Introduction to Lecture Course on Wind Energy Systems

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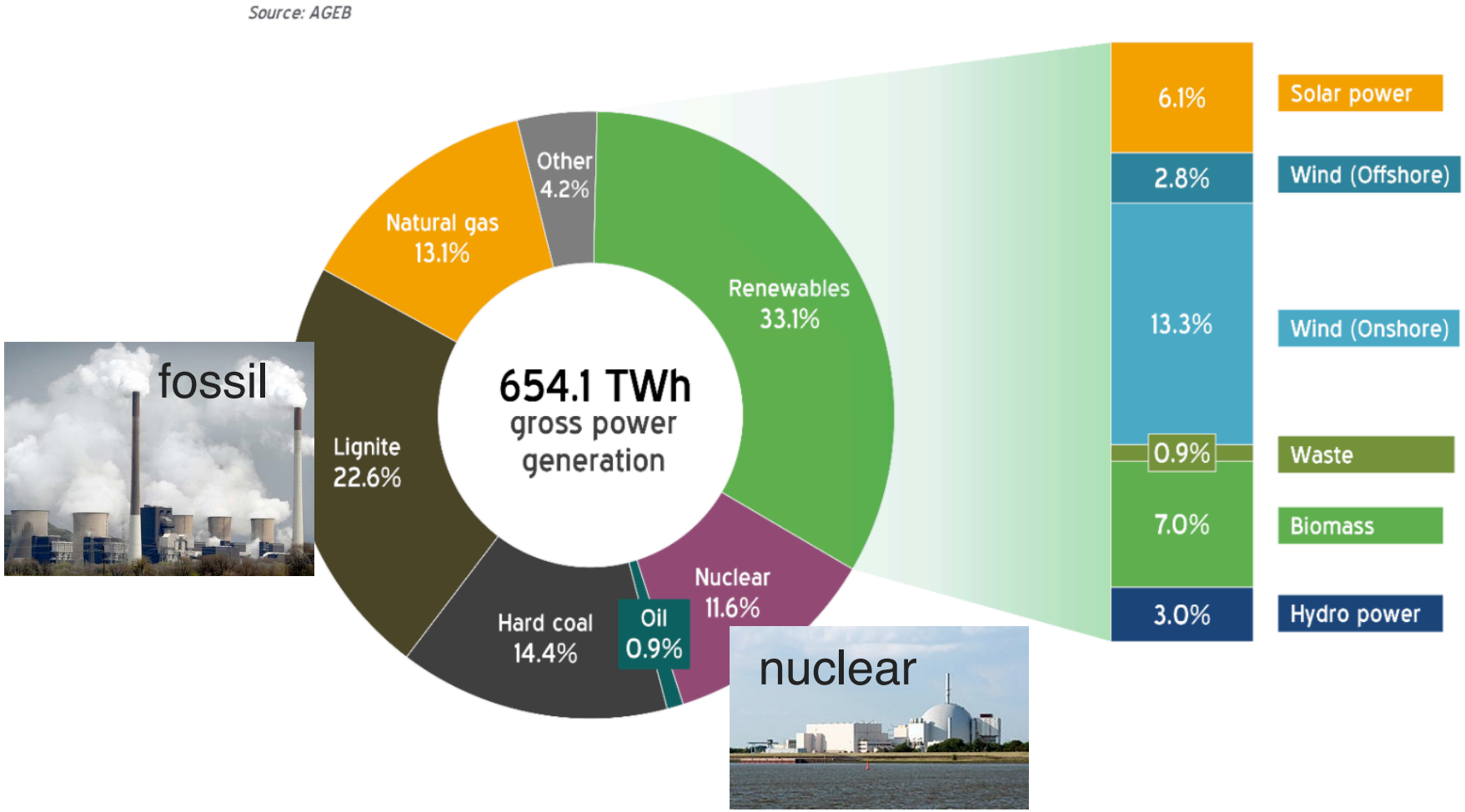
Freiburg, April 17, 2018

2022: The last German nuclear power plant stops operation

Neckarwestheim

Today, 66% of Germany's electricity is of nuclear or fossil origin



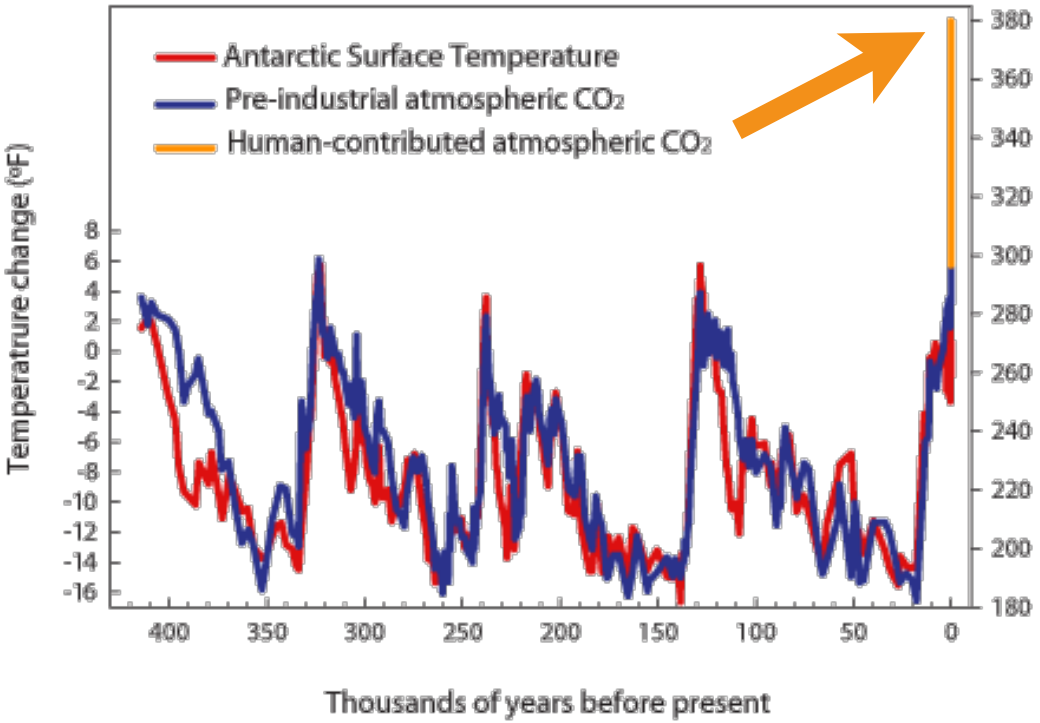
(https://energytransition.org/2018/01/german-energy-consumption-2017/
also see: https://www.energy-charts.de/energy_pie.htm)

