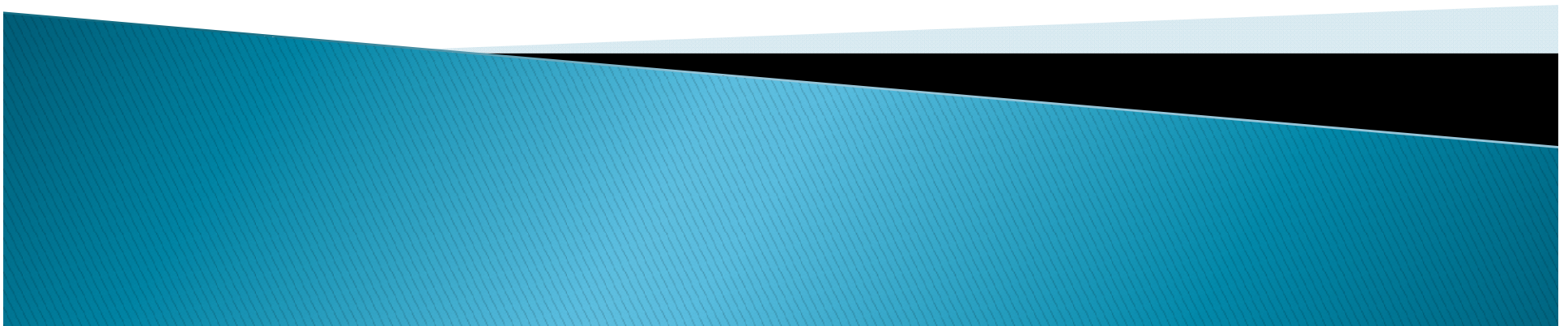


Renewable Energy Systems

EE—325



Energy Budget of the Earth

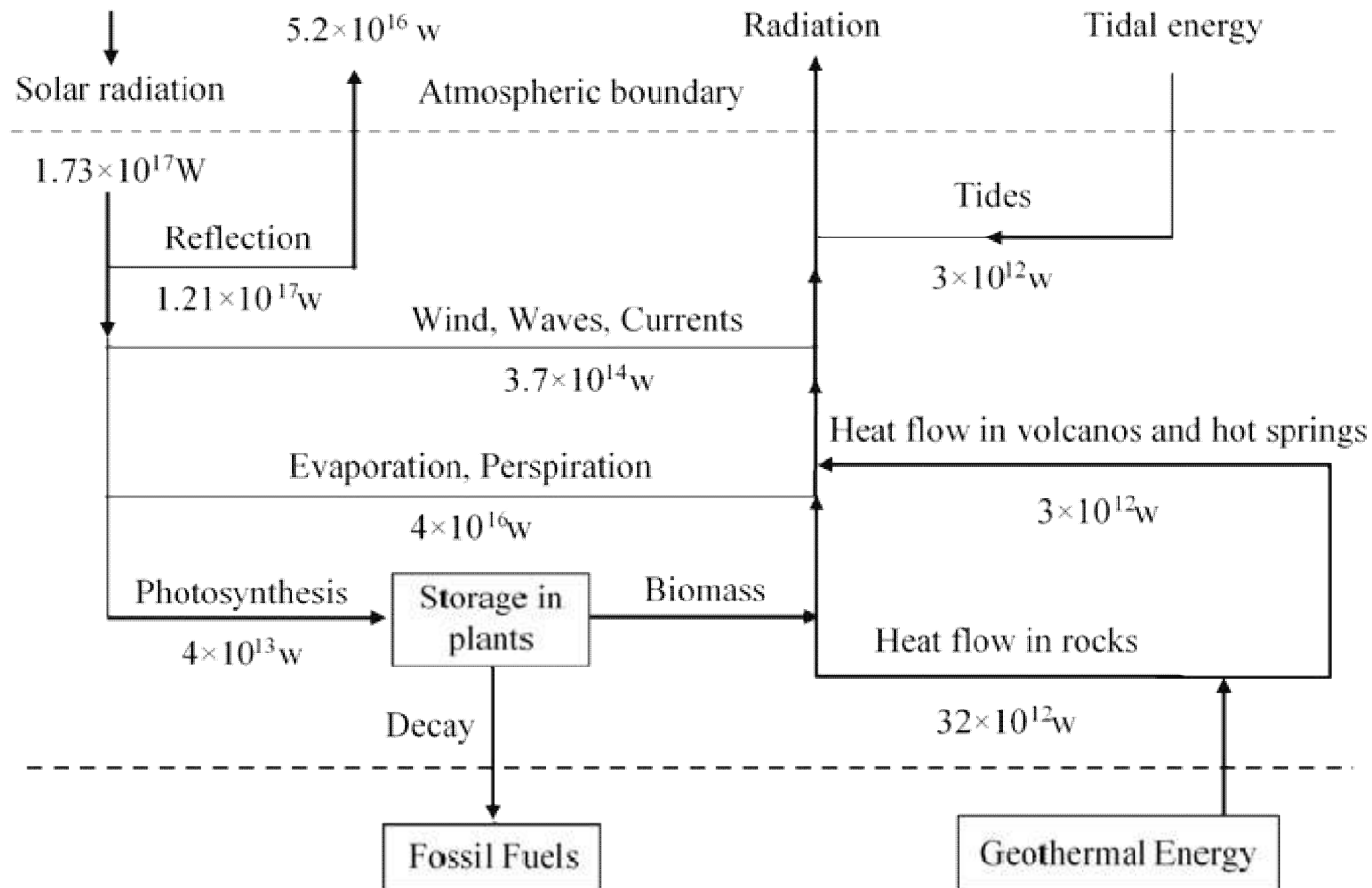


Figure 1.1. Energy Flow Diagram [2].

