





The Emick Family Ranch



Water Flowing in a Pipe with Cross-section A and Velocity V



x is position of a parcel of water;
 dx is the distance the parcel moves in the element of time dt .

$$\text{Mass Flow \{kg/s\}} = \rho A dx / dt = \rho AV$$

Mass is conserved; ρ and A are constant for this situation;
therefore, V must also be constant.

Note that if there is a short section where A is reduced,
then V must increase through the restriction.

Water Flowing in a Pipe with Cross-section A and Velocity V

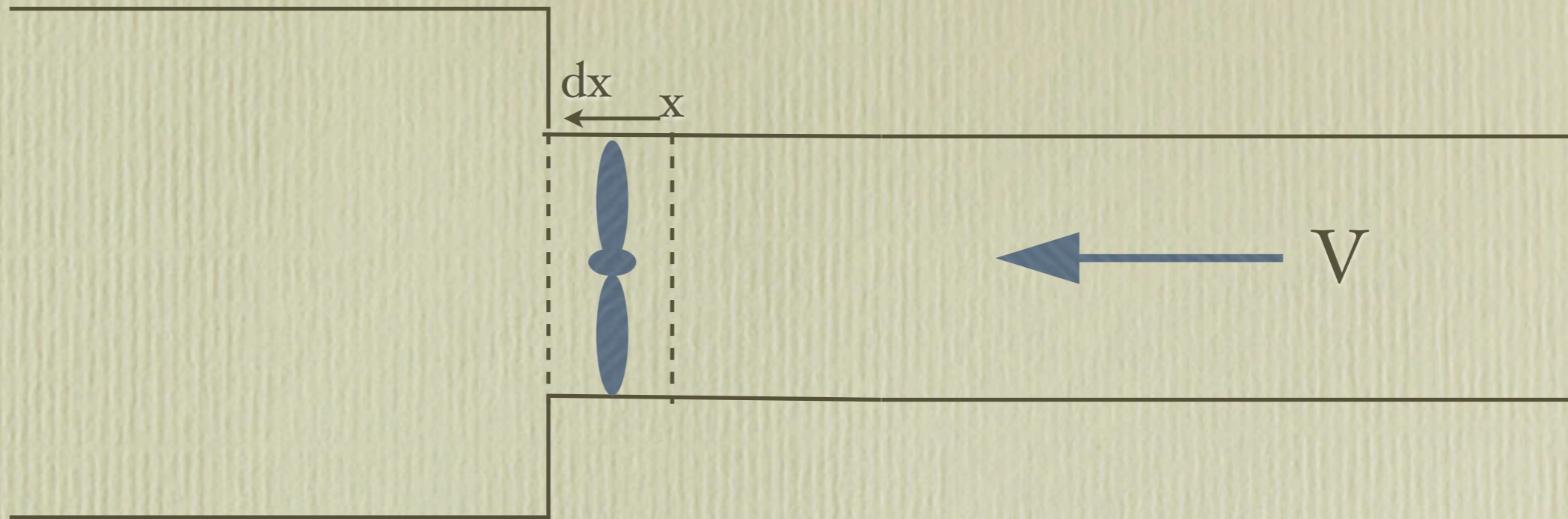


x is position of a parcel of water;
 dx is the distance the parcel moves in the element of time dt .

$$\text{Mass Flow \{kg/s\}} = \rho A dx / dt = \rho A V$$

$$\text{Energy Flow \{J/s\}} = \frac{1}{2} \rho A dx V^2 / dt = \frac{1}{2} \rho A V^3$$

