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hamburger sternwarte

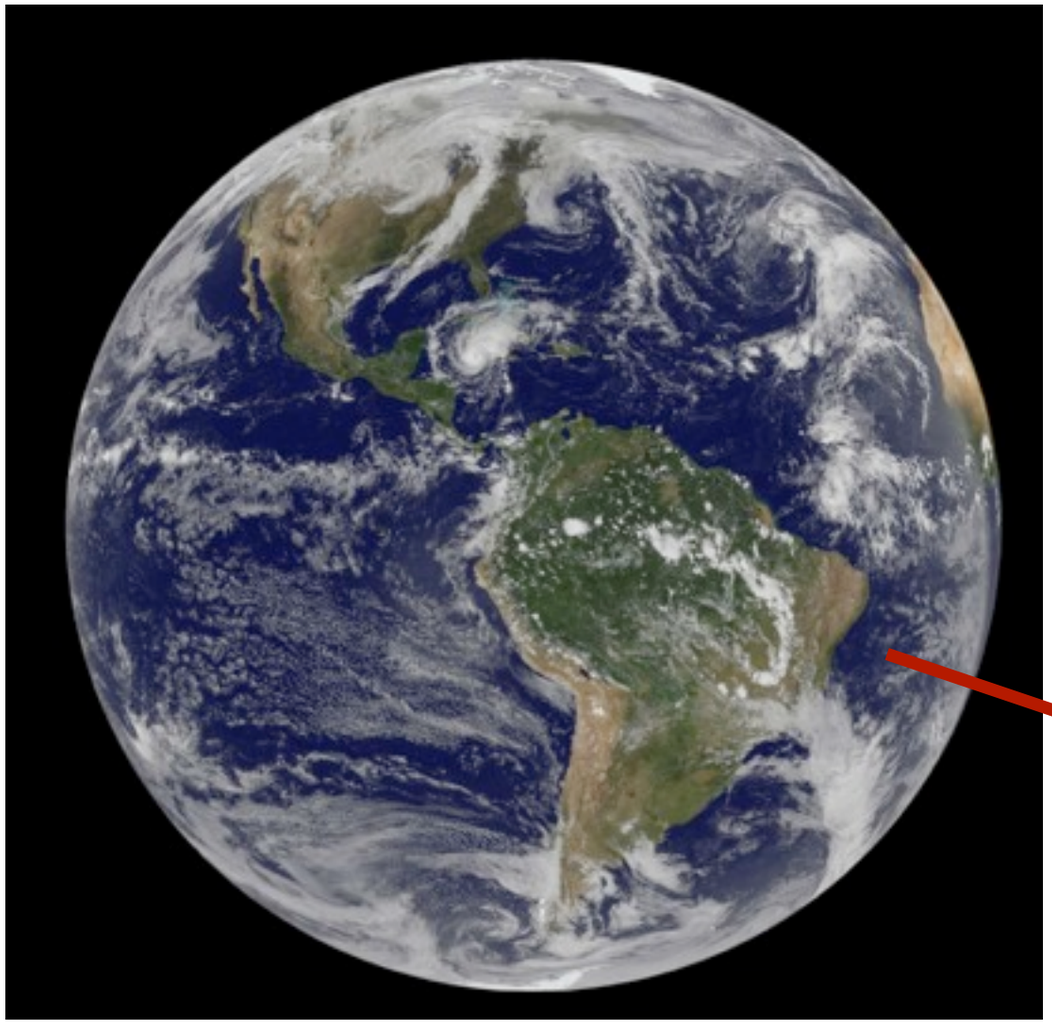
Regenerative Energy Source and its Exploitation

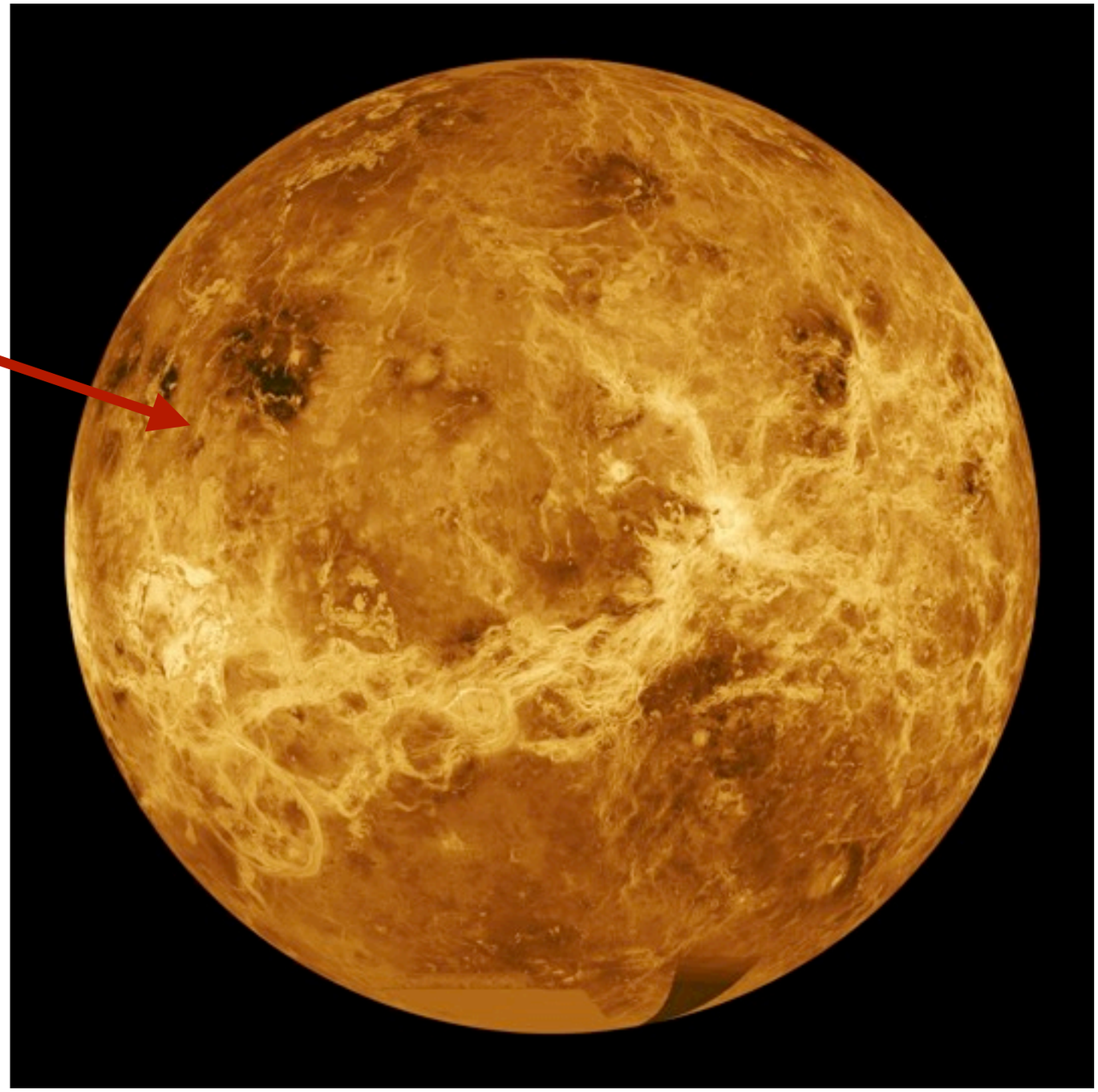
an Astrophysical Point of View

Prof. Dr. Robi Banerjee
Hamburger Sternwarte
University of Hamburg

Why?

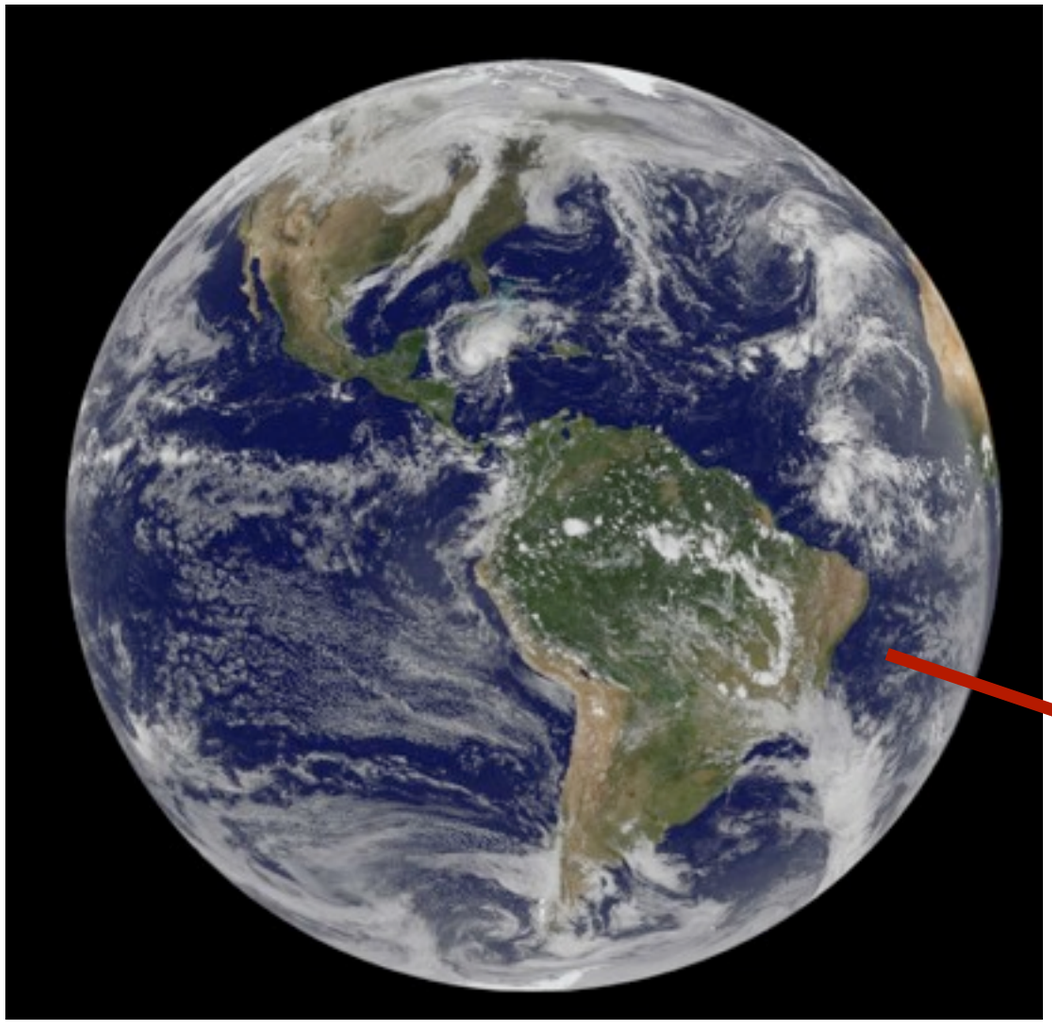
Why?

