?

→ The reasonable power means the actual power that can be extracted for a given TCR and rotor configuration .

→ This could be found by looking over the relationship between the TCR and number of rotor blades shown on the next slide figure.

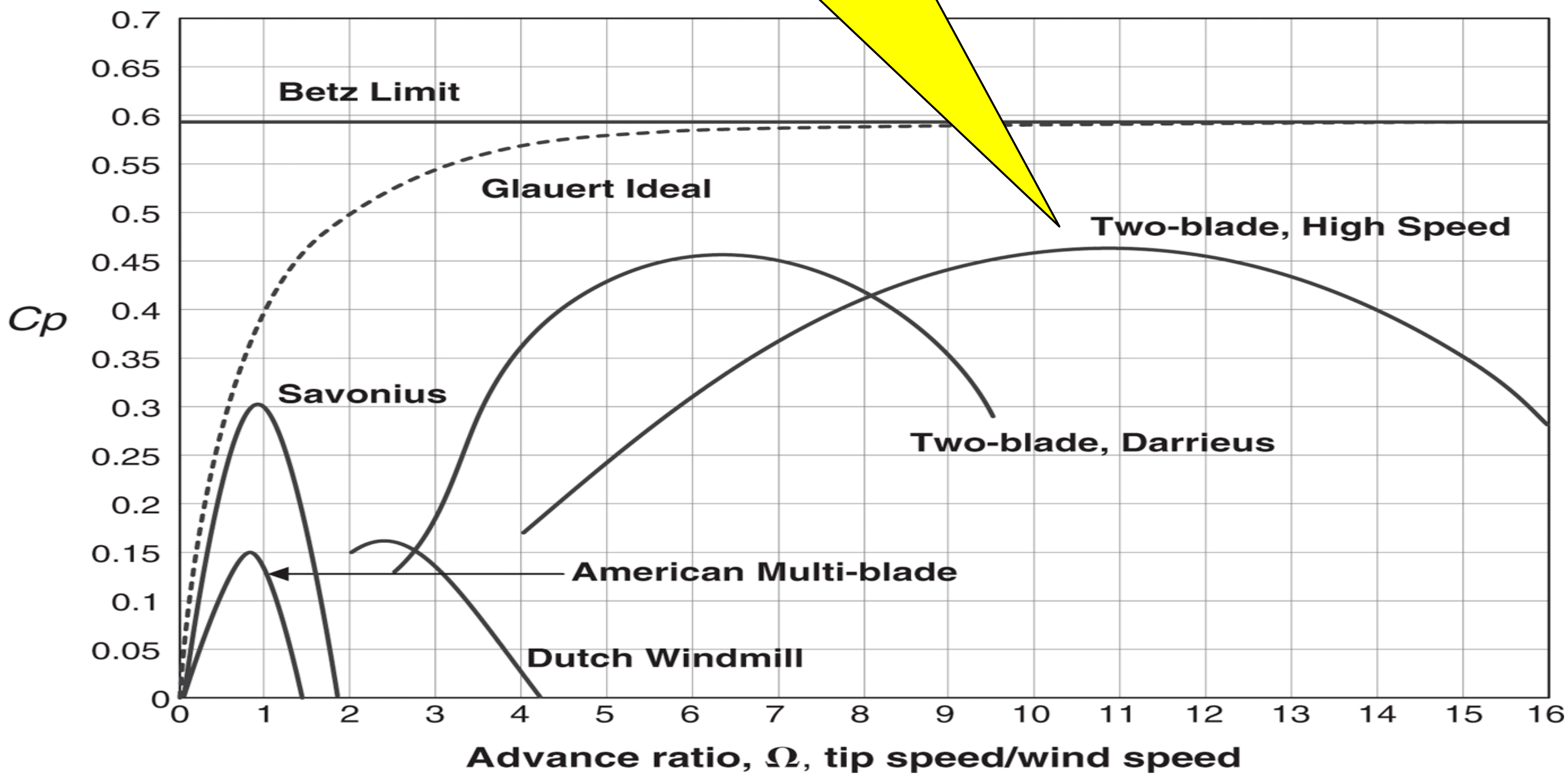
→ For (two blades) at maximum **Cp=0.46,** we pick the value of tip ratio **λ=11**. Therefore the reasonable power is :

$$\mathrm{P}_{\mathrm{r}\,esonable} = Cp_{(actual)}.P_{available} = 0.46 * 64.84kW = 29.4kW$$

∴ → The reasonable power is : 29.4kW

Example Problem#1

For λ=11;Cpmax=0.46



Example Problem#1

Step#4: The rotor speed and torque: Taking into account that the tip ratio is 11, and the diameter is 10m the rotor speed is :

$$\lambda = \frac{Rotor \quad speed}{Wind \quad velocity} = \frac{r.\omega}{Ve}; \Rightarrow \quad and \quad \rightarrow \quad f = \frac{\omega}{2\pi}$$

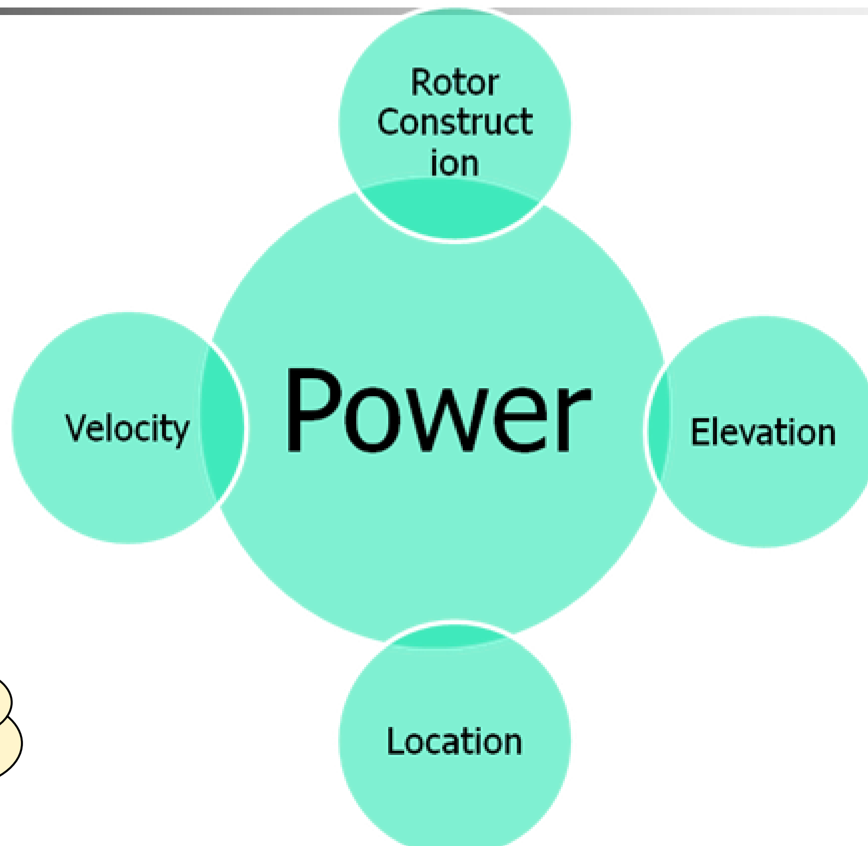
$$11 = \frac{5m.\omega}{40\ kM\ /\ hr} \Rightarrow \omega = 24.4\ rad\ /\ s \rightarrow$$

$$n = \frac{60.\omega}{2\pi} = \frac{60 * 24.4}{2\pi} = 233\ rpm\ .$$

$$\tau = \frac{\Pr esonable}{\omega} = \frac{29.8kW}{24.4rad/s} = 1221.3N.m$$

Therefore, the rotor blades will rotates at speed of 233rpm, and with acting on the shaft torque of 1221.3N.m. Now depending on the frequency and speed ratio of the gearbox, the generator speed and configuration is selected (number of of poles, power, frequency……)

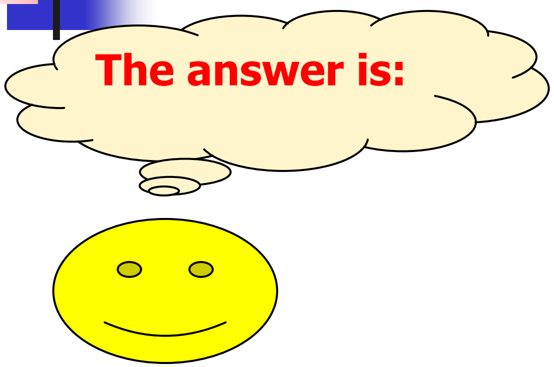
WIND ENERGY RESOURCES AND WEIBULL DISTRIBUTION



Now, the question is:

Is it efficient to montage/build the wind turbine system everywhere without any restrictions?