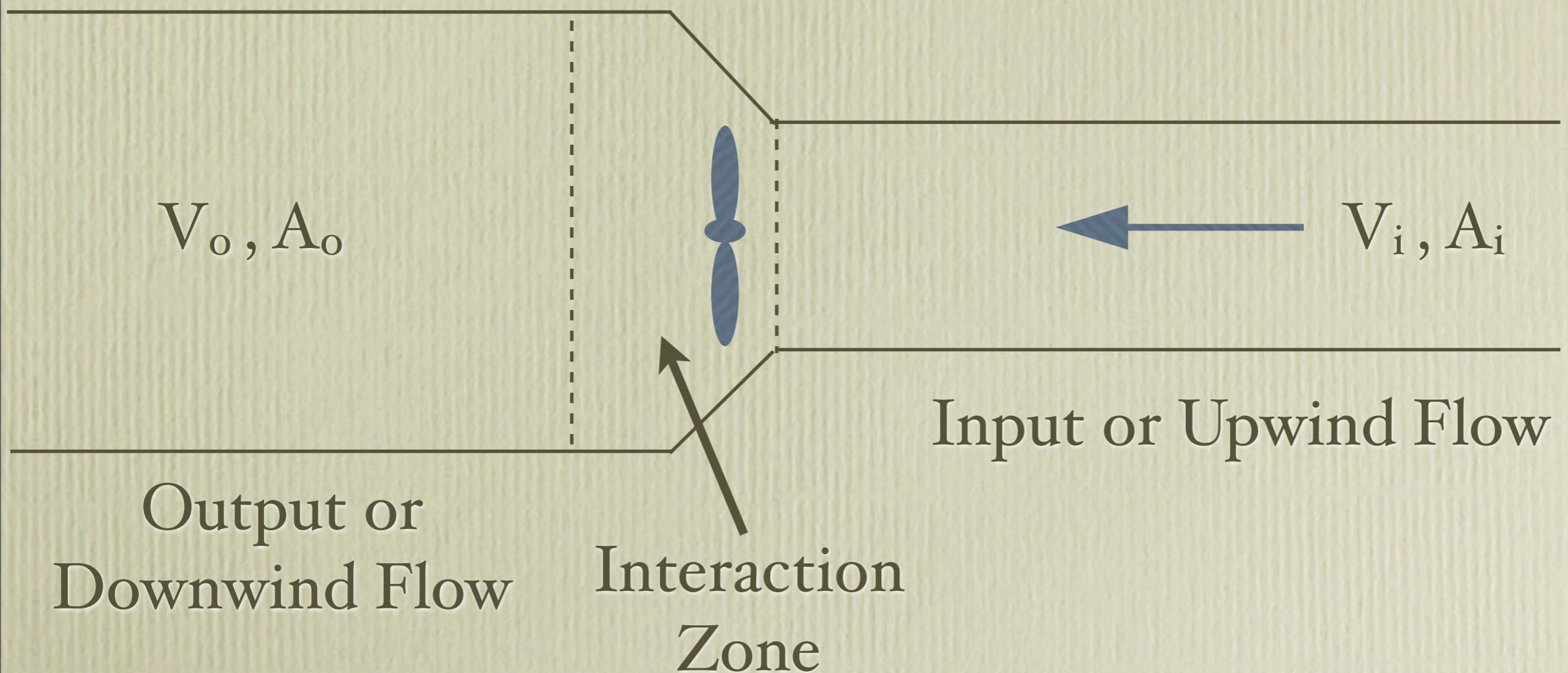
If we place a device in the flow as depicted above to extract energy from the flow, then by the second equation V must decrease, but this is not allowed by the first equation. Logically, if the water on the left is moving more slowly than the water on the right, there is insufficient space on the left for water on the right to go. The water must slow to the velocity of the water on the left; in which case no energy is extracted from the flow.



The problem is solved by increasing the cross-sectional area on the left; now the water can move more slowly but still conserve the mass flow.

The amount of energy that can be extracted is controlled by the increase in cross-sectional area.

Working with wind generators is slightly different because air is compressible; however, the same principles that we found for the water example still apply for the wind. If we extract energy from the wind, the outflow will require a larger cross-sectional area. The drawing below depicts the wind generator interaction.



- The equations that we used for water apply here as well.
- The behavior of the flow in the interaction zone is complex. Some of the air will pass between the generator blades and maintain its input velocity. Some of the air interacts with the blades producing the generator rotation. And, some of the air goes around the generator.
- In the interaction zone downwind of the generator turbulence mixes the air parcels producing an average flow velocity V_o .
- Farther downwind turbulent interactions with the flow beyond the generator will produce an overall average flow.
- Recall that the pressure depends only upon the mass of air over a point. The only pressure perturbations in the wind generator flow are in the interaction zone.





Turbine Trivia

The Rotor:

- ⑥ From cuff to tip, a 1.5 MW wind turbine blade measures approximately 112 feet (34 meters) and weighs 35,000 pounds.
- ⑥ The diameter of the three-blade rotor set measures approximately 231 feet (70.5 meters) – 10% longer than the wingspan of a jumbo jet. A Boeing 747-400 has a wingspan of about 210 feet (64 meters).
- ⑥ The blades on each 1.5 MW wind turbine make 11-20 full revolutions per minute – one revolution every 2-3 seconds.

