



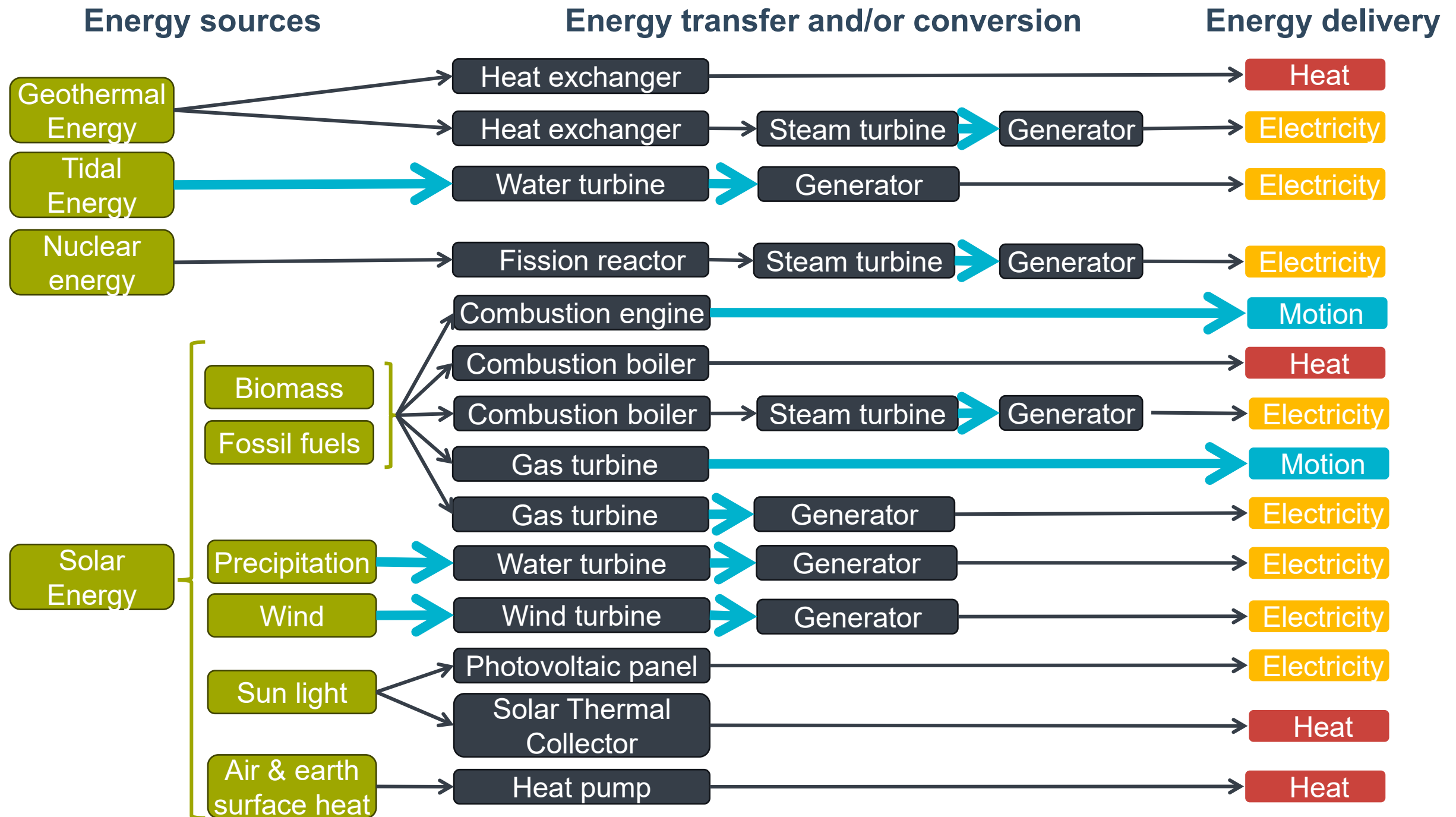
Motion Delivery

Renewable Energy Integration in the Energy System

Tadeo-Baldiri Salcedo-Rahola & Ruben van Duren

Research Group Energy in Transition

THE HAGUE
UNIVERSITY OF
APPLIED SCIENCES

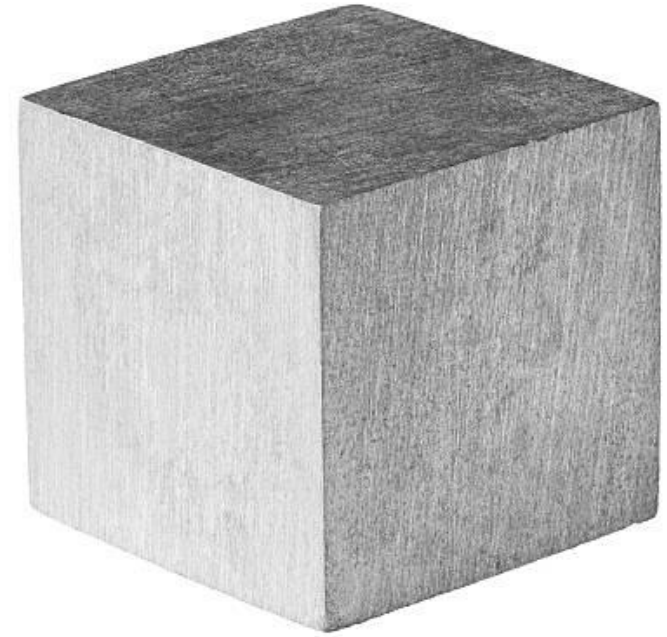


Motion energy = Kinetic energy

$$E_{motion} = KE = \frac{1}{2} \cdot m \cdot v^2 [J]$$

$$m = mass [kg]$$

$$v = velocity \left[\frac{m}{s} \right]$$



Velocity

Linear velocity

Unit	Where it is used
m/s	physics, engineering
km/h	cars, transportation
mph	UK, US road speeds