WIND ENERGY RESOURCES…cont'd



No !, Why ?,… because :

1. Wind velocity varies from one site to another, and this called wind distribution or known as "*Wind Energy Resource Atlas*",

2. Most of the Nations/ Countries have their own National Renewable Energy Labs (NREL). For example the United States NREL has the site www.nrel.gov, that gives the designer overall description and statistics about the regions and sites where the wind energy is harvesting.

3. A unique feature is an assessment of the "**CERTAINTY** " of the wind data. The wind data (wind density) are rated from 1(lowest degree) to 4(the highest degree) of the certainty.

The coming figure illustrates the wind density distribution of USA.

WIBULL DISTRIBUTION

Statistics of Wind Energy Resources

Several statistical methods are used to predetermine the harvesting places and sites for wind power energy.

One of these statistical methods is called **Weibull distribution**, which states that the occurrence of a given wind speed over a year can be expressed by the following distribution:

$$h(v,k,c)=\frac{k}{c}\left(\frac{v}{c}\right)^{k-1}.\exp\left[\left(\frac{v}{c}\right)^{k}\right]$$

Where ***c*** is a scale parameter , ***k*** is a shape parameter, and ***v*** is the wind velocity.

P.E.S.P.R.U

WIBULL DISTRIBUTION……cont'd

The shape parameter controls the shape of the distribution; the large the shape parameter, the closer to distribution comes to being Gaussian distribution.

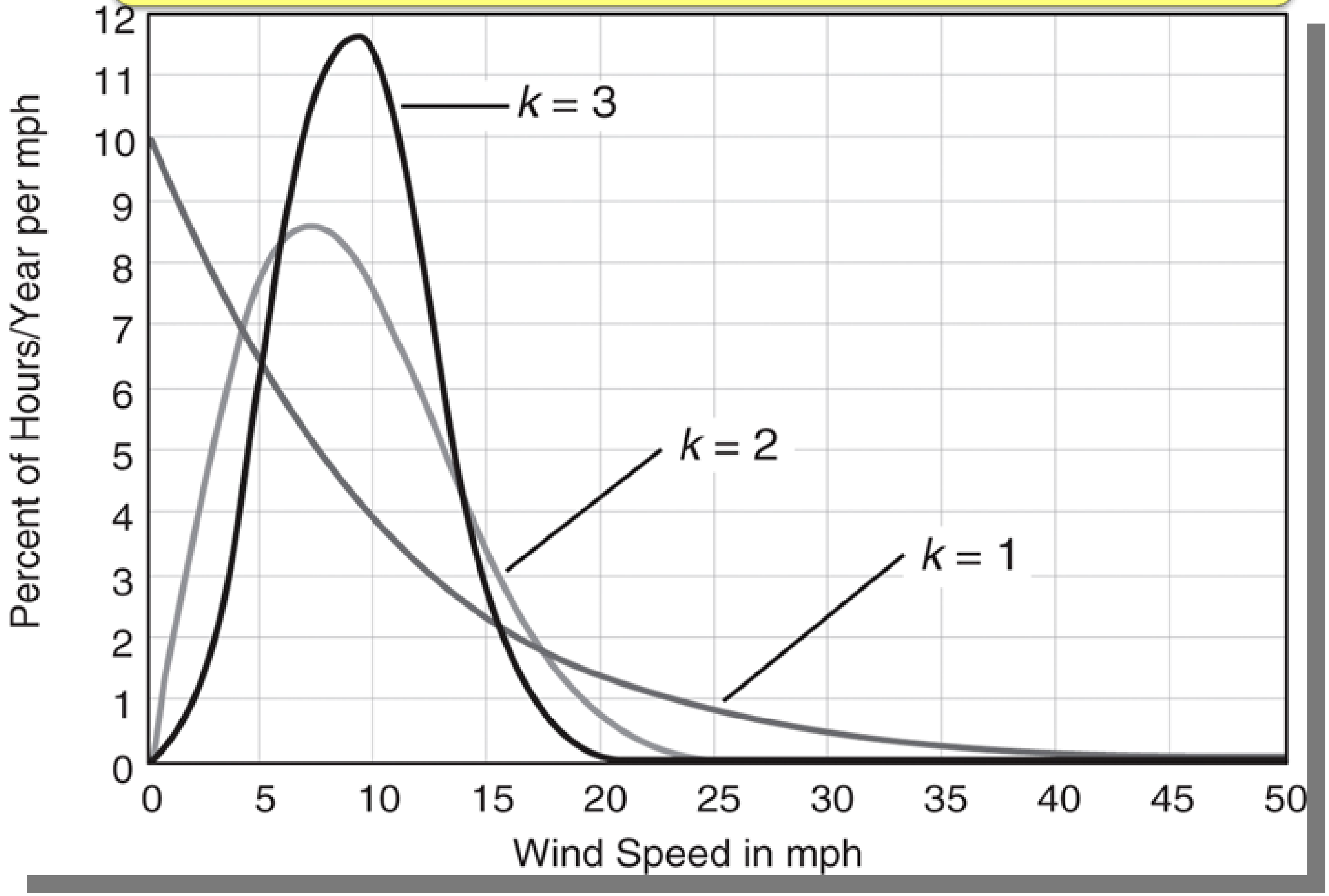
While the scale parameters controls the value of the mode (most probably wind speed). The larger the scale parameter, the higher the mode and the lower the probability of a given speed less that the mode.

The shape parameter is dimensionless, while the scale parameter must have the same unit as the speed.

Usually for wind turbines the shape parameter is taken to be **k=2**, because it provides a generally acceptable match for the wind speed distribution at most sites.

WIBULL DISTRIBUTION……cont'd

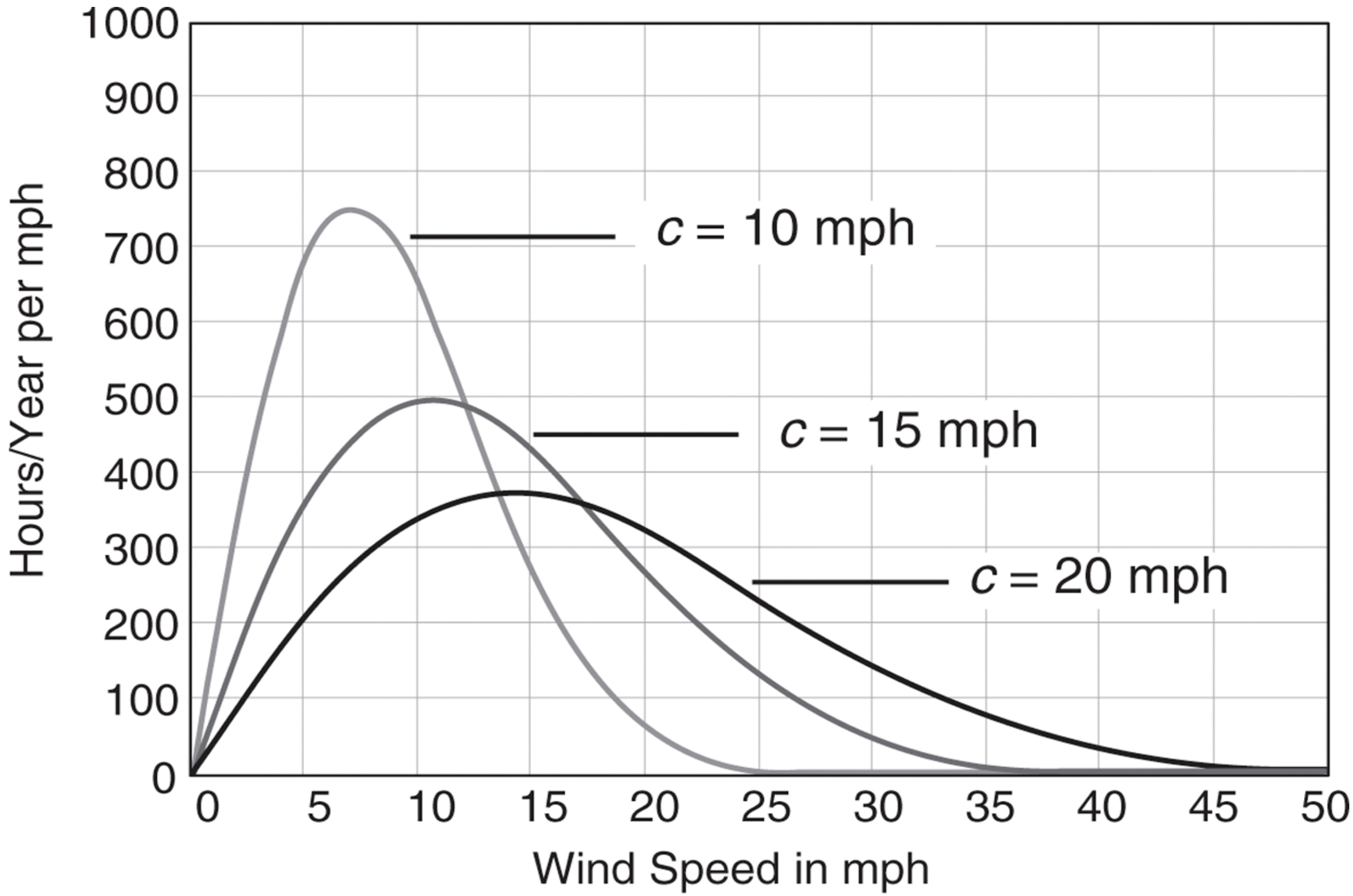
This figure represents the probability distributions in percentages for various values of shape parameter *k* (*k=1,2,3*) at given *c*