Energy Budget of Earth

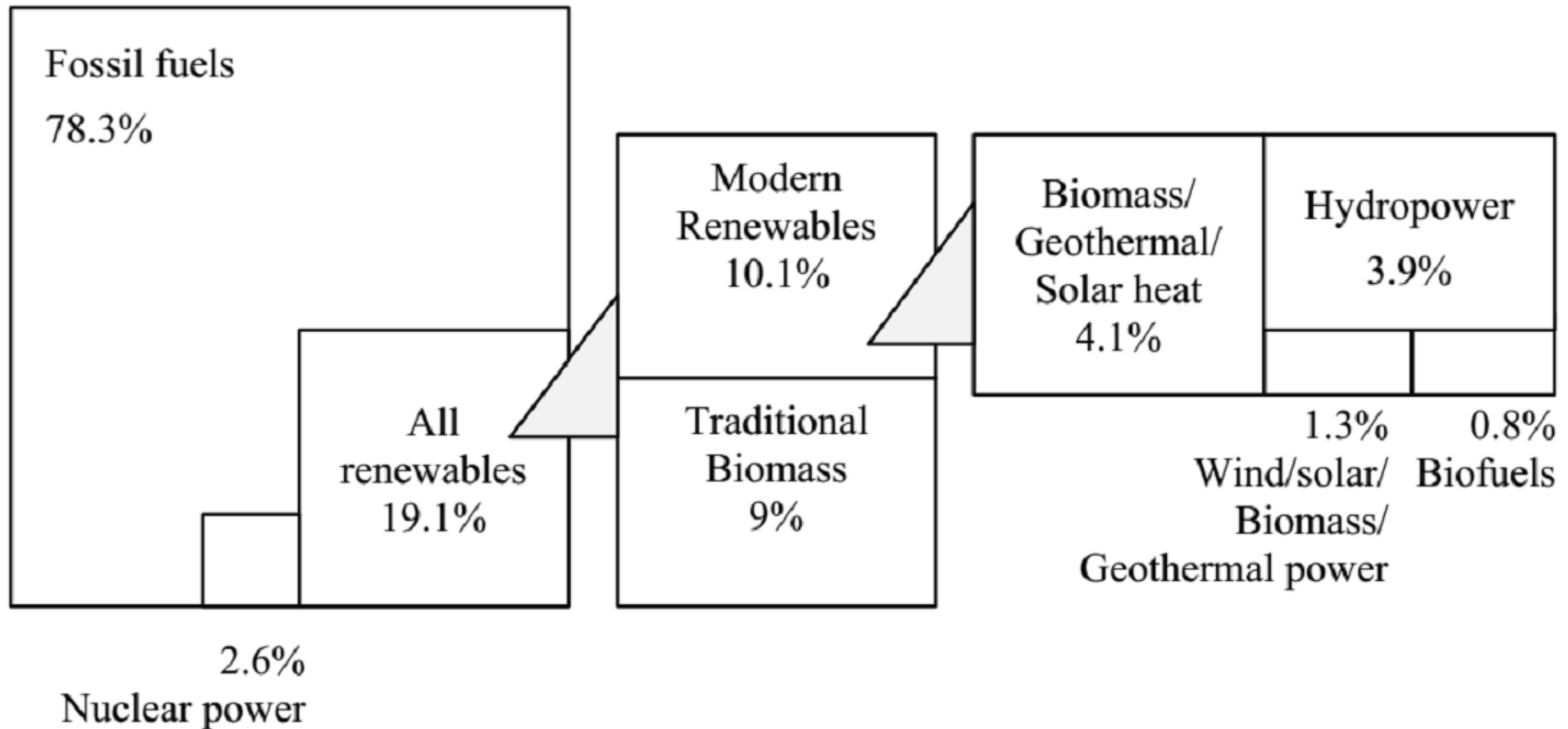


Figure 1.2. Per cent contribution to world energy, 2013 [3].

Electricity Production Processes

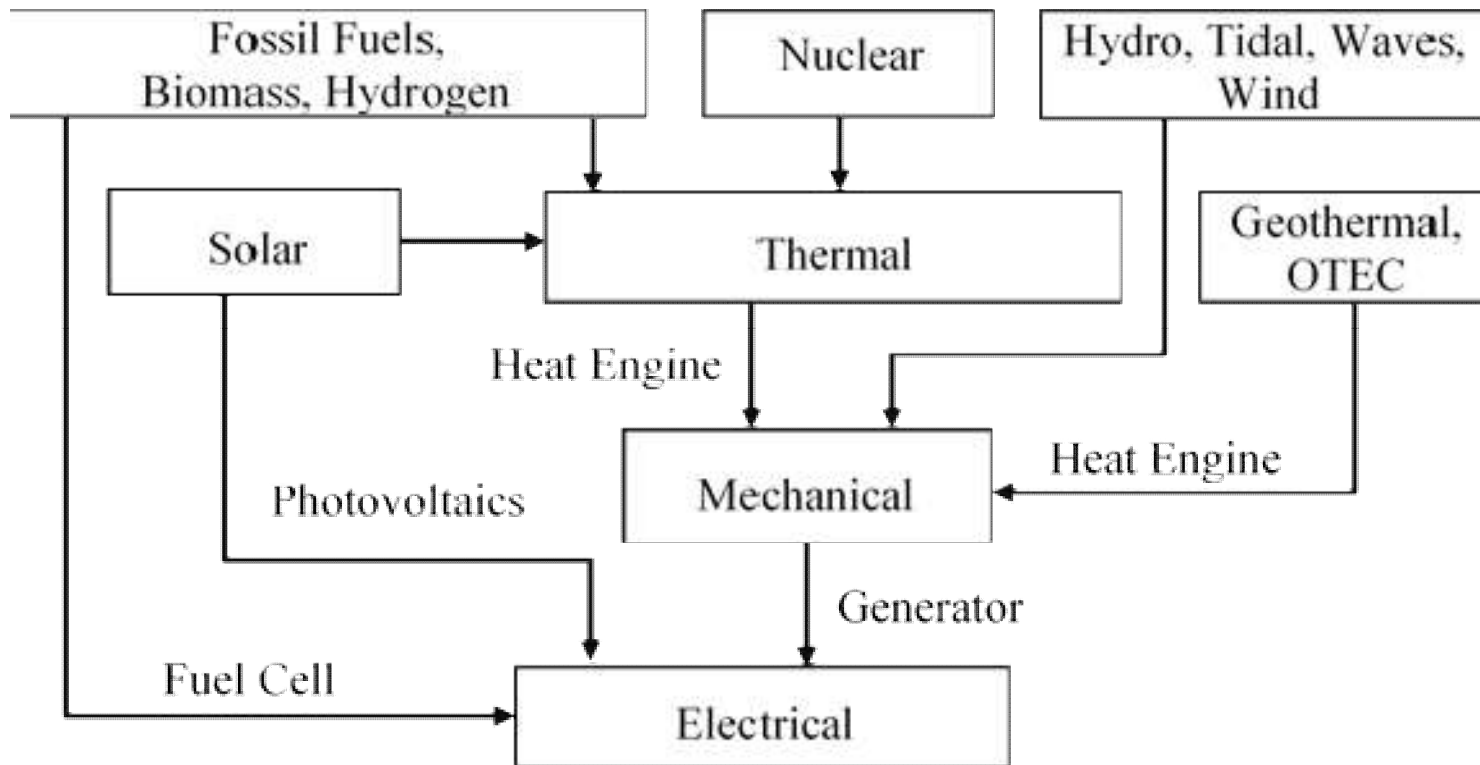
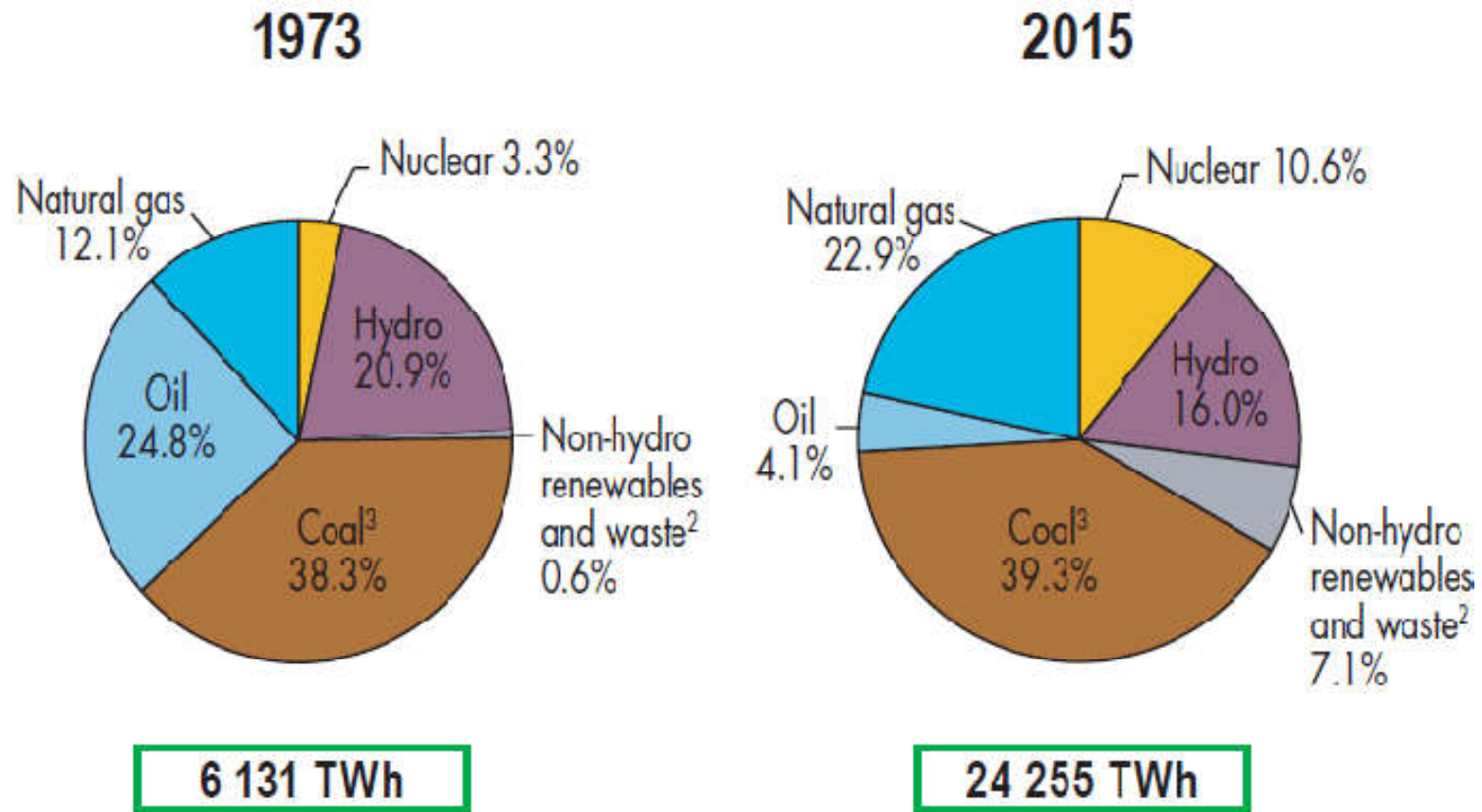