Angular velocity

Unit	Where it is used
rad/s	physics
RPM	engineering

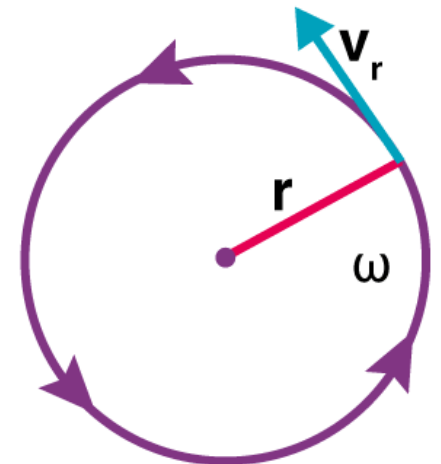
RPM = revolutions per minute

$$\omega = \frac{\theta}{t}$$

$$\omega = \text{angular velocity} \left[\frac{\text{rad}}{\text{s}} \right]$$

$$\theta = \text{angle velocity} [\text{rad}]$$

$$t = \text{time} [\text{s}]$$



$$v_r = r \cdot \omega [\text{m/s}]$$

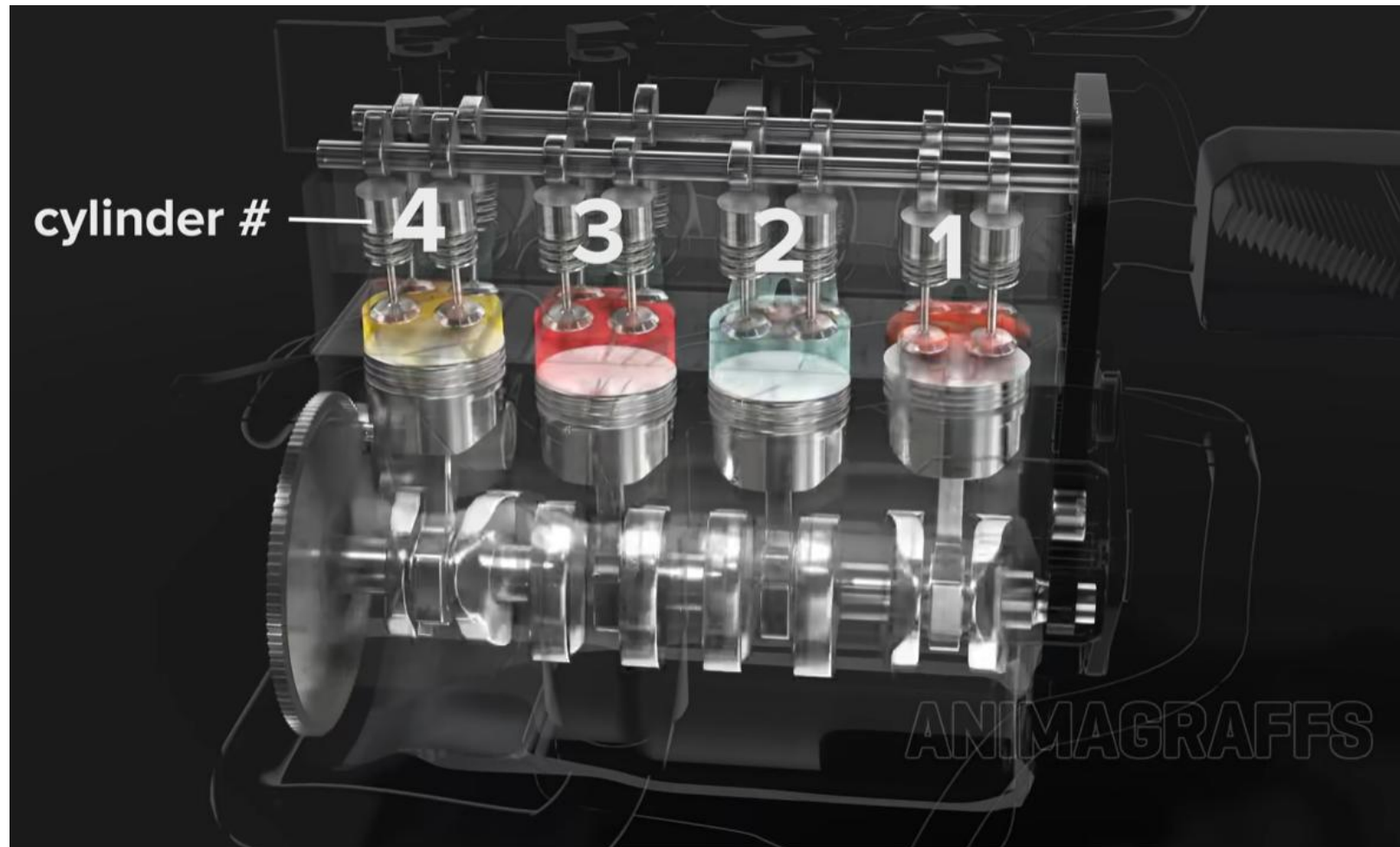
Combustion engine

Biomass

Fossil fuels

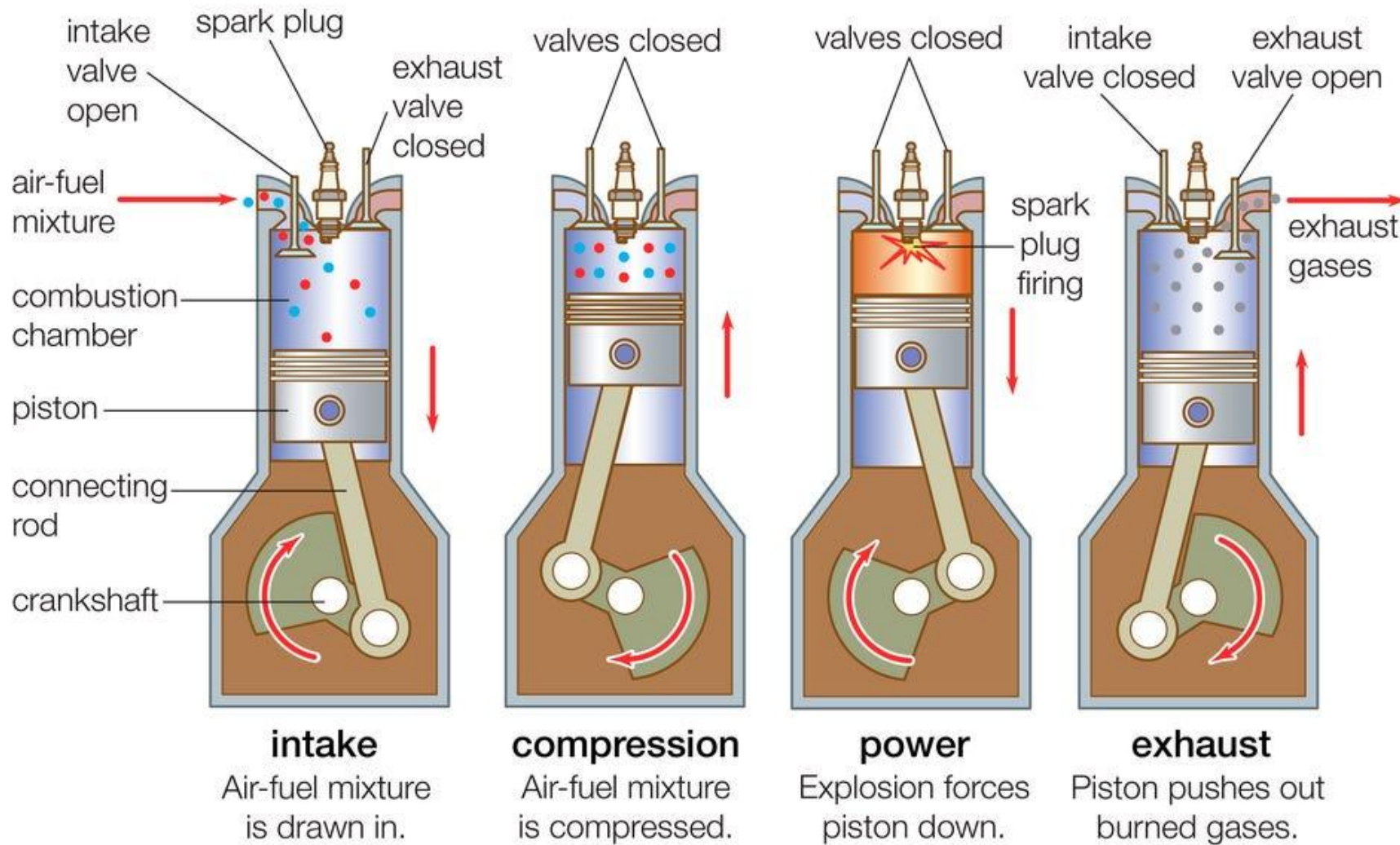
Combustion engine

Motion

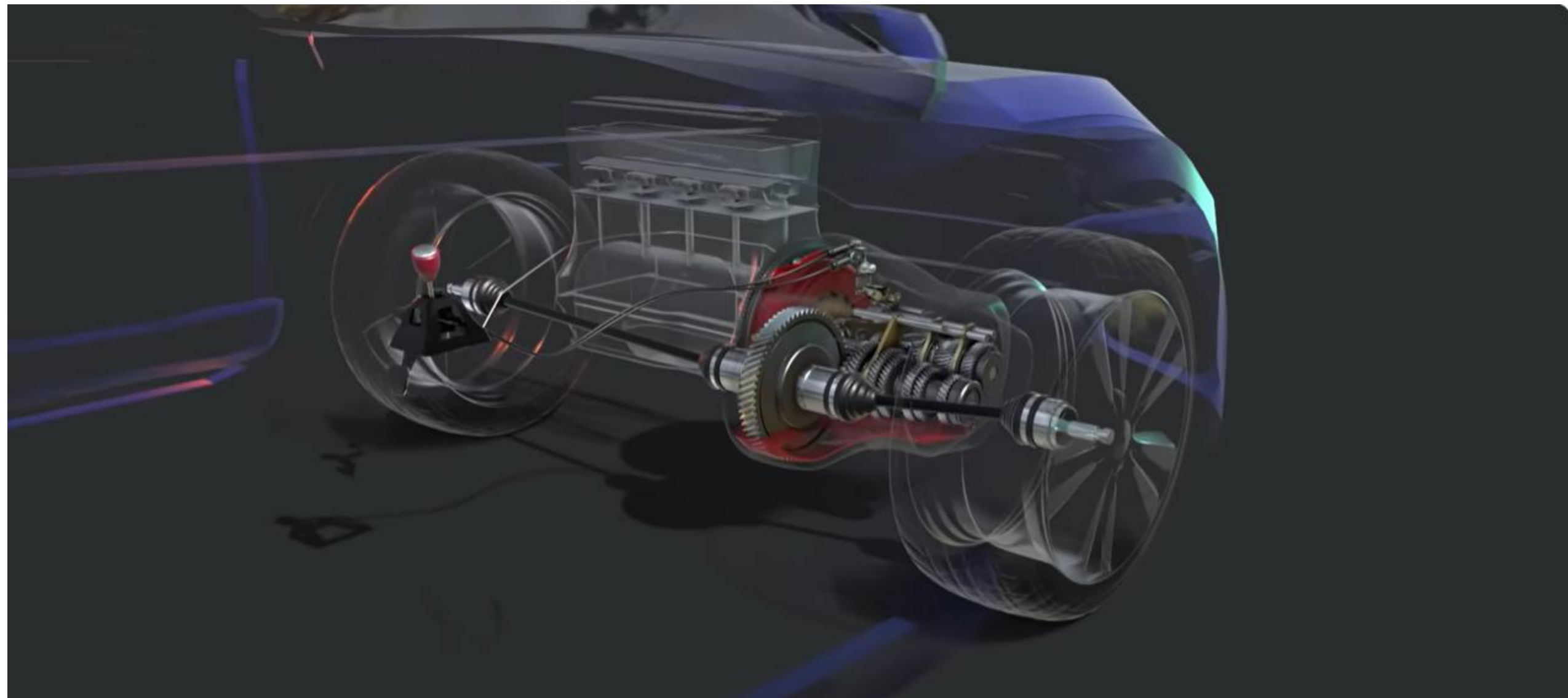


[How a car engine works](#), Animagraffs

Combustion engine



Combustion engine



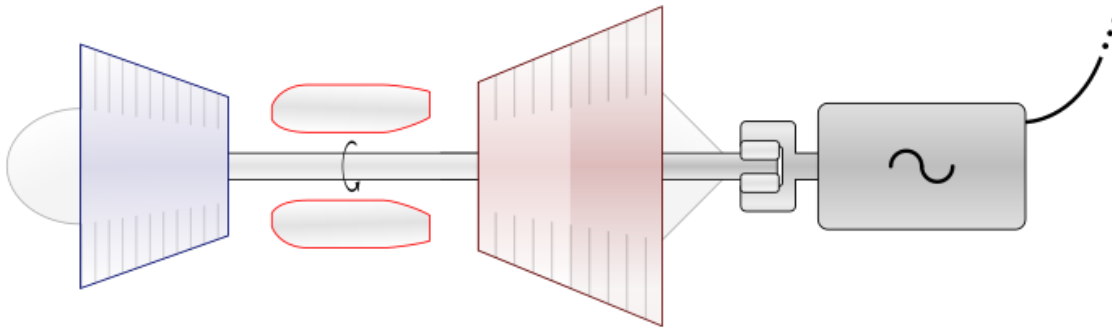
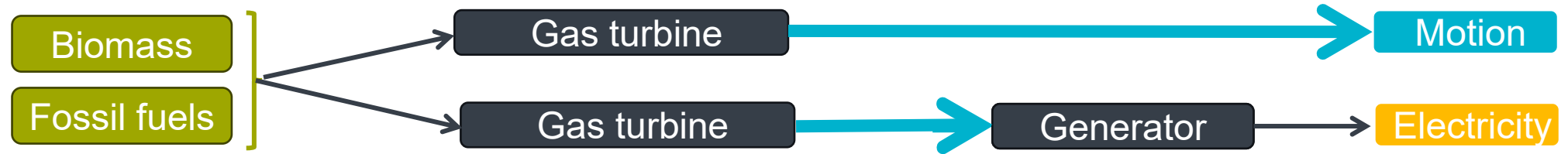
[How a Manual Transmission and Clutch Works](#), Animagraffs

Combustion engine advantages vs disadvantages

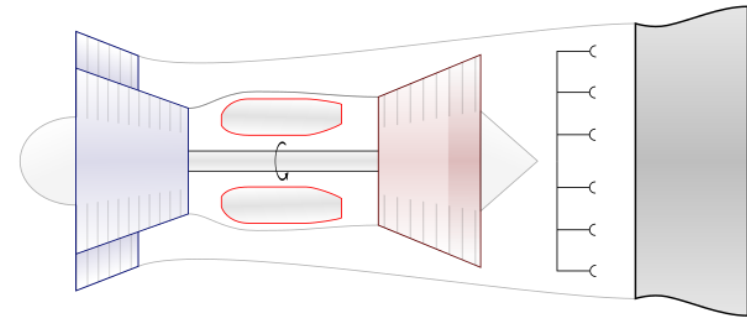
- High power output relative to size
- Quick refueling (minutes instead of hours)
- Mature and widely available technology
- Extensive global fuel infrastructure
- Reliable in many environments and conditions
- Suitable for long-range and heavy-duty use

- Low efficiency 25-30% (significant energy lost as heat)
- Produces CO₂ and harmful air pollutants
- Relies on finite fossil fuels
- Many moving parts → wear, maintenance, and complexity
- Generates noise and vibrations
- Environmental impact (climate change and air quality)

Gas turbine

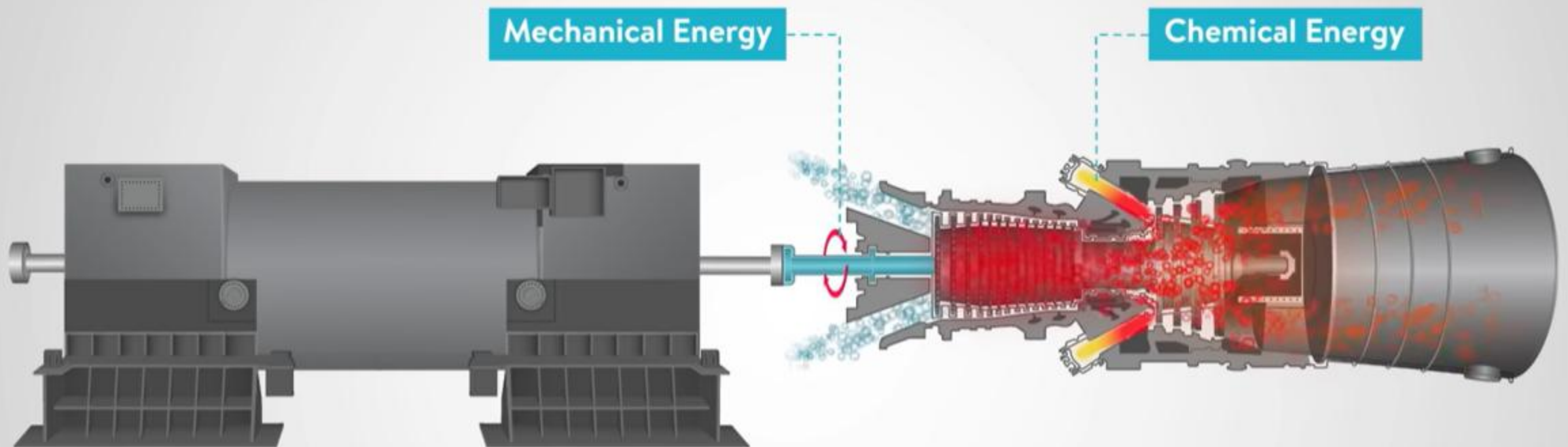


Turboshaft (shown as electric generator)