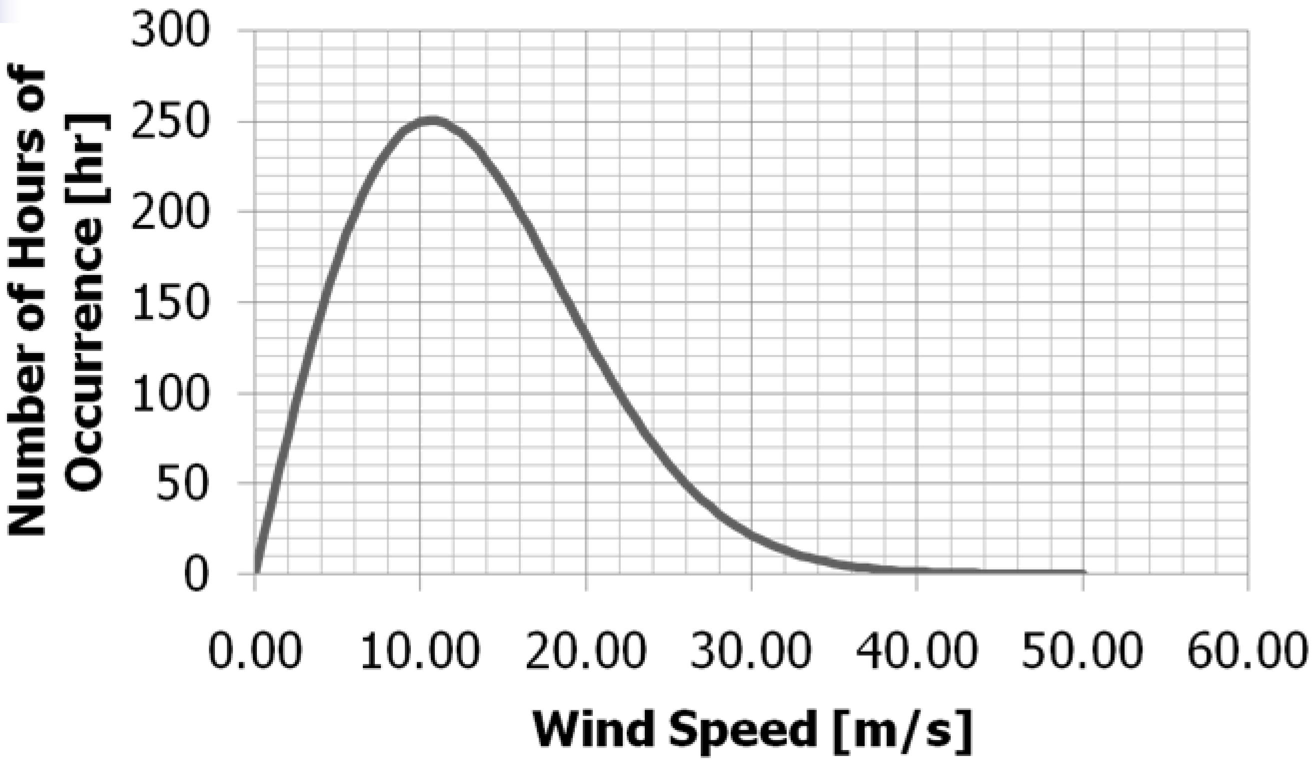
WIBULL DISTRIBUTION……cont'd

This figure represents the probability distributions in percentages for various values of scale factor

(*k=10, 15, 20 mph*) at given *k=2*



WIBULL DISTRIBUTION......cont'd



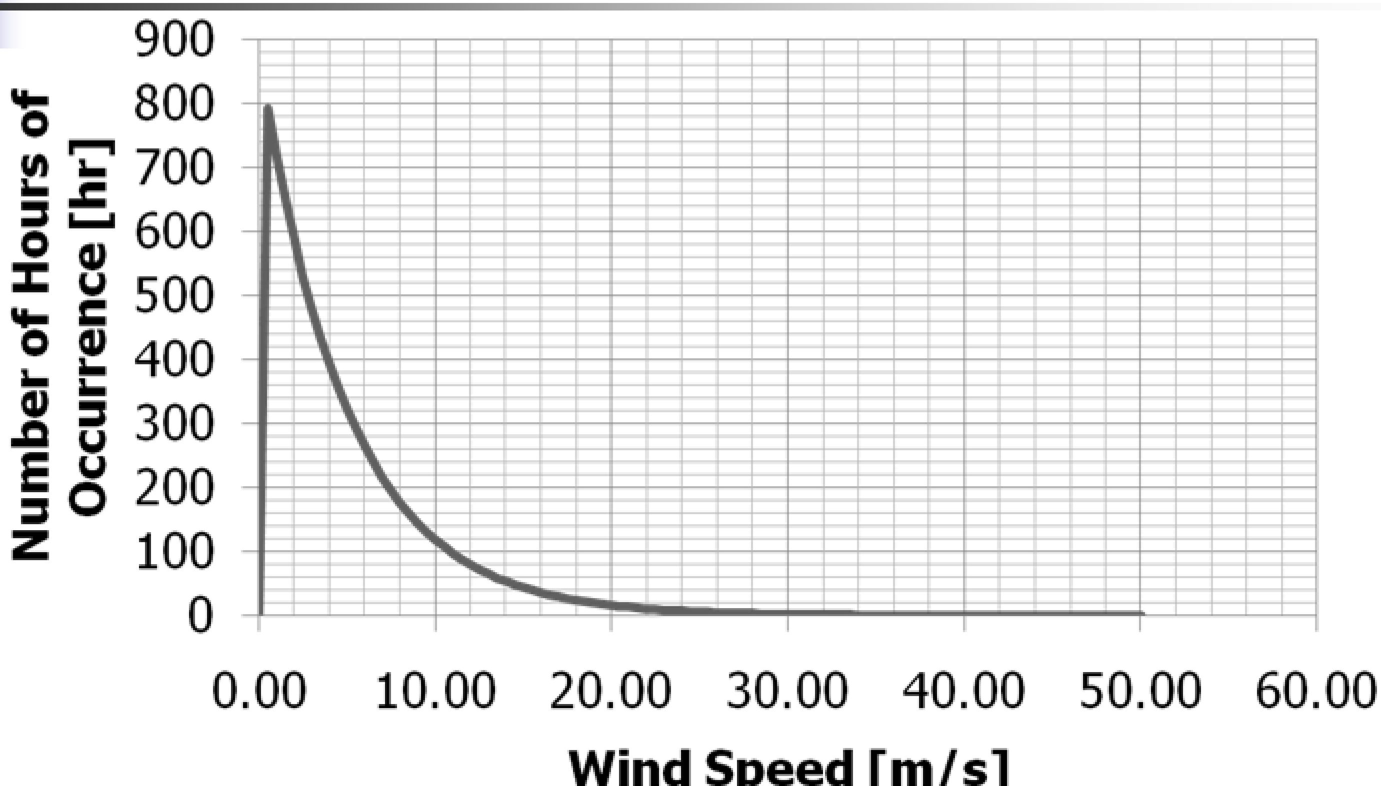
K=2

C=15 m/s

EXCEL SHEET CALCULATIONS

Description of excel program and varying the shape and scale factor in order to observe the occurrence of the speed probability.