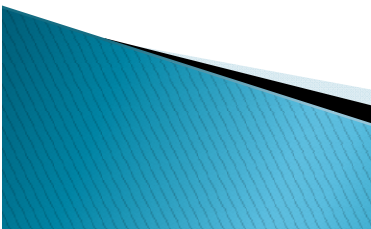
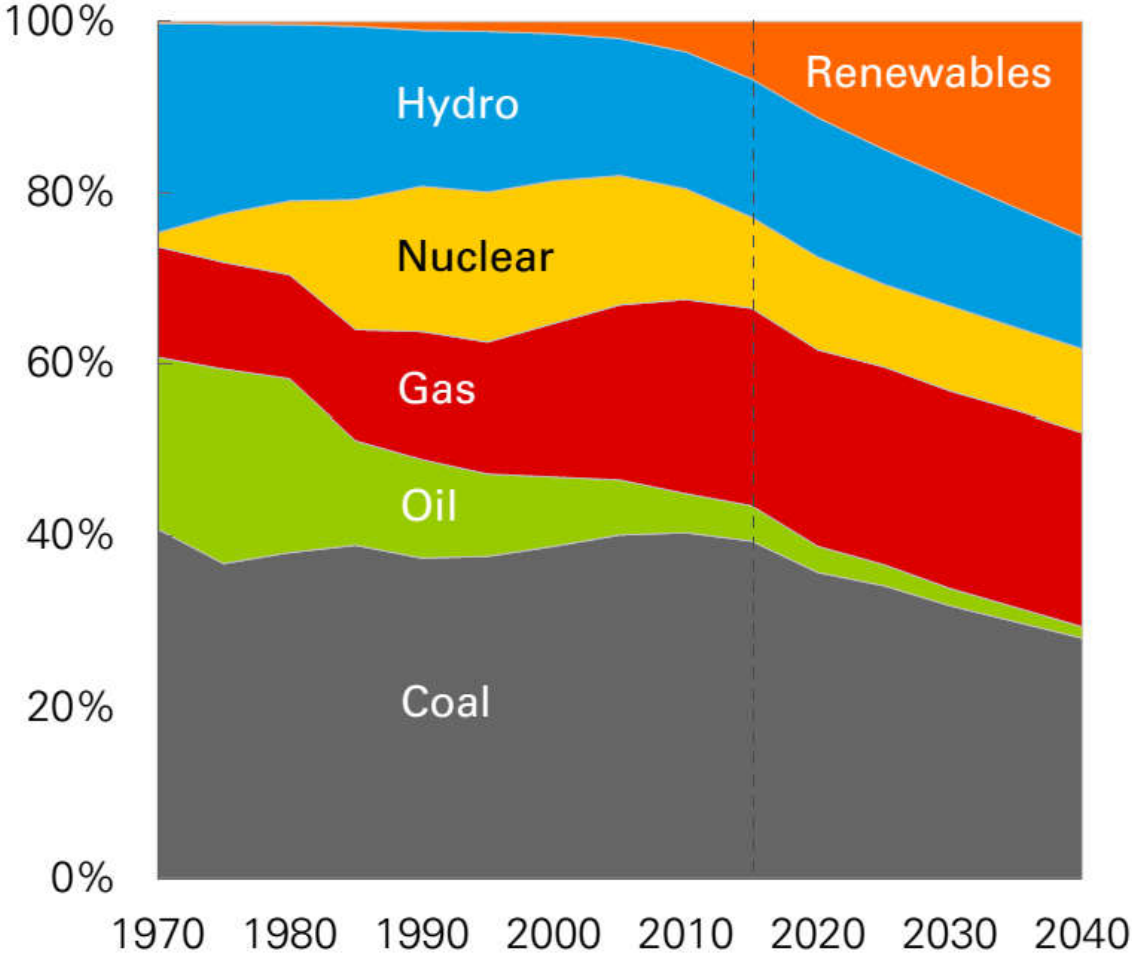
Figure 1.4. Conversion from a variety of energy forms into electricity.

World Electricity by Source



2. Includes geothermal, solar, wind, tide/wave/ocean, biofuels, waste, heat and other.
3. In these graphs, peat and oil shale are aggregated with coal.

Historical Development



Pakistan's energy Mix

Table 1.8. Pakistan installed capacity in MW and energy mix [19].

As on 30th June	2012	2013	2014	2015	2016
Hydel					
WAPDA Hydel	6,516	6,733	6,902	6,902	6,902
IPPs Hydel	214	214	214	214	214
Sub-Total	6,730	6,947	7,116	7,116	7,116
% Share (Hydel Installed Capacity)	28.65	29.28	30.02	28.51	28.04
Thermal					
GENCOs with PEPCO	4,785	4,785	4,590	5,762	5,762
K-EL Own	2,381	2,359	1,951	1,874	1,874
IPPs					
Connected with PEPCO	8,312	8,342	8,700	8,696	8,696
Connected with K-EL	252	252	252	252	252
CPPs/SPPs connected with K-EL	239	203	200	35	35
Sub-Total	15,969	15,941	15,693	16,619	16,619
% Share (Thermal Installed Capacity)	67.99	67.19	66.21	66.58	65.50
Nuclear					
CHASNUPP (I&II)	650	650	650	650	650
KANUPP	137	137	137	137	137
Sub-Total	787	787	787	787	787
% Share (Nuclear Installed Capacity)	3.35	3.32	3.32	3.15	3.10
Renewable Energy (Wind, Solar & Bagasse)					
RE Power Plants connected with PEPCO	1	50	106	439	852
Sub-Total	1	50	106	439	852
% Share (RE Installed Capacity)	0.00	0.21	0.45	1.76	3.36
Total Installed Capacity of the Country	23,487	23,725	23,702	24,961	25,374

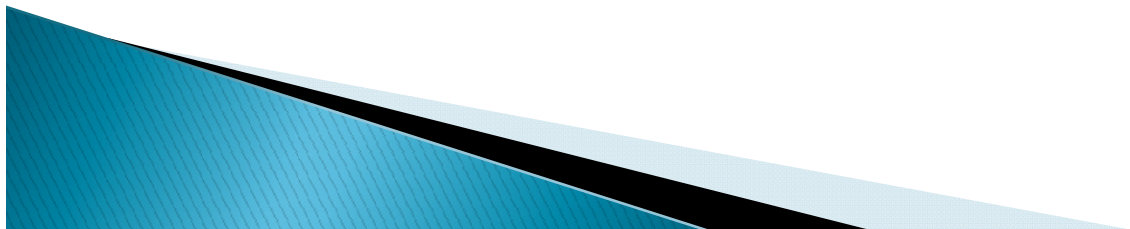
Pakistan: RE Installed Capacity

Power Station	Primary Fuel	Alternate Fuel	2011-12	2012-13	2013-14	2014-15	2015-16
F: Renewable Energy (connected with PEPCO system)							
Zorlu Enerji Pakistan	Wind	Wind	6	32	134	156	166
FFC Energy	Wind	Wind	0	0	129	139	135
Three Gorges First Wind Farm	Wind	Wind	0	0	0	80	149
Foundation Wind Energy-I	Wind	Wind	0	0	0	27	115
Foundation Wind Energy-II	Wind	Wind	0	0	0	56	123
Quaid-e-Azam Solar Park	Solar	Solar	0	0	0	26	158
Jamal Din Wali-II	Bagasse + Biomass		0	0	9	163	159
Jamal Din Wali-III	Bagasse + Biomass		0	0	0	132	151
Rahim Yar Khan Mills	Bagasse	Bagasse	0	0	0	32	77
Chiniot Power	Bagasse	Bagasse	0	0	0	0	169
Sapphire Wind	Wind	Wind	0	0	0	0	98
Appolo Solar	Solar	Solar	0	0	0	0	29
Best Green Solar	Solar	Solar	0	0	0	0	10
Crest Solar	Solar	Solar	0	0	0	0	10
Total Renewable Energy (connected with PEPCO system) (F)			6	32	272	811	1,549