Turbine Trivia

The 1.5 MW Wind Turbine:

- ⑥ Together, the Fenner Wind Power Facility's 108 wind turbines add 162 megawatts of clean wind power to the Colorado electricity grid.
- ⑥ The 108 turbine installation will provide enough clean, renewable electricity to annually serve approximately 52,000 average American homes.
- ⑥ With a capacity of 1.5 MW, one wind turbine can supply the annual electricity needs of more than 400 average American homes.

Turbine Trivia

The Nacelle:

- ⑥ The nacelle, manufactured of fiberglass, functions as a housing to protect the integrated drivetrain, generator, hydraulic brake, yaw gears and other components from the outside environment. With all of its internal components, the nacelle weighs approximately 113,000 pounds.
- ⑥ It also provides a weather-protected, enclosed and spacious environment for field personnel to perform service and maintenance work.
- ⑥ The nacelle is well illuminated with interior electric lights and skylight hatches which provide additional lighting and ventilation. A hinged hatch at the front end of the nacelle gives easy and safe access to the blades and hub. When the rotor is stopped and secure, there is access via a hatch in the spinner to the inside of the hub for maintenance functions.

Turbine Trivia

The Tower:

- ⑥ The 1.5 MW wind turbine sits atop a steel, tubular tower.
- ⑥ It weighs approximately 190,000 lbs. and is approximately 263 feet tall (80 meters).
- ⑥ The tower has been designed in accordance with the Uniform Building Code, the International Electrotechnical Committee's 1400-1 Standard, Germanischer Lloyd's Rules and Regulations for Wind Turbine Design (DIBT), and a type approval under German Bauamt Office (DIBT).

Area ~ 4657 m²

Air Density ~1 kg/m³

Wind Velocity ~ 12 m/s (~27 mi/hr)

