Department of Electrical and Electronics Engineering

Higher Colleges of Technology

EEL 2023
Power Generation and Transmission

2016 Fall Semester

LO 1: Describe the layout of common electrical power generation plants

A. Understanding Demand and Consumption
B. Peak power station
C. Selection of site
D. Hydraulic power plants
E. Nuclear power plants
F. Wind energy
G. Comparison of the five sources of energy

Course: EEL- 2023 Power Generation and Transmission
Class Instructor: Dr. Haris M. Khalid,
Faculty, Electrical and Electronics Engineering Department
Webpage: www.harismkhalid.com

كلّيـــات الـتـقـنـيـة العلـيـــا
HIGHER COLLEGES OF TECHNOLOGY

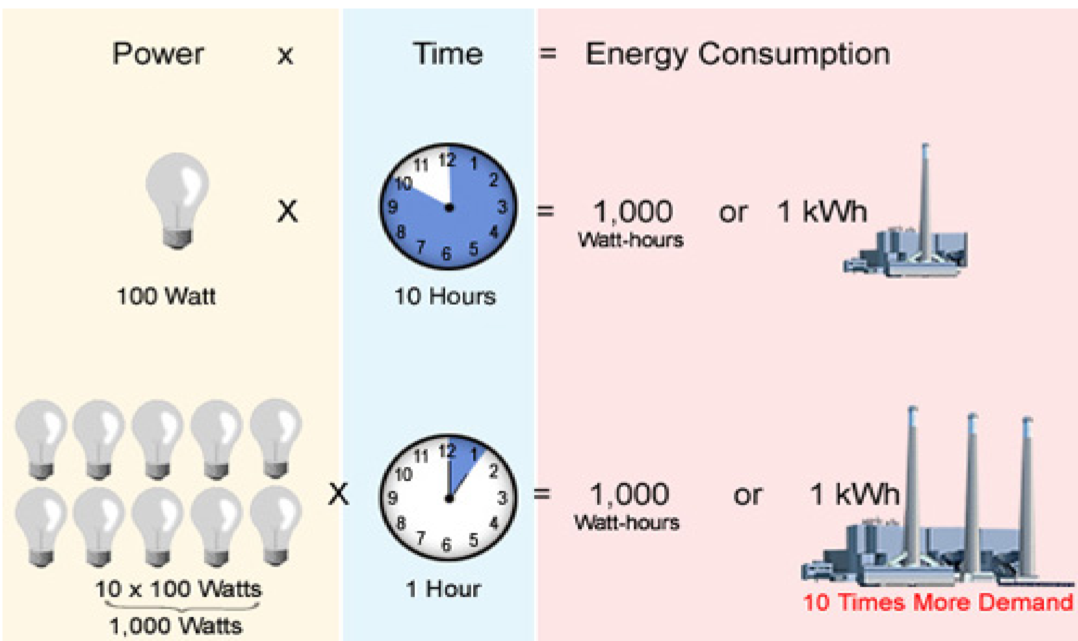
A. *Understanding Demand and Consumption*

Demand = KW

Consumption = KWH

The difference between demand (KW) and consumption (KWH) is vital to your choices in reducing your energy costs. A simple way to see the difference between demand and consumption is by considering two examples.

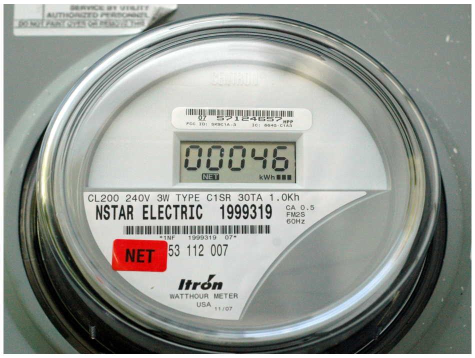
LIGHTING EXAMPLES: One 100-watt light bulb burning for 10 hours consumes 1,000 watt-hours or 1 kWh. The entire time it is on, it requires or "demands" 100 watts or 0.1 kW from the utility. That means the utility must have that 0.1 kW ready whenever the customer turns the lamp on.