WIBULL DISTRIBUTION……cont'd



K=2

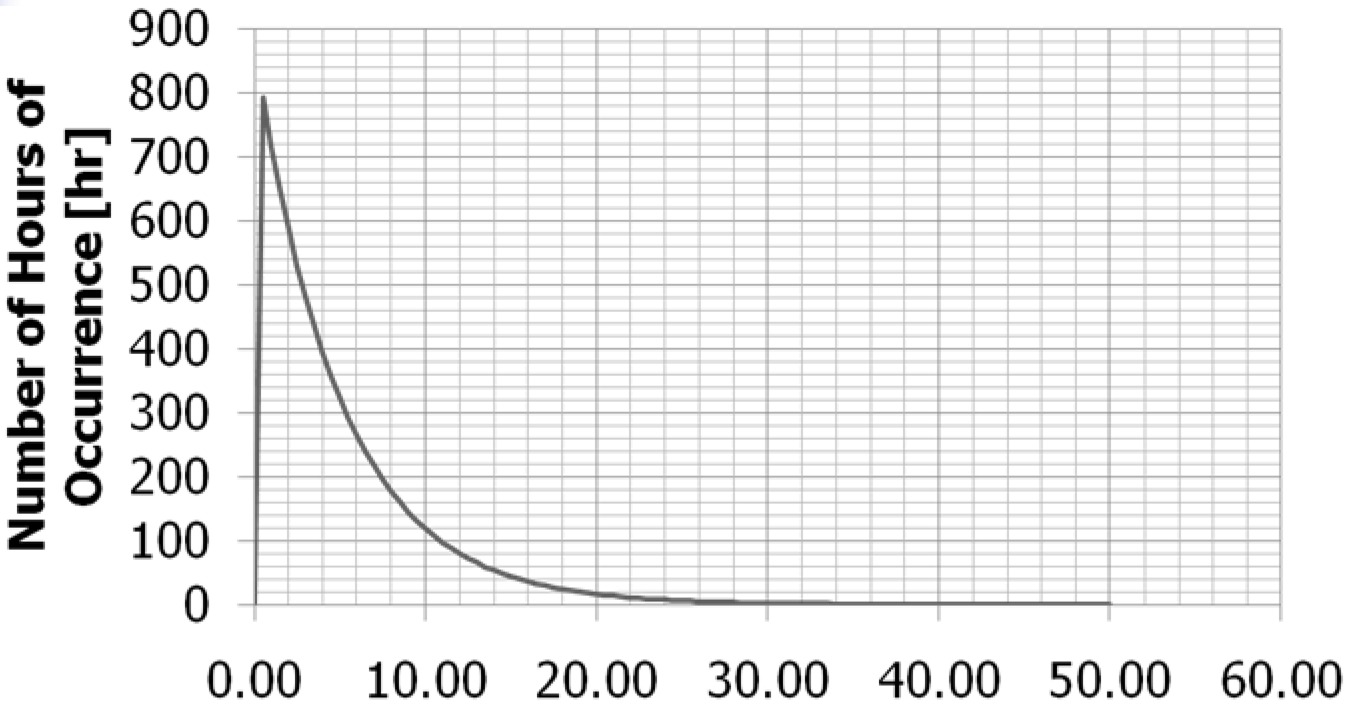
C=5 m/s

EXCEL SHEET CALCULATIONS

Description of excel program and varying the shape and scale factor in order to observe the occurrence of the speed probability.

WIBULL DISTRIBUTION......cont'd

K=1



C=5 m/s

EXCEL SHEET CALCULATIONS

Description of excel program and varying the shape and scale factor in order to observe the occurrence of the speed probability.

WIBULL DISTRIBUTION……cont'd

From Weibull distribution, the following conclusion can be drawn :

The smaller the value of c (c=10mph) the more hours at small wind speeds values occurs.

As the value of c increases (c=15,..=20mph), the mode wind speed increases and the number of hours per year at wind speeds higher than the mode speeds increases also.

The scale factor has direct effect on the available hours per year with a given speed, and when design the turbine this parameter plays great role in determining the sizing, reliability and cost of the turbine.

Application of Wiebull Distribution in Wind Energy.....

Now the question is

How does the Weibull distribution related to assessing the metrics of wind energy ?

This should be realized as follows

1. The mode speed presents the probable metric speed in a distribution.

2. The mean speed is defined as

$$V_{mean} = \int_{0}^{\infty} h(v, k, c).v.dv$$

P.E.S.P.R.U

Application of Wiebull Distribution in Wind Energy…..cont'd

3

- Since the wind power is proportional to the cube of the wind speed, the average power density available for collection per unit of swept area is:

$$Power_{avail} = \int_0^{\infty} \frac{1}{2}.\rho.h(v,k,c).v^3.dv$$

4

- The speed of interest for wind energy is the root-mean-cube speed:

$$Vrmc = \sqrt[3]{\int_0^{\infty} h(v,k,c).v^3.dv}$$

5

- The average annual power density available becomes:

$$Power_{avail} = \frac{1}{2}\rho.V^3 rmc$$

Application of Wiebull Distribution in Wind Energy.....cont'd

6

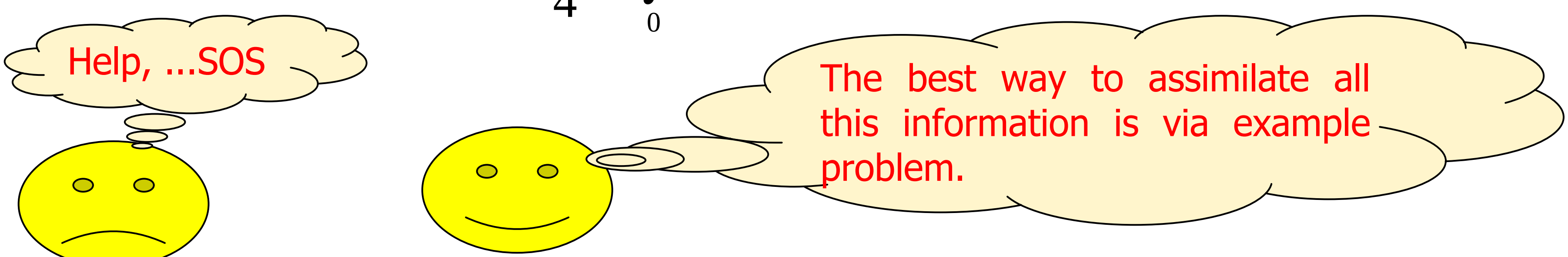
- The actual extracted power can be assigned to be 50% (for modern turbines) of the average available power , and it becomes:

$$Power_{ext} = \frac{1}{2} Power_{avail} = \frac{1}{4} \rho . V^{3} rmc, Watt$$

7

- The total energy that can be extracted per year (8760 hrs) for a given distribution is :

$$Energy_{ext} = \frac{1}{4} . \rho . \int_{0}^{\infty} h(v,k,c).8760 . v^{3} . dv, Whr / year$$

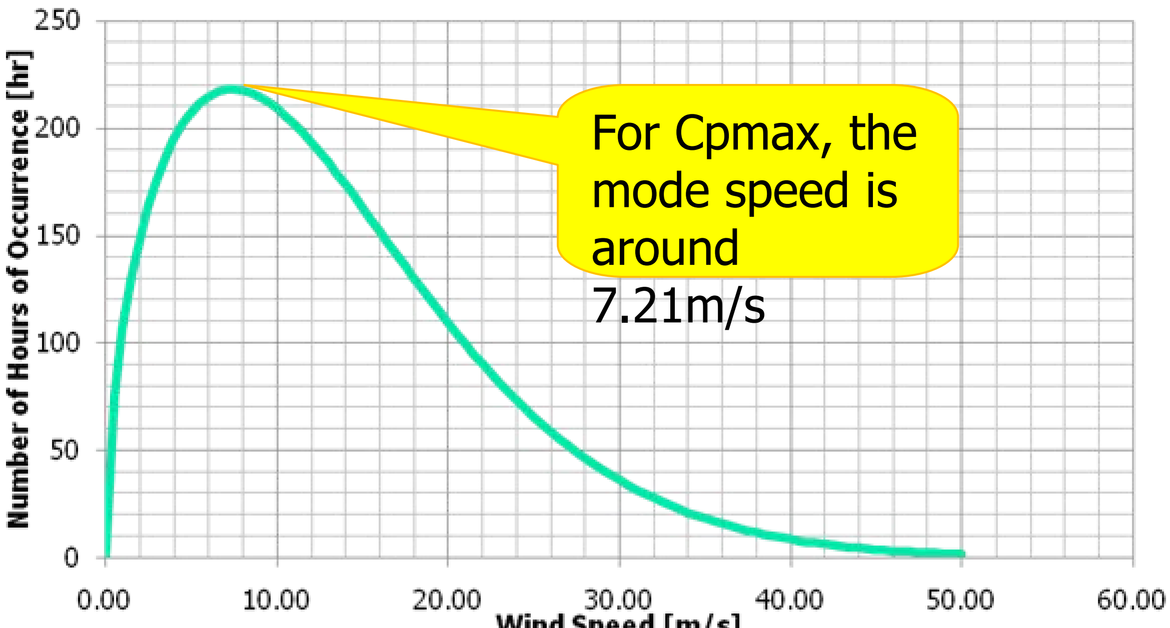


Example Problem#2

Find Vmode, Vmean, Vrms, the power density available distribution, and the power extracted per m2 for a wind turbine at a site corresponding to a Weibull wind distribution with c=15m/sec and k=1.5. The air density is 1.225kg/m3 .

