Wind Energy Systems

An Online Continuing Education Course for Engineers

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Lee Layton, P.E.

Introduction

The United States faces many challenges as it prepares to meet its energy needs in the twenty-first century. Electricity supply crises, fluctuating natural gas and gasoline prices, heightened concerns about the security of the domestic energy infrastructure and of foreign sources of supply, and uncertainties about the benefits of utility restructuring are all elements of the energy policy challenge. Wind energy is an important part of the diverse energy portfolio that is needed for a stable, reliable energy sector in the United States.

Wind is one of the lowest cost renewable generation sources. Wind turbines range in size from small 5 kW units to large utility scaled units of 2-3 megawatts. Wind turbines for utility applications are usually grouped together into large 50-100 MW wind farms.

Of course, wind generators need wind to produce power and lots of it. A large wind generator will require wind speeds of over 25 mph to reach its nameplate output rating.

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 vegetation.

The terms *wind energy* and *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.

A wind turbine works by using the wind to turn blades, which spin a shaft, which connects to a generator and makes electricity.

By the end of 2025 there was over 153 gigawatts (GW) of wind generation installed in the United States and producing 454,000 gigawatt hours annually. The interest in wind is being driven by global warming, high natural gas prices, and public policy.

The US has about 1,250 GW of electric generation.

The pie chart in Figure 1 on the following page shows the total electric energy production in the United States in 2025 by fuel type. As you can see in the chart, natural gas is the predominate fuel source (40%) while coal is now only 20% (compared to over 50% in 2005) and nuclear power accounts for 20% of the production in the US. Non-hydroelectric renewables make up about 10% of the total energy production in the United States.

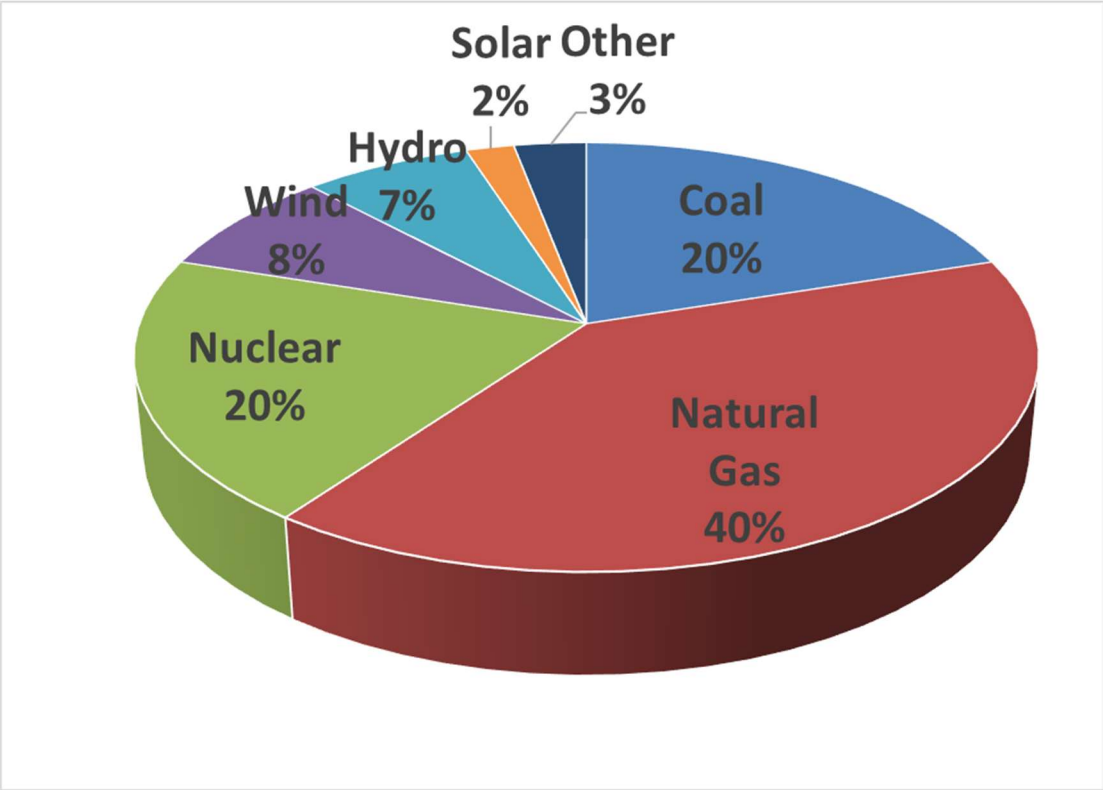

Figure 1

The next chart (Figure 2) shows how the 10% of non-hydro renewable energy production in the United States is distributed. Wind is the largest renewable energy producer and accounts for about 66% of the renewable energy production. Solar is next at 25%. Biomass waste is next at 5% of the renewable energy production, followed by geothermal energy (4%) municipal solid waste (MSW) at 1%.