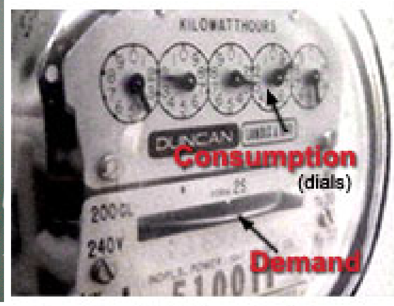


Similarly, ten 100-watt light bulbs burning for 1 hour consume 1,000 watt-hours or 1 kWh.

Note that in both examples, the **consumption is 1 kWh**, however, look how differently the second situation impacts the utility from a demand perspective. The serving utility must now be prepared to provide **ten times as much 'capacity'** in response to the "demand" of the 10 light bulbs operating all at once.

If both of these customers are billed for their consumption only, both will get the same bill for 1 kWh of energy. And that is the way most residential customers are billed. But the requirement for the utility to meet this energy requirement is very different. In the second case, the utility has to have **10 times** more generating 'capacity' to provide the second customer's brief high demand for power compared to the first case.





Residential Electric Meter

Commercial Electric Meter

Commercial and Industrial customers are often billed for their **hourly consumption patterns** and their **peak demand for energy**. These customers often have special meters that measure both, unlike residential meters that just record total consumption in a time period, usually one month.

Most homes have a pretty similar demand profile and the meters capable of measuring both demand and consumption are much more expensive. Far too expensive to justify having one on every home. So all most residential customers need to be concerned with now is consumption billing. As the cost of metering drops, and as automatic metering advances, we may see increased use of demand billing for homes.

Electric power use, is metered in two ways: on maximum kilowatt use during a given time period (i.e., kW **demand** typically measured in 15-minute or <u>30-minute intervals</u>) and on total cumulative **consumption** in kilowatt hours (kWh). A customer's electric rate is set using a complex process of tracking cost of services and often seeking regulatory approvals.

The general theory is that demand charges reflect the utilities' fixed costs of providing a given level of power availability to the customer, and energy charges reflect the variable portion of those costs as the customer actually uses that power availability.

Power companies often use a meter that records the power use during either a 15- or 30-minute time window. The average power used during that window is used to calculate the kW demand. The peak demand used for billing purposes in any month can be:

1. <u>**Time of Day:**</u> Dependent on the time of day (i.e., on-peak {usually during the day} and off-peak {usually at night time periods) and/or the day of the week (e.g., Monday through Friday and separately for weekends): The metering system tracks the highest usage anytime during the month under the appropriate time windows. These pricing

schedules are generally referred to as Time of Use (TOU) rates.

2. **Seasonally Differentiated:** For example, the demand charge might be higher during the summer than during the winter, or vice versa.

3. **Declining Blocks:** This is where the demand charge up to a given level is at one price with the price declining above that level. For example, the demand charge might be $10 per kW up to 10,000 kW demand, and drop to $6 per kW for demands in excess of 10,000 kW.

4. **Interruptible Blocks:** The demand charge depends upon whether the customer can reduce electrical demand to a given level if it is notified in advance by the utility. The price reduction often varies with the time of notice (i.e., the discount is higher if shorter notice is given). Some utilities also offer direct load control for air conditioning and water heating equipment, the utility itself can cycle this equipment on and off for brief periods.

5. **Ratchet**: Certain rate designs incorporate minimum billing demands based upon historical peak demands. For example, if the peak demand last summer was 500 kW and the rate design has a 50% ratchet, the minimum billing demand would be 250kW (500 kW times 50%) for the following eleven months, regardless of whether the actual demands were lower.

The meter recording kWh power use during either a 15- or 30-minute time window also tallies total kWh use. This meter is read at roughly monthly intervals and total power use is billed according to applicable pricing schedules. The type of energy charge pricing in common use includes:

1. **Time of day:** For example, on-peak and off-peak time periods and/or the day of the week (e.g., Monday through Friday):

These pricing schedules are generally referred to as **Time of Use** (TOU) rates.

2. **Seasonally Differentiated:** For example, the energy charge might be higher during the summer than during the winter, or vice versa.

3. **Declining Blocks:** This is typically where the energy charge to a given level is at one price and that price declines above that level. For example the energy charge might be $0.05 per kWh for the first 100,000 kWhrs used in a month and drop to $0.04 per kWh for the next 100,000 kWh.