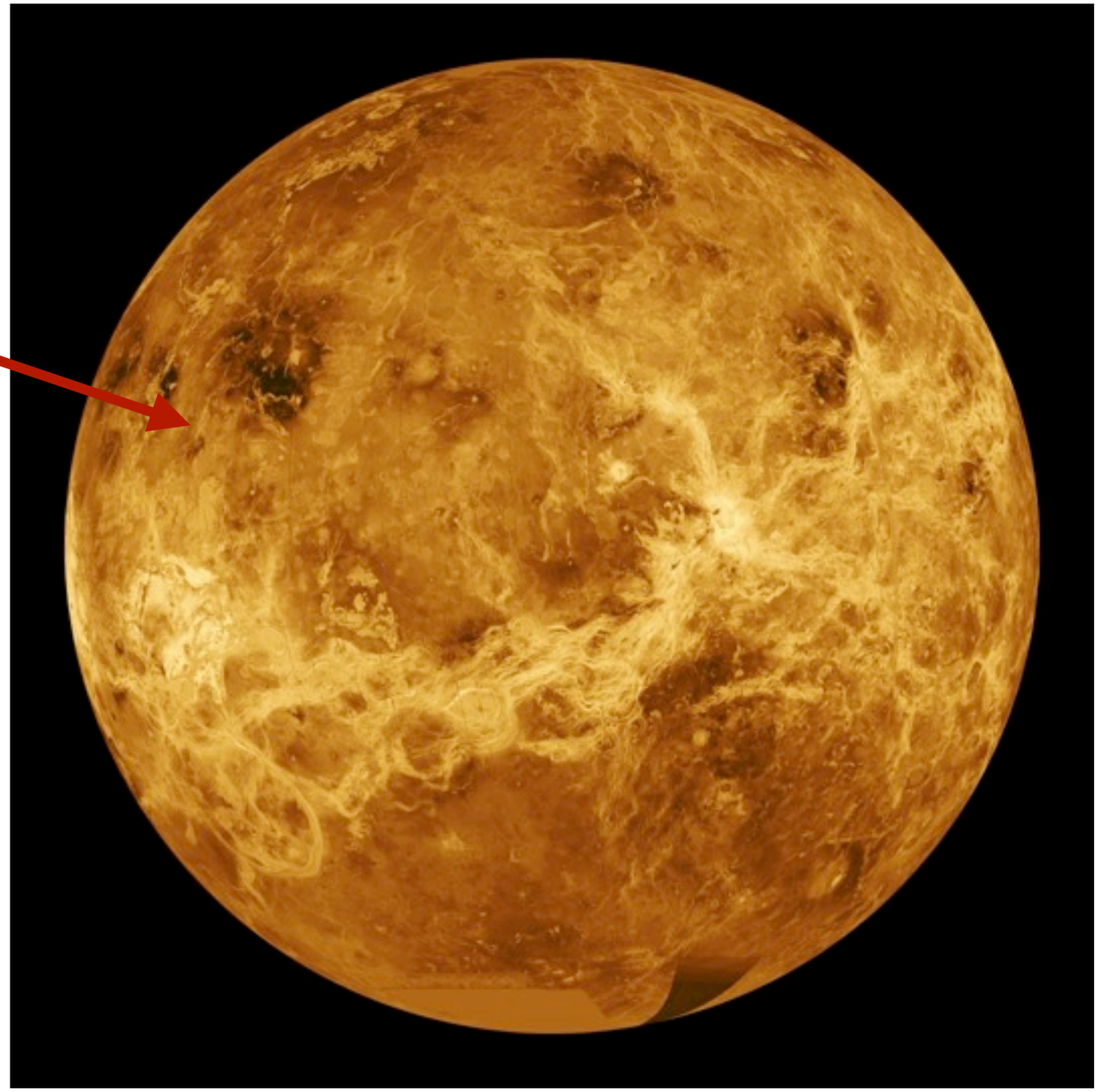




Venus' atmosphere:
96% CO_2

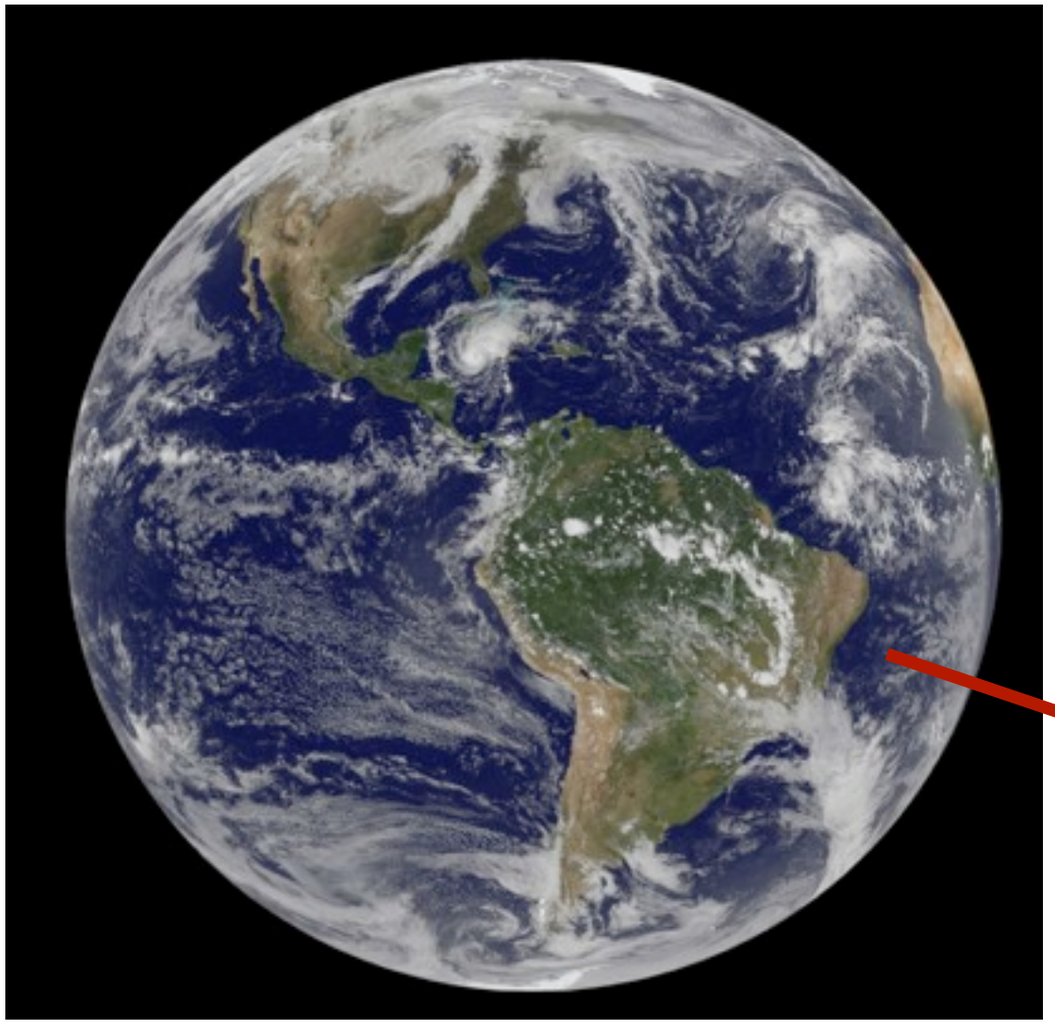
Why?

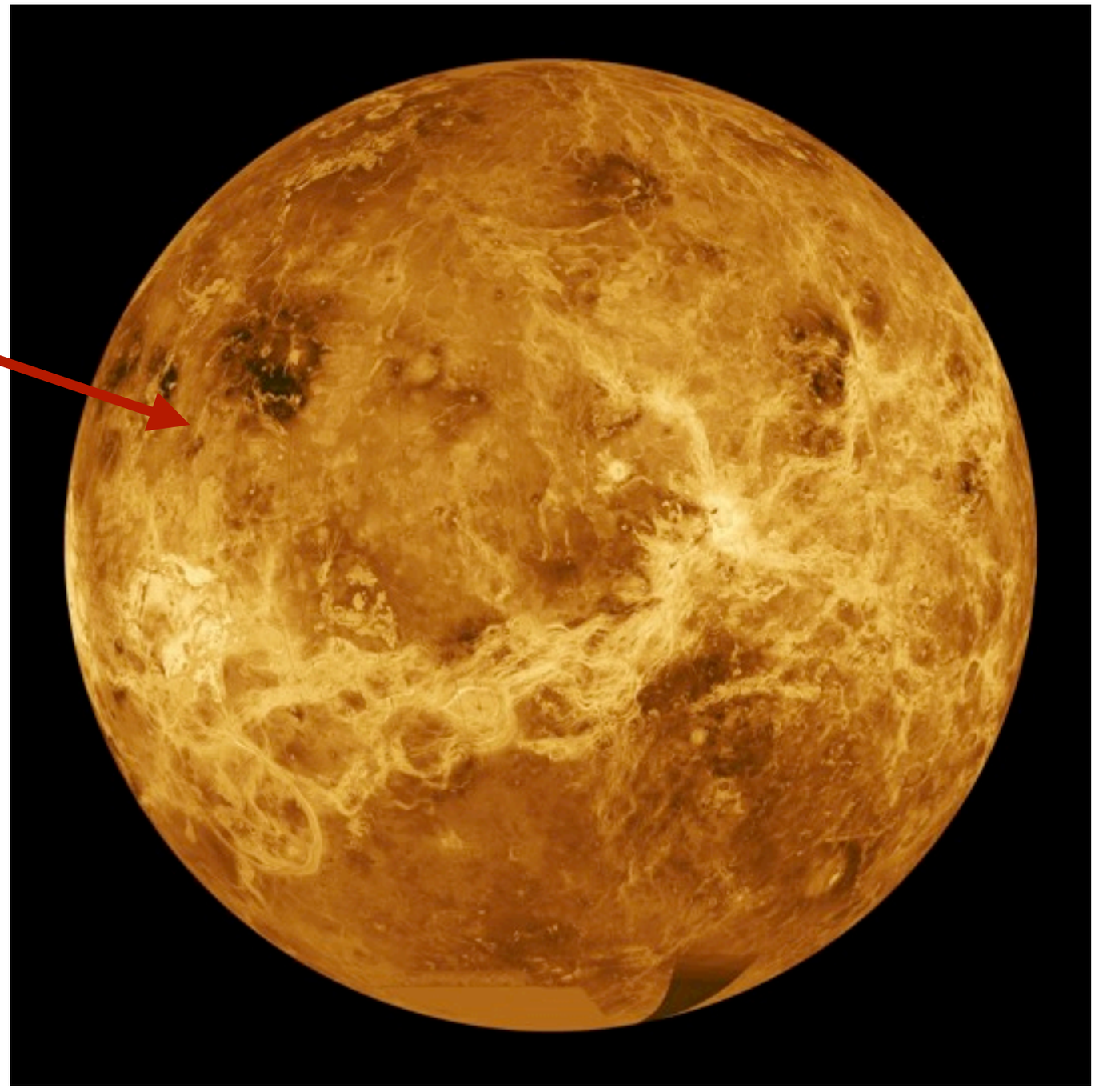




- anthropogenic climate change
- limited resources

Why?