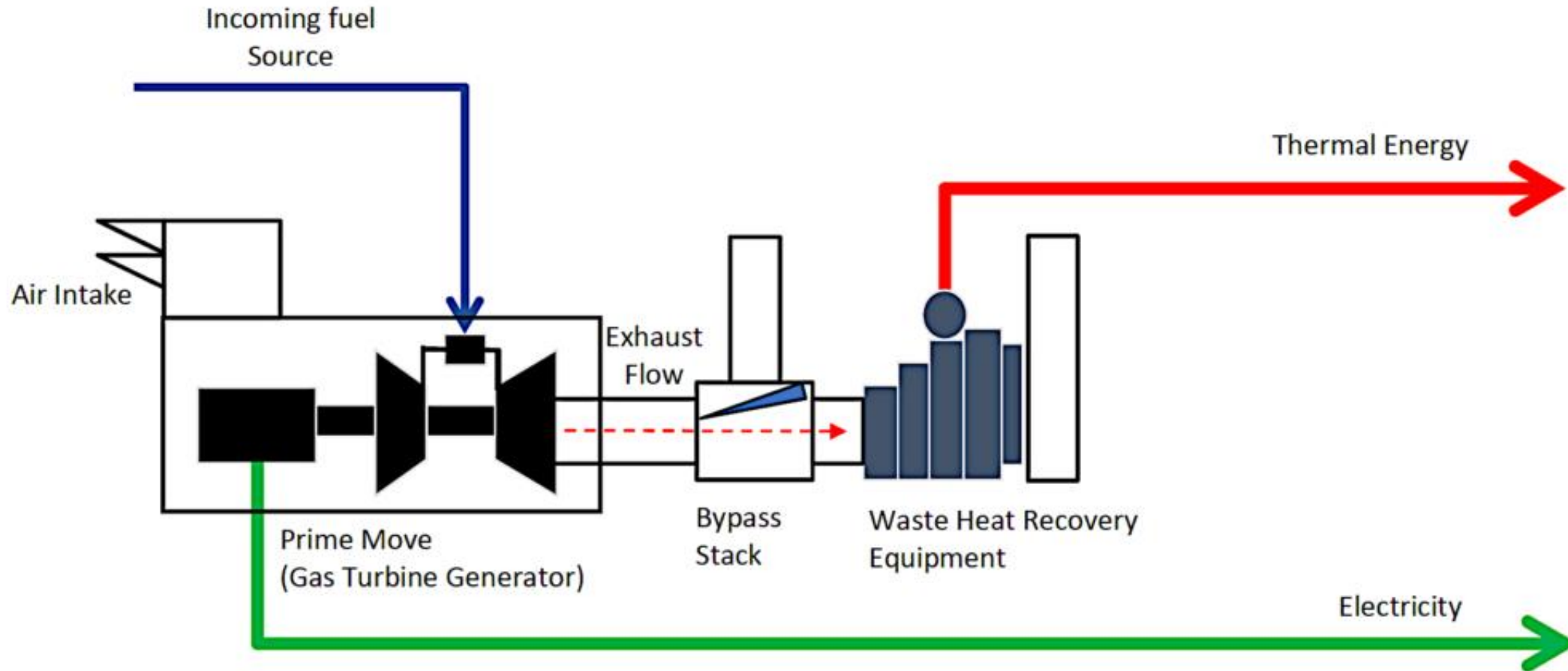


Turbojet

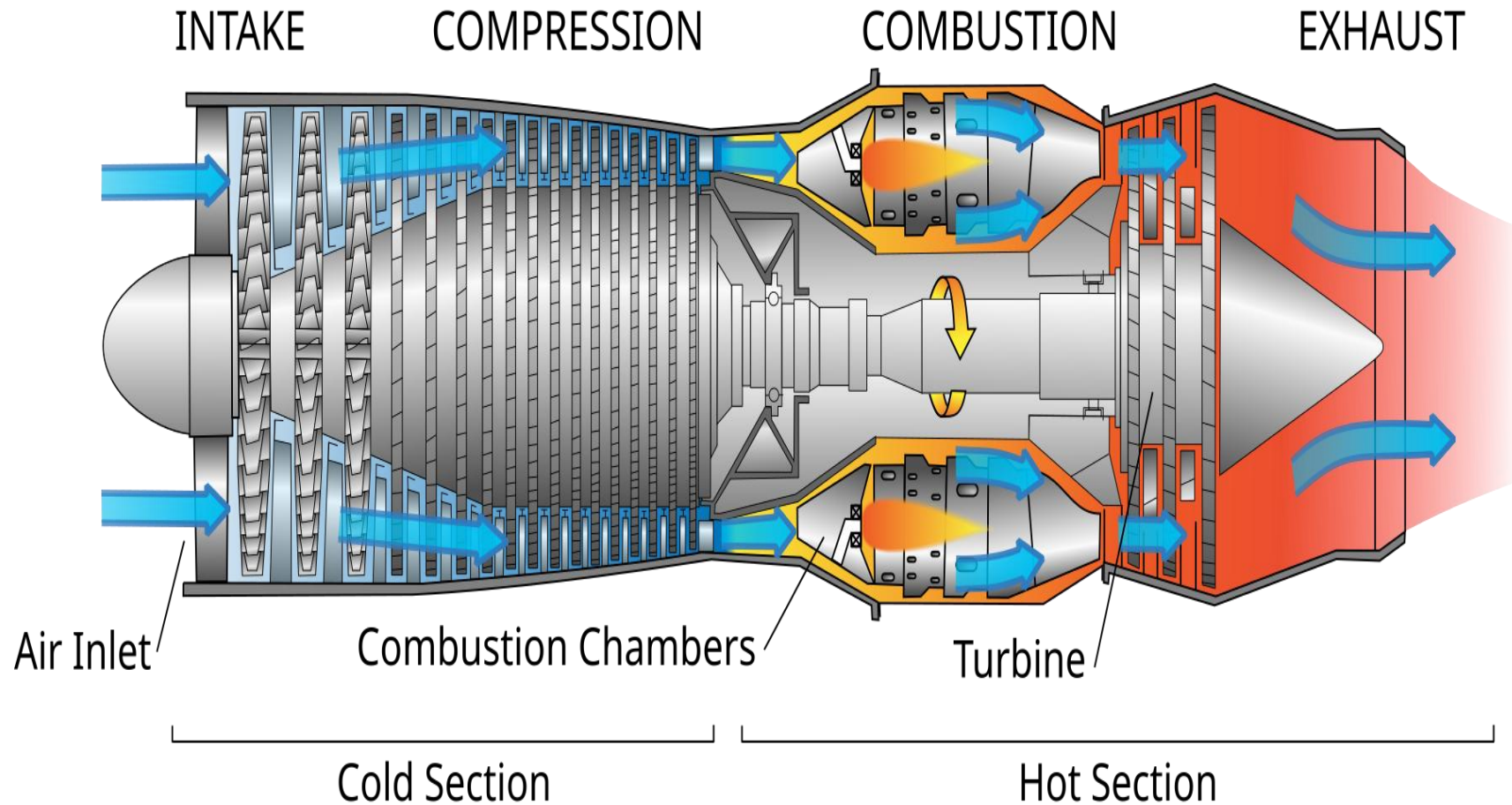
Gas turbine (power plant)



Gas turbine (power plant) cogeneration



Gas turbine (airplane)

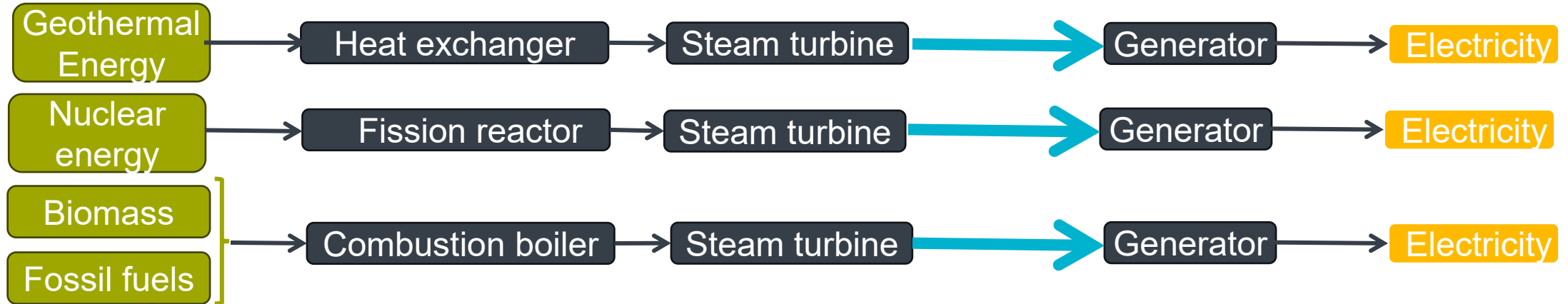


Gas turbine advantages vs disadvantages

- High power-to-weight ratio
- Continuous and smooth operation
- Fewer moving parts than piston engines (high reliability)
- Compact design for the power produced
- Fast start-up compared to steam power plants
- Can achieve high efficiency in combined-cycle systems

- Lower efficiency when used alone (especially at partial load)
- Operate at very high temperatures (advanced materials required)
- Sensitive to operating conditions (temperature, air quality)
- Depend on high-quality fuels (e.g., natural gas, kerosene)
- Produce emissions (CO₂ and NO_x)
- High manufacturing and maintenance costs

Steam turbine



<https://www.britannica.com/science/geothermal-energy>

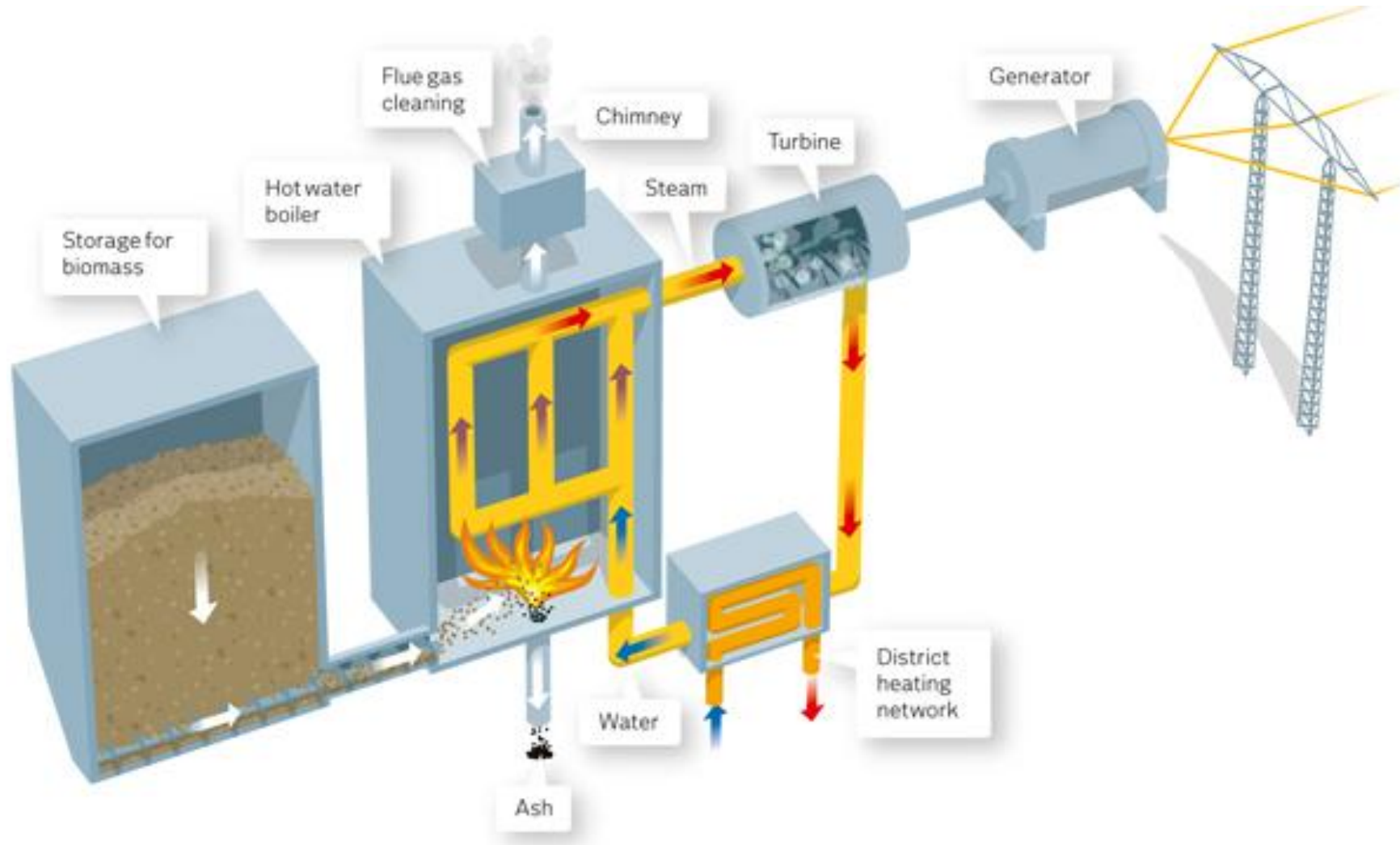


<https://www.alpiq.com/energy/assets/thermal-power-plants/goesgen-nuclear-power-plant>