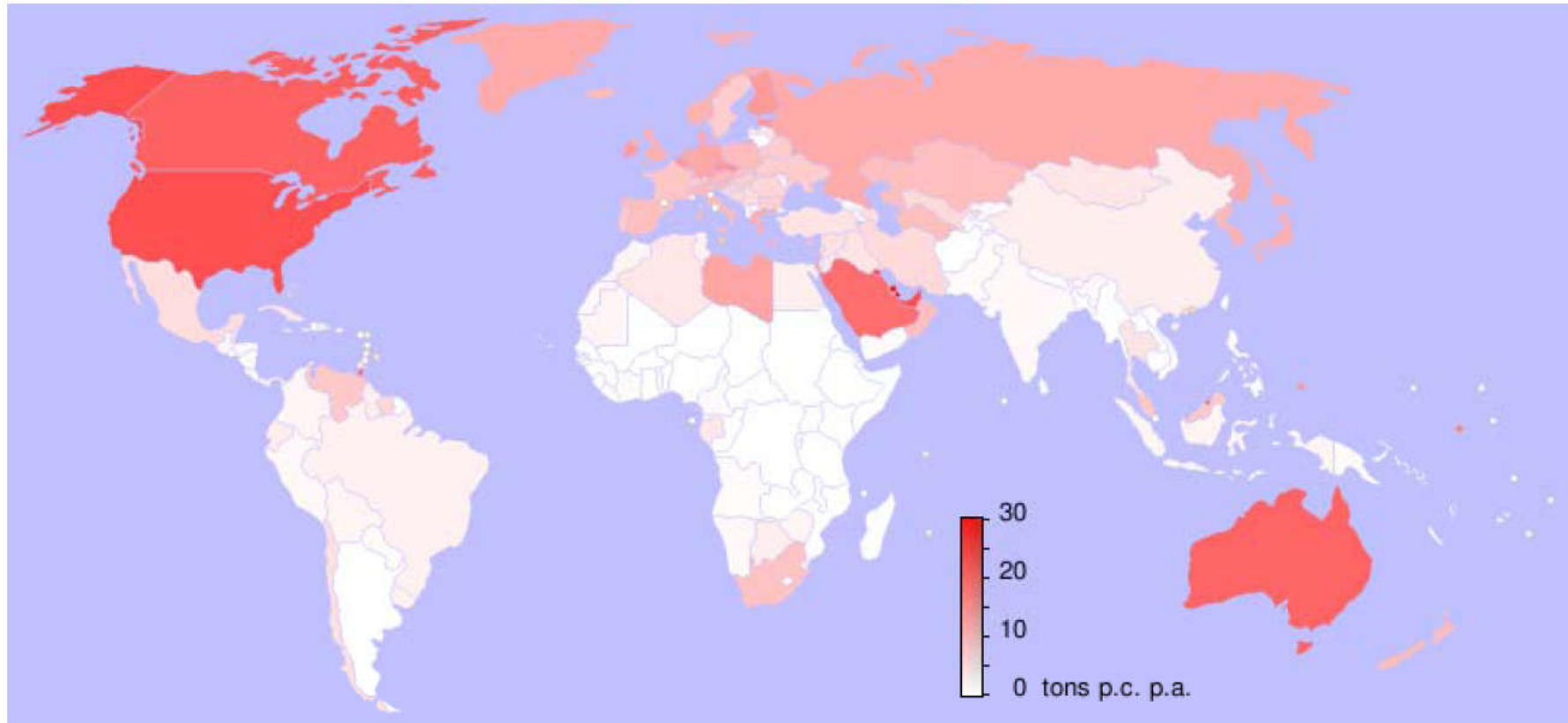
Environmental Issues

Table 1.7. Lifecycle GHG emissions from various generation technologies [18].

Technology	Tones CO _{2e} /GWh		
	Mean	Low	High
Lignite	1,054	790	1,372
Oil	733	547	935
Natural Gas	499	362	891
Solar PV	85	13	731
Biomass	45	10	101
Nuclear	29	2	130
Hydroelectric	26	2	237
Wind	26	6	124



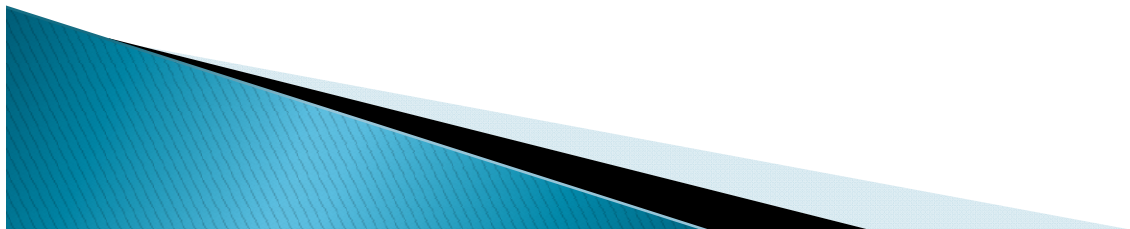
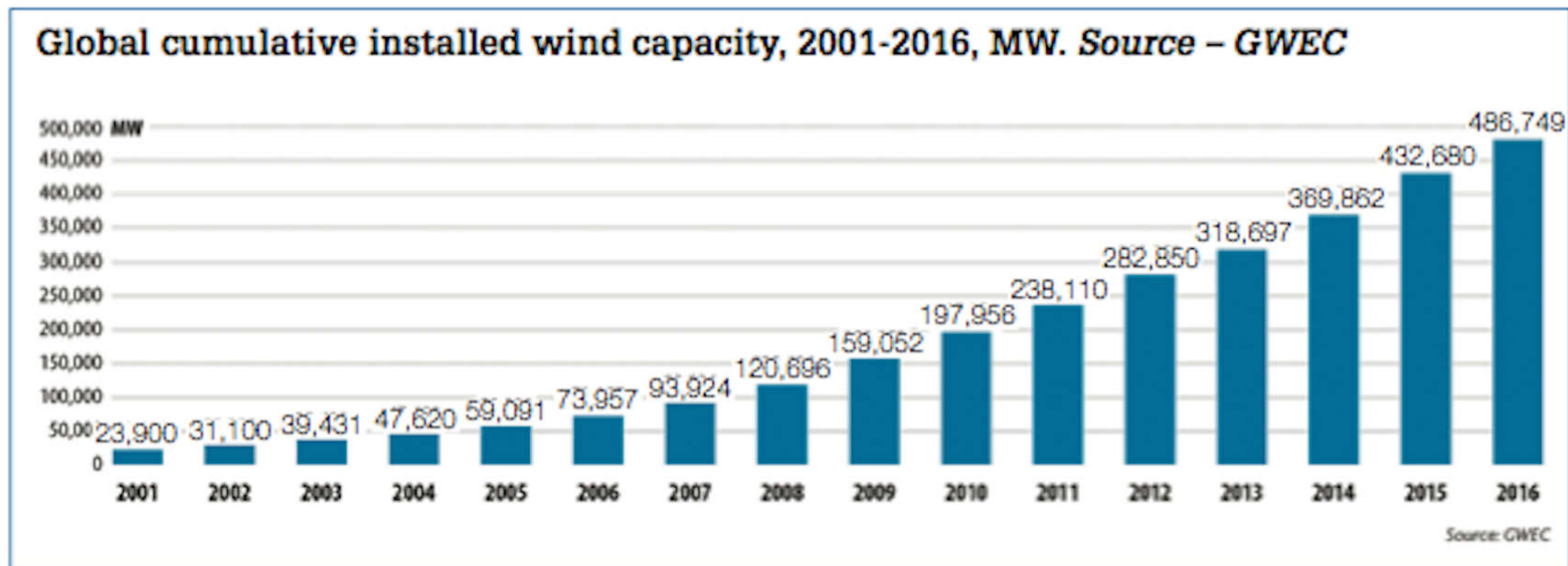
CO₂ Emissions Per Capita, 2004



This map illustrates per capita carbon dioxide emissions (in tons) at a country-level. The highest per capita emissions are found in the U.S., followed by Canada, Australia, and Saudi Arabia. Alternatively, most countries in Africa, Asia, and South America depict low per capita carbon emissions.