Solution: The solution will be listed in five steps as follows:

Step#1: Using Wiebul distribution/Excel sheet we found that the **probable wind speed occurs at** 7.21m/s as well shown on the figure.



P.E.S.P.R.U

Example Problem#2

Step#2: The power density for the mode speed is :

$$P_{density}(V_{mode}) = \frac{1}{2}\rho_a . V_{mode}^{3} = 229.56\ W/m^2$$

Step#3: The mean wind speed is :

$$V_{mean} = \int_0^\infty h(v,k,c).v.dv = 13.541\, m/s$$

Step#4: The power density for the mean speed is :

$$P_{density}(V_{mean}) = \frac{1}{2}\rho_a . V_{mean}^{3} = 1521\ W/m^2$$

Step#5: The root mean cube speed Vrmc is :

$$Vrmc = \sqrt{\int_0^\infty h(v,k,c).v^3.dv} = 18.889\, m/s$$

Step#6: The power density for the cube speed is :

$$P_{density}(Vrmc) = \frac{1}{2}\rho_a . V_{rmc}^{3} = 4134\ W/m^2$$

Example Problem#2

Step#7: The available power is :

$$Power_{avail}(v) = \int_{0}^{100\,m/s} \frac{1}{2}.\rho.h(v,k,c).v^3.dv$$

Step#8: The extracted annual energy is

$$Energy_{ext}(v) = \frac{1}{4}.\rho.\int_{0}^{100\,m/s} h(v,k,c).8760\,.v^3.dv = 1.811x10^4\,kWhr\,/\,year\,.m^2$$

This means that each **meter square** of the turbine area (swept area) gives us an energy of **18110 kW-hr/ year**. Therefore, having a 10m blade diameter of a wind turbine gives us a annually power of : **78.539m^2*18110 kW-hr/year =1422356 kW-hr/year =1.422 MW-hr/ year**

Example Problem#2

Now the described results can be obtained by using MathCAD for solving the weibull equations and related to this equation power parameters.

Also by using Excel Sheet for Weibul distribution we be able to determine the annual extracted power for a given **k** and **c** in particular for (k=1.5 & c=15m/s))

$mph := \frac{mi}{hr}$ define mph as miles per hour

$kW := 1000 \cdot watt$ define kW

$\rho := 1.225 \cdot \frac{kg}{m^3}$ density

$h(v, k, c) := \frac{k}{c} \cdot \left(\frac{v}{c}\right)^{k-1} \cdot e^{-\left(\frac{v}{c}\right)^k}$ Weibull distribution function definition.

$PowerDen(V) := 0.5 \cdot \rho \cdot V^3$ Power density function definition.

$c := 15 \cdot \frac{m}{sec}$ $k := 1.5$ specify values of the scale parameter and shape parameter

$V_{mode} := 7.21 \cdot \frac{m}{sec}$ $PowerDen\left(V_{mode}\right) = 229.563 \frac{watt}{m^2}$

$$V_{mean} := \int_{0 \cdot \frac{m}{sec}}^{\infty \cdot \frac{m}{sec}} \frac{k}{c} \cdot \left(\frac{v}{c}\right)^{k-1} \cdot e^{-\left(\frac{v}{c}\right)^k} \cdot v \, dv$$

Definition of mean speed, Equation (4-19).

$V_{mean} = 13.541 \frac{m}{sec}$ $PowerDen\left(V_{mean}\right) = 1.521 \times 10^3 \frac{watt}{m^2}$

$$V_{rmc} := \sqrt[3]{\int_{0 \cdot \frac{m}{sec}}^{1000 \cdot \frac{m}{sec}} \frac{k}{c} \cdot \left(\frac{v}{c}\right)^{k-1} \cdot e^{-\left(\frac{v}{c}\right)^k} \cdot v^3 \, dv}$$

Definition of rmc speed, Equation (4-21).

$V_{rmc} = 18.899 \frac{m}{sec}$ $PowerDen\left(V_{rmc}\right) = 4.134 \times 10^3 \frac{watt}{m^2}$

Example Problem#2

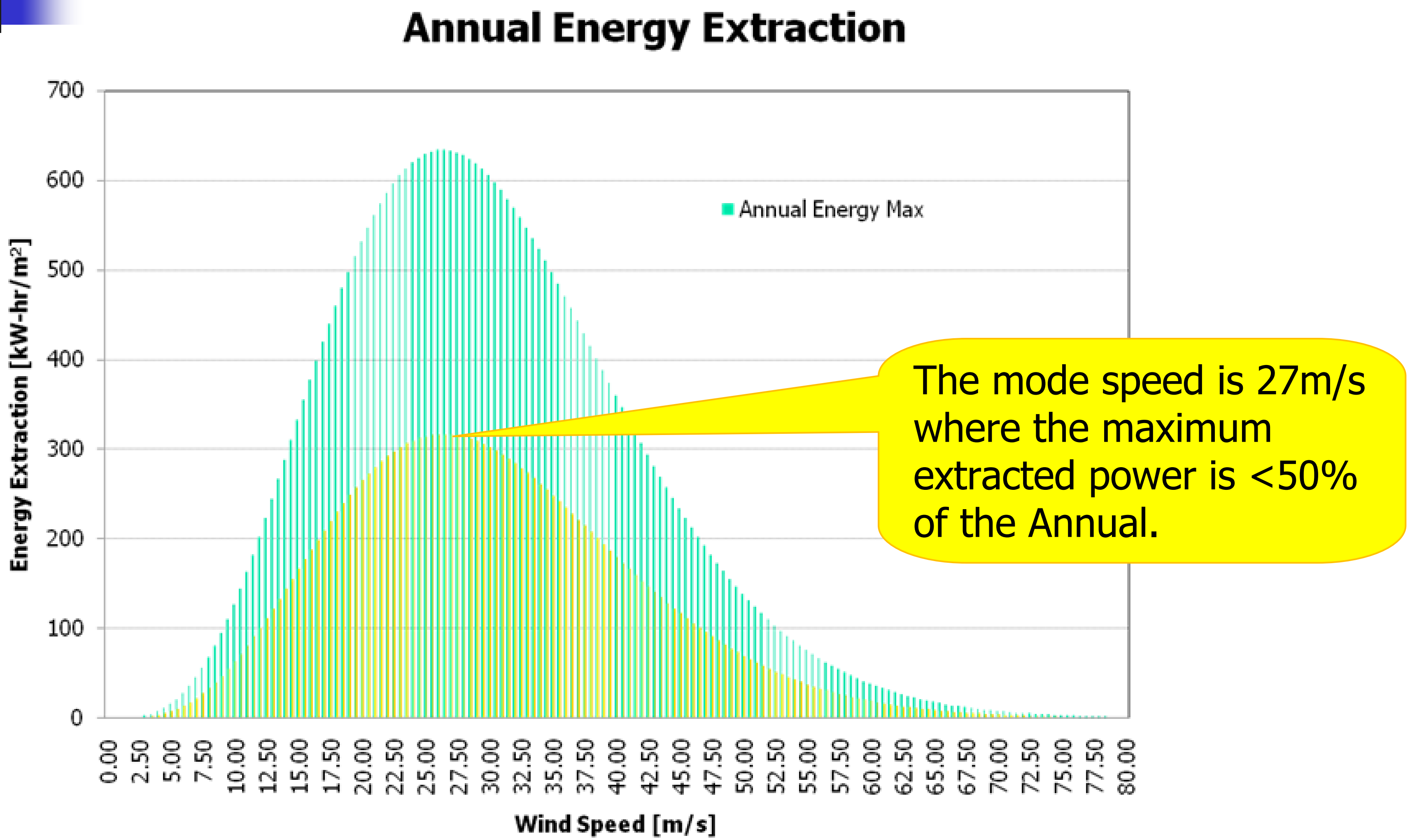
$$\text{Power}(v) := 0.5\cdot\rho\cdot h(v,k,c)\cdot v^3$$ Power density available with Cp = 1.0.

$$v := 0 .. 50\cdot\frac{m}{sec}$$ wind velocity range

$$\text{Energy} := \int_{0\cdot\frac{m}{sec}}^{1000\cdot\frac{m}{sec}} 0.25\cdot\rho\cdot\left[\frac{k}{c}\cdot\left(\frac{v}{c}\right)^{k-1}\cdot e^{-\left(\frac{v}{c}\right)^{k}}\right]\cdot 8760\cdot\frac{hr}{yr}\cdot v^3\,dv$$

$$\text{Energy} = 1.811\times 10^4\,kW\cdot\frac{hr}{yr\cdot m^2}$$

Example Problem#2



Example Problem#3

Case study:

Known that the wind speed in Palestine, approximately 8m/s in winter season, and we need an actual energy of 20kWhr.