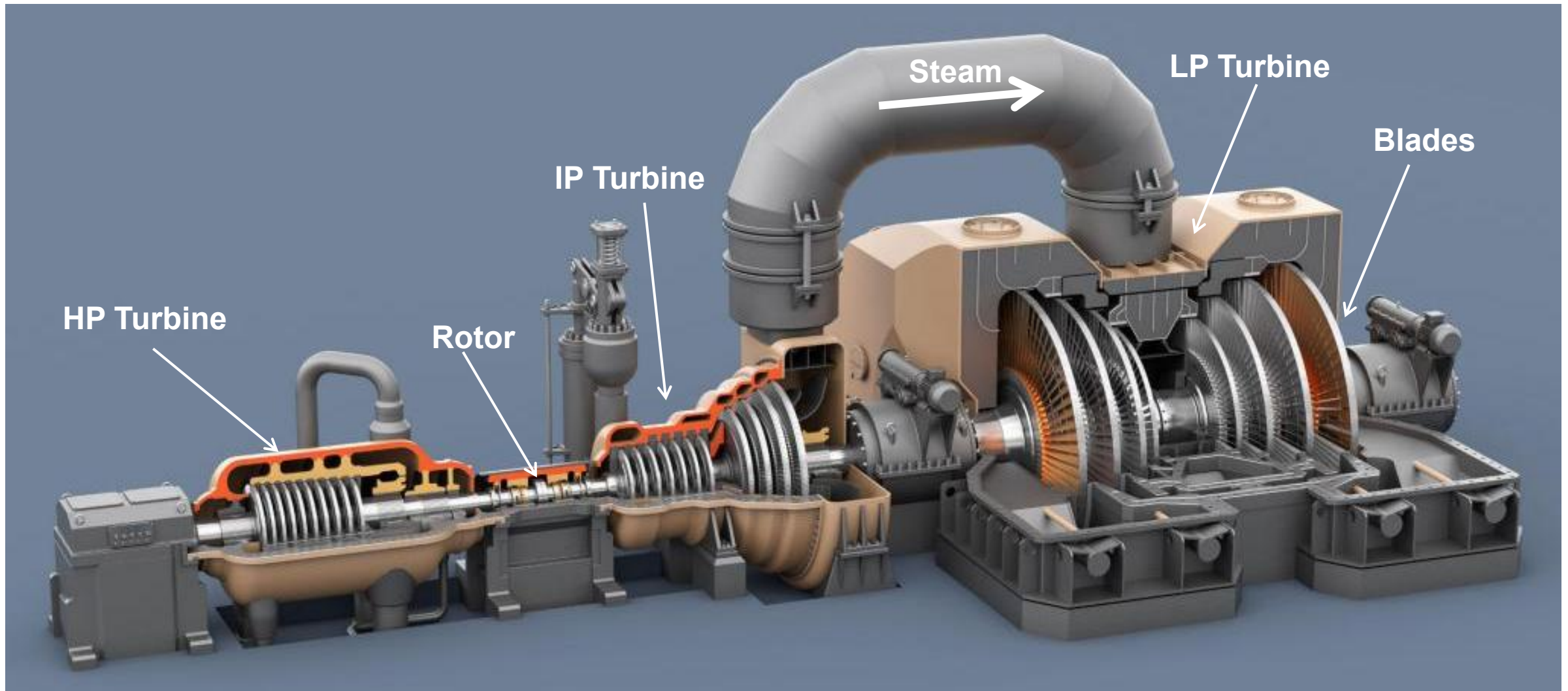


<https://www.valmet.com/energyproducti on/energy-solutions/biomass-to-energy>

Power plant with steam turbine



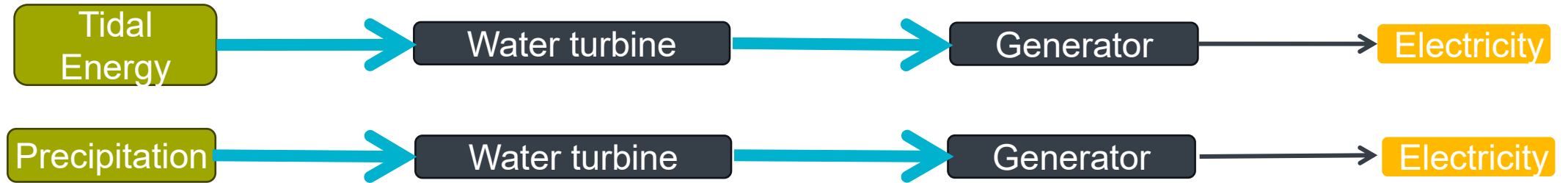
Steam turbine



Steam turbine advantages vs disadvantages

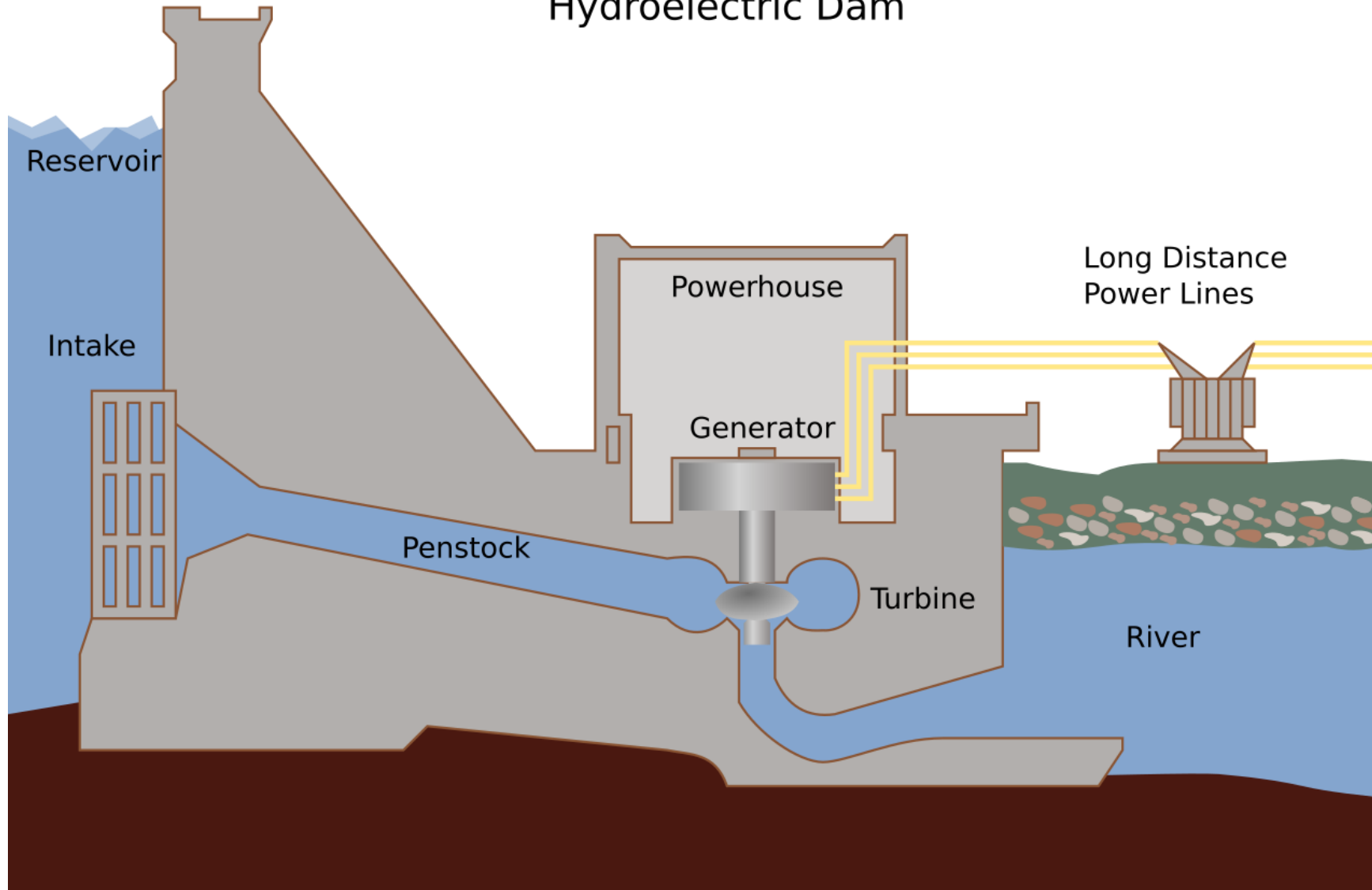
- High efficiency at large, steady power output
 - Suitable for very large-scale electricity generation
 - Long lifetime and high reliability
 - Fewer moving parts compared to piston engines
 - Can use various heat sources (fossil, nuclear, solar, biomass)
 - Smooth and continuous operation
- Require complex systems (boiler, condenser, pumps)
 - Large size and high installation cost
 - Slow start-up and less flexible to changing loads
 - Energy losses through waste heat (especially in condenser)
 - High water usage for cooling
 - Environmental impact depends on heat source (e.g., emissions from fossil fuels)