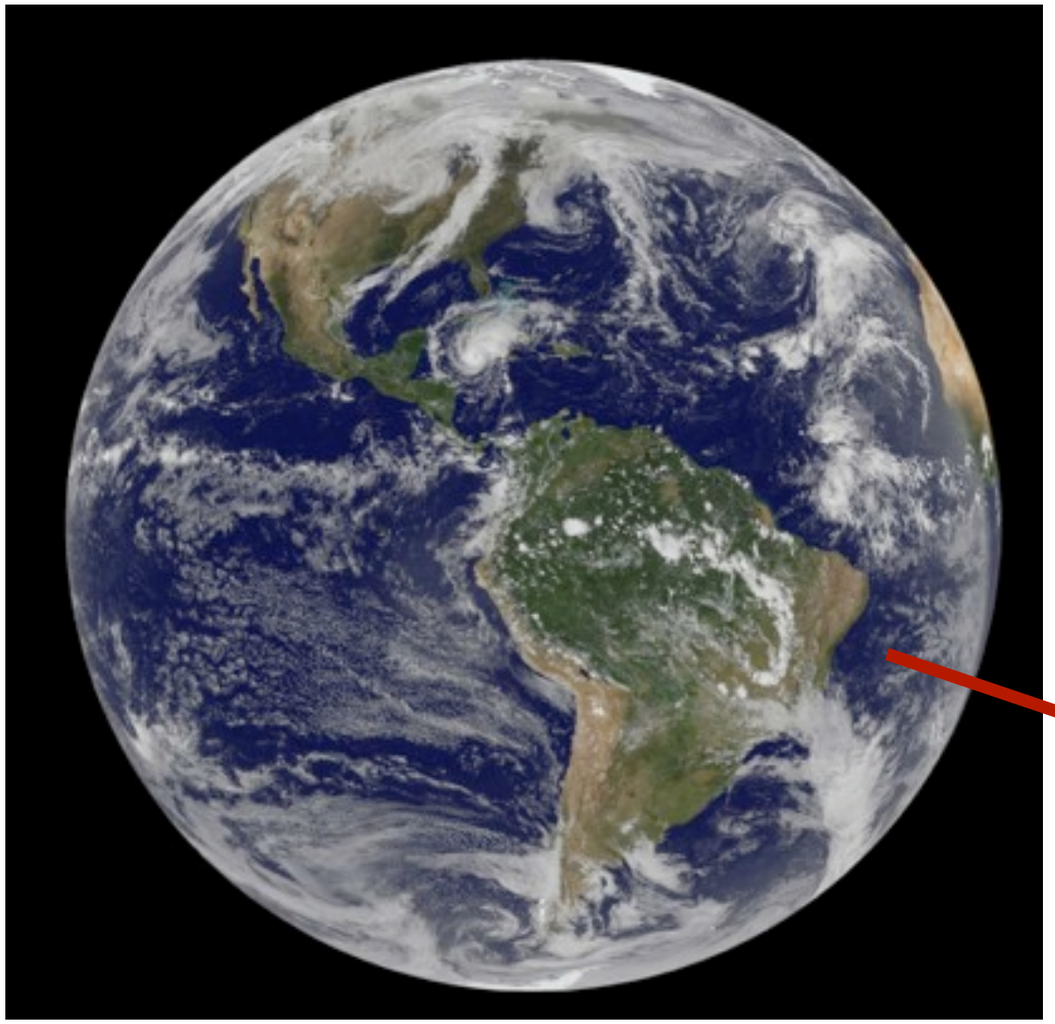


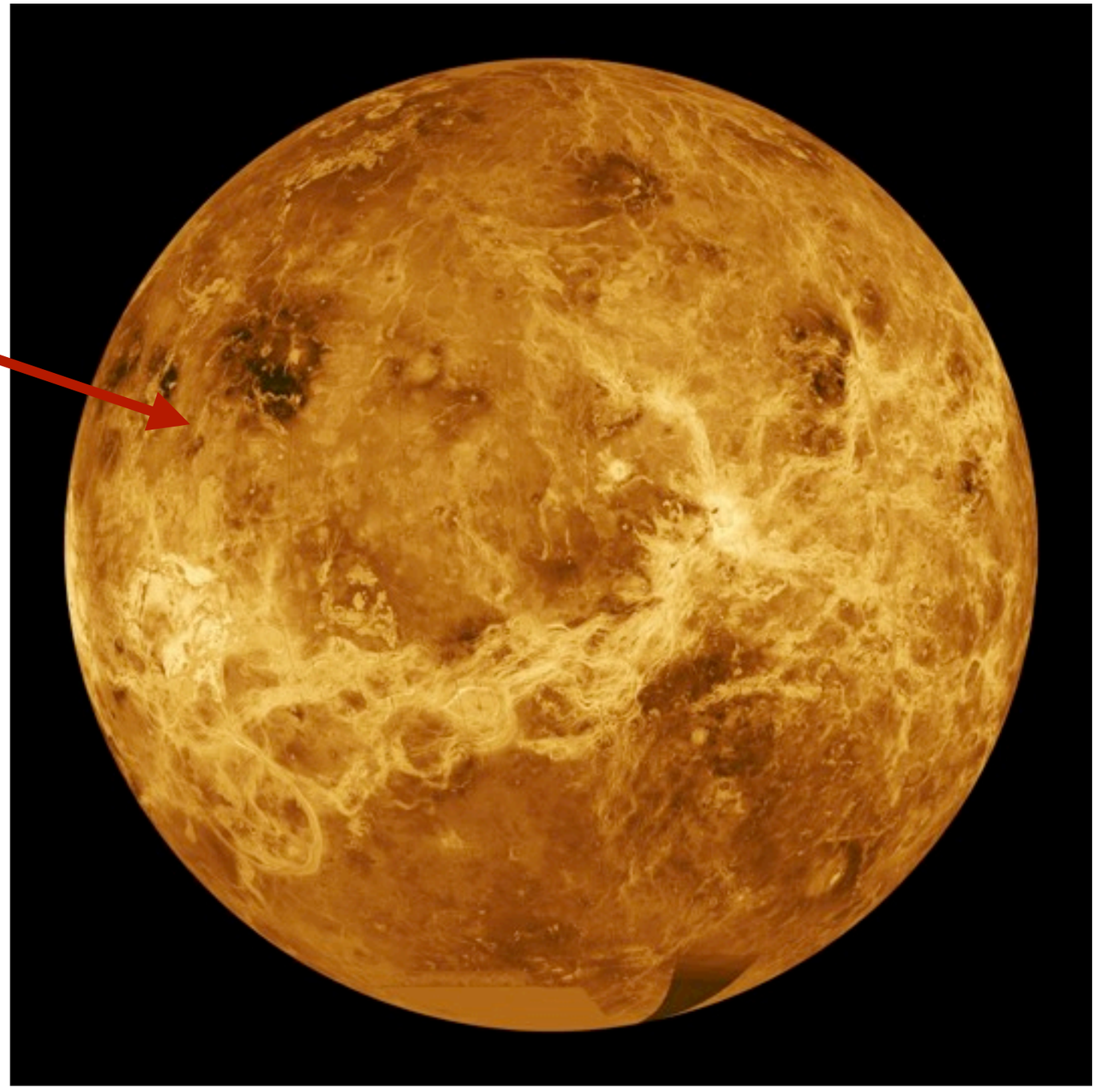


- anthropogenic climate change

- limited resources
- responsible handling

Why?