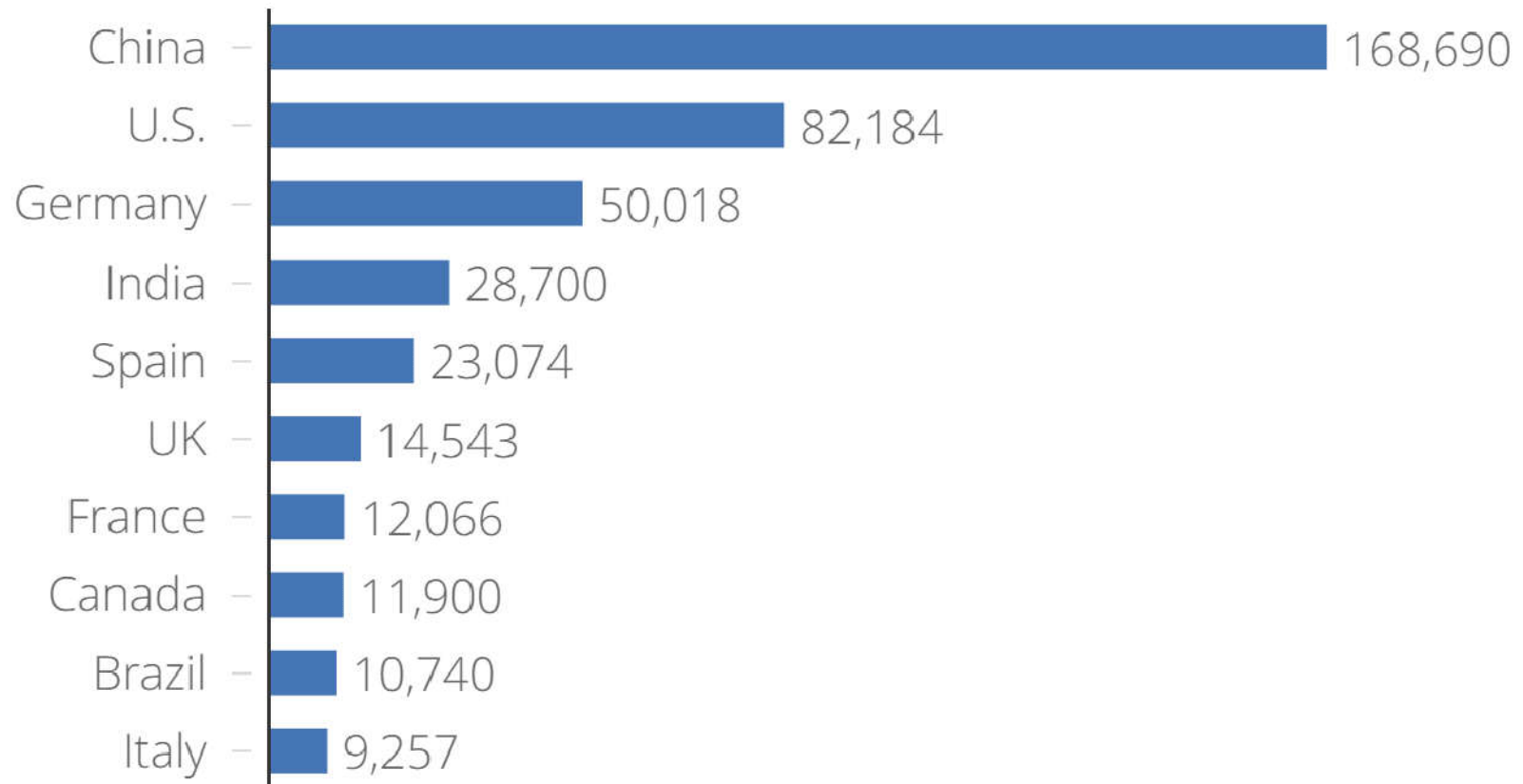
Data from the US Department of Energy's Carbon Dioxide Information Analysis Center

Global Cumulative Installed Wind Capacity



Top 10 Installed Wind Capacity

Top 10 Cumulative Installed Capacity at the End of 2016 (in MW)



Win Power Potential of Pakistan

Wind Potential

- Wind Potential: 346,000 MW
- Gharo-Keti Bandar wind corridor (60 KM along the coastline and more than 170 km deep towards the land) alone has a potential of approx. 50,000 MW.



Pakistan Renewable Energy Potential

Renewable Energy Potential

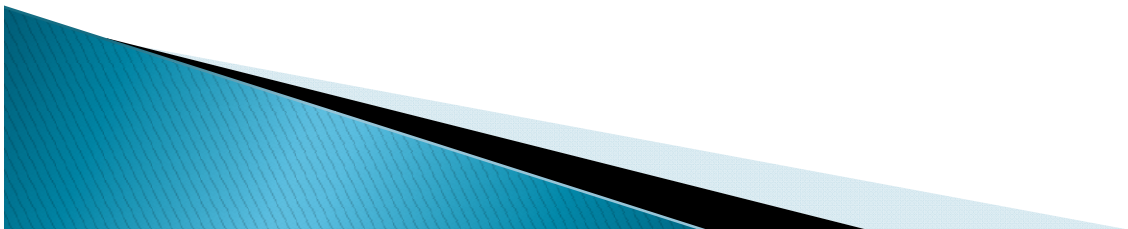
Solar	2.9 Million MW
Bagasse Cogeneration	1,800 MW
Waste to Power	500 MW
Mini & Small Hydel	2,000 MW

Source: Alternative Energy Development Board (AEDB)