B. Peak power station

Power plants that generally run only when there is a high demand, known peak power stations for electricity. Because they supply power only occasionally, the power supplied commands a much higher price per kilowatt hour than base load power. Peak load power plants are used in combination with base load power plants, which supply a dependable and consistent amount of electricity, meeting the minimum demand.

C. Selection of site

In general, both the construction and operation of a power plant requires the existence of some conditions such as water resources and stable soil type. Still there are other criteria that although not required for the power plant, yet should be considered because they will be affected by either the construction or operation of the plants such as population centers and protected areas.

The following list covers most of the factors that should be studied and considered in selection of proper sites for power plant construction:

Transportation network: Easy and enough access to transportation network is required in both power plant construction and operation periods.

Gas pipe network: Vicinity to the gas pipes reduces the required expenses.

Power transmission network: To transfer the generated electricity to the consumers, the plant should be connected to electrical transmission system, therefore the nearness to the electric network can play a roll.

Geology and soil type: The power plant should be built in an area with soil and rock layers that could stand the weight and vibrations of the power plant.

Earthquake and geological faults: Even weak and small earthquakes can damage many parts of a power plant intensively. Therefore, the site should be away enough from the faults and previous earthquake areas.

Topography: It is proved that high elevation has a negative effect on production efficiency of gas turbines. In addition, changing of a sloping area into a flat site for the construction of the power plant needs extra budget. Therefore, the parameters of elevation and slope should be considered.

Rivers and floodways: obviously, the power plant should have a reasonable distance from permanent and seasonal rivers and floodways.

Water resources: For the construction and operating of power plant different volumes of water are required. This could be supplied from either rivers or underground water resources. Therefore, having enough water supplies in defined vicinity can be a factor in the selection of the site.

Environmental resources: Operation of a power plant has important impacts on environment. Therefore, priority will be given to the locations that are far enough from national parks, wildlife, protected areas, etc.

Population centers: For the same reasons as above, the site should have an enough distance from population centers.

Need for power: In general, the site should be near the areas that there is more need for generation capacity, to decrease the amount of power loss and transmission expenses.

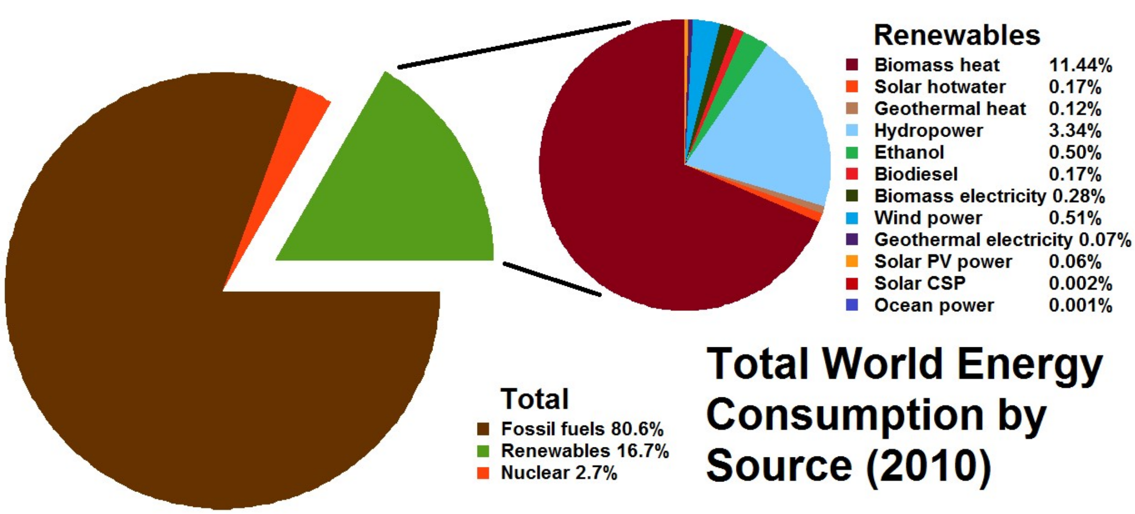
Climate: Parameters such as temperature, humidity, wind direction and speed affect the productivity of a power plant and always should be taken into account.

