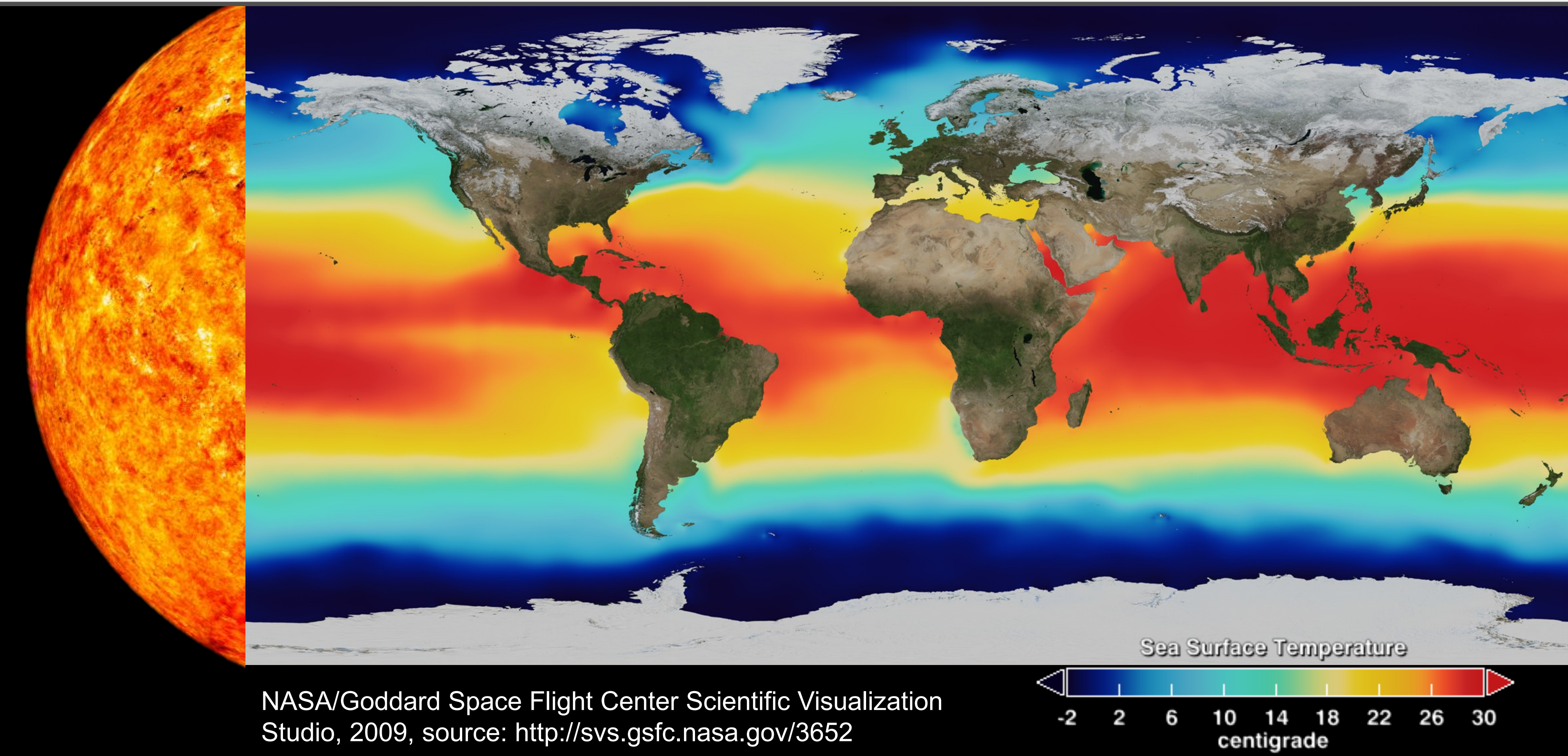
# Renewable energy generation

## 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

$$E_{kin} = {}^{1}/_{2} * m * v^{2}$$

$$[\mathrm{J}] = {}^{1}/_{2} * [\mathrm{kg}] * [\mathrm{m\,s^{-1}}]$$

$$P_{wind} = {}^{E_{kin}}/_{t} = {}^{1}/_{2} * \dot{m} * v^{2}$$

$$[\mathrm{W}] = {}^{1}/_{2} * [\mathrm{kg\,s^{-1}}] * [\mathrm{m\,s^{-1}}]$$

# PRIMARY ENERGY POTENTIAL

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

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

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

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

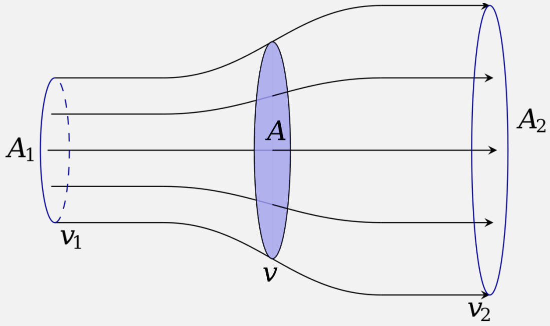
$$P_{wind} = {}^{1}/_{2} * \rho * A * v^3$$