Water turbine

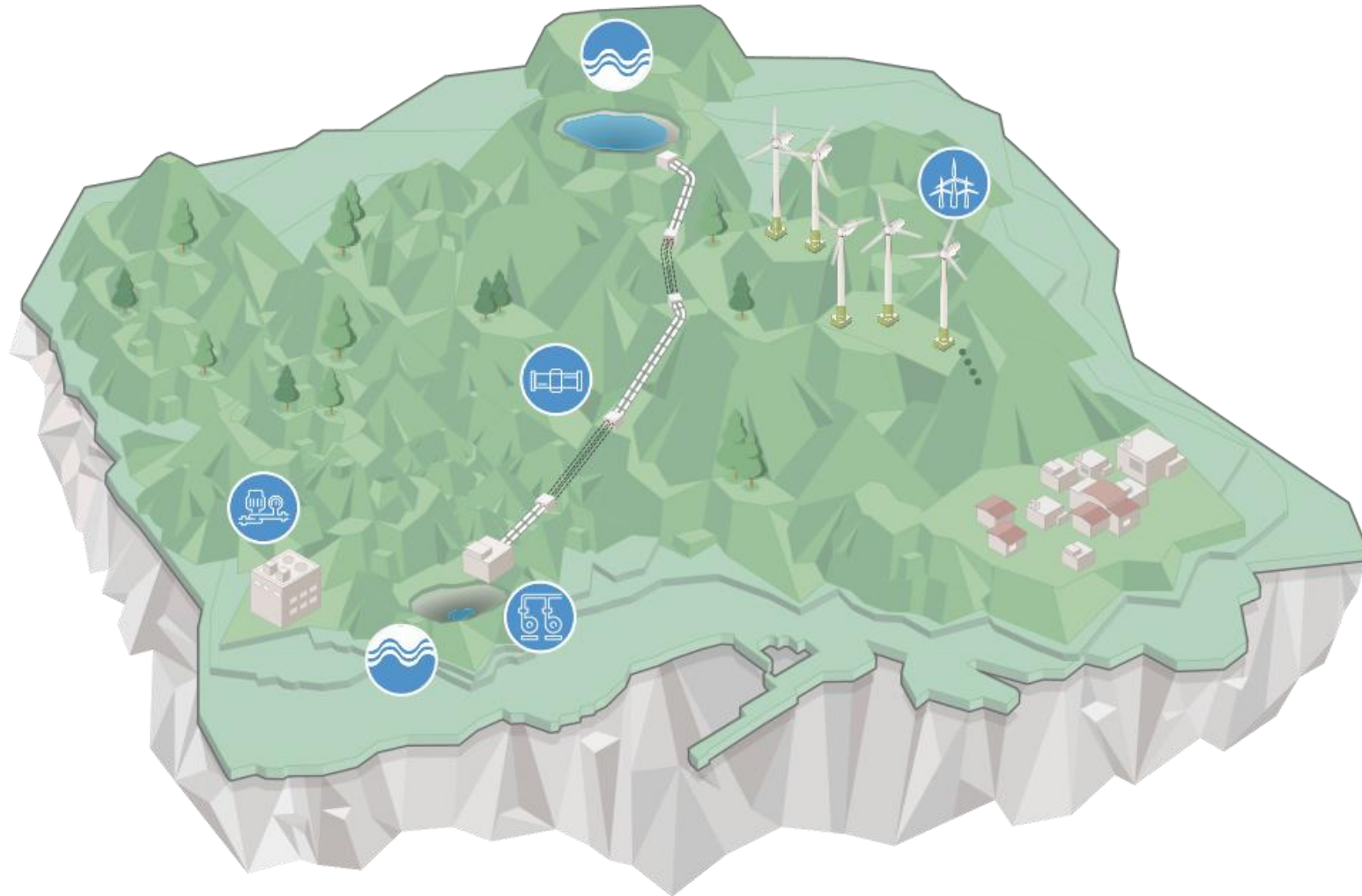


Water turbine. Dammed hydro.

Hydroelectric Dam



Water turbine. Pumped storage.



Water turbine. Power calculation

$$P_{turbine} = \varphi_V \cdot \rho \cdot g \cdot H \cdot \eta$$

φ_V = water flow [m^3/s]

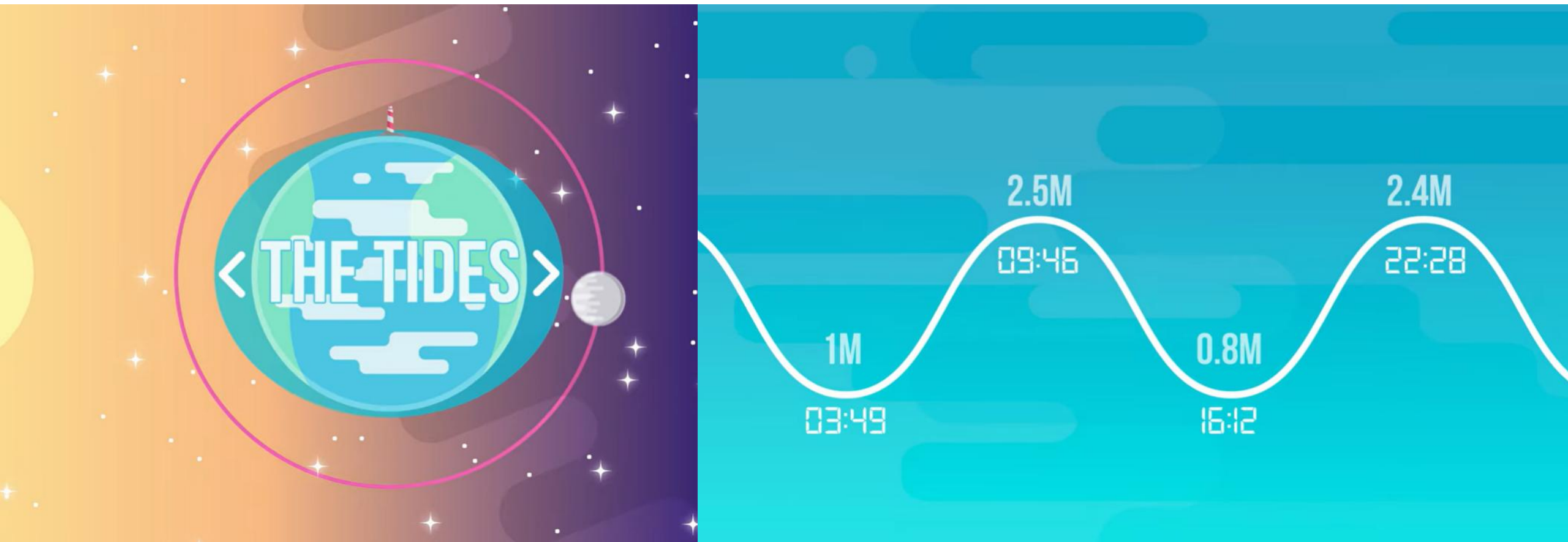
ρ = water density = 1000 [kg/m^3]

g = gravitational constant = 9,81 [m/s^2]

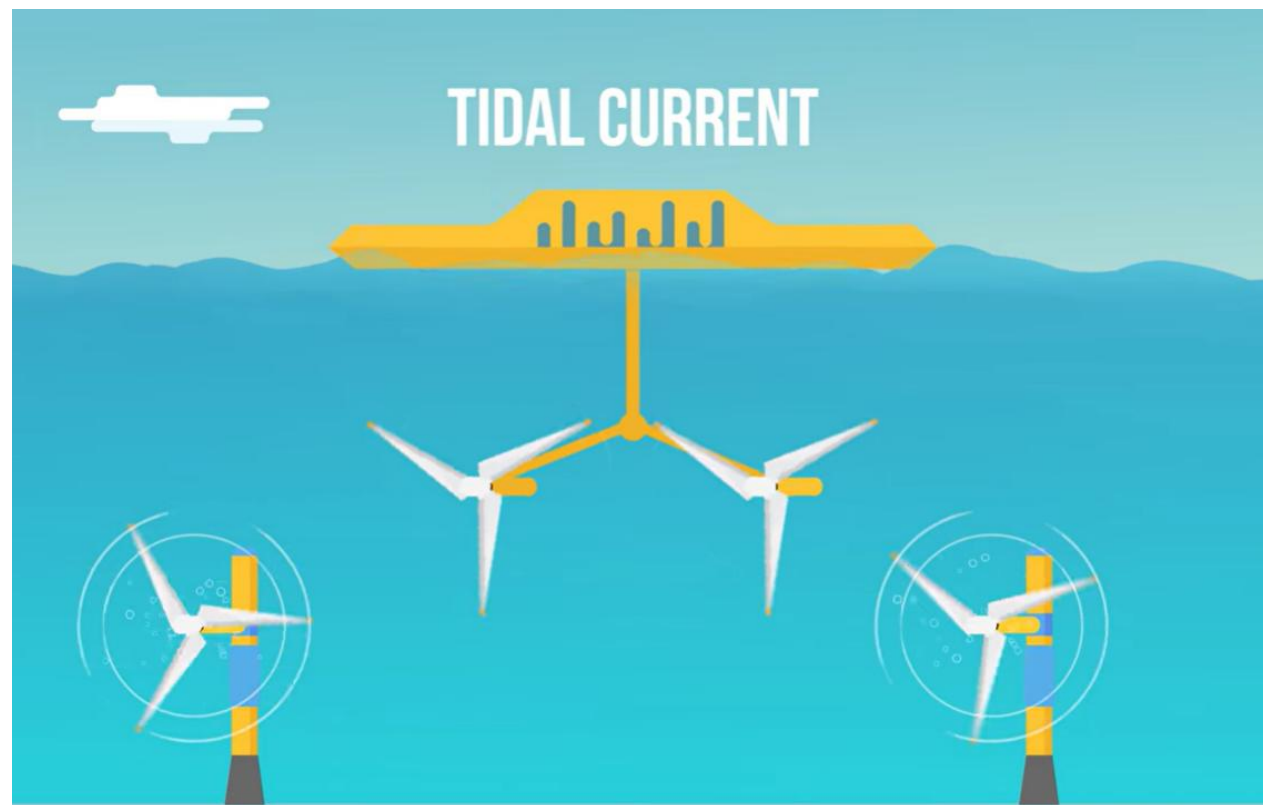
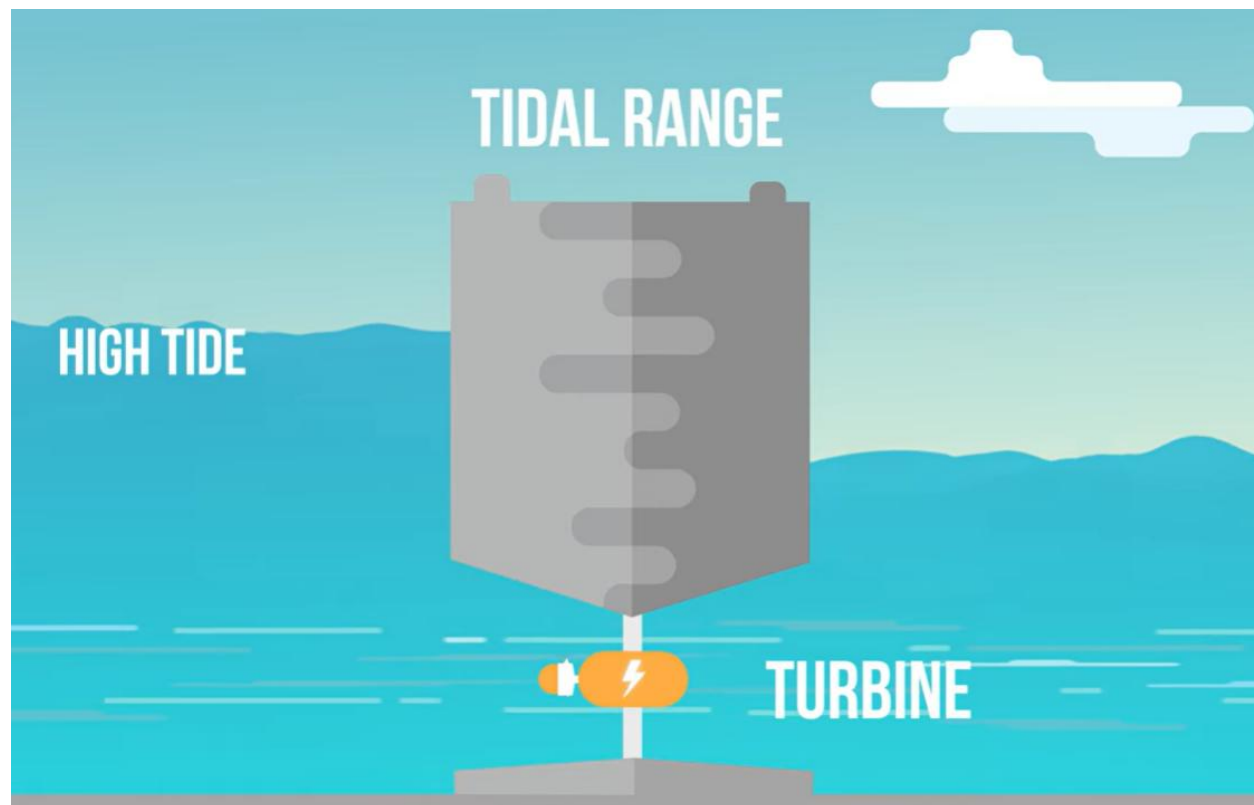
H = height difference [m]