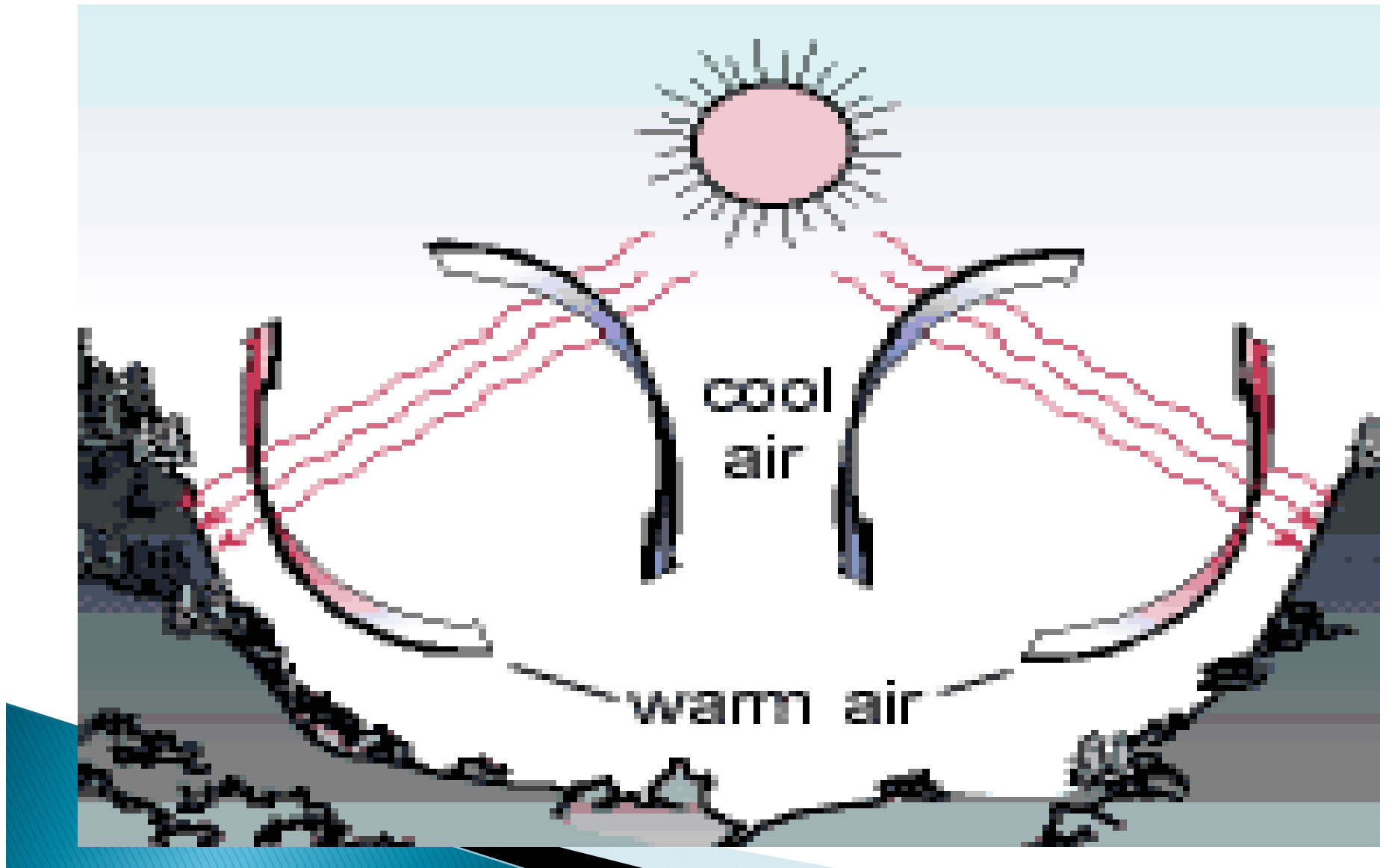


Wind Energy

- All renewable energy (except tidal and geothermal power), ultimately comes from the sun
- The earth receives 1.74×10^{17} watts of power from the sun
- About one or 2 percent of this energy is converted to wind energy (which is about 50-100 times more than the energy converted to biomass by all plants on earth)
- Wind turbines convert the kinetic energy of the wind into mechanical energy first, and then into electricity if needed.



Where Does the Wind Come From?



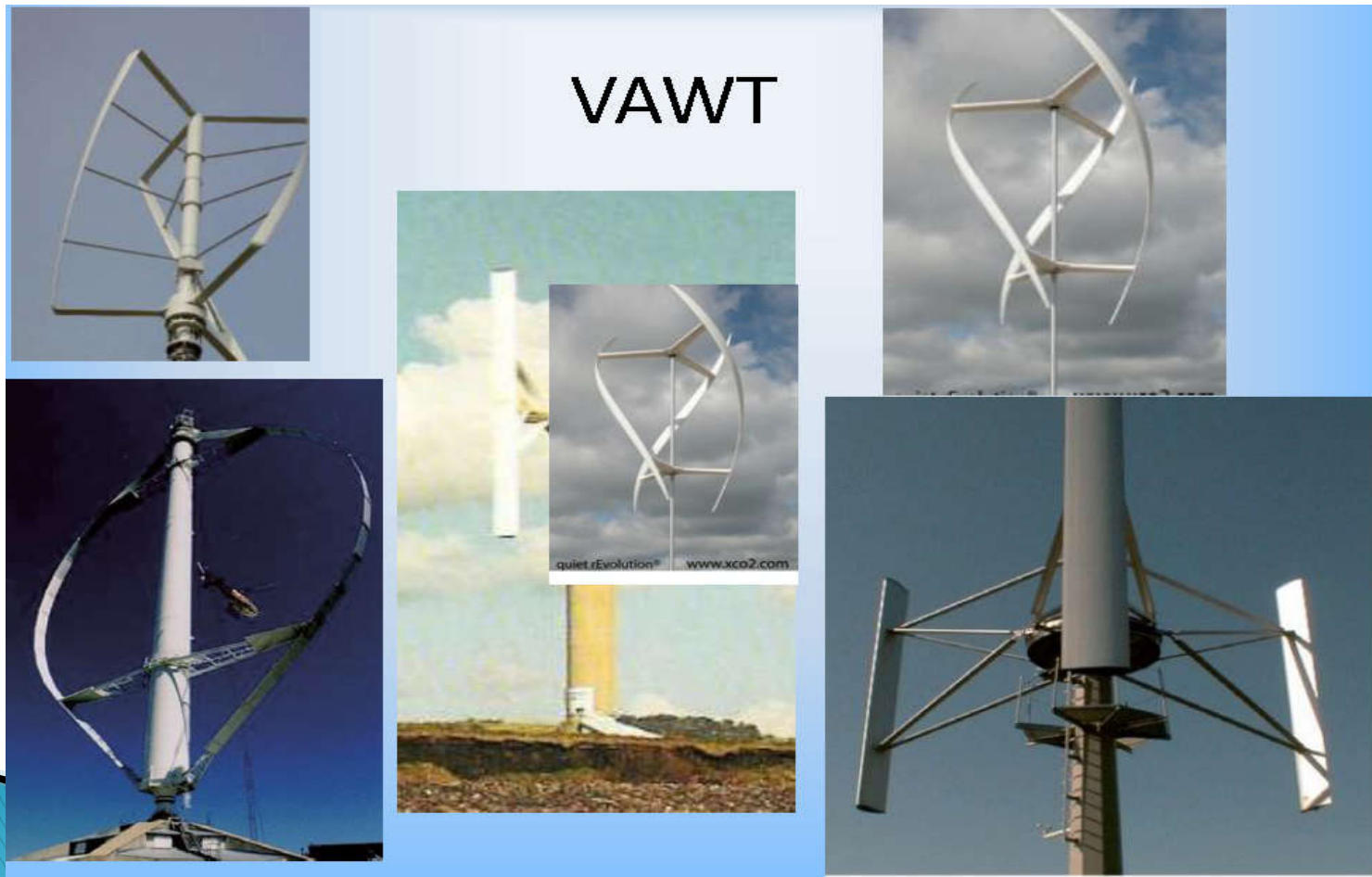
Wind Turbine Design

Horizontal Axis Lift Force Turbines (HAWT)