- anthropogenic climate change

- limited resources
- responsible handling
- improvement of quality of live

World Demand of Energy

about 505 Exa Joule per year

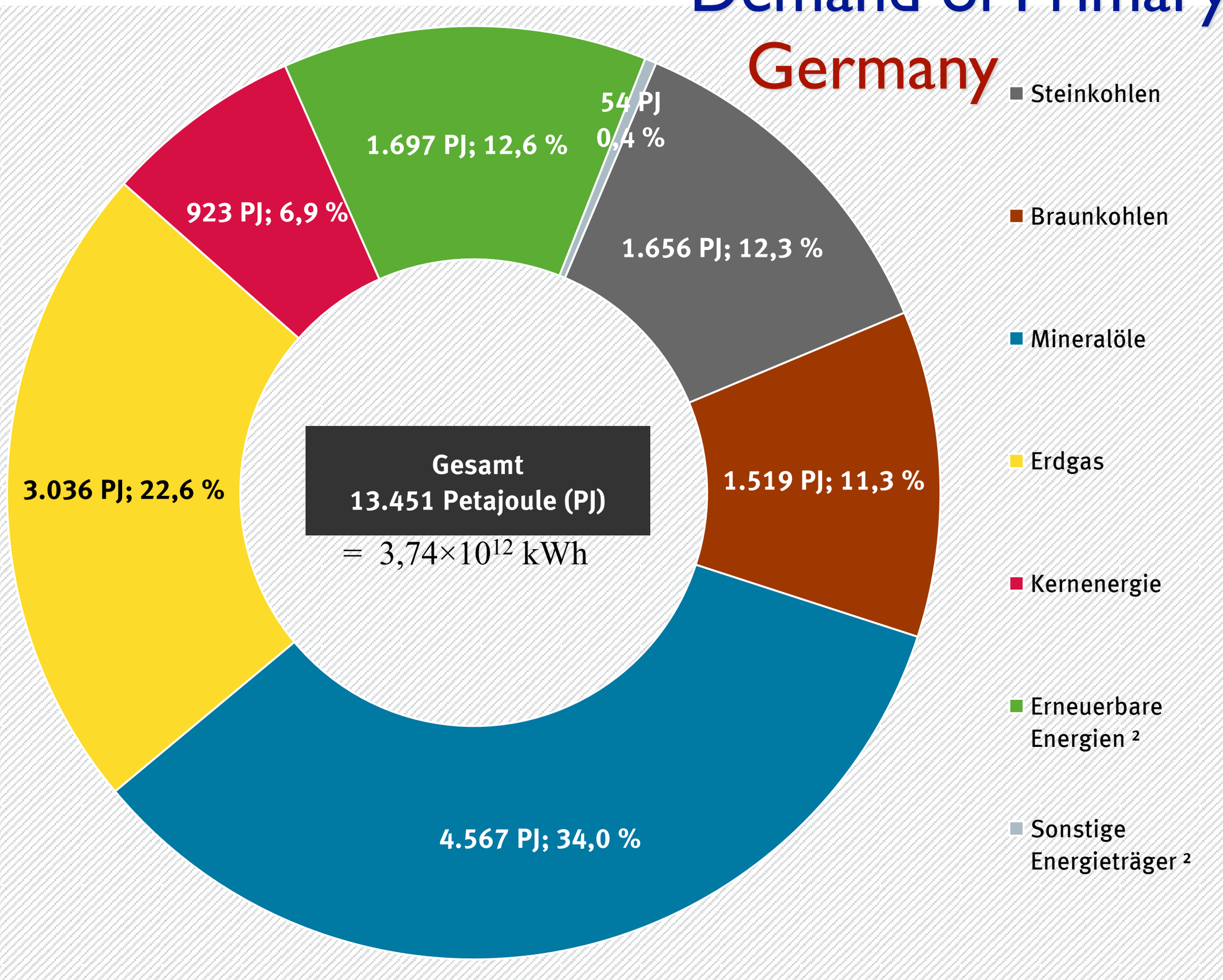
≈ 140 Billion kWh / a

average power demand: ≈ 16 TW

Demand of Primary Energy

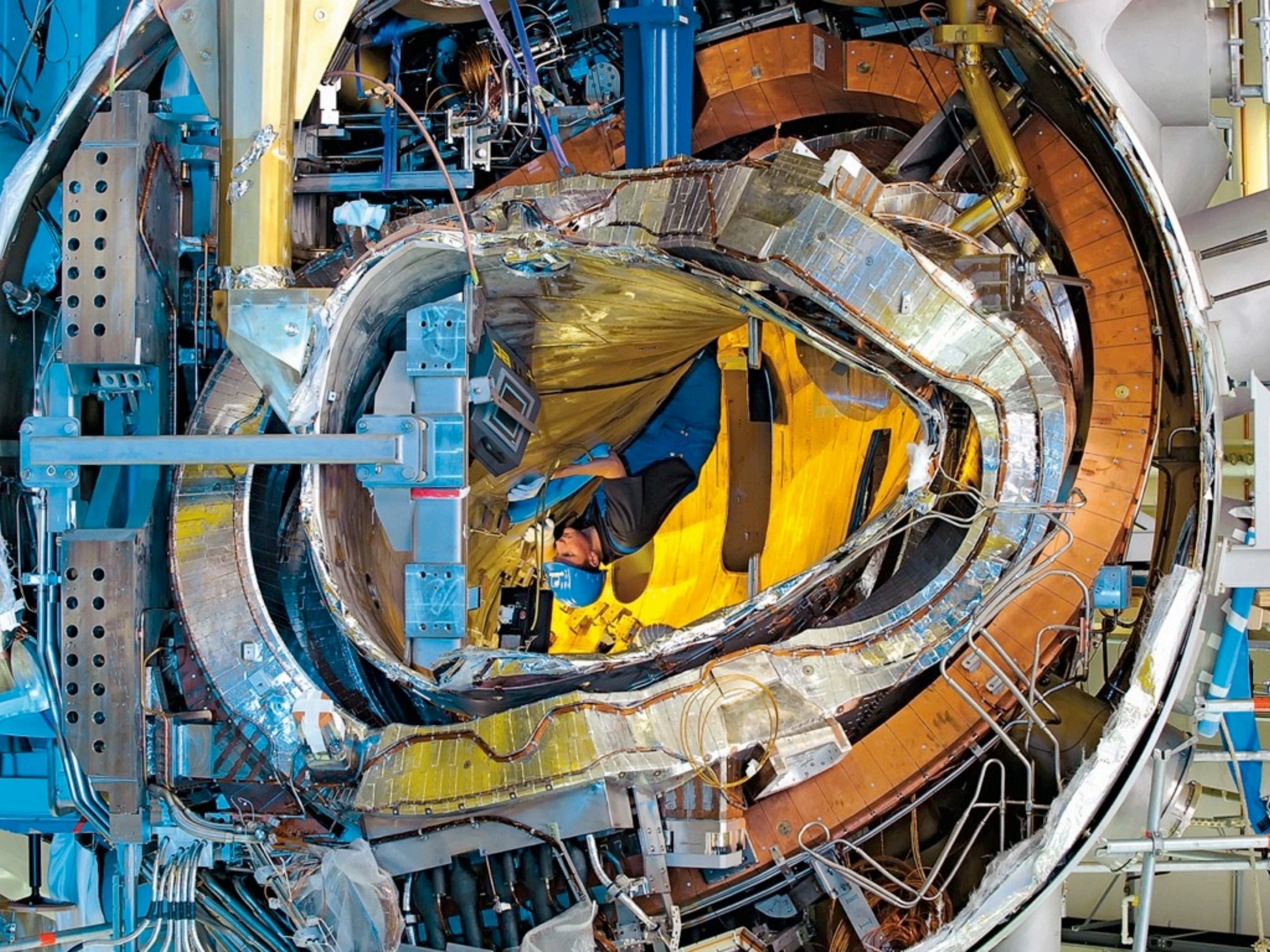
Germany

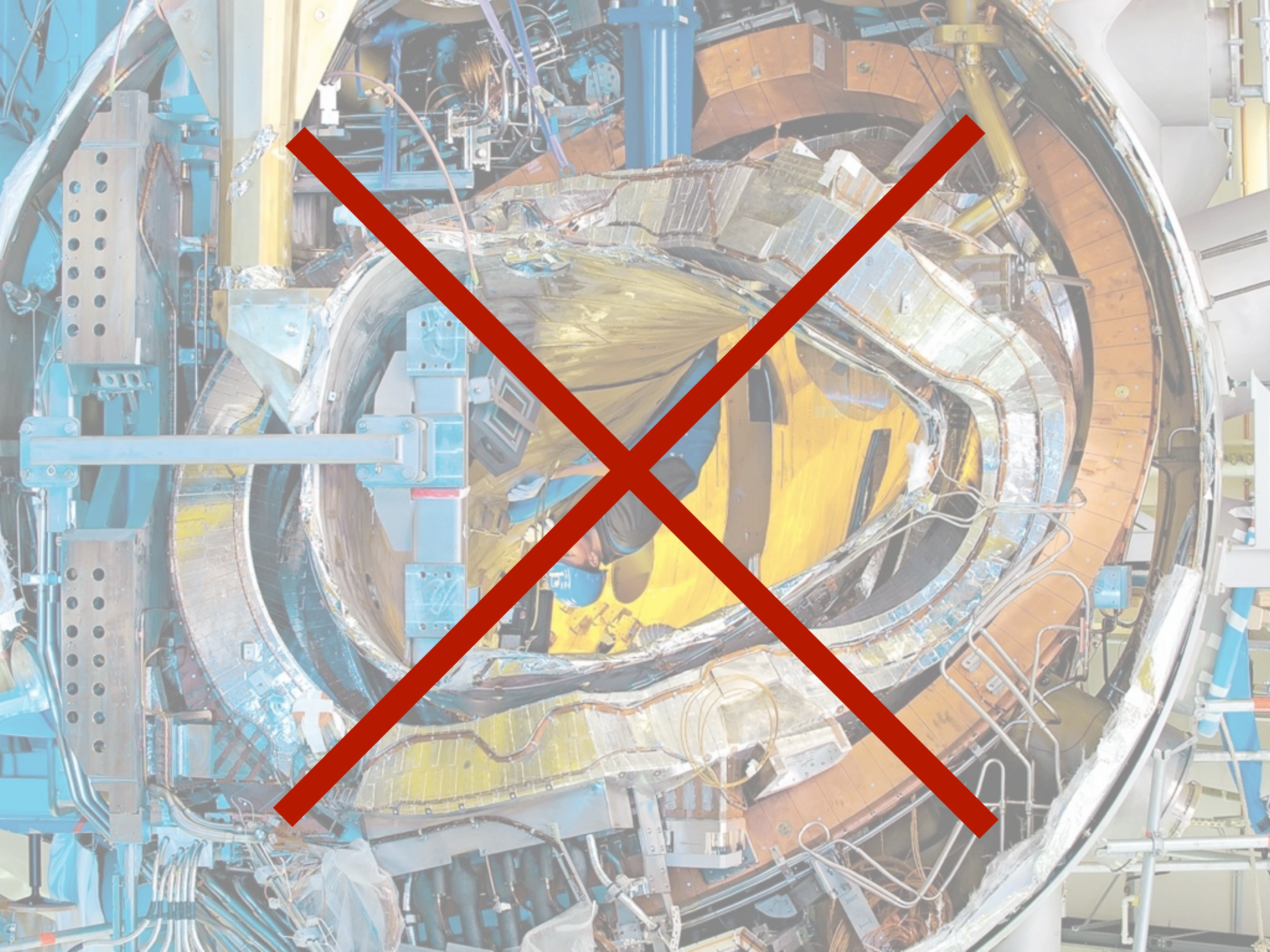
2016*

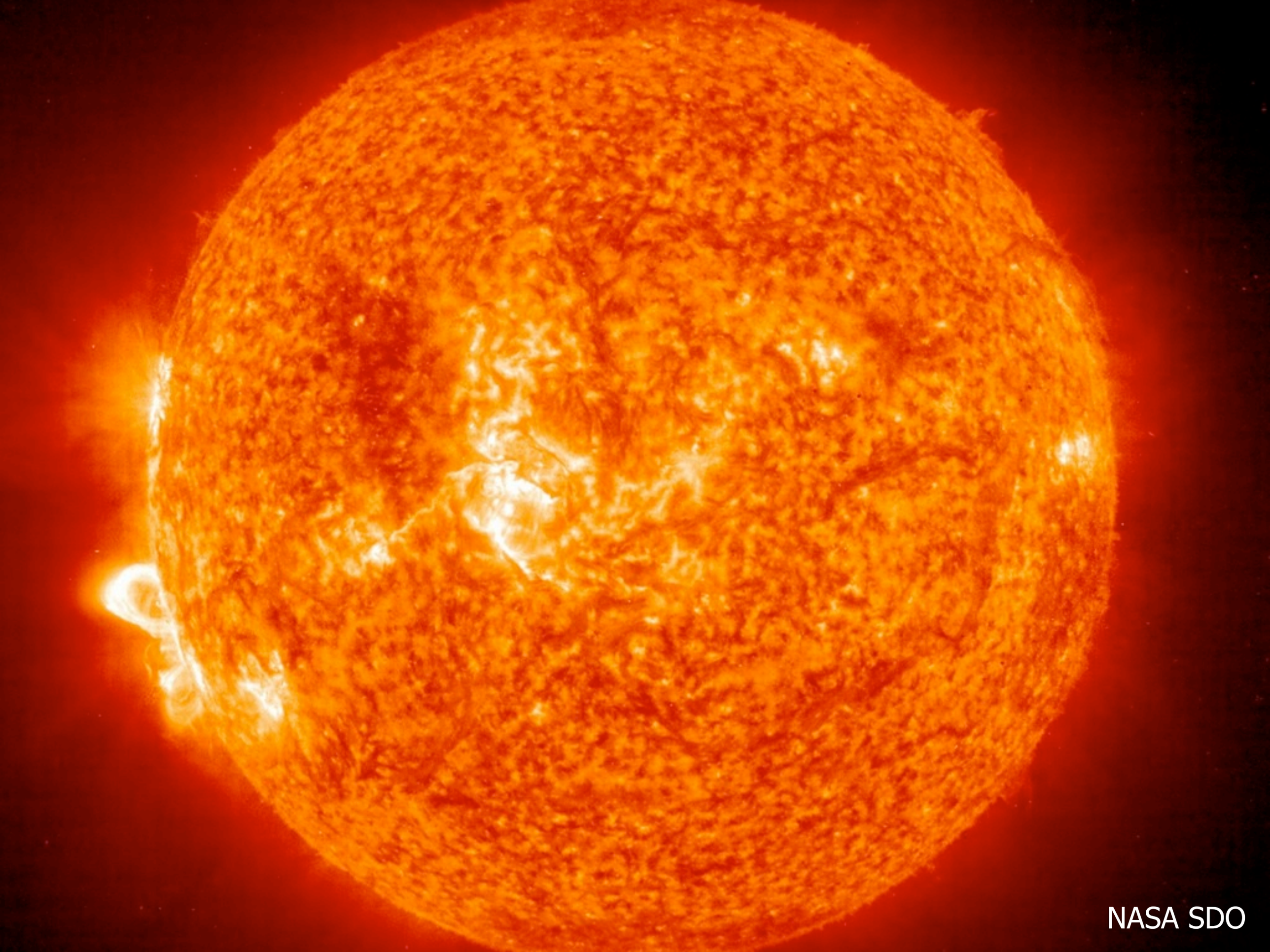


Quelle: Arbeitsgemeinschaft Energiebilanzen (AGEB), Auswertungstabellen zur Energiebilanz für die Bundesrepublik Deutschland 1990 bis 2016, Stand 09/2017

CO_2-free / renewable energy resources






NASA SDO

The Sun

- constant total power:

$$L_\odot = 3\times10^{26}\ \mathrm{W} = 3\times10^{14}\ \mathrm{TW}$$

- at Earth surface (distance ~ 150 Mio km)

$$L_\oplus \approx 1.74\times10^{17}\ \mathrm{W} \approx 174.000\ \mathrm{TW}$$

- per unit area: solar constant

$$\mathbf{s_\oplus = 1.36\ kW/m^2}$$

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- Sun generates **winds!**

low wind : $75\ \mathrm{W/m^2}$
(5 m/s)

strong wind : $10\ \mathrm{kW/m^2}$

The Sun

- at Earth surface

$L_\oplus \approx 1.74 \times 10^{17}\,\mathrm{W} \approx 174.000\,\mathrm{TW}$

→ more than **10.000 times** world power demand!

→ less than **50 minutes** to supply the Earth's energy demand of an entire year!

DESERTEC-EUMENA

- Concentrating Solar Power
- Hydro
- Photovoltaics
- Biomass
- Wind
- Geothermal

DESERTEC FOUNDATION

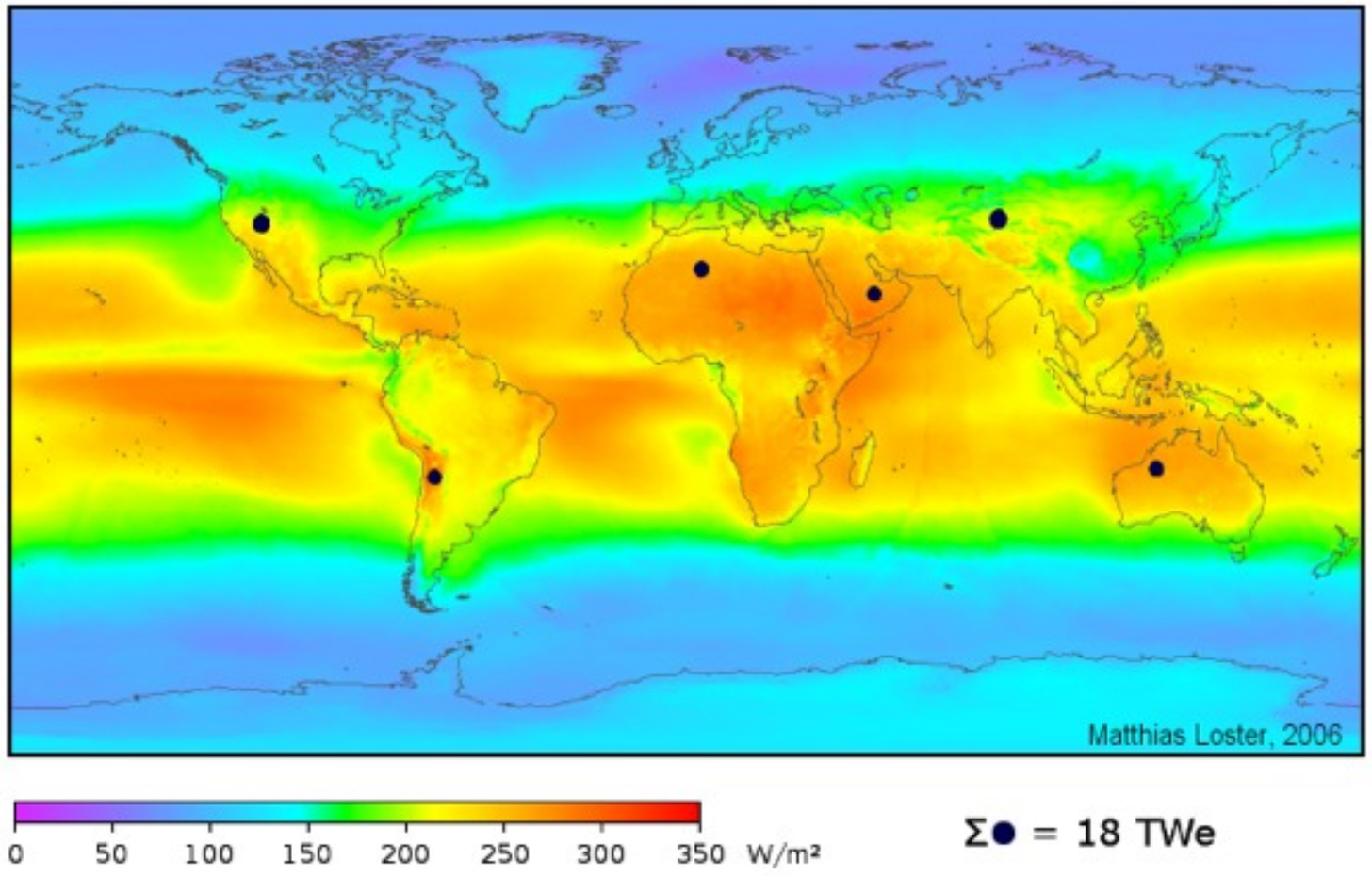
CSP collector areas for electricity

World 2005	90.000 km²
EU-25 2005	16.000 km²
MENA 2005	3.025 km²
TRANS-CSP Mix EUMENA 2050	