η = turbine efficiency (80% – 90%)

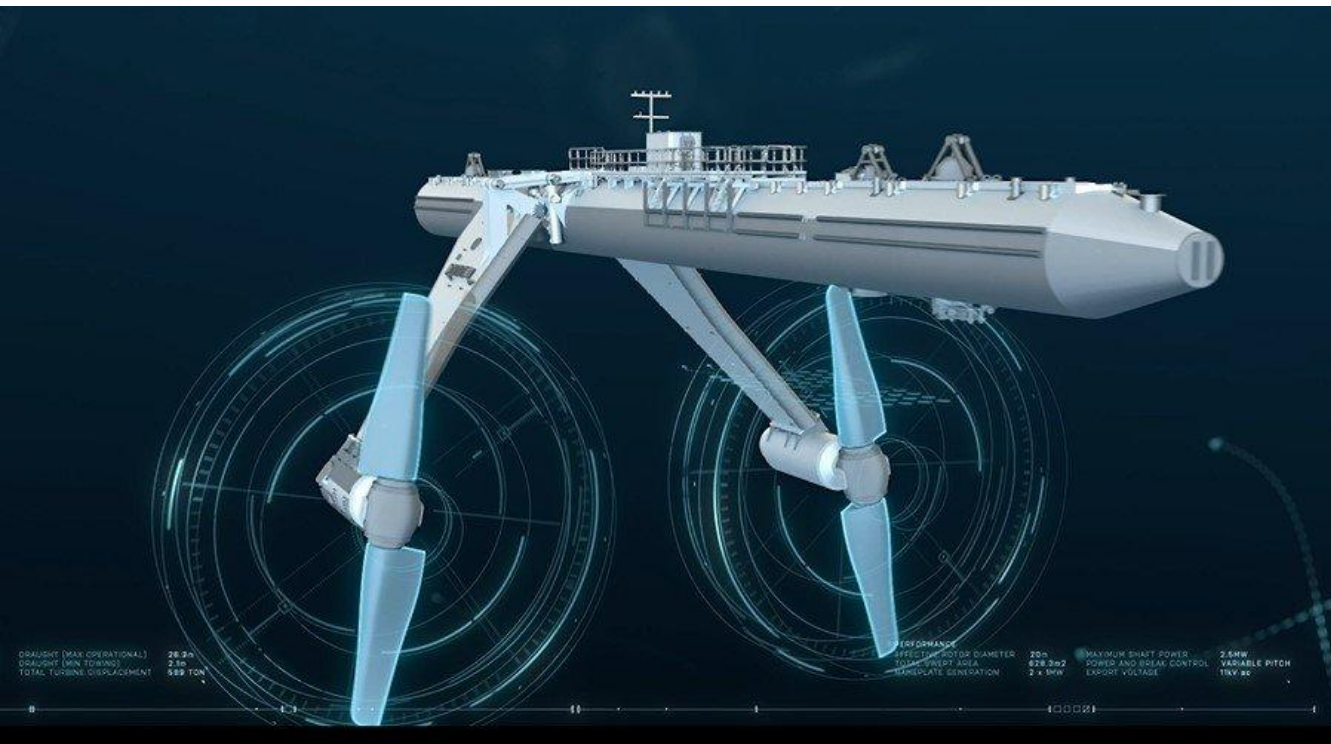
Tidal energy



Water turbine. Tidal energy



Water turbine. Tidal energy.



Water turbine advantages vs disadvantages

- Very high efficiency (often above 90% in hydro systems)
 - Renewable energy source (water cycle and ocean tides)
 - Low direct emissions during operation
 - Reliable and suitable for continuous operation (especially hydro with reservoirs)
 - Predictable energy production in tidal systems (based on tidal cycles)
 - Fast response to changes in electricity demand (hydropower)
 - Long lifespan and relatively low operating costs
 - Can contribute to energy storage (e.g., pumped hydro systems)
- Dependent on suitable locations (rivers, elevation differences, or strong tidal currents)
 - High initial construction cost (dams, marine installations, infrastructure)
 - Environmental impacts (river ecosystems, fish migration, marine habitats)
 - Potential social impacts (land use, displacement for large dams)
 - Energy output affected by seasonal variations and drought (hydropower)
 - Tidal systems are still emerging → higher costs and less mature technology
 - Marine environments increase maintenance challenges (corrosion, biofouling)
 - Limited number of viable sites for large-scale deployment

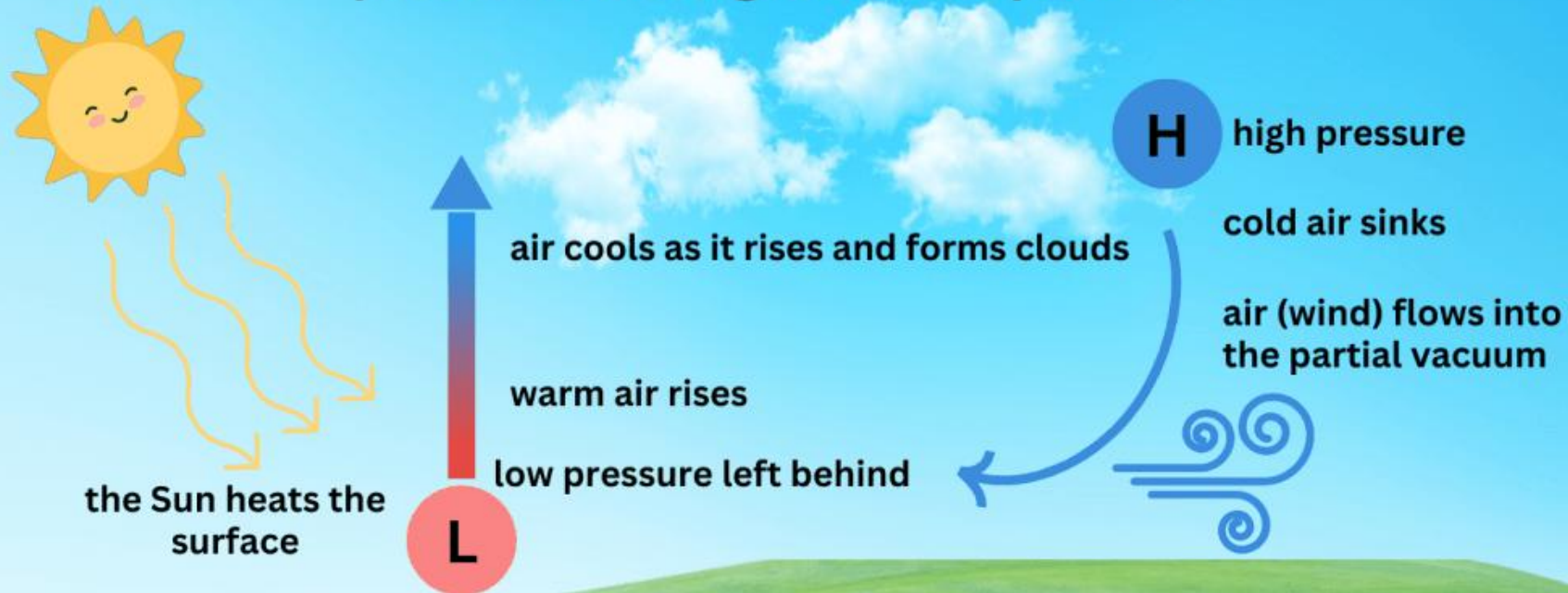
Wind turbine



Wind

What Causes Wind?

Wind is the movement of air from a region of high pressure to a region of low pressure.

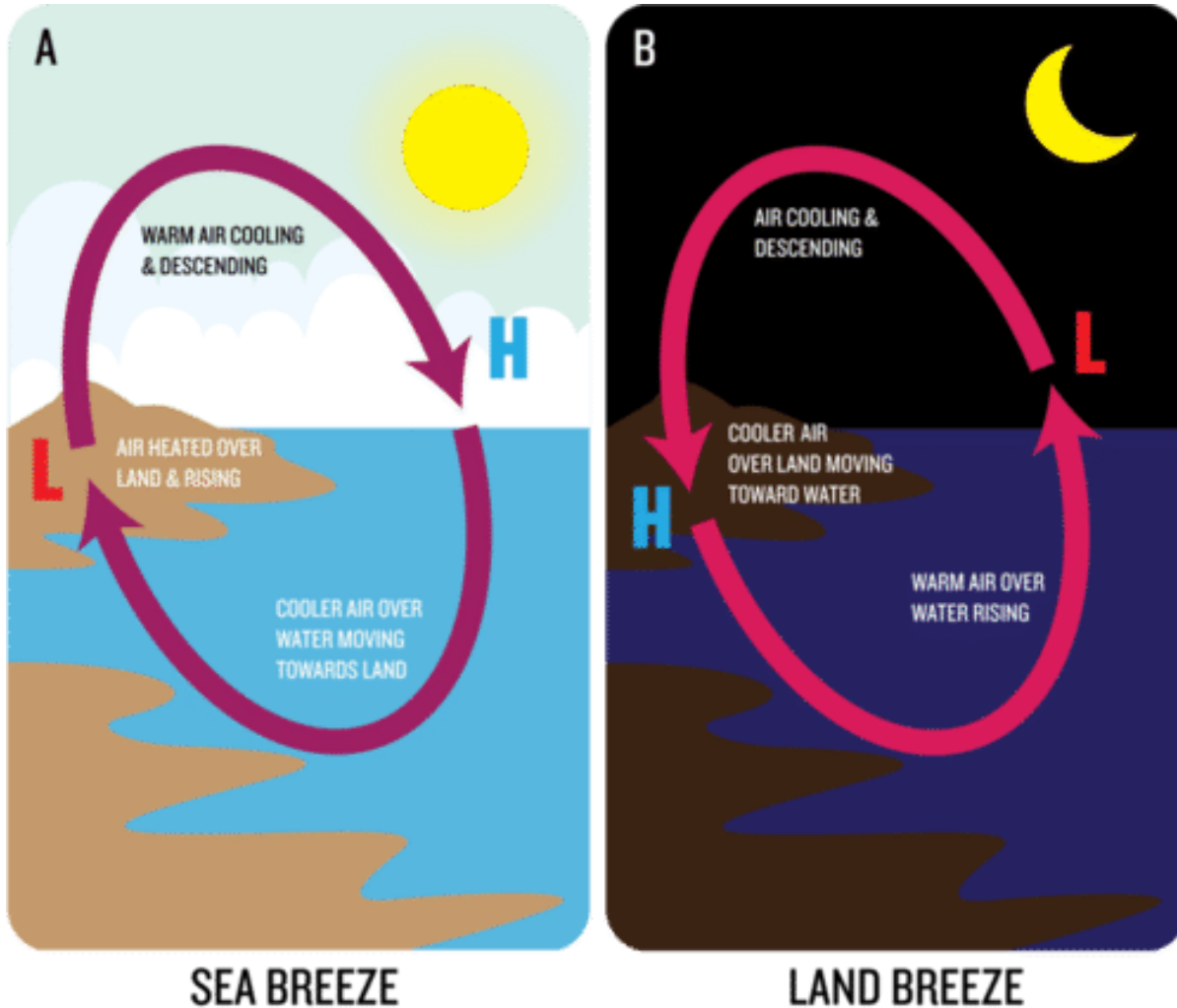


Temperature drives air pressure, so ultimately wind comes from unequal heating of the Earth.