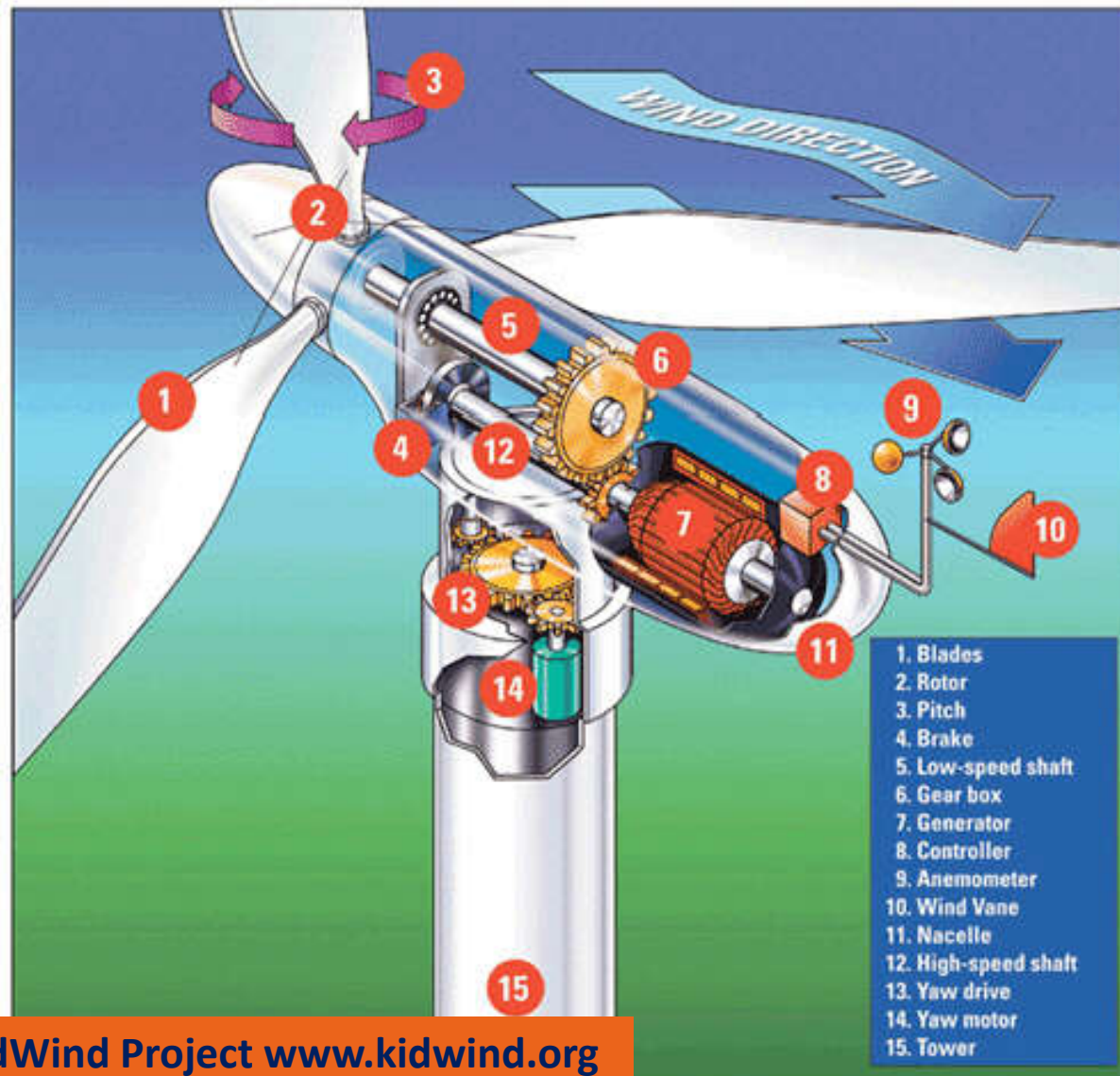


Wind Turbine Design

Vertical Axis Lift-Force Turbines (VAWT)



Wind Turbine Components



Source: The KidWind Project www.kidwind.org

Brief History of Windmills

- ▶ One significant development of 18th century was the introduction of scientific testing and evaluation of windmills.
- ▶ An Englishman, Johan Smeaton, discovered three basic principles for windmills which are still applicable:

Speed of blade tip is ideally proportional to speed of wind

The maximum torque is proportional to square of wind speed

The maximum power is proportional to the cube of wind speed.

- ▶ 18th century European windmills represented culmination of one approach to using wind for mechanical power and included a number of features which were later incorporated into some early electricity generating wind turbines



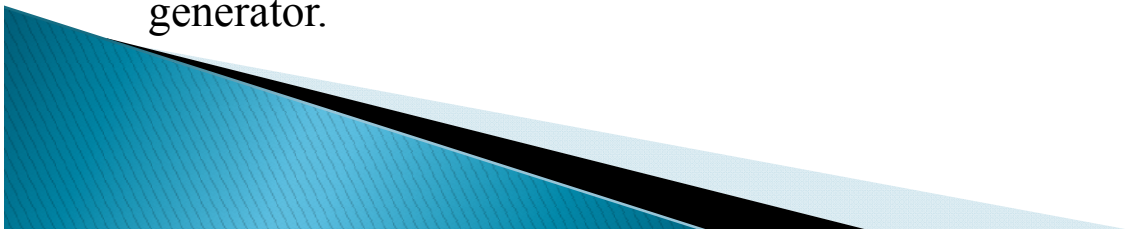
Brief History of Windmills

- ▶ When European wind mills were entering their final years, another type of windmills came into widespread use in USA for pumping water. These mills had
 - Multiple blades also known as fan type
 - Effective regulating system



Early Wind Generation of Electricity

- ▶ First wind turbine to generate electricity was developed in 1888 in USA.
- ▶ By the middle of last century around 6 million windmills were in operation in USA for mechanical power and decentralized electricity.
- ▶ When the central grid reached every farm, at the beginning of 20th century in USA, the use of electricity produced by the windmills reduced
- ▶ In Denmark between 1891 and 1918 more than 100 electricity generating turbines of 20-35kW size were built. The electricity generated was used for the production of hydrogen as fuel.
- ▶ Just after world war-II, 200 kW Gedser turbine with three blades was erected in Denmark. It used aerodynamic stall for power control replaced the synchronous generator with induction generator.



Early Wind Generation of Electricity

- ▶ A two blade turbine (Smith-Putnam Machines) of diameter 53.3 meter with power rating of 1.25 MW was developed in 1930s. It suffered a blade failure in 1945 and the project was abandoned.



Danish Geoswift



Smith-Putnam achine

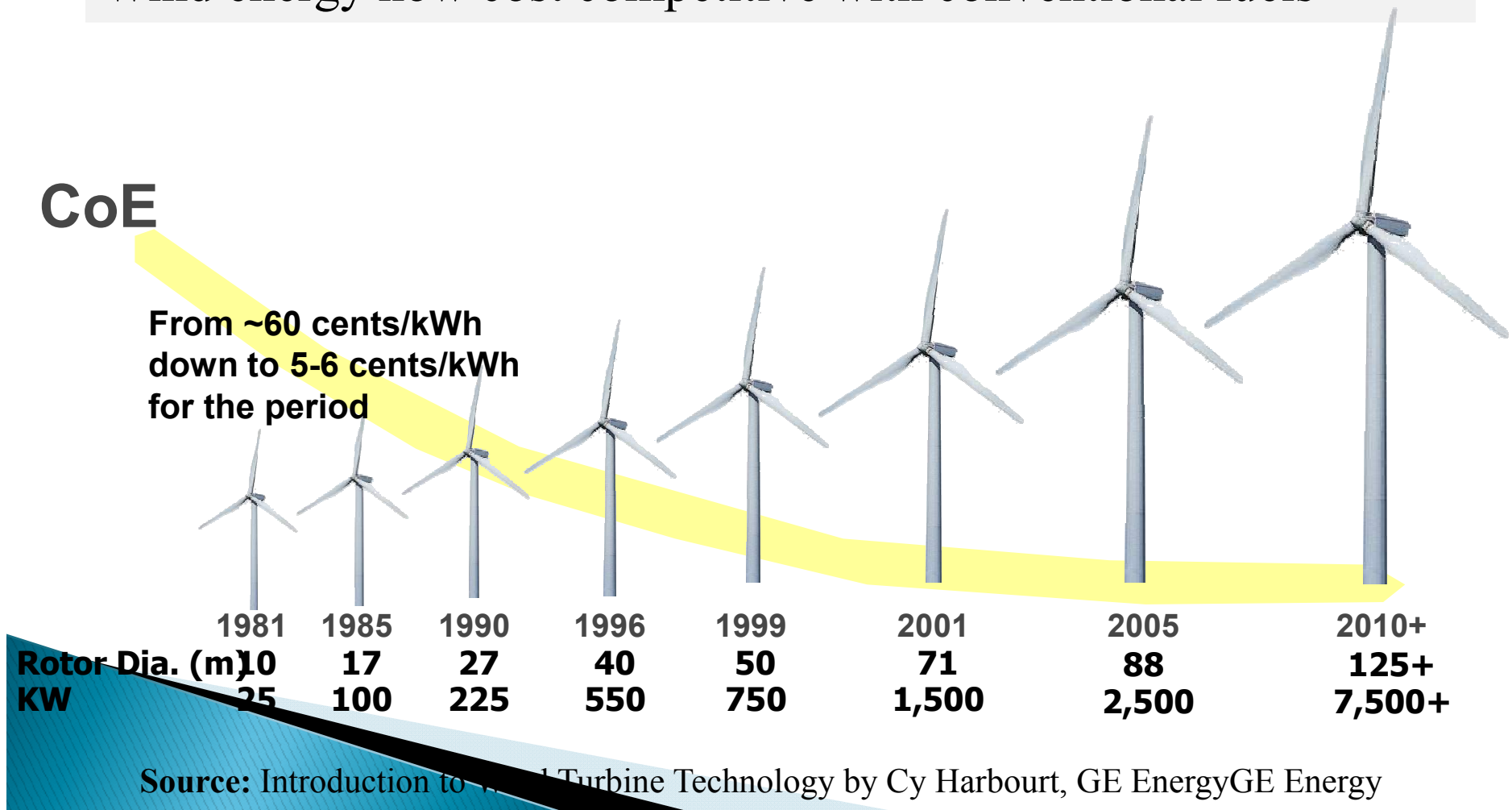
The Re-emergence of Wind Energy

- ▶ In late 1960's global warming concerns and continued apprehension about Nuclear power resulted in a strong demand for wind generation.
- ▶ Field of wind energy blossomed in 1970's after oil crisis with large infusion of research money in USA, Denmark and Germany to find alternative sources of energy.
- ▶ By the early 1980s the incentives for alternative sources of energy vanished in USA. But with the continued investment until recently, Europe led in terms of technology and wind capacity installations.
- ▶ The twenty first century has seen some of the major European suppliers of wind turbines have established their manufacturing facilities to China, India, and USA.
- ▶ In recent times the size of wind turbines has increased from 25kW to 6 MW with machines up to 10MW under design.