Determine 1- the Turbine data

2- the actual annual energy.

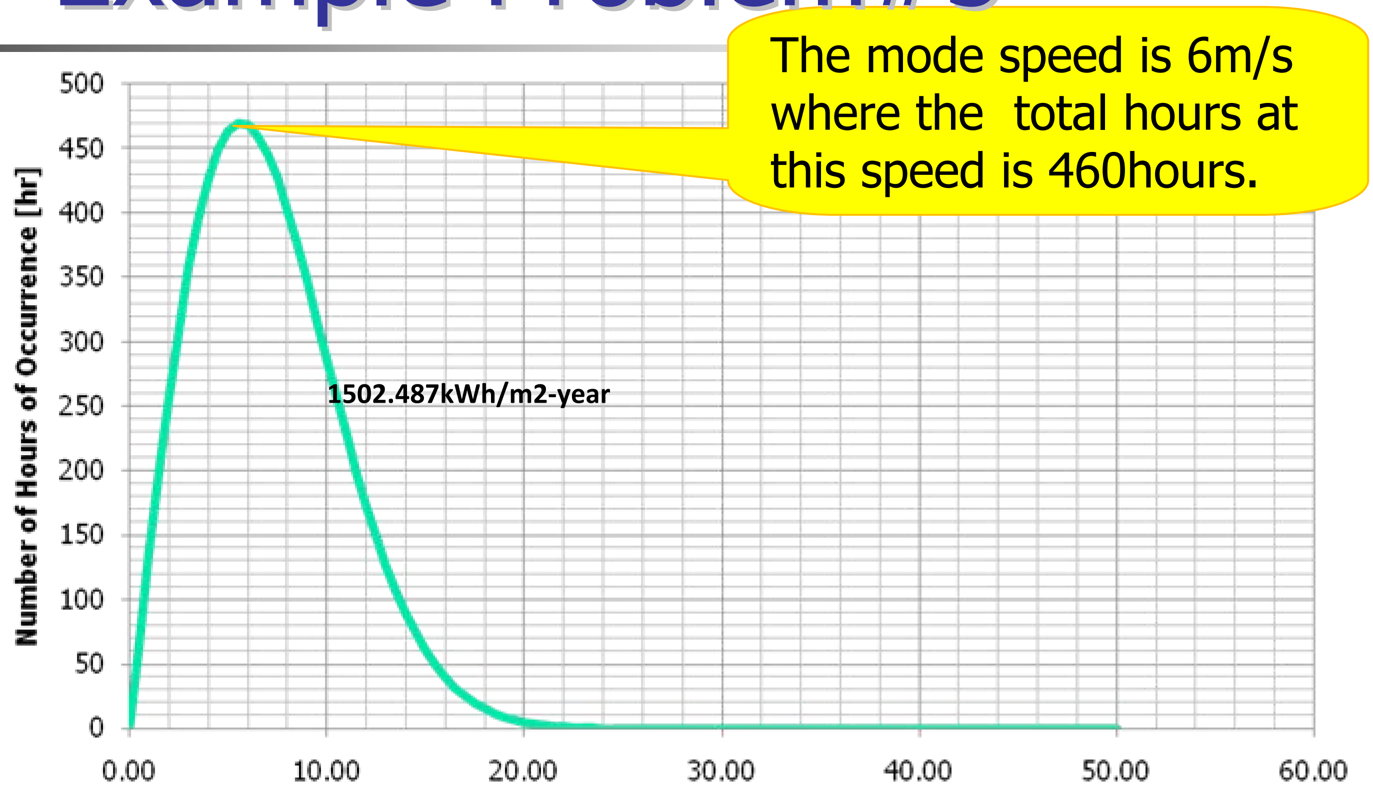
Assume that the air density for warm climate is 1.12kg/m3

Solution: According to the given data : c=8m/s; ρ=1.12kg/m3; K=2; and Cp=45%, the following steps:

Step#1: Using Wiebul distribution/Excel sheet we found that the **probable wind speed occurs at** 6 m/s as well shown on the figure.

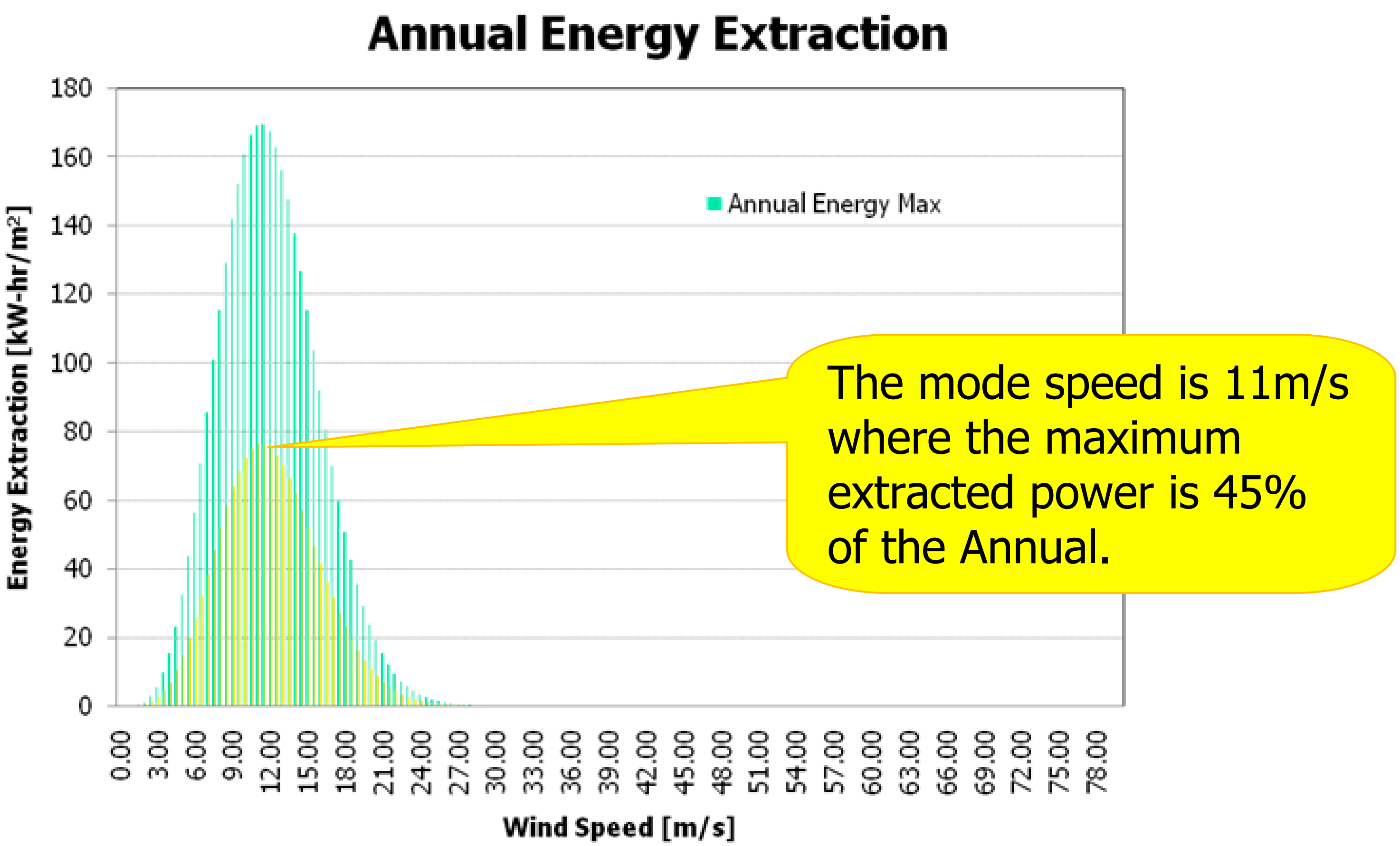
Example Problem#3

Step#2: Reading the data form the excel sheet/graph



The mean speed is Vmean=7.09m /s ;
Thr rmc speed Vrmc=8.79 m/s
The power density per m2 is $P_{density}$ (V_{rmc})= 375.58 kW/m2
The obtained annual energy per m2 is Energy=1502.48 kWhr/m2-year

