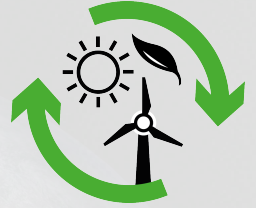


Renewable energy generation

Wind Energy Potential

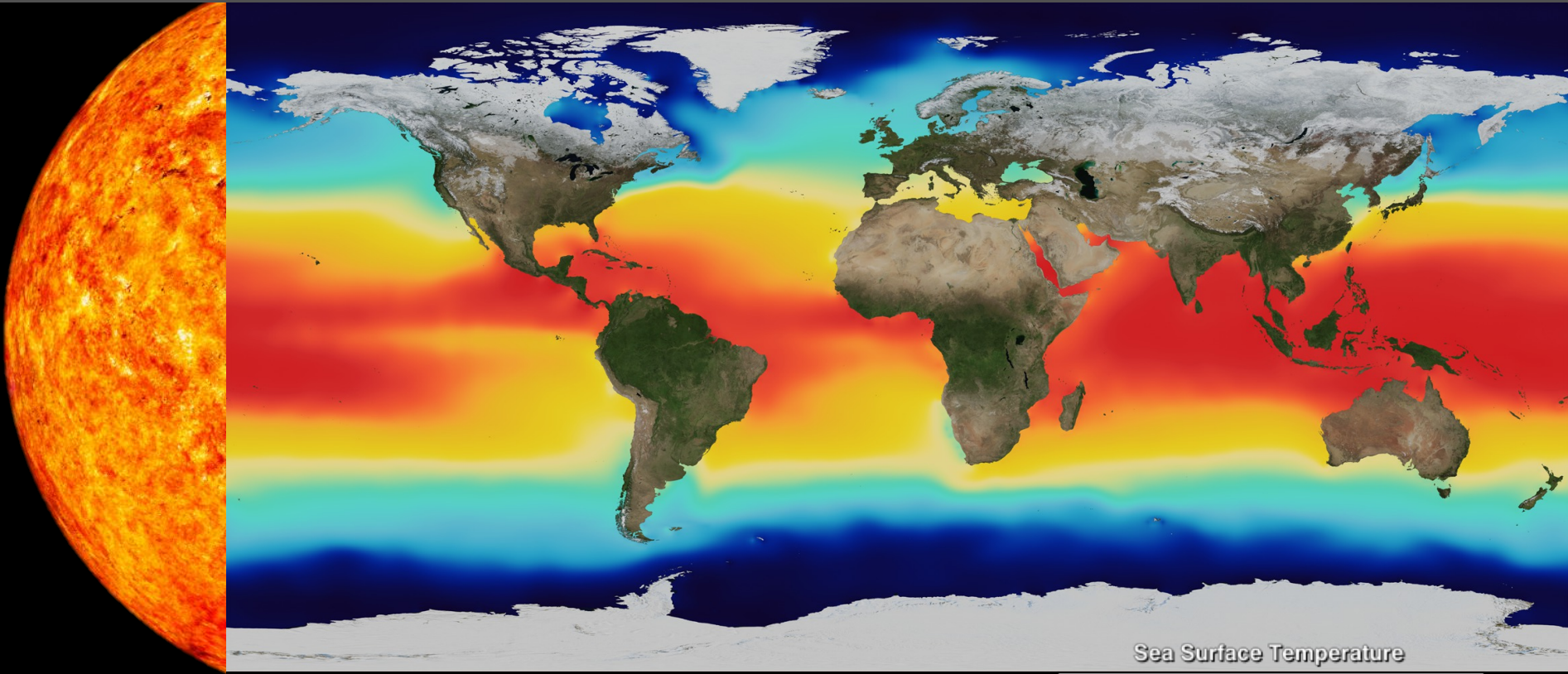
Professor Arno Smets



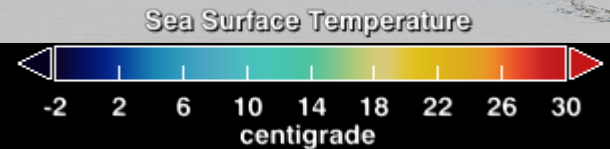
Wind Energy Technology



The Principles



NASA/Goddard Space Flight Center Scientific Visualization Studio, 2009, source: <http://svs.gsfc.nasa.gov/3652>