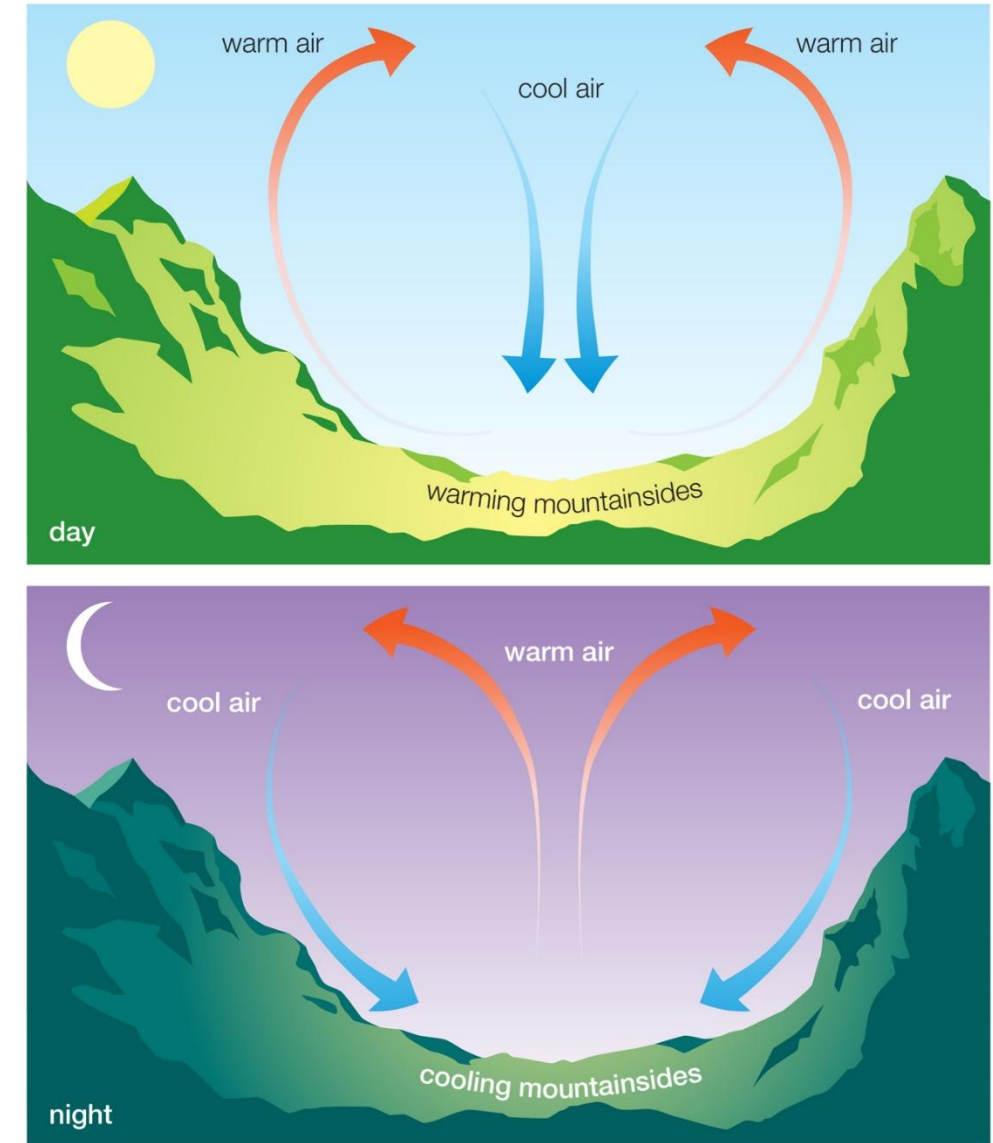
sciencenotes.org

https://sciencenotes.org/what-causes-wind-to-blow/#google_vignette

Local Wind

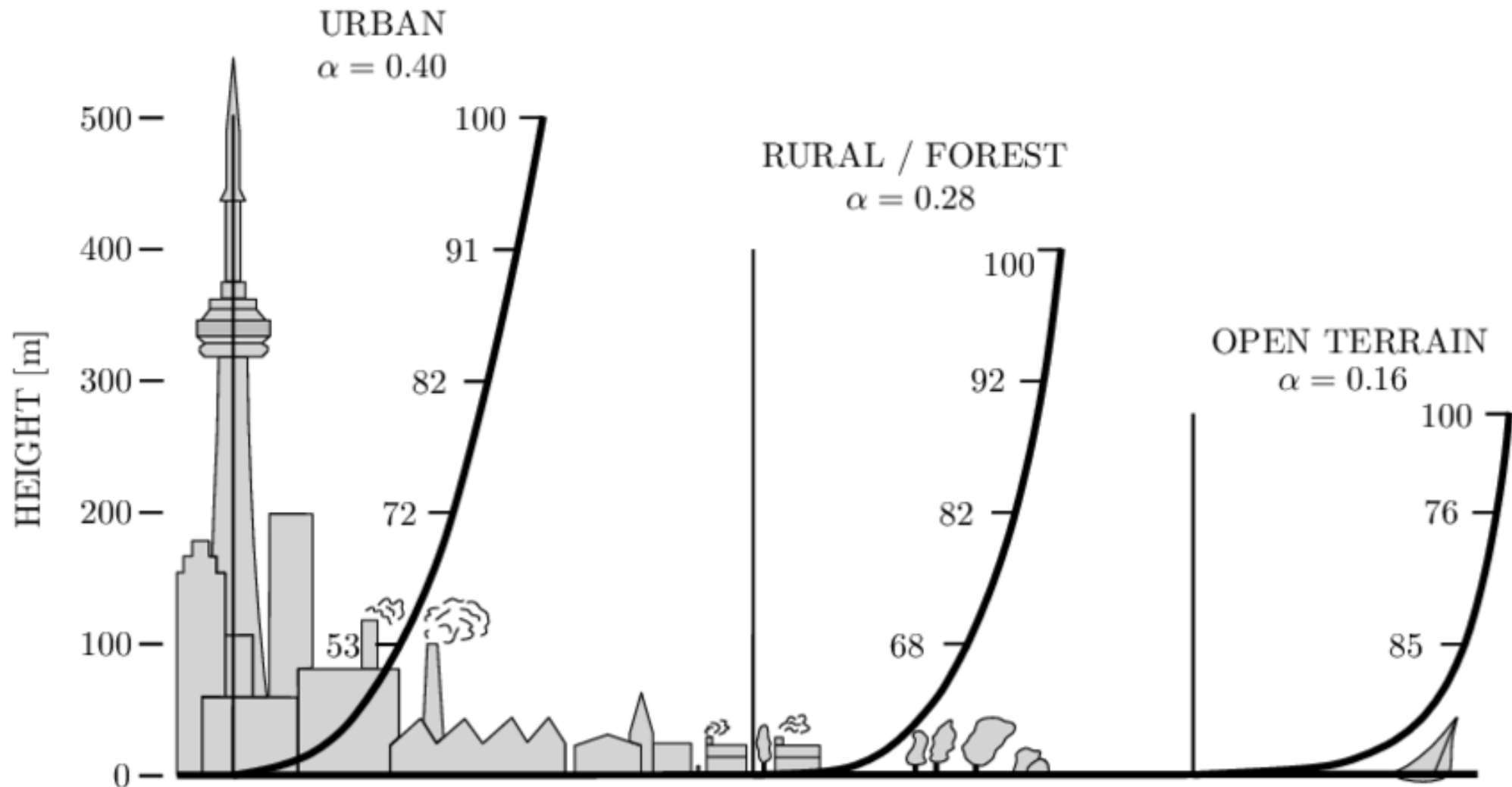


Valley and mountain breezes



© 2011 Encyclopædia Britannica, Inc.

Wind speed profile



Wind speed profile

$$v_2 = v_1 \cdot \left(\frac{z_2}{z_1} \right)^a [m/s]$$

$$v = \text{wind speed} \left[\frac{m}{s} \right]$$

$$z = \text{height} [m]$$

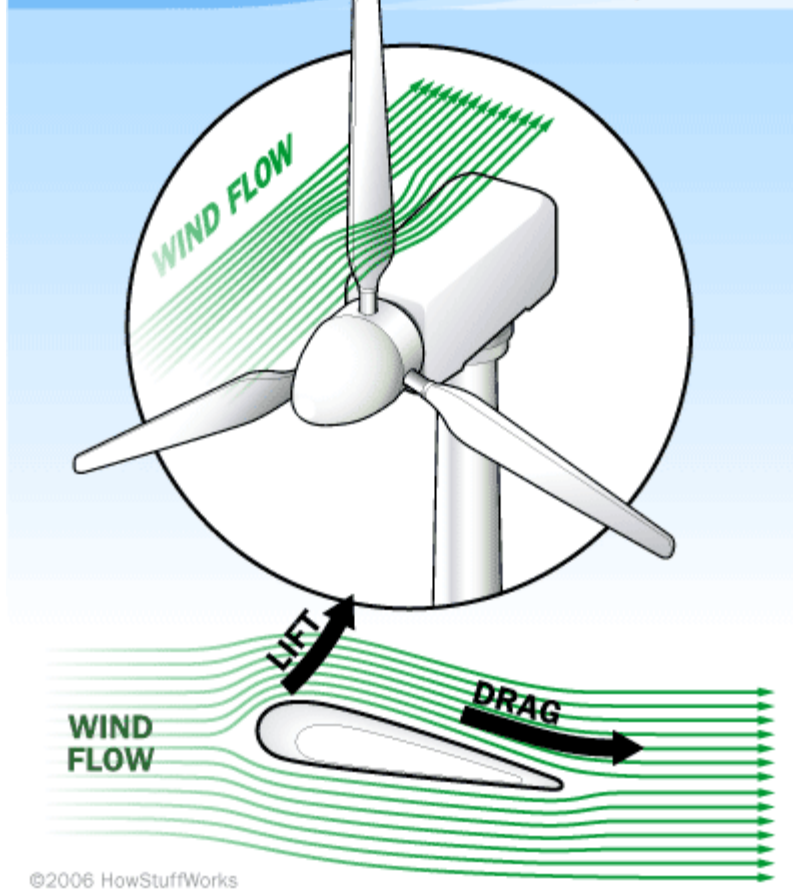
$$a = \text{power law exponent}$$

Terrain description	Power law exponent, α
Smooth, hard ground, lake or ocean	0.10
Short grass on untilled ground	0.14
Level country with foot-high grass, occasional tree	0.16
Tall row crops, hedge, a few trees	0.20
Many trees and occasional buildings	0.22- 0.24
Wooden country- small towns and suburbs	0.28- 0.30
Urban areas with tall buildings	0.4