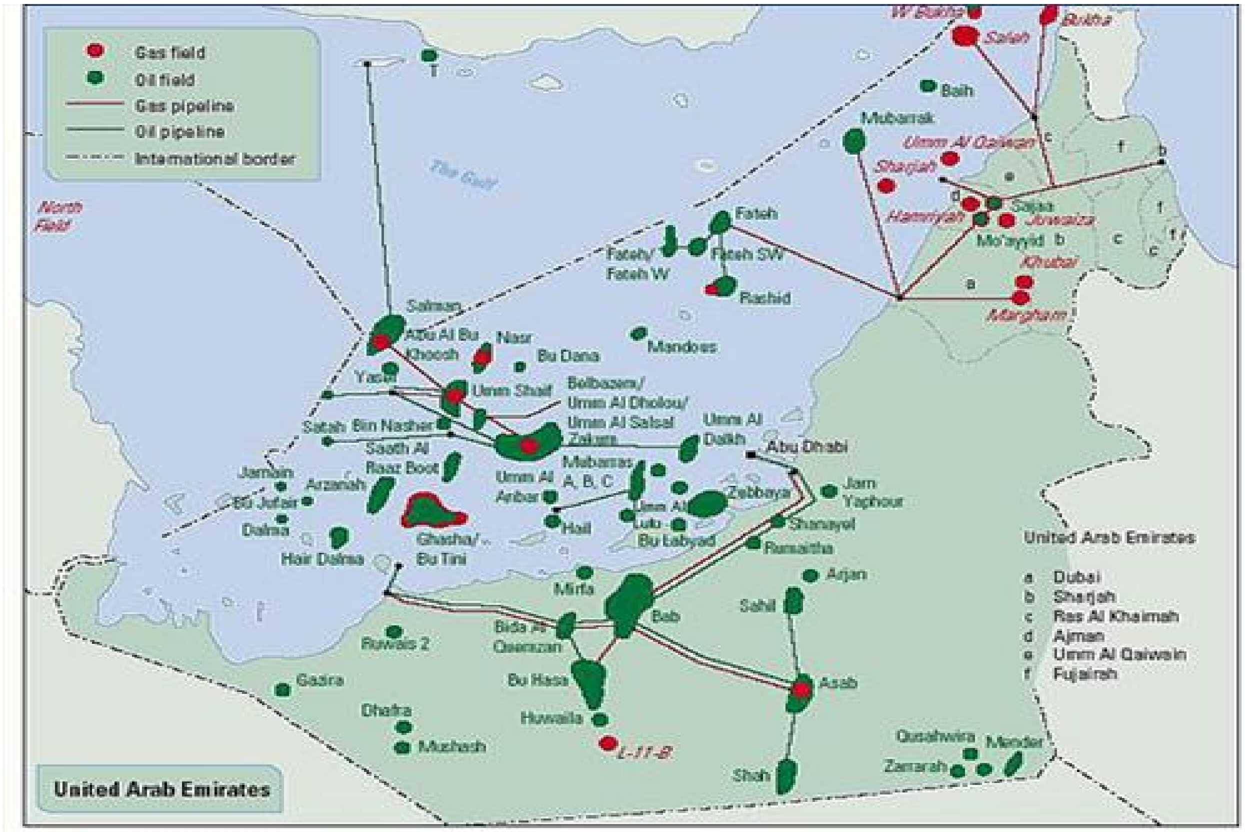
Land cover: Some land cover types such as forests, orchard, agricultural land, pasture are sensitive to the pollutions caused by a power plant. The effect of the power plant on such land cover types surrounding it should be counted for.