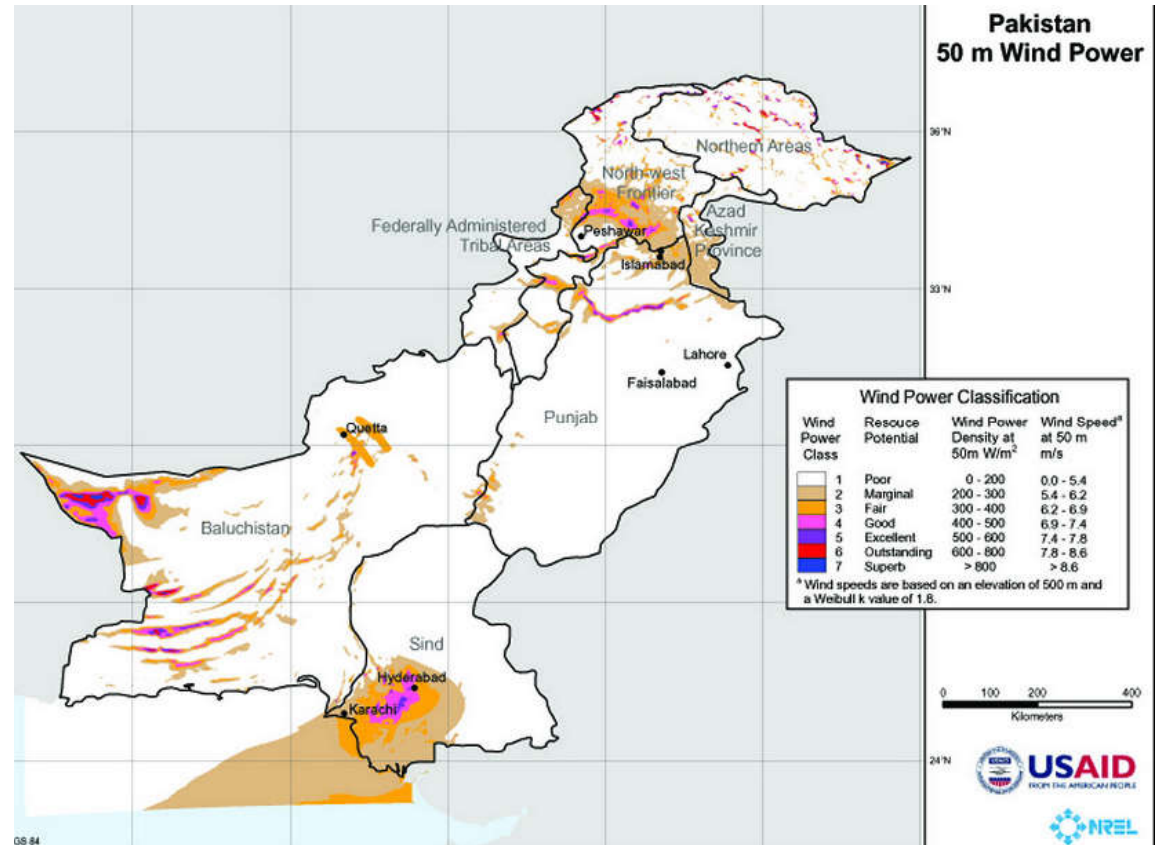
The Re-emergence of Wind Energy

Increased size, improved performance and technology innovation
Wind energy now cost competitive with conventional fuels



Wind Power in Pakistan

- According to a recent USAID report Pakistan, has the potential of producing approximately 150,000MW of wind energy
- The first 50MW energy wind power project started working in Jhimpir, Sindh in December 2012.



- The government plans to achieve up to 2,500MW from wind energy by the end of 2015

Wind Power in Pakistan

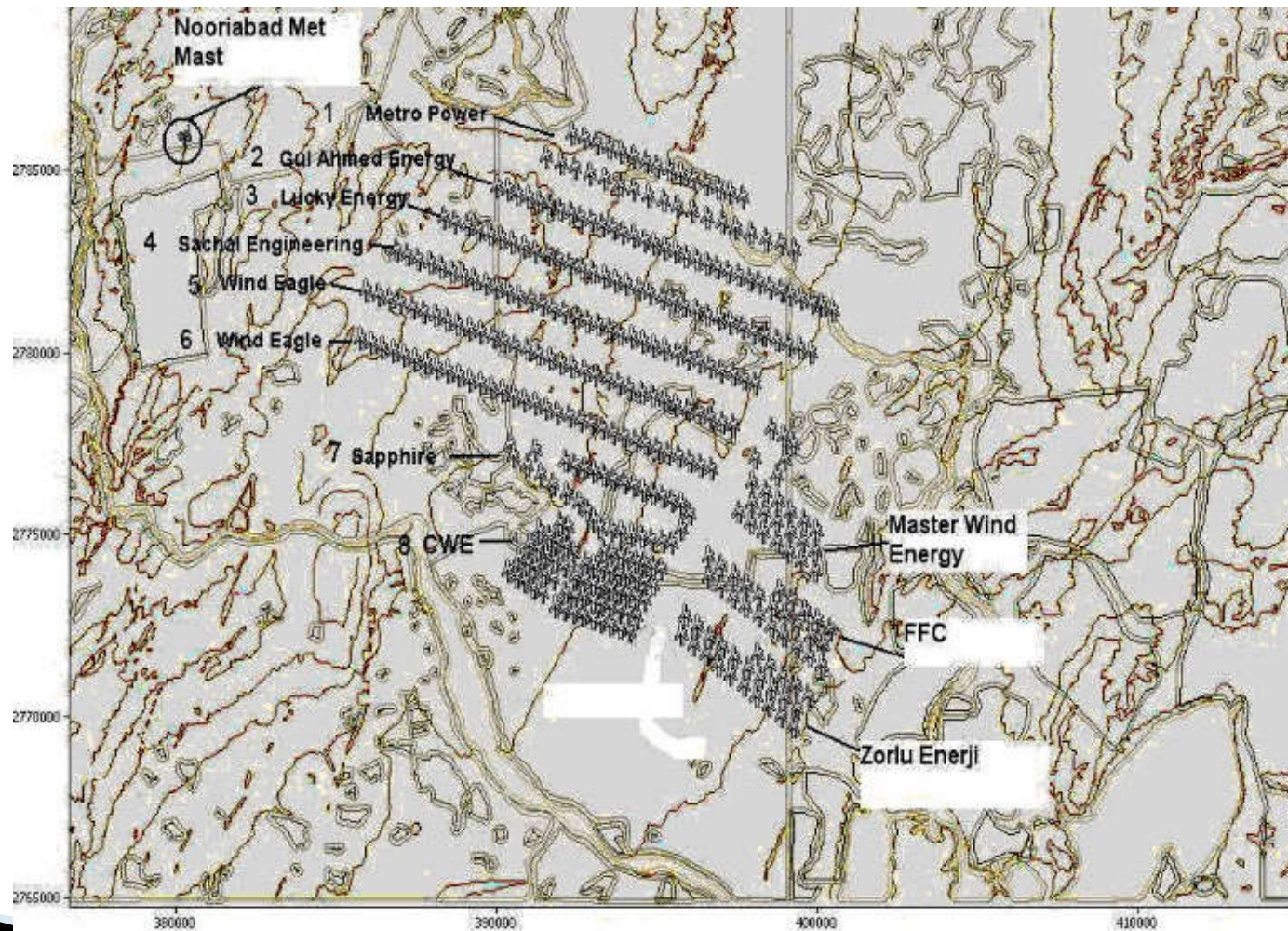
49.5 MW Wind Farm at Jhampir The 1st Wind Farm of Pakistan



ZORLU Enerji Pakistan Limited
A company of ZORLU ENERJI Group`

July 2013, 50.4 MW Jhampir wind power started selling power to NTDC

Wind Power in Pakistan



Land has been allocated to IPPS and various are at various stages of development