Example Problem#3



Example Problem#3

Step#3: Determine the blade dimensions…

$$Energy_{ext}(v) = 1502.48\,kWhr\ /\ year.m^2$$

$$Energy_{ext}(v)/hr = 1502.48\,kWhr\ /\ year.m^2 / 8760\,hrs = 0.1715\,kWhr\ /\ m2$$

The swept /blade area is:

$$Area = 20\,kWhr\ /\ 0.1715\,kWhr\ /\ m^2 = 116.61m^2$$

The blade diameter is:

$$D = \sqrt{\frac{4.Area}{\pi}} = 12.18m \Rightarrow R = 6.1m$$

The Solidity – Tower height = >3xR = 18.5 m

Discussion:
Wind Energy Systems

Day Three Agenda

Wednesday, 12/05/2010 (For Trainees)	
09:30 - 10:45	Using Computer Simulation for Wind Energy System Design
10:45 - 11:00	Coffee Break
11:00 - 13:00	Using Computer Simulation for Wind Energy System Design
13:00 - 14:00	Lunch Break
14:00 - 17:00	Visit to Imnaizel

Workshop Trainer: Professor Akram Ahmad Abu-aisheh
University of Hartford, West Hartford, CT, USA
abuaisheh@hartford.edu

Computer Simulation Tools for Wind Energy Systems

The following webinars will be very helpful to evaluate the tools that MathWorks provide for Energy Production. http://www.mathworks.com/energy-production/

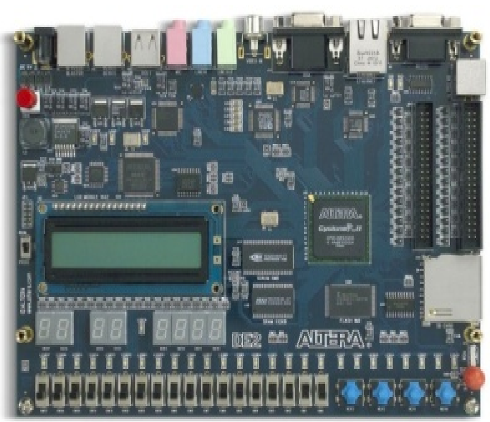
- Wind energy simulation:
- http://www.mathworks.com/programs/wind_turbine_webinars/?BB=1

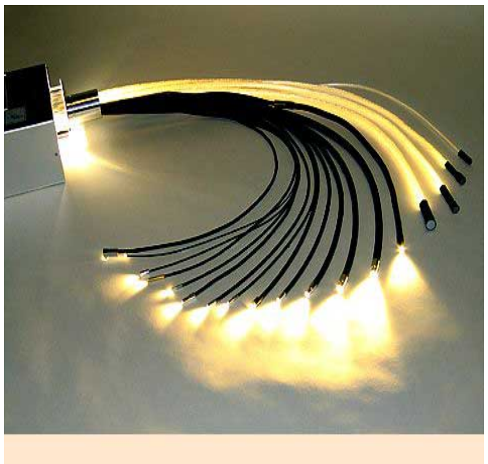
Day Four Agenda

Thursday 13/05/2010 (For Trainees)	
09:30 – 10:15	Presentation: High Efficiency Illumination
10:15 - 10:30	Coffee Break
10:30 - 13:00	Hybrid, Solar and Wind, Energy "Hands on" Training
13:00 - 14:00	Lunch Break
14:00 – 14:30	Panel Discussion: "AC vs. DC"
14:30 - 15:30	Closing Session

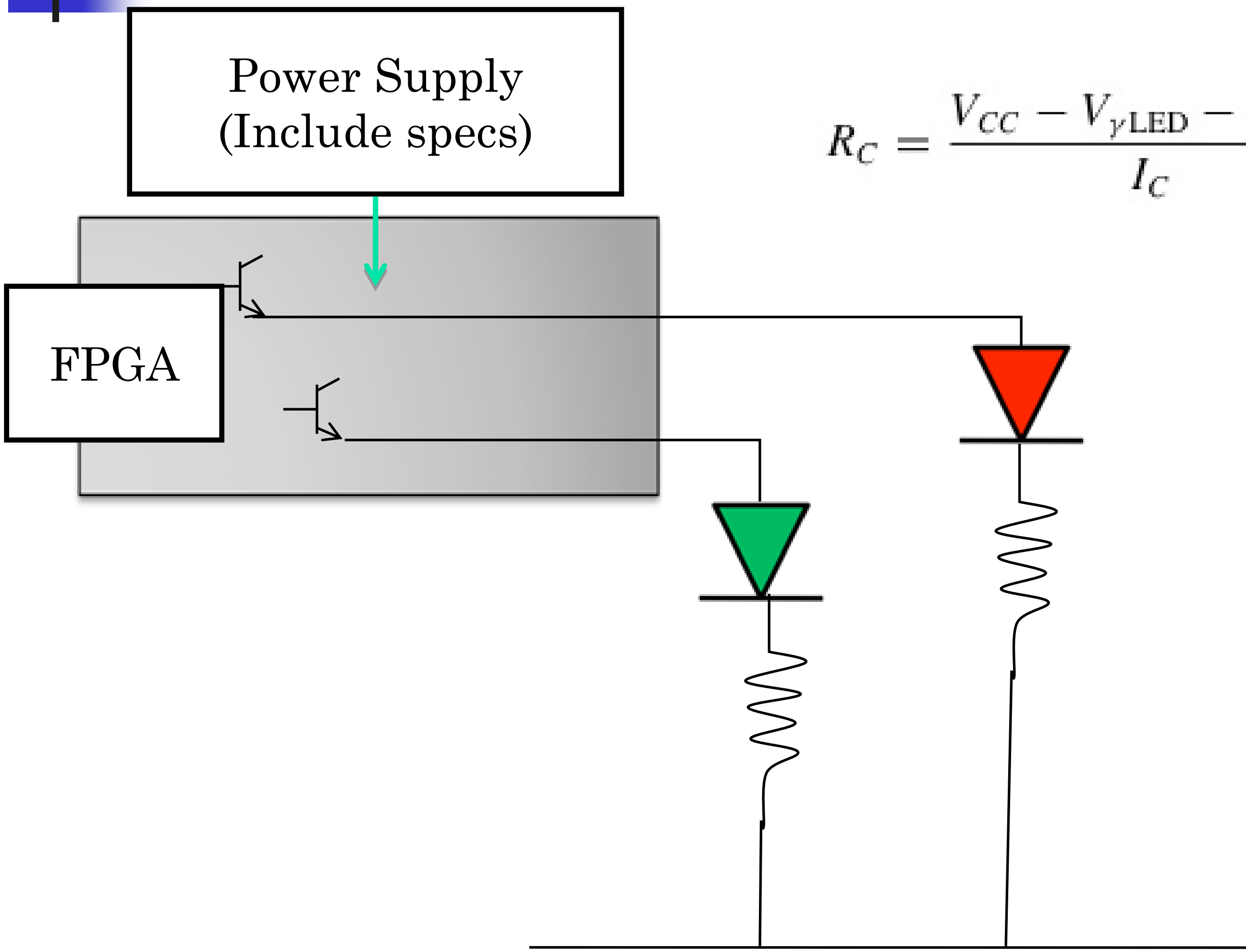
Workshop Trainer: Professor Akram Ahmad Abu-aisheh
University of Hartford, West Hartford, CT, USA
abuaisheh@hartford.edu