Energy Flow = Power = 4.02 MW

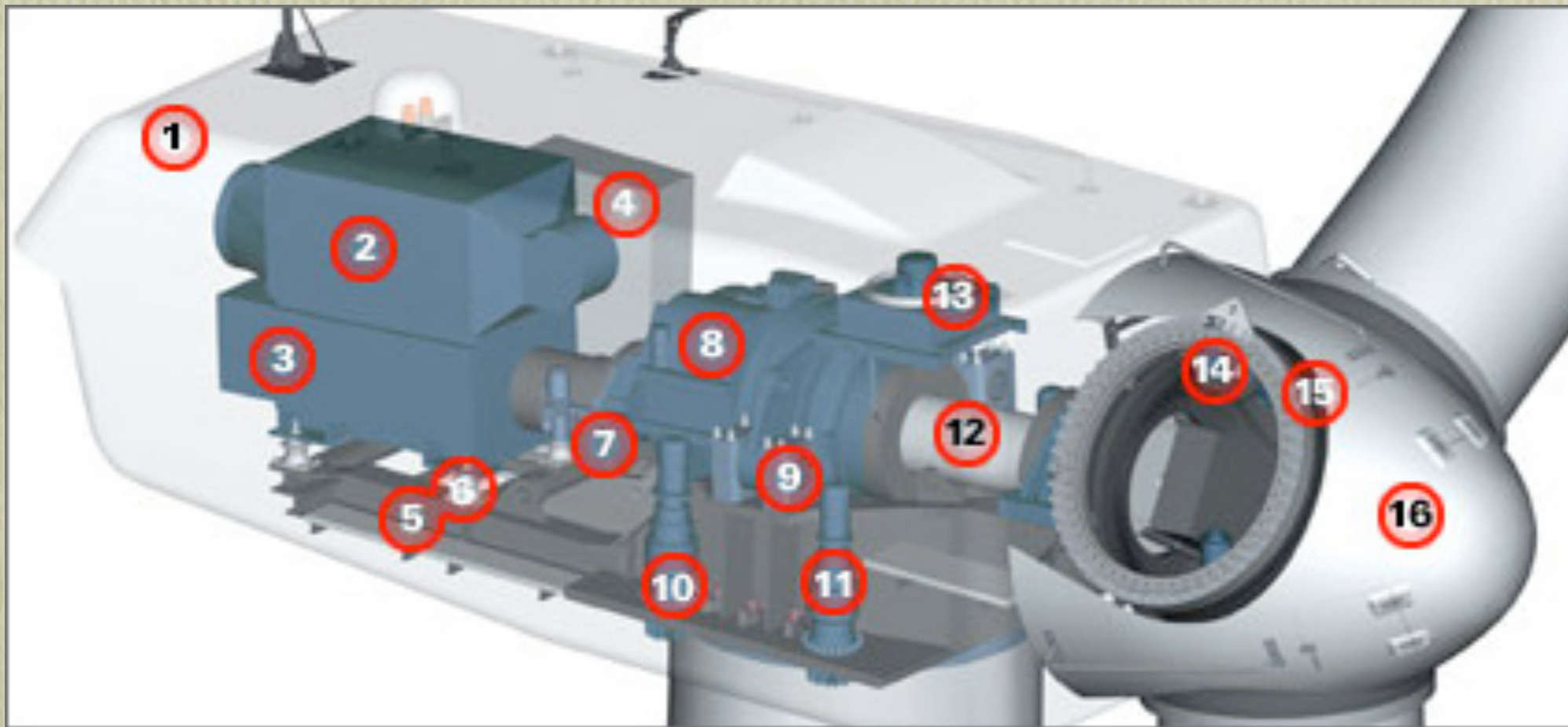
Efficiency at 12 m/s ~ 37.3%

Efficiency at 20 m/s ~ 8.1%

See also:

www.gewindenergy.com

<http://shell.com/emick>



- 1. Nacelle
- 2. Heat Exchanger
- 3. Generator
- 4. Control Panel
- 5. Main Frame
- 6. Impact Noise Insulation
- 7. Hydraulic Parking Brake
- 8. Gearbox
- 9. Impact Noise Insulation
- 10. Yaw Drive
- 11. Yaw Drive
- 12. Rotor Shaft
- 13. Oil Cooler
- 14. Pitch Drive
- 15. Rotor Hub
- 16. Nose Cone

Operating Data

1.5sle

Rated capacity

1,500 kW

Cut-in wind speed

3.5 m/s

Cut-out wind speed 600 s average

25 m/s

Cut-out wind speed 30 s average

IEC s: 28 m/s

Cut-out wind speed 3 s average

IEC s: 30 m/s

Cut-back-in wind speed 300 s average

IEC s: 22 m/s

Rated wind speed

12 m/s

Rotor

1.5sle

Number of rotor blades

3

Rotor diameter

77 m

Swept area

4,657 m²

Rotor speed (variable)