The Principles





PRIMARY ENERGY POTENTIAL

$$E_{kin} = 1/2 * m * v^2 \quad [J] = 1/2 * [kg] * [m s^{-1}]^2$$

$$P_{wind} = E_{kin}/t = 1/2 * \dot{m} * v^2 \quad [W] = 1/2 * [kg s^{-1}] * [m s^{-1}]^2$$

PRIMARY ENERGY POTENTIAL

$$\dot{m} = \rho * A * v$$

$$[\text{kg s}^{-1}] = [\text{kg m}^{-3}] * [\text{m}^2] * [\text{m s}^{-1}]$$

$$A = \pi * \left(\frac{D}{2}\right)^2$$

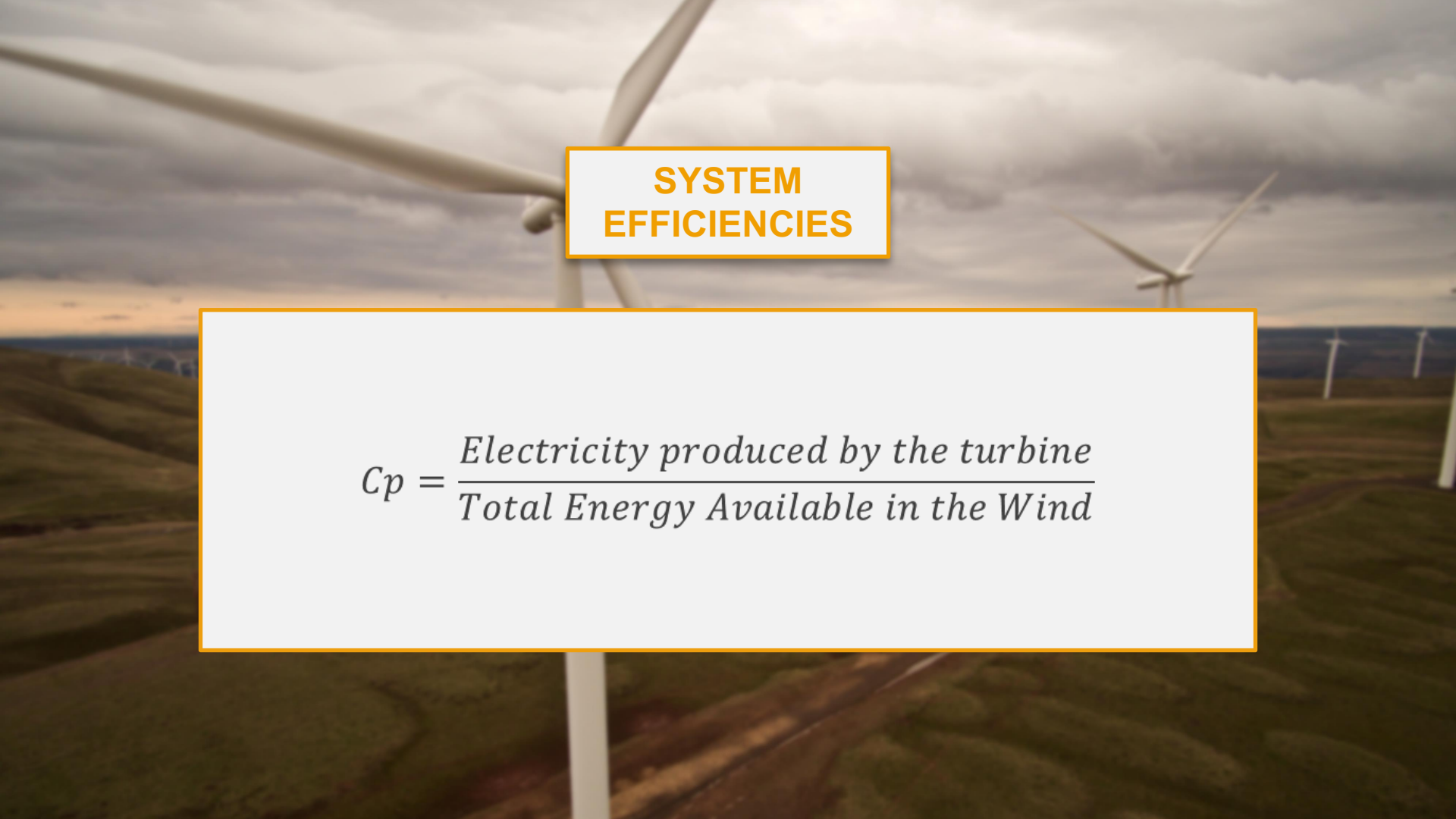
$$[\text{m}^2] = \pi * \left(\frac{[\text{m}]}{2}\right)^2$$

$$P_{wind} = \frac{1}{2} * \rho * A * v^3$$

$$[\text{W}] = \frac{1}{2} * [\text{kg m}^{-3}] * [\text{m}^2] * [\text{m s}^{-1}]^3$$