Direct Solar Power

- average global solar power:

  ~ 165 W/m²



installed facilities*:

- ~ 456 GW for hot water
  (*China*: 325 GW)
- ~ 4,8 GW solar heat power plants
  (*Spain*: 2,3 GW, *USA*: 1.7 GW)

*Source: Renewables 2017, Global Status Report REN21

PS10 & PS20

Solar Thermal Power Plants

11 + 20 MW

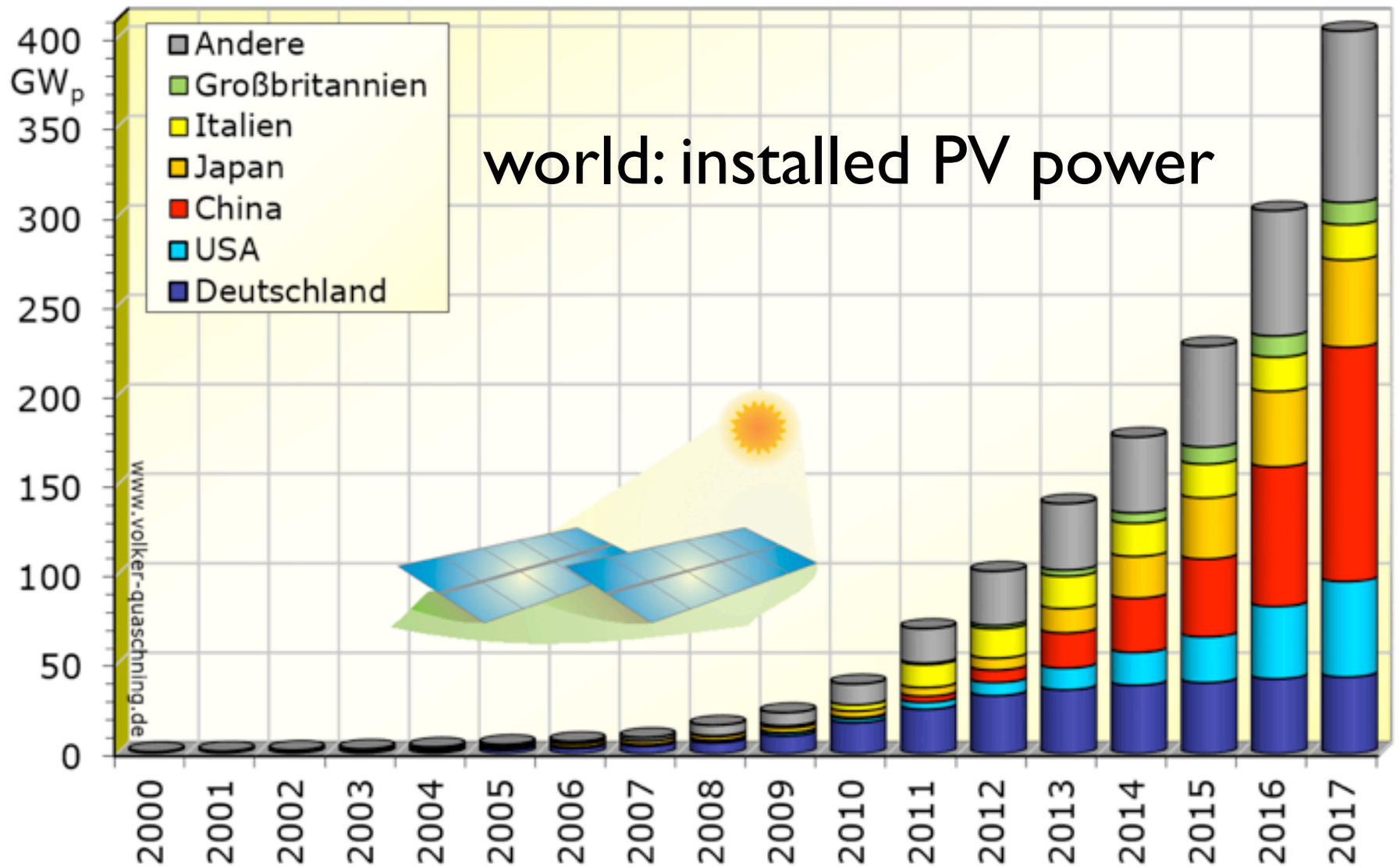
Sevilla, Spain

Photovoltaics

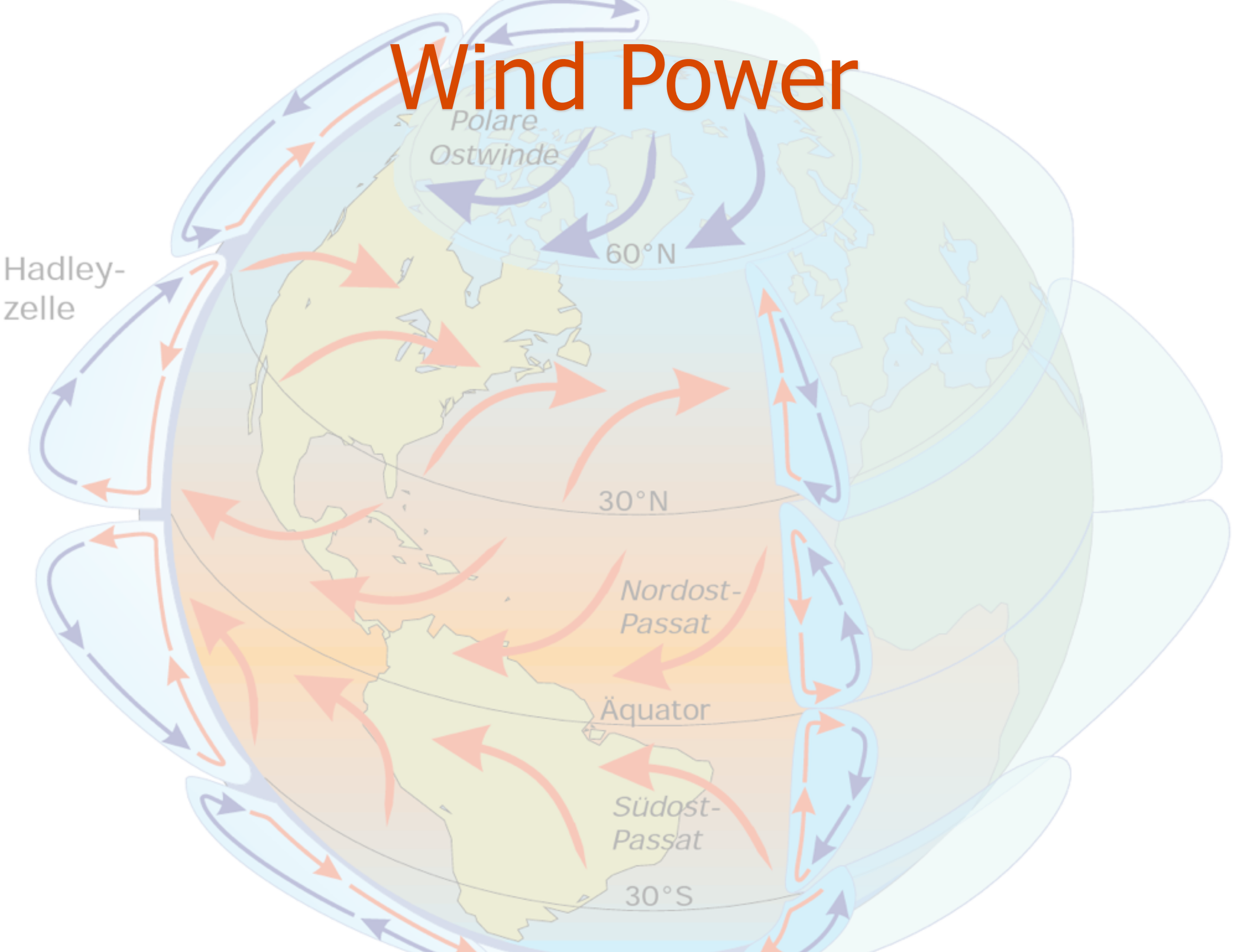
Photo electric effect
(Albert Einstein 1905, Nobel price 1921)

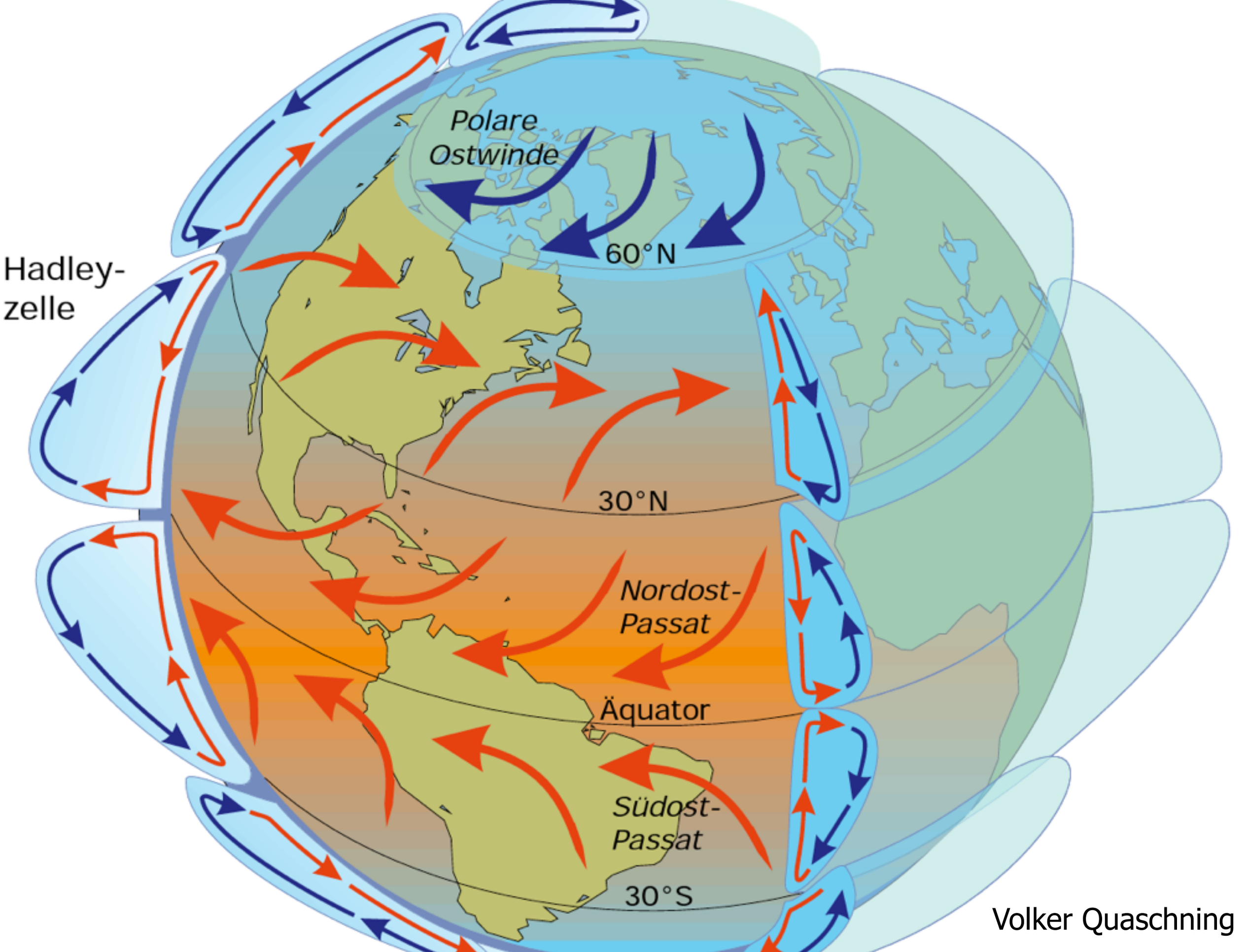
- electric power generation
  also at lower intensity