10.1 - 20.4 rpm

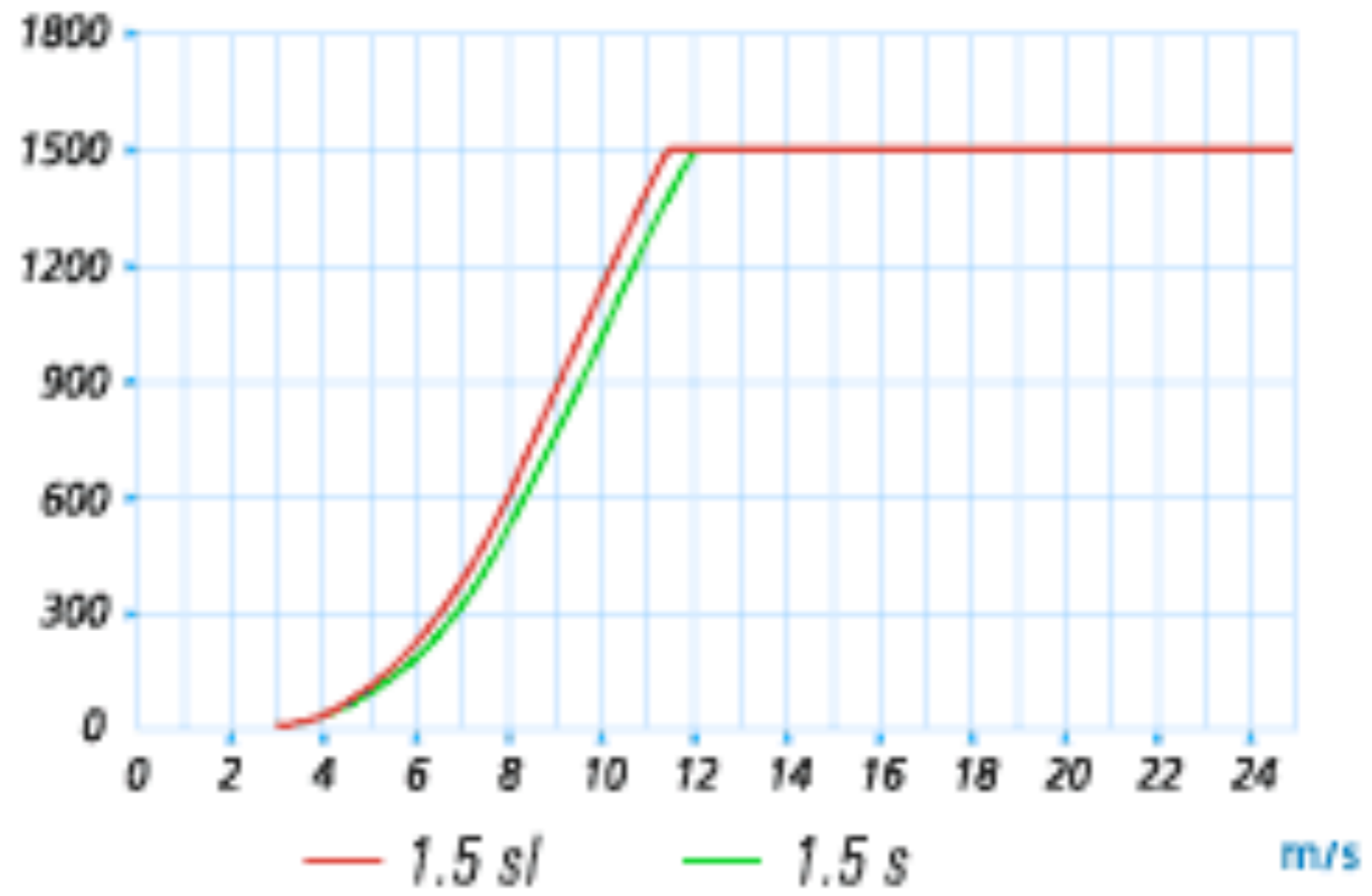
Tower

1.5sle

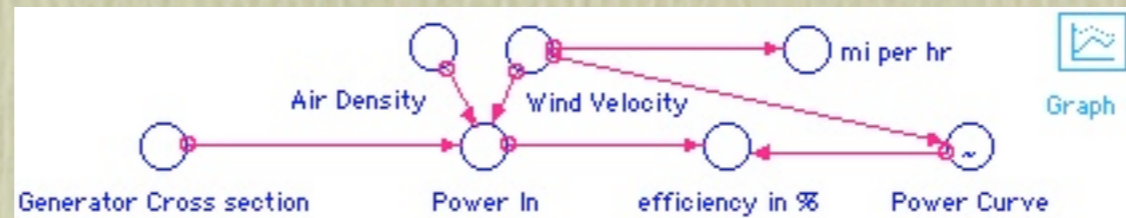
Hub heights (m)

61.4+ / 64.7+ / 80+ / 85+

Powercurve : 1.5 MW



STELLA Model of the Wind Generator Efficiency



Air_Density = 1 {kg/m³}

efficiency_in_% = (Power_Curve/Power_In)*100

Generator_Cross_section = 4657 {m²}

mi_per_hr = Wind_Velocity {m/s}*3600 {s/hr} /1000 {m/km}*0.62 {mi/km}

Power_In = (0.5*Air_Density * Generator_Cross_section * Wind_Velocity³)/10⁶ {megaWatts}

Wind_Velocity = TIME {make velocity the independent variable}

Power_Curve = GRAPH(Wind_Velocity)

(0.00, 0.00), (1.00, 0.00), (2.00, 0.00), (3.00, 0.00), (4.00, 0.03), (5.00, 0.08), (6.00, 0.18), (7.00, 0.33), (8.00, 0.52), (9.00, 0.75), (10.0, 1.01), (11.0, 1.26), (12.0, 1.50), (13.0, 1.50), (14.0, 1.50), (15.0, 1.50), (16.0, 1.50), (17.0, 1.50), (18.0, 1.50), (19.0, 1.50), (20.0, 1.50), (21.0, 1.50), (22.0, 1.50), (23.0, 1.50), (24.0, 1.50), (25.0, 1.50), (26.0, 1.50), (27.0, 1.50), (28.0, 1.50), (29.0, 1.50), (30.0, 1.50)