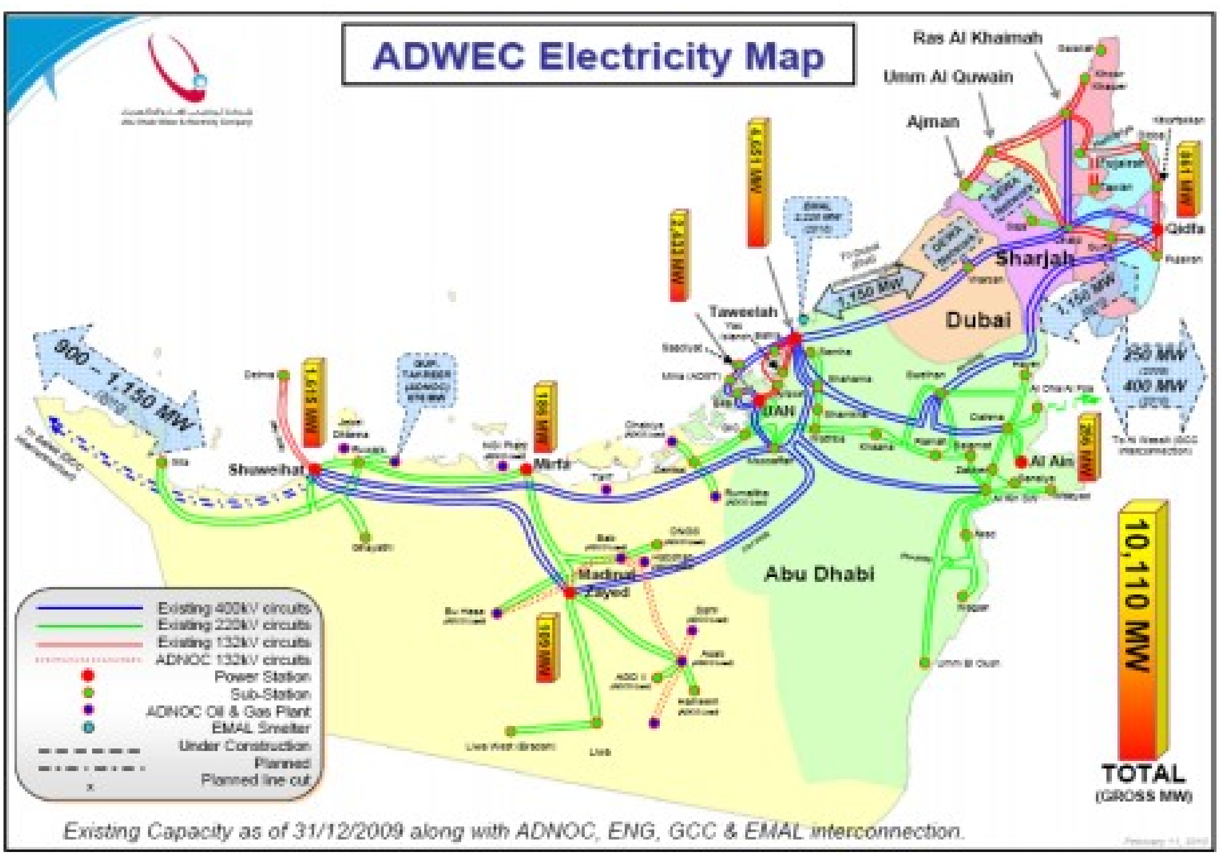
Area size: Before any other consideration, the minimum area size required for the construction of power plant should be defined.

Distance from airports: Usually, a power plant has high towers and chimneys and large volumes of gas. Consequently, for security reasons, they should be away from airports.

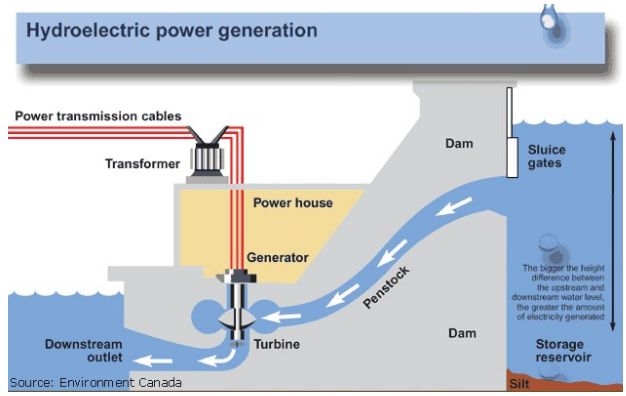
Archeological and historical sites: Usually historical building …are fragile and at same time very valuable. Therefore, the vibration caused by power plant can damage them, and a defined distance should be considered.