Presentation:
High Efficiency Illumination

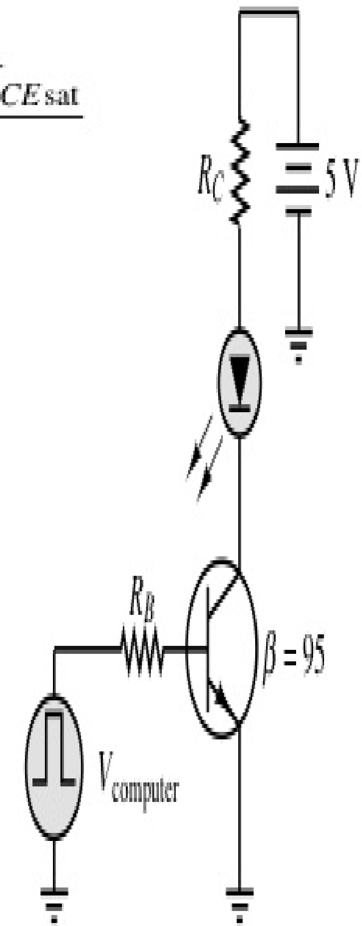




LED Illumination Control



$$R_C = \frac{V_{CC} - V_{\gamma \mathrm{LED}} - V_{CE\,\mathrm{sat}}}{I_C}$$



LED Control Technologies

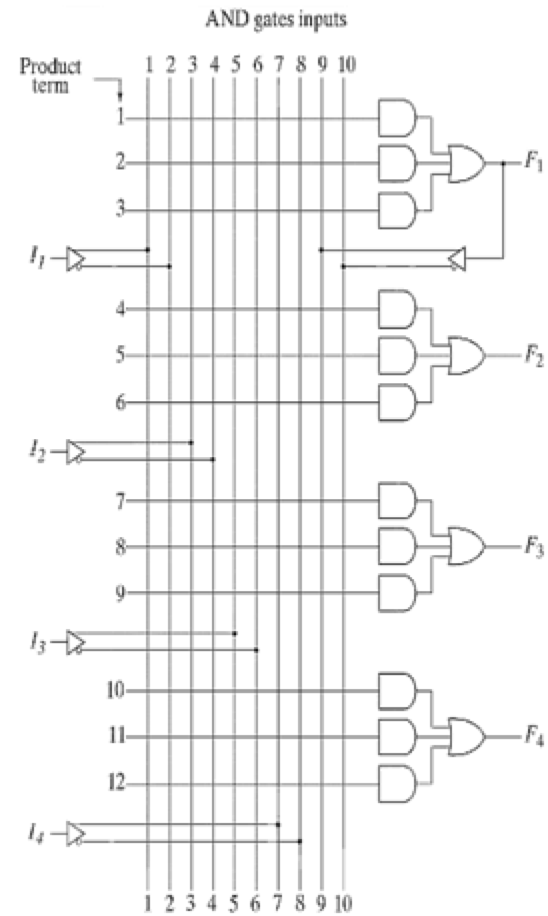
- TTL chips
- PAL / PLA
- CPLD
- FPGA

TTL: TRANSISTOR-TRANSISTOR LOGIC

- Class of digital circuits built from bipolar junction transistors (BJT) and resistors.
- It is called *Transistor–Transistor Logic* because both the logic gating function and the amplifying function are performed by transistors.
- Consume more power.
- Slower.

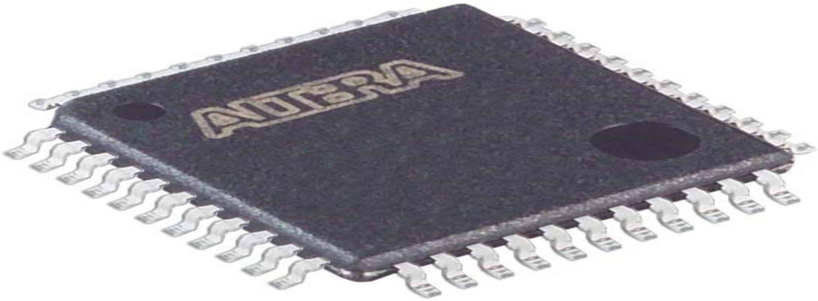
PAL/PLA

- The PLA has a set of programmable AND gate planes, which link to a set of programmable OR gate planes, which can then be conditionally complemented to produce an output.
- Used to implement combinational logic circuits.
- Not field programmable.
- Each PAL device is “one-time programmable" (OTP), meaning that it could not be updated and reused after its initial programming.



CPLD: COMPLEX PROGRAMMABLE LOGIC DEVICE

- Is a programmable logic device with complexity between that of PALs and FPGAs.
- CPLDs form the logic functions with sea-of-gates.
- Non-volatile configuration memory.
- EEPROM



FPGA: FIELD-PROGRAMMABLE GATE ARRAY

- FPGAs are integrated circuit boards designed to be configured by the customer or designer after manufacturing—hence "field-programmable‟. FPGAs Exhibit the following:

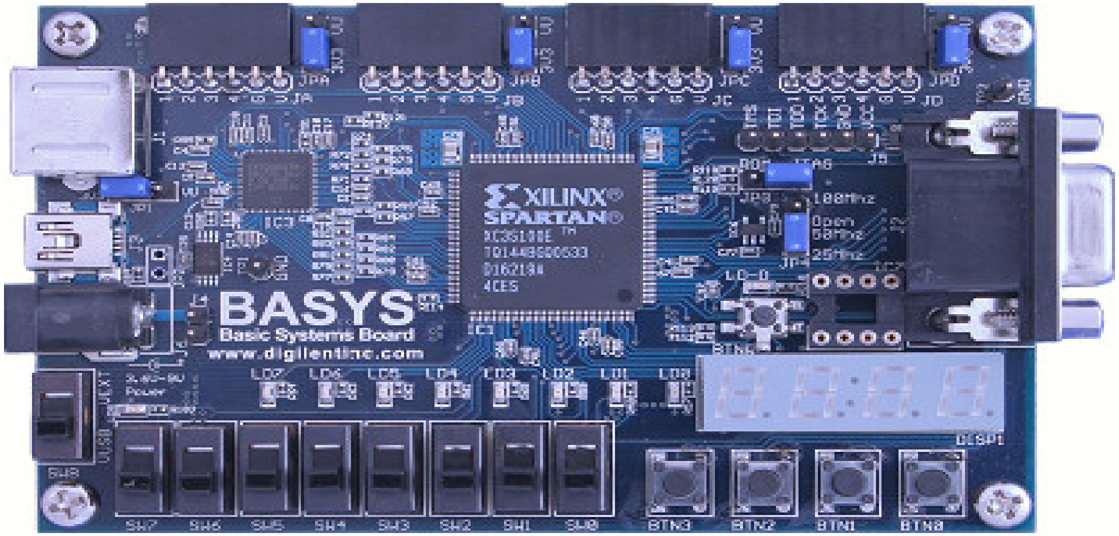
- Faster that TTL, PAL/PLA and CPLDs.
- Ability to re-program in the field to fix bugs low.
- Lower non-recurring engineering costs.

SUPER FLUX LED’S

- Low power consumption.(220-230mW)
- Junction temperature 125°C.
- Low maintenance costs.
- High Luminance.
- Typical forward voltages: 2.2V – 3.9V
- Typical forward current: 70 mA/50 mA.
- Offer higher flux and intensity when compared to Phlatlight led’s.
- Lifetime is higher than Phlatlight led’s (1.6million hrs).
- More choices of viewing angles.

DIGILENT FPGAs

- Digilent's Xilinx-based programmable logic boards are built around the latest FPGA technologies and time-tested solutions that offer robust performance at a very low price. Most boards feature on-board USB power & programming, and cost less.



BASYS Board Specifications

- FPGA features 18-bit multipliers, 72Kbits of fast dual-port block RAM, and 500MHz+ operation.
- USB 2 port for FPGA configuration and data transfers.
- Three on-board voltage regulators (1.2V, 2.5V, and 3.3V) that allow use of 4V-12V external supplies.
- The four on-board 6-pin connectors can accommodate any of Digilent's low-cost "PMOD" accessory circuits, making it easy to add A/D and D/A converters, motors, sensors, and a variety of other devices and circuits.

Panel Discussion: “AC vs. DC”

“AC vs. DC” Panel Discussion

The Westinghouse / Edison War continues…

Did you know if Edison had his way, all generation and transmission of electrical power including the outlets in your house would provide direct current (DC) instead of alternating current (AC) that we have today?

Around the turn of the 20th century, Nikola Tesla invented alternating current generation, transmission and AC induction motors. He then licensed his patents to George Westinghouse and the war with Edison began.

http://energyzarr.typepad.com/energyzarrnationalcom/2009/02/ac-vs-dc-the-westinghouse-edison-war-continues.html

Closing Session:

Issues to be followed up:

1-
2-
3-

Plans for promoting sustainable energy:

1-
2-
3-

Plans for proposals and research cooperation in sustainable energy:

1-
2-
3-

Conclusions:

1-
2-
3-