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

# SYSTEM EFFICIENCIES

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

# SYSTEM EFFICIENCIES




Betz Limit

Maximum mechanical efficiency 59.3%

ENERGY YIELD

Seasonal & Daily Intermittency

Cut-off Speed

Maintenance & Repair

# Calculation Example

## Given Information

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

## Gather Useful Values

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

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

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

## Calculate Potential

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

# Calculation Example

## Calculate Potential

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

## Calculate Actual Power

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

# Calculation Example: Wind turbine in Denmark

## Given Information

Nominal Capacity = $5.07\ [\mathrm{GW}]$ & Energy Yield = $14.13\ [\mathrm{TWh}]$

## Calculate Capacity Factor

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

## ADVANTAGES

- Large Energy Potential

## CHALLENGES

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

# Global Perspective

## Given Information

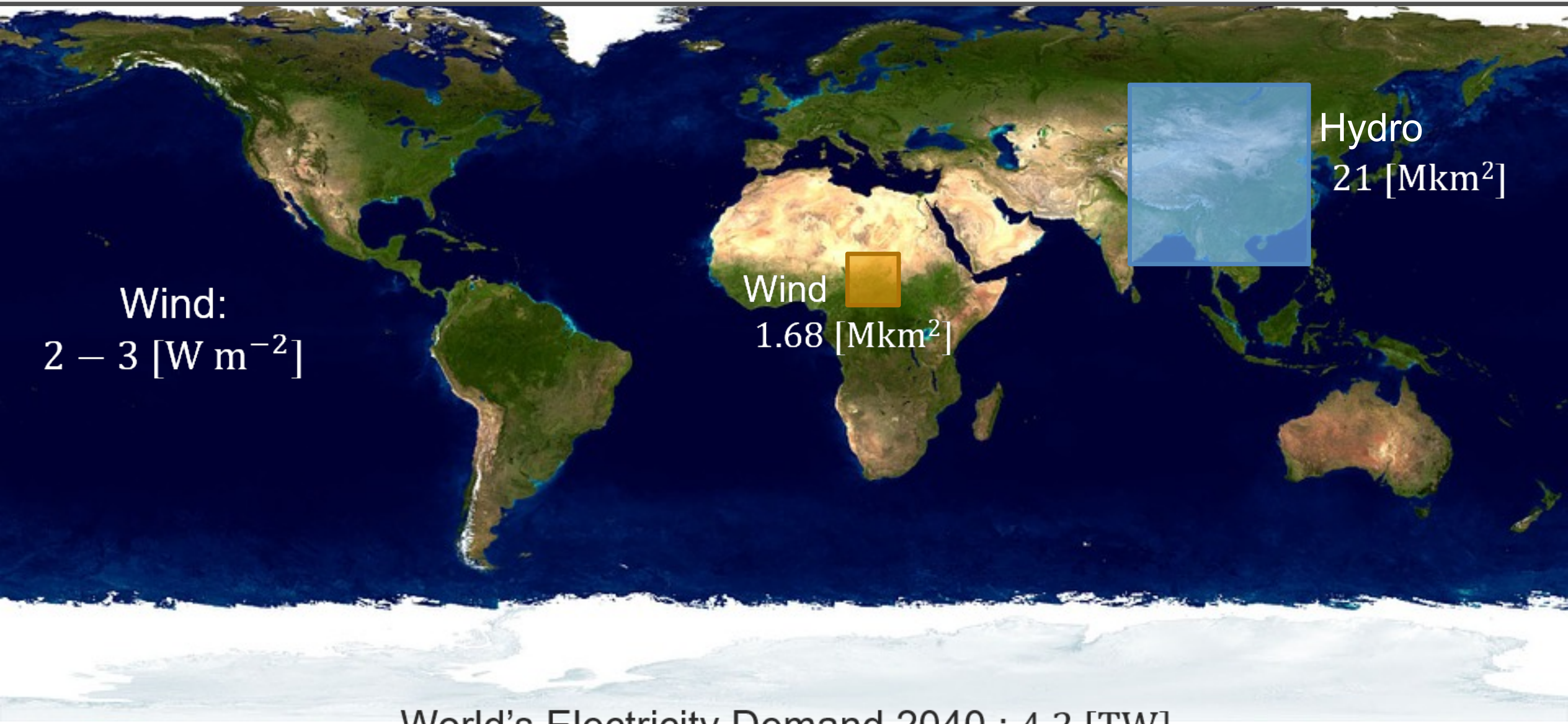
Global Energy Yield= $960\ [\mathrm{TWh\ year}^{-1}]$    Global Population = $7.5 * 10^{9} [\mathrm{person}]$

## Other Units

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

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

# Global Perspective




World's Electricity Demand 2040 : $4.2 \ [\mathrm{TW}]$

# Thank you for your attention!