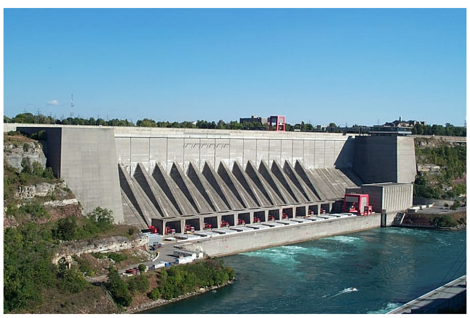

Gas field
Oil field
Gas pipeline
Oil pipeline
International border
The Gulf
North Field
Salman
Abu Al Bu Khoosh
Nasr
Bu Dana
Umm Shaif
Mandoos
Fateh
Fateh/ Fateh W
Fateh SW
Rashid
Mubarrak
Umm Al Qaiwain
Sharjah
Hamriyah
Sajaa
Jirwaiza
Mo'ayyid
Khubai
Margham
Saleh
Bukha
W Bukha
Baih
Umm Al Dalkh
Abu Dhabi
Zakum
Umm Al Salsal
Belbazem/ Umm Al Dholou/
Yasat
Satah
Bin Nasher
Saath Al Raaz Boot
Jarnain
Arzanah
Bu Jufair
Dalma
Hair Dalma
Ghasha/ Bu Tini
Umm Al Anbar
Mubarras A, B, C
Hail
Umm Al Lulu
Bu Labyad
Zabbaya
Jarn Yaphour
Shanayel
Ramaitha
Arjan
Mirfa
Bab
Sahil
Bida Al Qemzan
Ruwais 2
Gazira
Bu Hasa
Asab
Dhafra
Huwaila
Mushash
L-11-B
Shah
Qusahwira
Mender
Zarrarah
United Arab Emirates
a Dubai
b Sharjah
c Ras Al Khaimah
d Ajman
e Umm Al Qaiwain
f Fujairah
United Arab Emirates


ADWEC Electricity Map
Ras Al Khaimah
Umm Al Quwain
Ajman
Sharjah
Dubai
Abu Dhabi
Qidfa
Taweelah
Shuweihat
Mirfa
Madinat Zayed
Al Ain
900 - 1,150 MW
1,750 MW
1,150 MW
250 MW
400 MW
10,110 MW
TOTAL
(GROSS MW)
Existing 400kV circuits
Existing 220kV circuits
Existing 132kV circuits
ADNOC 132kV circuits
Power Station
Sub-Station
ADNOC Oil & Gas Plant
EMAL Smelter
Under Construction
Planned
Planned line cut
Existing Capacity as of 31/12/2009 along with ADNOC, ENG, GCC & EMAL interconnection.

D. Hydraulic power plants



Hydroelectric Power -- what is it? It=s a form of energy … a renewable resource. Hydropower provides about 96 percent of the renewable energy in the United States. Other renewable resources include geothermal, wave power, tidal power, wind power, and solar power. Hydroelectric powerplants do not use up resources to create electricity nor do they pollute the air, land, or water, as other powerplants may. Hydroelectric power has played an important part in the development of this Nation's electric power industry. Both small and large hydroelectric power developments were instrumental in the early expansion of the electric power industry. Hydroelectric power comes from flowing water … winter and spring runoff from mountain streams and clear lakes. Water, when it is falling by the force of gravity, can be used to turn turbines and generators that produce electricity.



The power that can be extracted from a waterfall depends on height and rate of flow. the size and physical location of a hydropower station depends therefore on these two factors. The available hydro power can be calculated by the equation:

$P = 9.8\ q\ h$

P = available water power [kW]

q = water rate of flow [m3/s]

h = head of waterfall [m]

9.8 = coefficient to take care of units

E. Nuclear power plants

The development of a peaceful, civilian nuclear energy program was based on an in-depth evaluation of the UAE’s future energy needs. An initial study determined that national annual peak demand for electricity is likely to rise to more than 40,000 megawatts by 2020, reflecting a cumulative annual growth rate of about 9% from 2007.

Even with adjustments to account for the worldwide economic slowdown, the projected demand is well beyond current capacity.