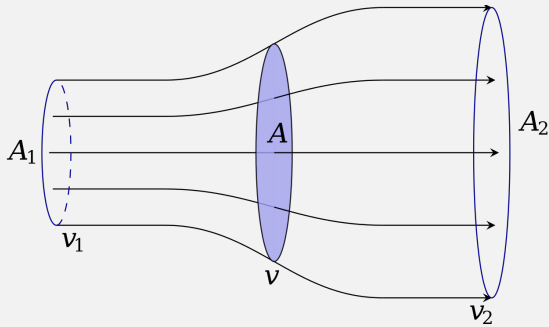


A photograph of a wind turbine farm in a hilly, green landscape under a cloudy sky. The turbines are white and spaced out across the terrain. The sky is overcast with grey and white clouds, and the ground is covered in green grass with some brown patches.

SYSTEM EFFICIENCIES

$$C_p = \frac{\textit{Electricity produced by the turbine}}{\textit{Total Energy Available in the Wind}}$$

SYSTEM EFFICIENCIES



Betz Limit

Maximum mechanical
efficiency 59.3%

A photograph of a wind turbine in a field of rolling green hills under a cloudy sky. The turbine is the central focus, with its three blades extending outwards. In the background, other turbines are visible on the horizon.

ENERGY YIELD

Seasonal &
Daily
Intermittency

Cut-off
Speed

Maintenance
& Repair



Calculation Example

Given Information

Rotor Diameter $D = 126$ [m] & Power Coefficient $C_p = 0.483$ at $v = 10$ [m s^{-1}]

Gather Useful Values

$$\rho = 1.23 \text{ [kg m}^{-3}\text{]}$$

$$A_{rotor} = \pi * \left(\frac{1}{2} * 126\right)^2 = 12469 \text{ [m}^2\text{]}$$

$$v_{avg} = 10 \text{ [m s}^{-1}\text{]}$$

Calculate Potential

$$P_{wind} = \frac{1}{2} * 1.23 \text{ [kg m}^{-3}\text{]} * 12469 \text{ [m}^2\text{]} * 10^3 \text{ [m}^3 \text{ s}^{-3}\text{]} = 7.7 \text{ [MW]}$$

Calculation Example

Calculate Potential

$$P_{wind} = 1/2 * 1.23[\text{kg m}^{-3}] * 12469[\text{m}^2] * 10^3[\text{m}^3 \text{s}^{-3}] = 7.7 [\text{MW}]$$

Calculate Actual Power

$$P_{Real} = 7.7 [\text{MW}] * 0.483 = 3.7 [\text{MW}]$$

Calculation Example: Wind turbine in Denmark

Given Information

Nominal Capacity = 5.07 [GW] & Energy Yield = 14.13 [TWh]

Calculate Capacity Factor

$$Cf = 14.3[\text{TWh year}^{-1}] * 1/8760 [\text{year h}^{-1}] * 1/5.07 [\text{GW}^{-1}] = 0.32$$



ADVANTAGES

- Large Energy Potential

CHALLENGES

- Low Capacity factor
- Endanger Grid Stability
- Good Wind Sites in Remote Locations

Global Perspective

Given Information

Global Energy Yield = 960 [TWh year⁻¹] Global Population = 7.5 * 10⁹ [person]

Other Units

$$E_{GlobalYield} = 960 \text{ [TWh year}^{-1}\text{]} * \frac{1}{7.5 * 10^9} \text{ [person}^{-1}\text{]} * \frac{1}{365} \text{ [year day}^{-1}\text{]}$$

$$E_{GlobalYield} = 351 \text{ [Wh person}^{-1}\text{day}^{-1}\text{]}$$

Global Perspective



World's Electricity Demand 2040 : 4.2 [TW]

Thank you for your attention!