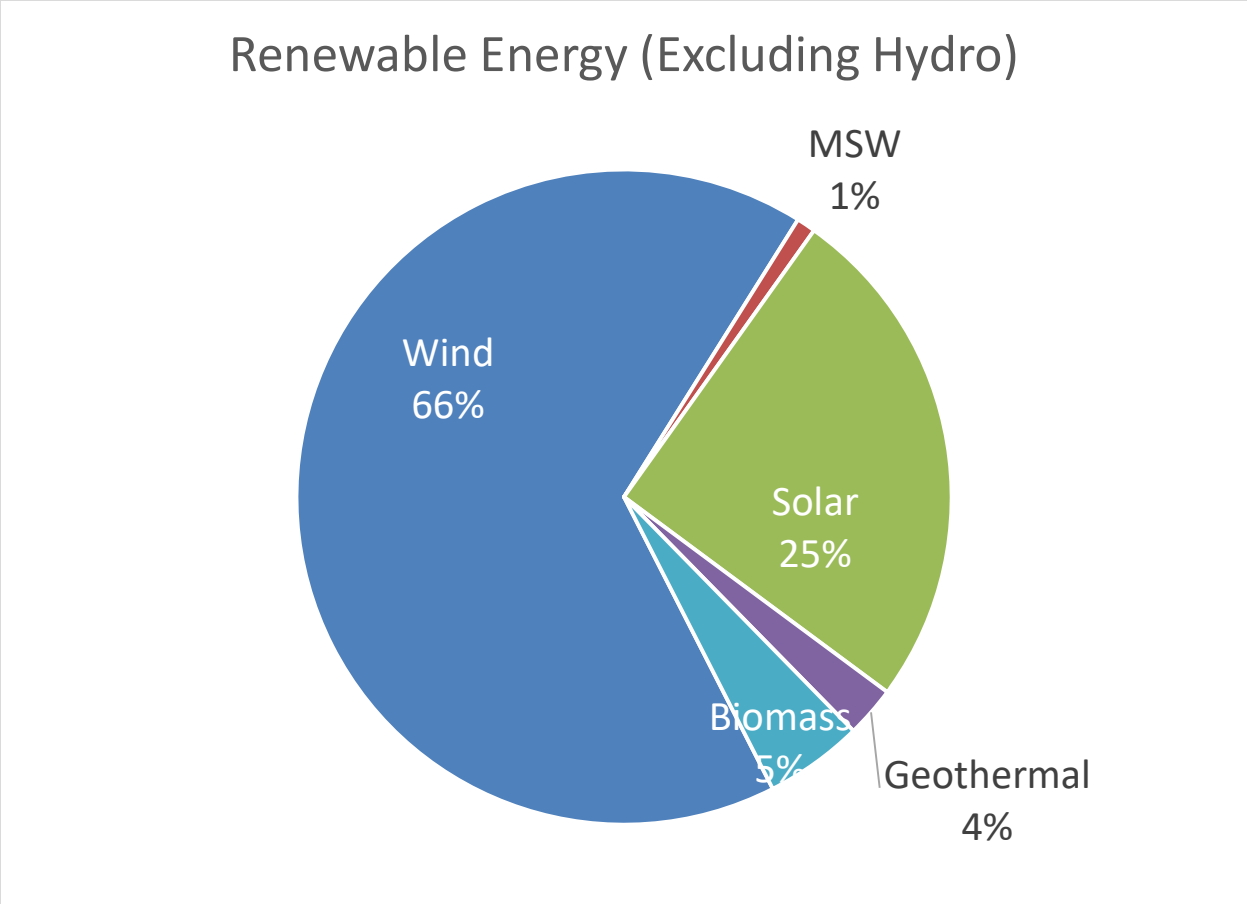

Figure 2

Wind energy is not a new concept. Since ancient times, the wind has been used as an energy source to pump water and for other purposes.

Since 1940 wind has been used – in limited applications – to produce electric energy. In 1940 the largest wind turbine of the time began operating on a Vermont hilltop known as Grandpa's Knob. This turbine, rated at 1.25 megawatts in winds of about 30 mph, fed electric power to the local utility network for several months during World War II.

The popularity of using the energy in the wind has always fluctuated with the price of fossil fuels. When fuel prices fell after World War II, interest in wind turbines waned. But when the price of oil skyrocketed in the 1970s, so did worldwide interest in wind turbine generators.

The chart in Figure 3 on the next page shows the growth in wind energy production. Wind energy has grown from less than 15,000 gigawatt hours (GWH) in 2005 to over 454,000 GWH in 2024, which is an annual increase of over 19%