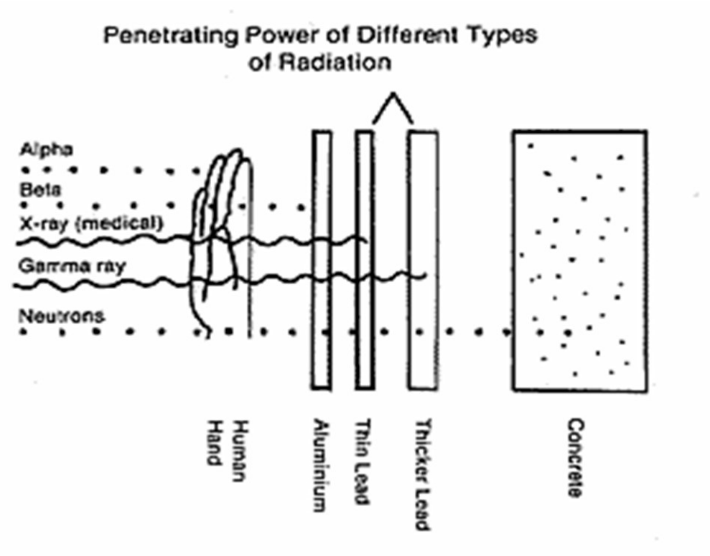
The UAE then studied options to meet this demand. This evaluation was wide-ranging and determined that:

- Natural gas that could be made available to the nation's electricity sector would be insufficient to meet future demand.
- The burning of liquids (crude oil and/or diesel) would be logistically viable but costly and environmentally harmful.
- Coal-fired power generation, while potentially cheaper, would be environmentally unacceptable, and potentially vulnerable from a security of supply standpoint.
- And finally, deployment of renewable and other alternative energy supplies, while desirable, would be able to supply only 6 to 7% of the required electricity generation capacity by 2020.

Despite the excitement that the word "nuclear" causes, a power plants that depends on atomic (Nuclear) energy operates in more or less the same way as a typical coal (or oil)-burning power plant. Both power plants heat water into pressurized steam, which drives a turbine generator. The key difference between the two plants is the method of heating the water.

While traditional steam thermal power plants burn fossil fuels, such as oil or gas, nuclear power plants generate heat from Nuclear fission. Nuclear fission occurs when one atom splits into two, or more, parts. This process releases energy (heat) and radiation. Nuclear fission happens naturally every day. Uranium, for example, constantly undergoes spontaneous fission at a very slow rate. This is why Uranium is radioactive, and why it is a natural choice for the induced fission that nuclear power plants require.

One of the major discoveries of modern physics is that the shorter the wave length of any wave radiation, the more energy each unit of it carries. Hence, X-rays and gamma rays are enormously more energetic than light. They penetrate much farther into all kinds of matter, and they produce much larger effects.



In addition to waves, atoms are now known to radiate a great deal of particles. These are all unimaginably tiny (measured in 100-trillionths of an inch,) unimaginably light, and known to us only indirectly through their effects. Some of the more important particles are: electrons, protons, neutron, alpha . . Etc.

Uranium found in nature consists largely of two isotopes, U-235 and U-238. Natural raw Uranium contains about 99.3% of the U-238 isotope, which does not contribute to the fission process. It only contains 0.7% of the U-235 isotope which is fissionable

The production of energy in nuclear reactors is from the 'fission' or splitting of the U-235 atoms.

Most reactors are Light Water Reactors and require the uranium to be enriched from 0.7% to 3% - 5% U-235 in their fuel.

Uranium Ore (0.7%)

Fuel Pellet (3.5%)

- **Most nuclear electricity is generated using just two kinds of reactors which were developed in the 1950s and improved since.**
- **New designs are coming forward and some are in operation as the first generation reactors come to the end of their operating lives.**
- **Around 13% of the world's electricity is produced from nuclear energy, more than from all sources worldwide in 1960.**

F. Wind energy

Wind is a form of **solar energy**. Winds are caused by the uneven heating of the atmosphere by the sun, the irregularities of the earth's surface, and rotation of the earth. Wind flow patterns are modified by the earth's terrain, bodies of water, and vegetative cover. This wind flow, or motion energy, when "harvested" by modern **wind turbines**, can be used to generate **electricity**.