- efficiency
  ~ 20%



Wind Power


Polare
Ostwinde
60°N
Hadley-
zelle
30°N
Nordost-
Passat
Äquator
Südost-
Passat
30°S


Hadley-
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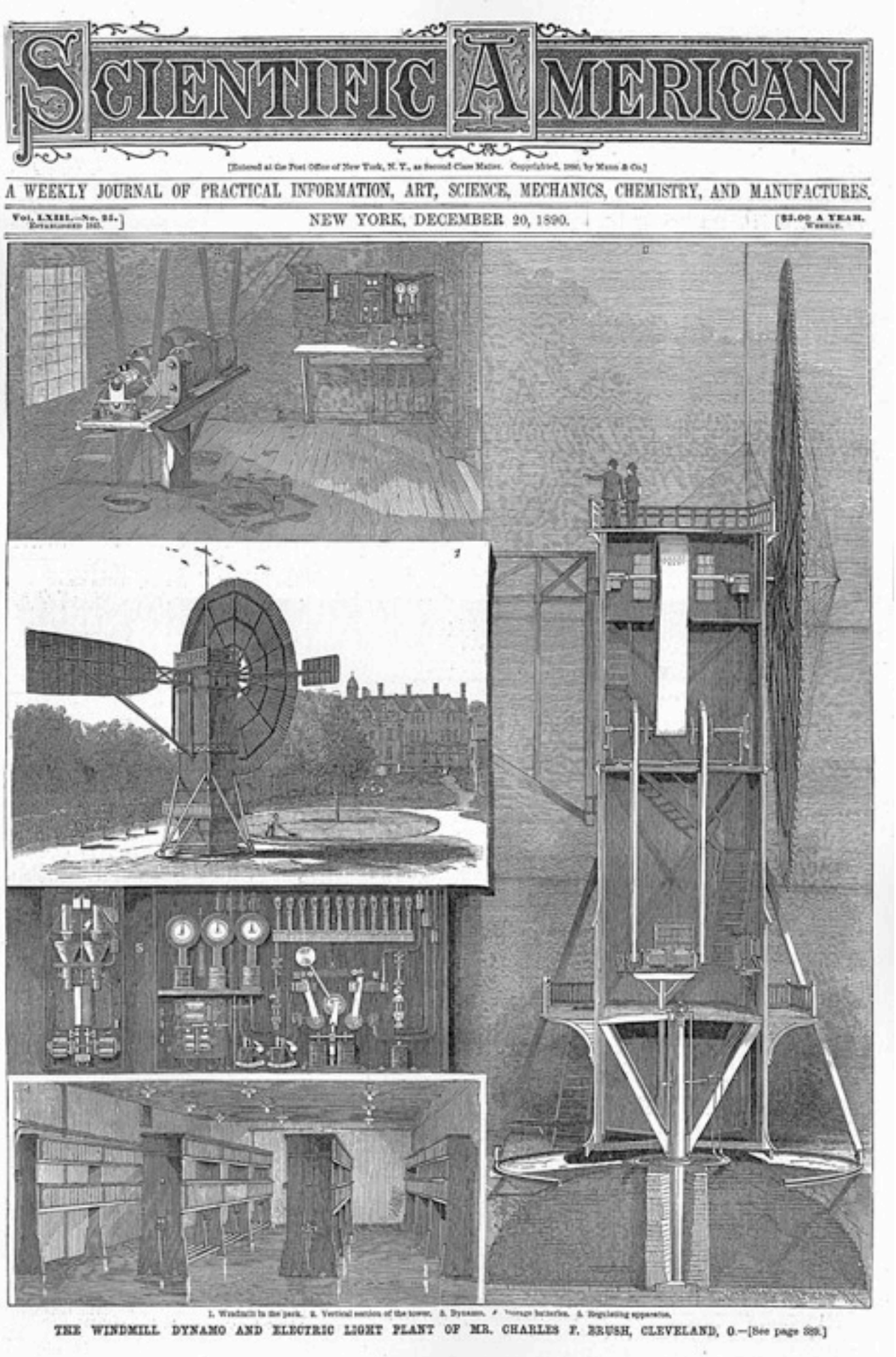
Volker Quaschning



SCIENTIFIC AMERICAN

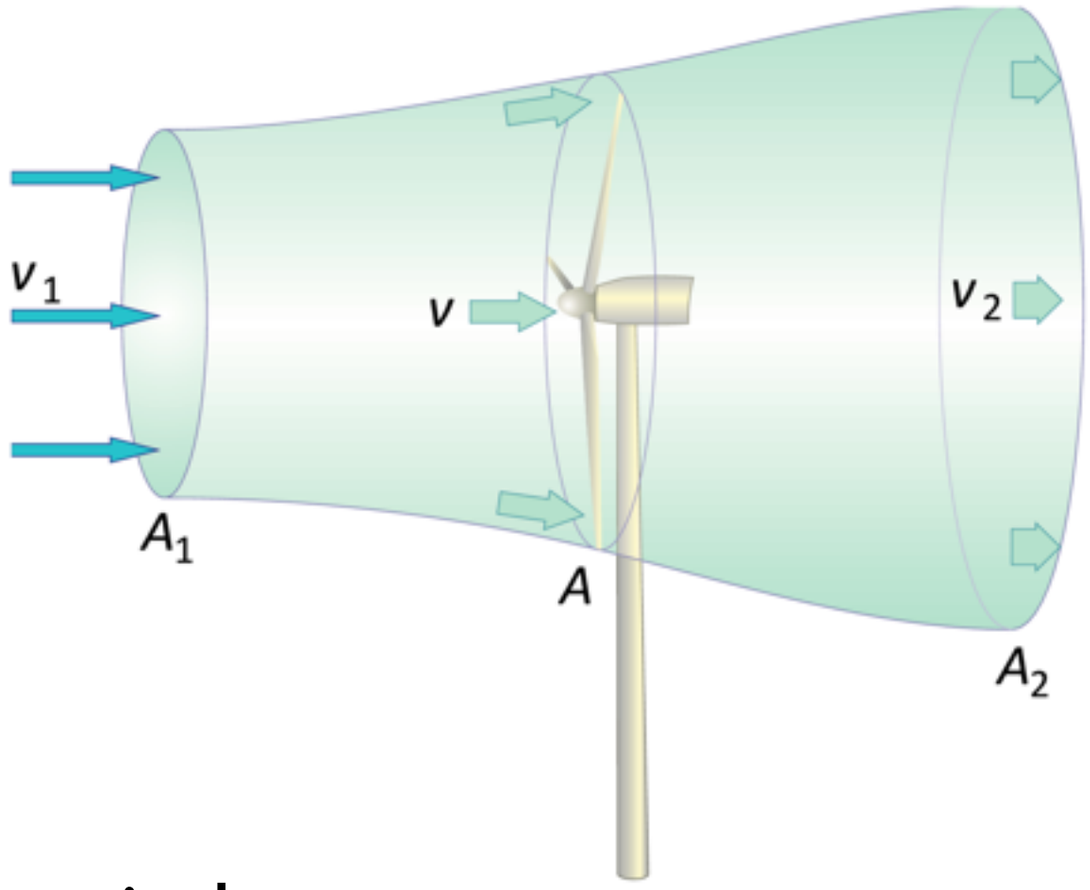
[Entered at the Post Office of New York, N. Y., as Second Class Matter. Copyrighted, 1890, by Munn & Co.]

A WEEKLY JOURNAL OF PRACTICAL INFORMATION, ART, SCIENCE, MECHANICS, CHEMISTRY, AND MANUFACTURES.

Vol. LXIII.—No. 25. [Established 1845.] NEW YORK, DECEMBER 20, 1890. [$3.00 A YEAR. Weekly.

1. Windmill in the park. 2. Vertical section of the tower. 3. Dynamo. 4. Storage batteries. 5. Regulating apparatus.

THE WINDMILL DYNAMO AND ELECTRIC LIGHT PLANT OF MR. CHARLES F. BRUSH, CLEVELAND, O.—[See page 389.]



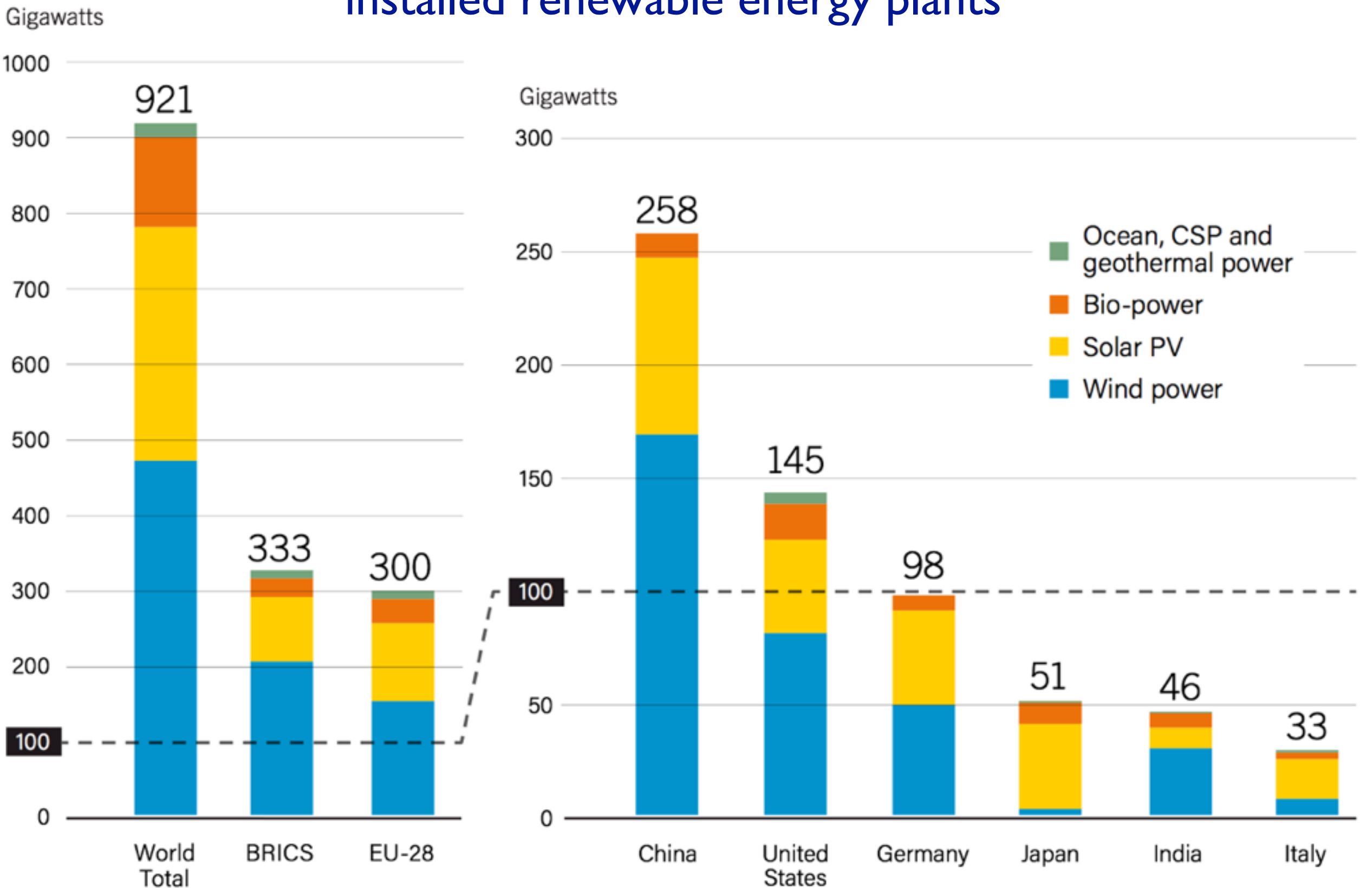
wind power density:

$$\propto v^3$$

$$c_{P,Betz} = \frac{16}{27} \approx 0{,}593$$

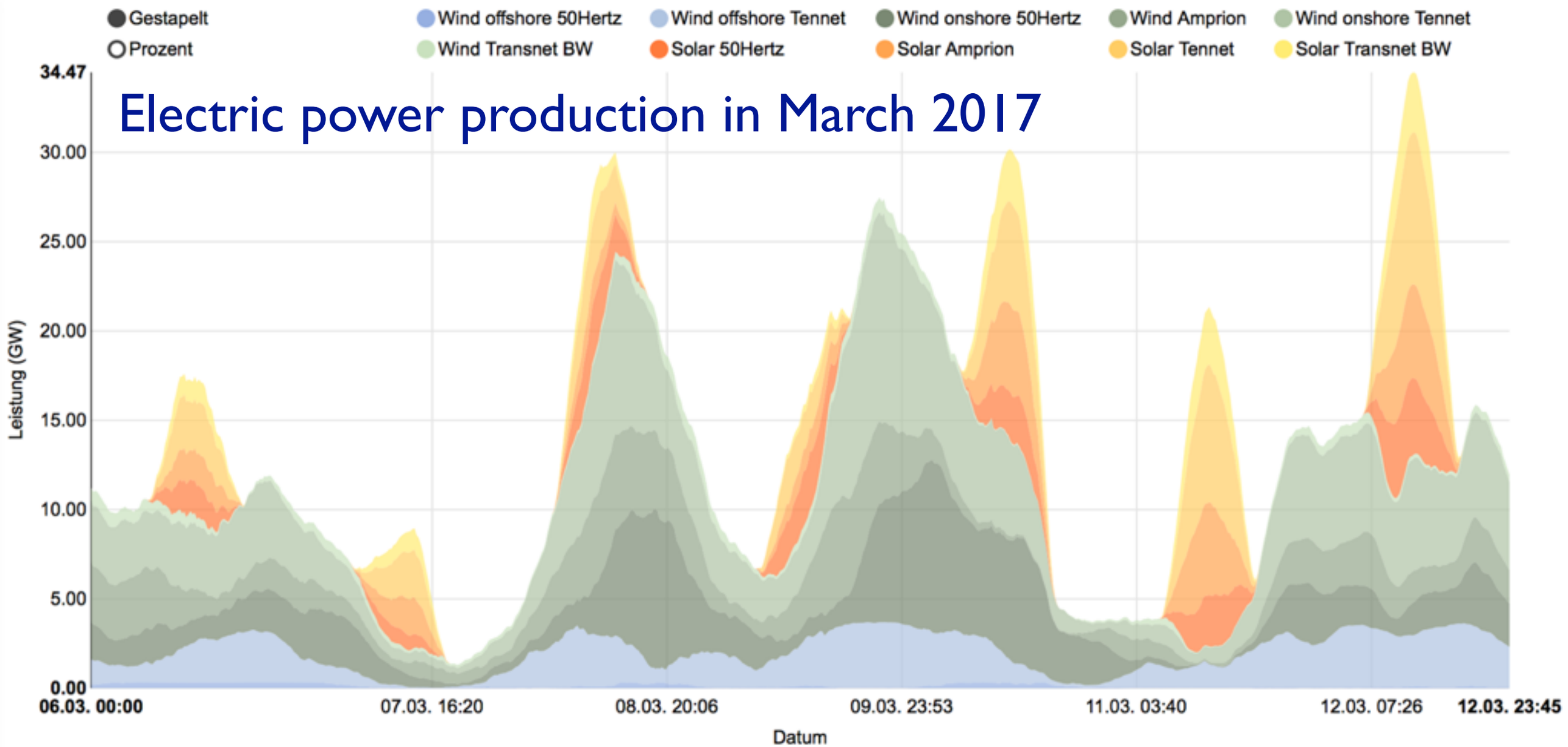
Wind power by Charles Brush in 1888

installed renewable energy plants



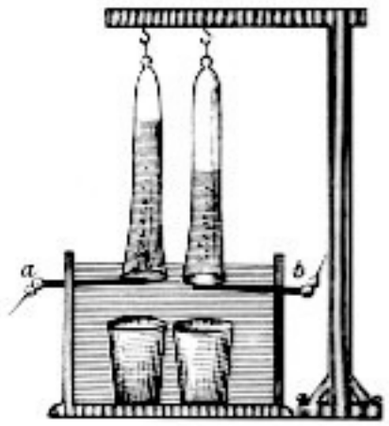
*Quelle: Renewables 2017, Global Status Report REN21

Transportation & Storage

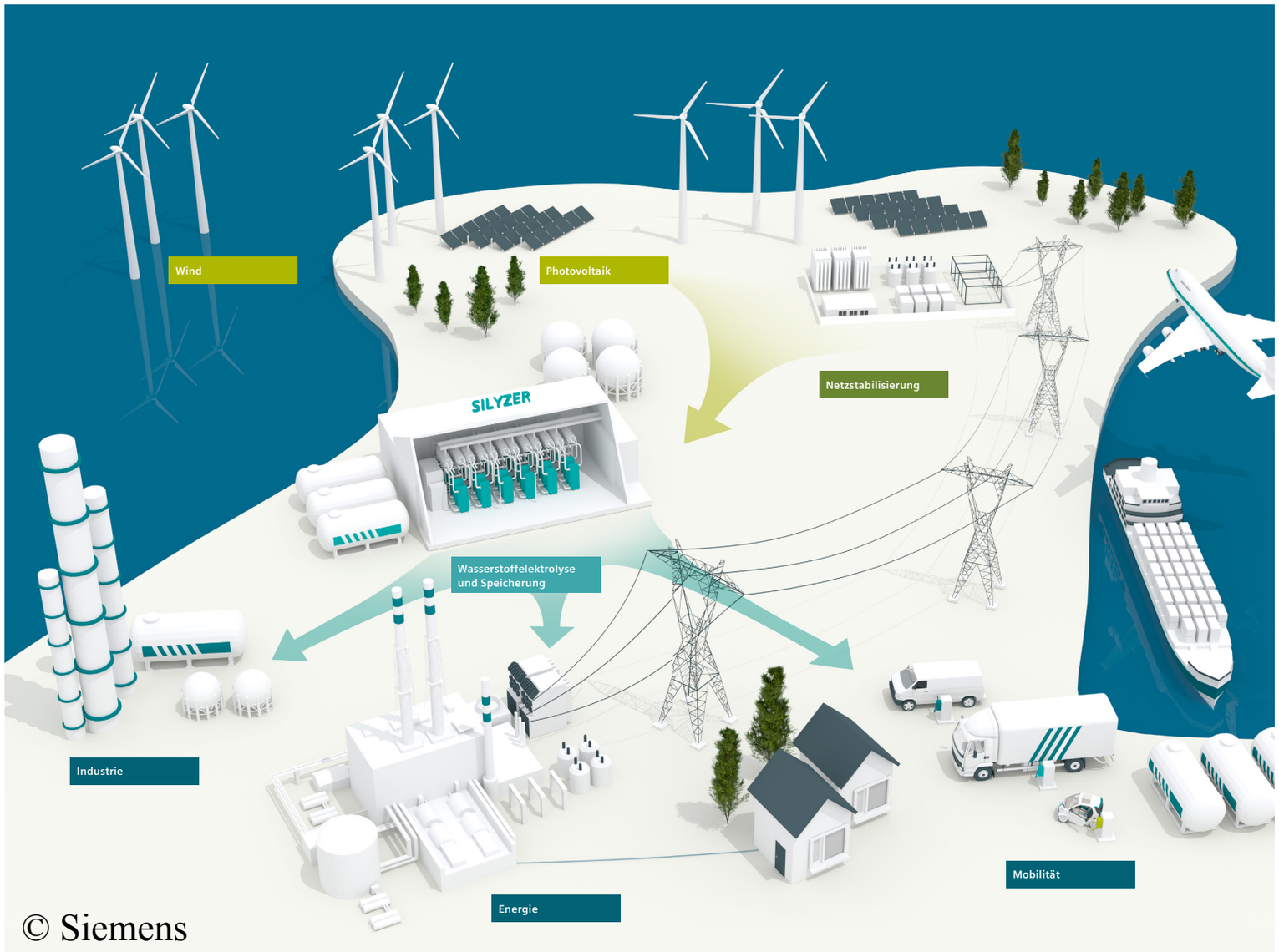


- strong local/regional dependence
- highly fluctuating

Power to Hydrogen



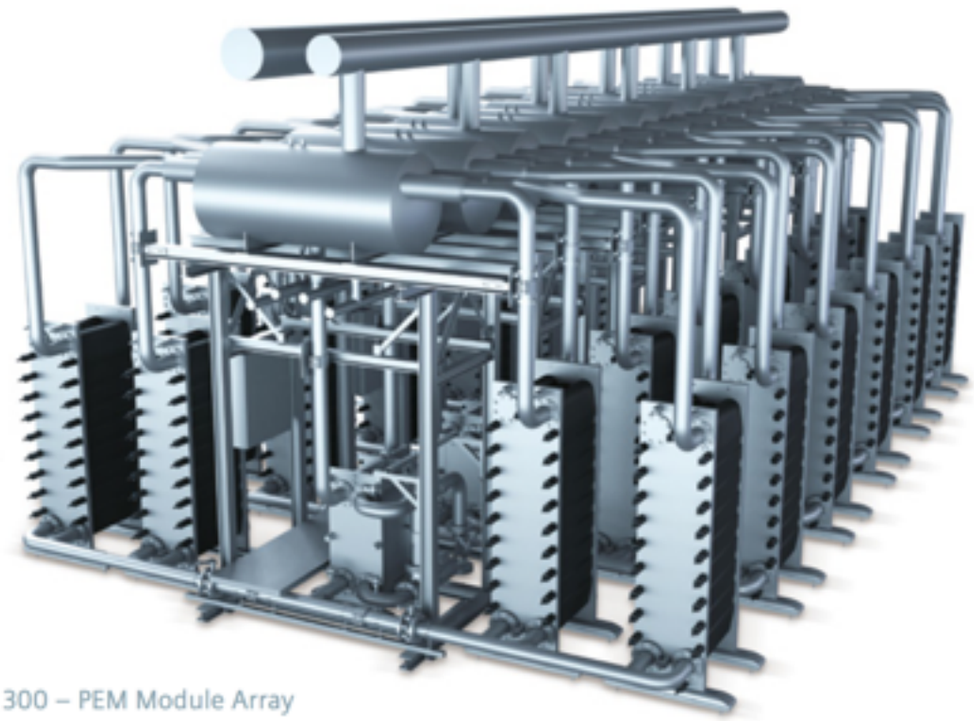
Johann Wilhelm Ritter 1800



© Siemens

- flexible: storage / mobility / heat
  ⇒ *sector coupling*
- highest energy density: 33 kWh/kg
- possible storage & transportation in gas pipelines (limited by law: max. 5%)