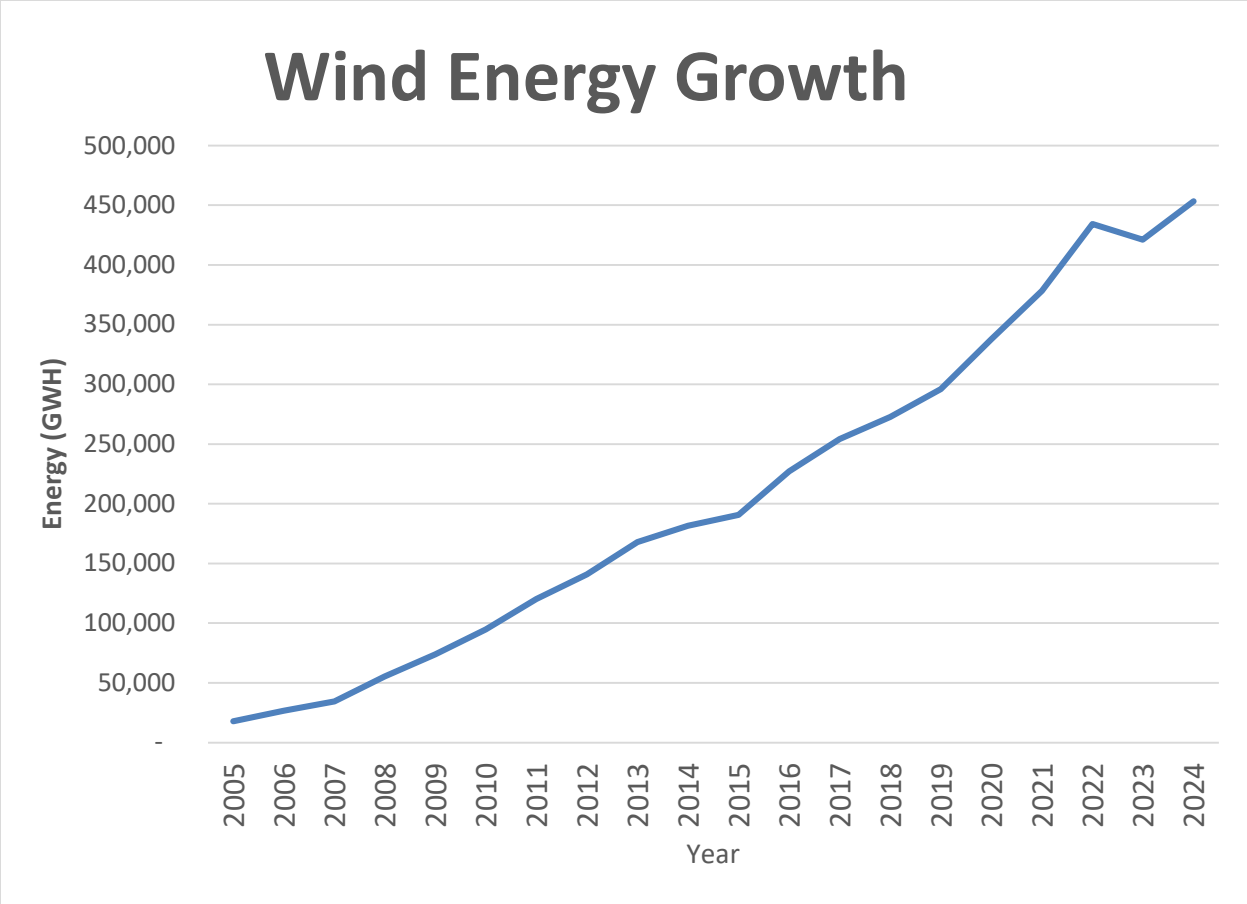

Figure 3

The wind turbine technology R&D that followed the oil embargoes of the 1970s refined old ideas and introduced new ways of converting wind energy into useful power. Many of these approaches have been demonstrated in "wind farms" or wind power plants — groups of turbines that feed electricity into the utility grid — in the United States and Europe.

Good wind areas, which cover 6% of the contiguous U.S. land area, have the potential to supply an amount of electricity equal to one and a half times the current electricity consumption of the United States. Of course, this does not mean that wind energy can be used to replace all other forms of electric energy generation. Wind is a variable energy resource and in practical applications will probably never be able to meet more than 20% of the nation's electric energy needs.

Estimates of the wind resource are expressed in wind power classes ranging from class 1 to class 7, with each class representing a range of mean wind power density or equivalent mean speed at specified heights above the ground. Areas designated class 4 or greater are suitable with advanced wind turbine technology under development today. Power class 3 areas may be

suitable for future technology. Class 2 areas are marginal and class 1 areas are unsuitable for wind energy development.

The advantages of wind energy include,

- Wind energy is fueled by the wind, so it is a clean fuel source. Wind energy does not pollute the air like power plants that rely on combustion of fossil fuels, such as coal or natural gas. Wind turbines do not produce atmospheric emissions that cause acid rain or greenhouse gases.
- Wind energy is a domestic source of [illegible] ates.
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- Good wind[illegible] oad centers.
- Wind resou[illegible] other uses for the land, and those alternative u[illegible] highly valued than electricity generation.
- Wind turbines can have a negative impact on aesthetics or "viewshed" of a community. This concern is especially prevalent in mountain areas where the residents do not want wind turbines to spoil their view.

In the next chapter we look at the components of a wind energy system and some of the associated operating characteristics. Then we will look at the wind resources in the United States, followed by a discussion of siting and interconnection of wind energy systems.