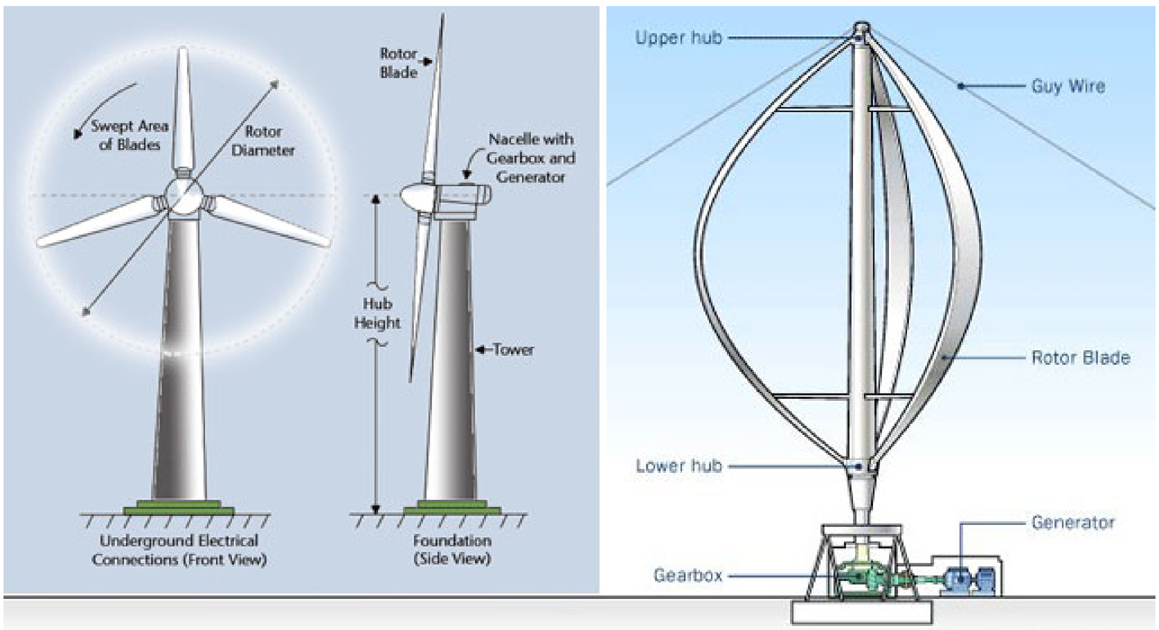
How Wind Power Is Generated?

The terms "**wind energy**" or "**wind power**" describe the process by which the wind is used to generate **mechanical power or electricity**. Wind turbines convert the kinetic energy in the wind into mechanical power. This mechanical power can be used for specific tasks (such as grinding grain or pumping water) or a generator can convert this mechanical power into electricity to power homes, businesses, schools, and the like.

Wind turbines, like aircraft propeller blades, turn in the moving air and power an **electric generator** that supplies an electric current. Simply stated, a wind turbine is the opposite of a fan. Instead of using electricity to make wind, like a fan, wind turbines use wind to make electricity. The wind turns the blades, which spin a shaft, which connects to a generator and makes electricity.

Wind Turbine Types

Modern wind turbines fall into two basic groups; the **horizontal-axis** variety, like the traditional farm windmills used for pumping water, and the **vertical-axis** design, like the eggbeater-style Darrieus model, named after its French inventor. Most large modern wind turbines are horizontal-axis turbines.



G. Comparison of the five sources of energy:

This table shows a comparison of the five sources of energy (Note that there is other source of energy as: +Geothermal energy, Tidal energy, Wave energy)

Solid Fuels	**Liquid Fuels**
Cheap	Expensive
Minimal odors	unpleasant odors
Requires simple burners	requires sophisticated burners
No climate constraints	Cold climates need regulation

Particulars	solar power	Wind power	Hydro power	Fuel power	Nuclear power
Initial cost	High	High	High	Lowest	Highest
Running cost	High	High	Low	Highest	Least
Reserves	Day time only	permanent	permanent	limited	abundant
Cleanliness	High	High	Highest	Lowest	Low
Simplicity	complex	complex	simplest	complex	Most complex
Reliability	Low	Low	Highest	Low	High

Note that: Fuel is the in the form of solid and Liquid

Solid: wood, charcoal, peat, coal, Hexamine fuel tablets, wood pellets, corn, wheat, rye

Liquid: Petroleum (Gasoline, Diesel, Kerosene), Natural gas (Compressed natural gas

Liquefied petroleum gas (LPG)), Synthetic fuel, Biodiesel, Ethanol and methanol, Liquid hydrogen