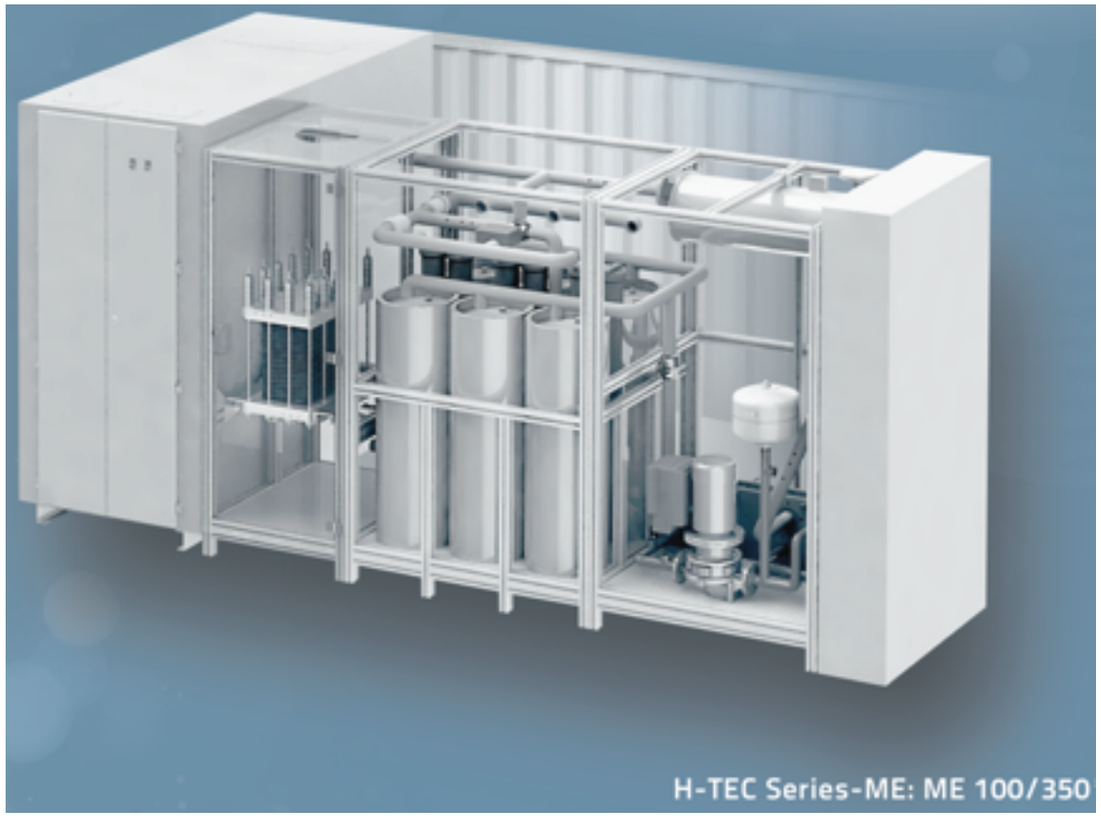
Examples: Electrolysers



SILYZER 300 – PEM Module Array

SIEMENS Silyzer 300 (PEM)

- 100 – 2000 kg/hour
  (~ 5 – 100 MW)



H-TEC ME 100/350 (PEM)

- 100 kg/day (4 kg/h)

Hydrogenics

- > 1.5 MW

e.g. Mobility

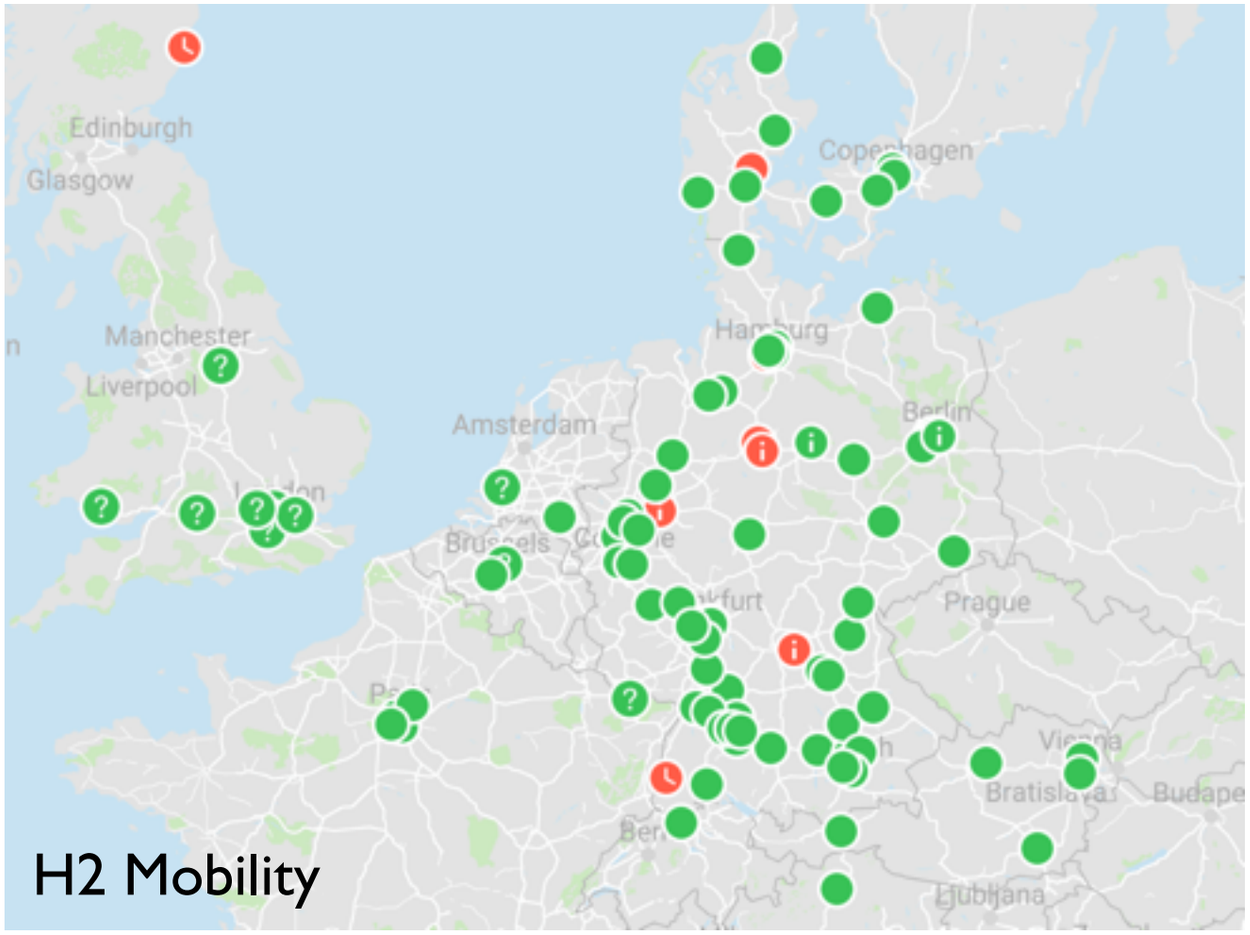
Mobility & Transport

- Fuel cell cars (e.g., Toyota MIRAI, Hyundai NEXO/ix35)
- standard fuel nozzle (e.g. , WEH H70)
- standard pressure for cars (700 bar) and trucks (350 bar)
- about 120 H_2 stations in Europe (ca. 65 in Germany, 100 by 2019)

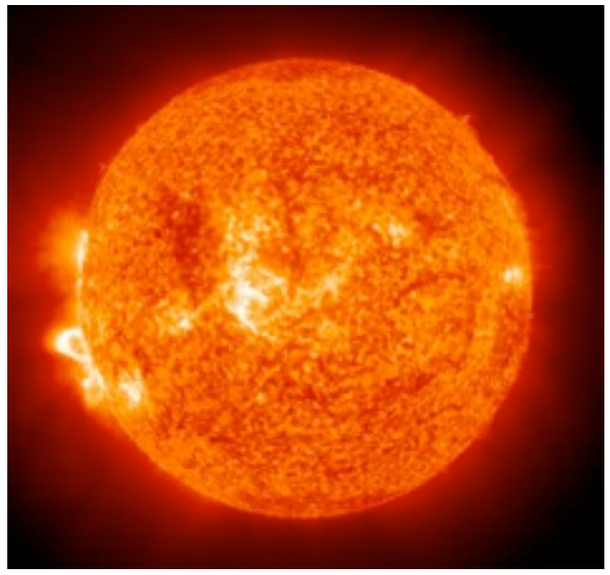
- Japan 2020: 160 H_2 stations
  40.000 cars

- Trucks: e.g. Nikola Motor

- Local trains: e.g. Alstom ‘Coradia’



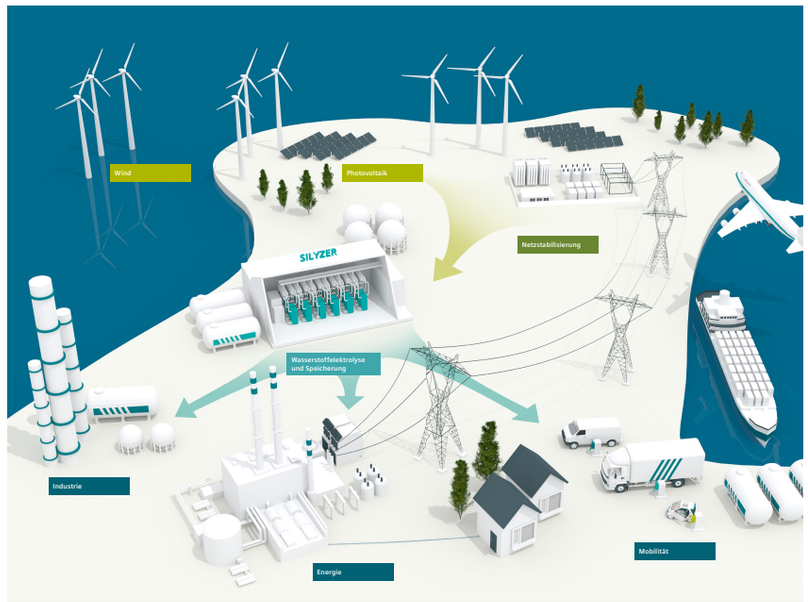
Summary



- renewable energy source *exists*:
  the **sun**

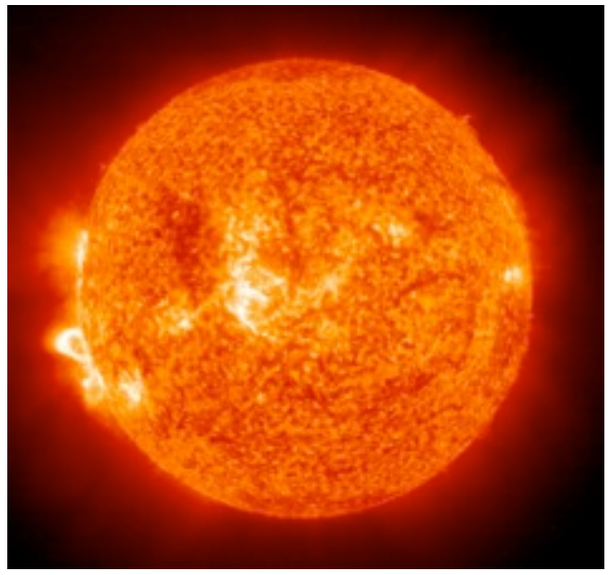
- the technology to tap it *exists*:
  wind power, solar thermal, PV, ...

- H_2 is the most *efficient* to store and transport renewable energy (sector coupling)



- the technology to utilise it *exists*
  and is ready for the mass market:
  electrolyser, fuel cells, storage tanks,
  cars, trucks, ...

Summary



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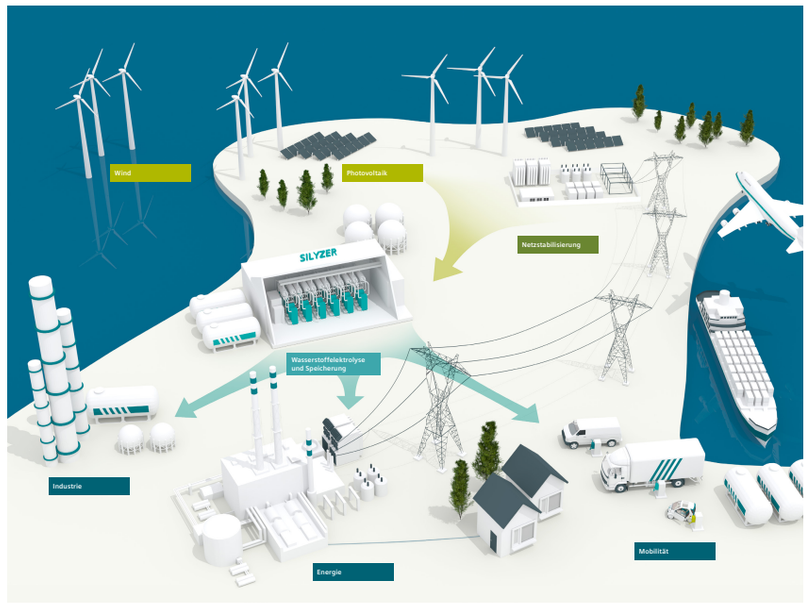

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let's get it going!