Objectives of this Module
At the conclusion of this module, you should:
• Understand why the wind blows
• Understand wind requirements for power generation
• Be able to use a wind map
• Be able to estimate wind power production
• Know that net metering exists
• Be able to calculate simple payback

Preview
• What makes the wind blow?
• How windy is it?
• Turning wind into power
• Efficiency of wind power
What makes the wind blow?
Topographic Interactions:

- Ridge top winds
- Shore breezes

How windy is it?
The wind rose plot

- Direction
- Speed (average, gust)
- Flow regime

How windy is it?
Measure wind speed on site

How windy is it?
Velocity and direction measurements

How windy is it?
Pennsylvania - Annual Average Wind Speed at 80 m
How windy is it?

Wind speed vs. height above the ground

How windy is it?

Velocity vs. height

\[ \frac{V_2}{V_1} = \left( \frac{h_1}{h_2} \right)^{0.14} \]

- \( P = 0.14 \) – rural conditions
- \( 0.28 \) – suburban
- \( 0.40 \) – urban

Turning Wind into Power

Power in wind (kinetic energy)

\[ P = \frac{1}{2} M' \cdot V^2 \]

- \( P \) = power (watts)
- \( V \) = airflow velocity (m/s)
- \( M' \) = mass flow rate of air (kg/s)
  \[ = \rho \cdot A \cdot V \]
  - \( \rho \) = air density (kg/m³)
  - \( A \) = cross sectional area of flow (m²)

Therefore, \( P = \frac{1}{2} \rho \cdot A \cdot V^3 \)

Turning Wind Power into Electricity

The Betz Limit

Turning Wind into Power

Efficiency of Wind Power

• Capacity factor = fraction of the turbine’s maximum annual output is actually generated
• Efficiency = how much of the wind’s energy is converted into useful power

Note: both are a function of the equipment, the location, and the way it is operated

Efficiency of Wind Power

\[
C = \frac{\text{Average annual kW output}}{\text{Rated maximum kW output}}
\]

Note: a capacity factor of 40% is considered very good, while 25% is a rough minimum for economical utility wind projects

Efficiency of Wind Power

• Efficiency could mean...
  – % of wind energy extracted by the blades
  – % of wind energy at “peak output” wind speed
  – Average for all wind speeds
  – Average for all wind speeds at a given location during a typical year
  – % of wind energy extracted by the blades and converted into electricity by the generator
  – % of wind energy extracted by the blades and converted into electricity that is delivered to the building

Effects of Height above Ground

• More height reduces wind interference by buildings and other features on the ground
• So, the higher the better
• You have seen this wind map before...note the overall color scheme and the color legend
• And, note the height above ground stated in the title

The 80 Meter Slide; Green, Yellow

The Effects of Height Above Ground

• Hold that thought, the one about predominant map color and the map color legend
• Now check out the 30 m wind map
• Any notable differences?
Now the 30 meter map; green

Ok, we have seen some wind speed differences related to height above the ground

Kestrel (a wind turbine manufacturer) specifies installation at 12 to 18 m (39 to 59 ft) above the ground

So, how high is that? What does it look like?

Our local installation is at 120 ft (36 m)

The Effects of Height above Ground

- Rated annual energy output: Calculated using an average wind speed of 5 m/s (11.2 mph). The energy output will likely net against your home energy use.
- Rated power output: Not as important but it affects the annual energy output. Power output is calculated at a wind speed of 11 m/s (24.6 mph).

So, what sort of performance can you expect from a wind turbine?
So, what sort of performance can you expect from a wind turbine?

- To recap, annual energy is based on average wind speed of 5 m/s
- If you install a wind turbine rated at 2.5 kilowatts (kW), you should expect an annual energy production of nearly 4,000 kilowatt-hours (kWh) if you experience the average rated wind speed (averaging 5 m/s)
- Back to the 30 m wind map...

So, what sort of performance can you expect from a wind turbine?

- Let’s look at offsetting some of your home energy use with a wind turbine
- If you are a West Penn Power residential customer, you are paying about 10¢ per kWh
- So, if you use the rated wind that produces the rated energy output of 4,000 kWh/yr, the value is $400/yr

So, what sort of performance can you expect from a wind turbine?

- If you can use “net energy metering,” you may expect to receive the full value for your wind turbine-produced electricity, assuming your home uses at least 4,000 kWh/yr
- If the installed cost of your wind turbine is in the $10,000 range, the simple payback is about 25 years
- As the car makers say, “Your mileage may vary.”

Let’s Try the Wind Calculator

Wind Calculator URL

http://www.windustry.org/resources/small-wind-calculator
Important Changes in the Law

Act 213 of 2004 & Act 35 of 2008
Laws created the framework that established
• Customer generators
• Net-metering
• Alternative energy credit market
• and permission to produce more electric than your account (farm) consumes…….

Wind Energy on Farms

Questions?