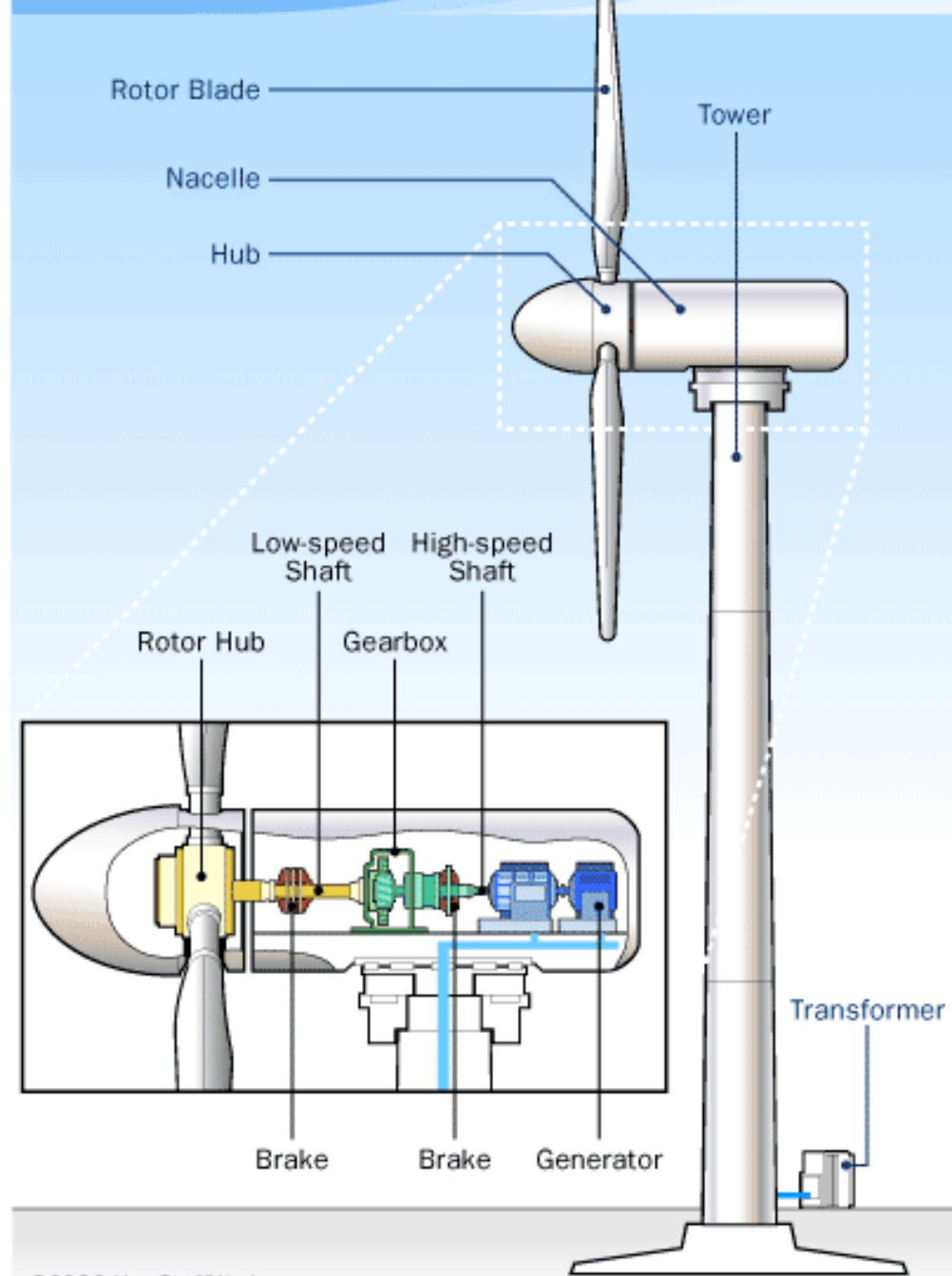
Wind turbine

How Wind Power Works Turbine Aerodynamics



<https://science.howstuffworks.com/environmental/green-science/wind-power.htm>

How Wind Power Works Horizontal-axis Turbine



Wind turbine power

$$P_{turbine} = C_p \cdot \frac{1}{2} \cdot \rho \cdot A \cdot v^3 [W]$$

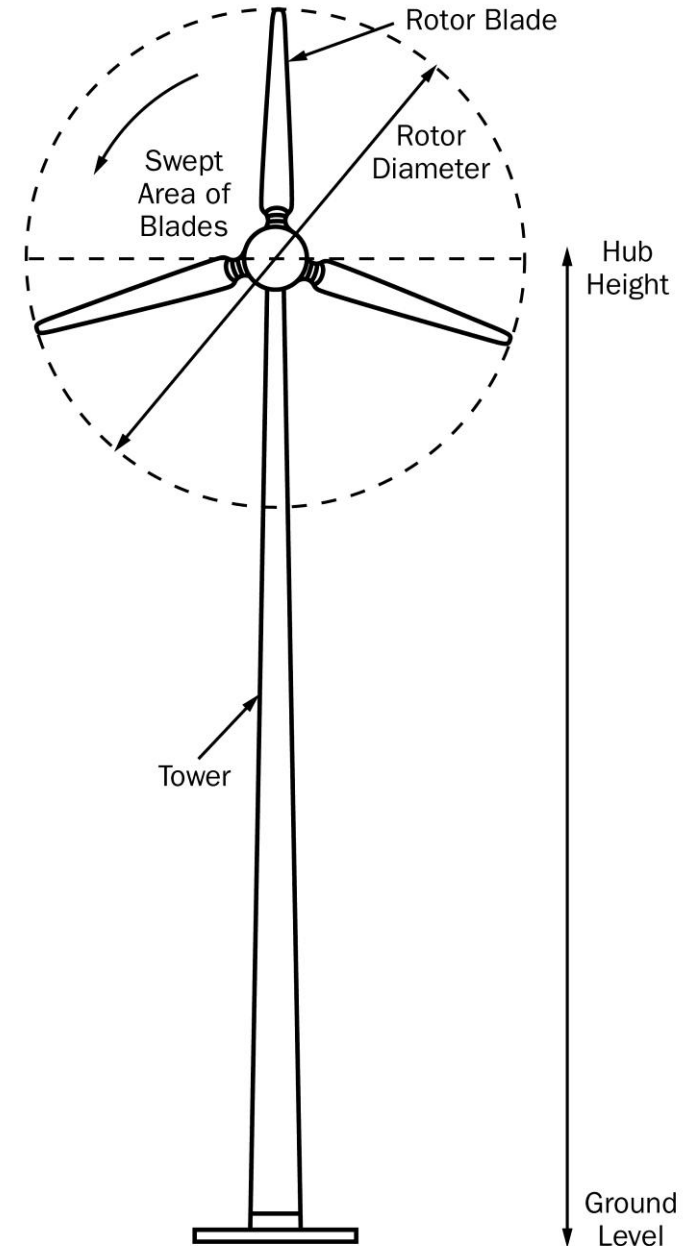
C_p = power coefficient

ρ = density of the air [kg/m^3]

v = speed at hub height [m/s]

A = swept area of the blades ($\frac{\pi}{4} \cdot D^2$) [m^2]

C_p is the power coefficient (efficiency) which is the percentage of power in the wind that is converted into mechanical energy, typically 0.35 to 0.45. The theoretical maximum is $16/27=0,5925$



Wind turbine advantages vs disadvantages

- Renewable and abundant energy source
- No direct emissions during operation
- Low operating and maintenance costs after installation
- Scalable (from small turbines to large wind farms)
- Suitable for both onshore and offshore deployment
- Quick installation compared to large power plants

- Variable and intermittent energy source
- Dependent on suitable wind conditions and locations
- Visual impact on landscape
- Noise generation
- Potential impact on wildlife (birds and bats)
- High initial investment, especially offshore
- Requires grid integration and/or energy storage for reliability

Do you want to know more?

This is a selection of Youtube videos that extend the content offered in this module

[How a car engine works](#), Animagraffs (Youtube)

[What is a Gas Turbine?](#), RealPars (Youtube)

[How Jet Engines Work](#), Animagraffs (Youtube)

[How does a steam turbine work?](#), LifeAda (Youtube)

[Hydropower](#), Student Energy (Youtube)

[Tidal Energy](#), TU Delft (Youtube)

[How do wind turbines work?](#) - Rebecca J. Barthelmie and Sara C. Pryor, Ted-ED (Youtube)

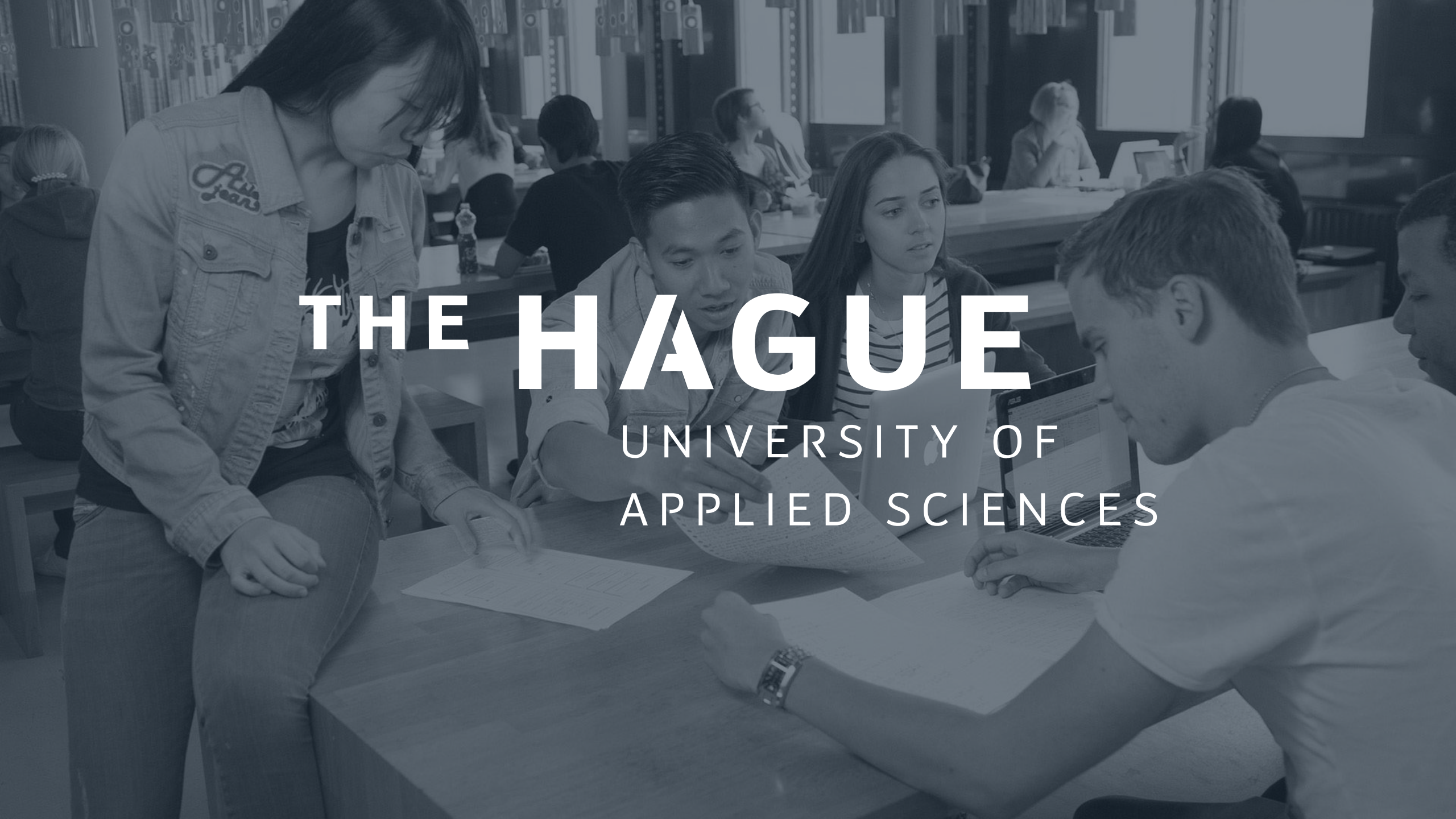
References

The references are accredited in each slide of the presentation.

General books used as reference are:

Ouwehand, J., Trynke, P., Post, E., Taal, A. (2012) Toegespaste Energietechniek, Sdu, Den Haag.

Ouwehand, J., Trynke, P., Gilijamse, W., Geus, J. de (2017) Duurzame energietechniek, Boom, Amsterdam.

A grayscale photograph of a modern classroom or study hall. In the foreground, a group of four students are gathered around a table. A young woman on the left, wearing a denim jacket with a 'Live Years' patch, is leaning over and pointing at a document. A young man next to her is also looking at the document. Behind them, another young woman is looking on. To the right, a young man is sitting at the table, looking at a laptop. In the background, other students are seated at long tables, and the room has large windows and decorative elements hanging from the ceiling.

THE HAGUE

UNIVERSITY OF
APPLIED SCIENCES