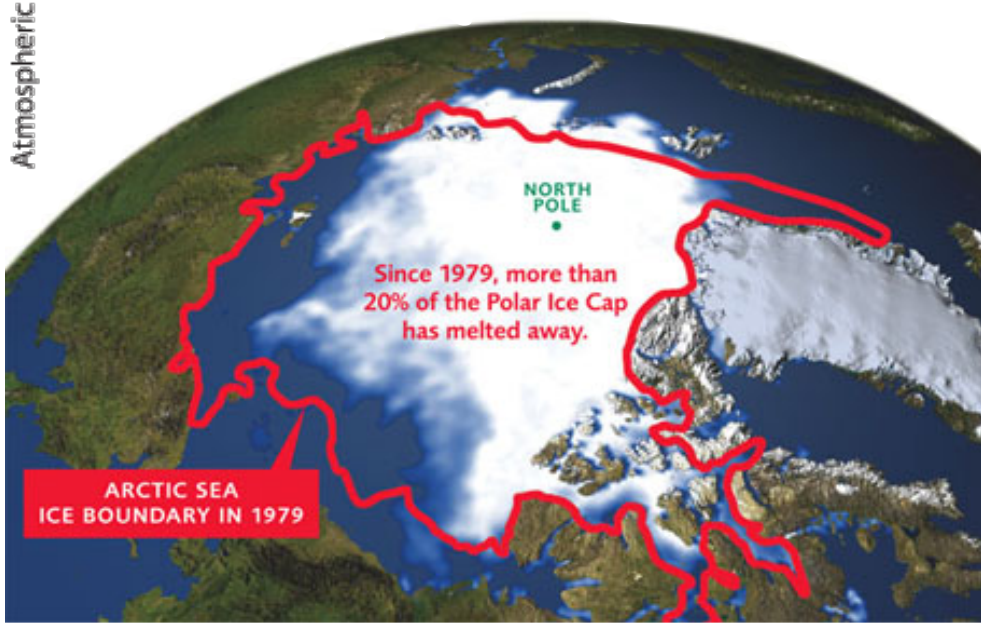
Do we need to get back to coal ?

Coal mine Limbourg-Meuse, 1901-1987 [wordpress]

There is already more CO_2 in the atmosphere than anytime since half a million years

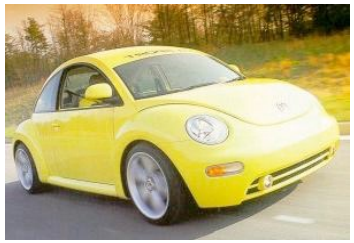
CO_2 increases global temperatures and melts arctic ice





Carbon Dioxide and Temperatures over last 500 000 years, and melting ice caps [C2ES / gws]

Our personal energy consumption: 5 kW

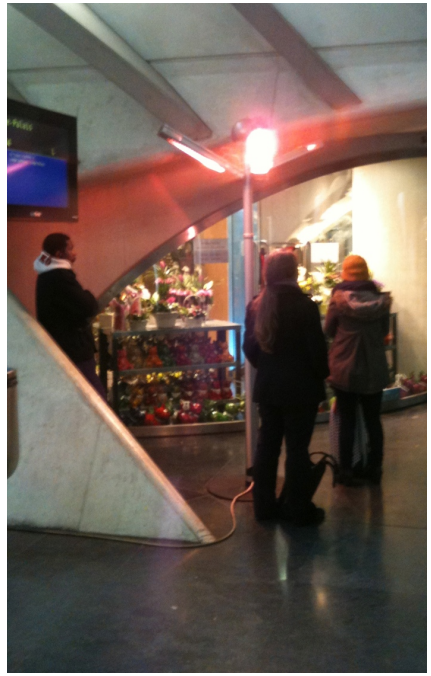


- a typical European needs 5 kW
(1 kW electricity + transport + heating …)

- this equals 120 kWh, or 12 litres of petrol, per day

- one return flight from Europe to China consumes about 1200 litres of kerosene per person (~100 days)

[MacKay 2009. wikipedia]



5 kW: one large electric heater, switched on from birth to death

Sustainable Energy Sources

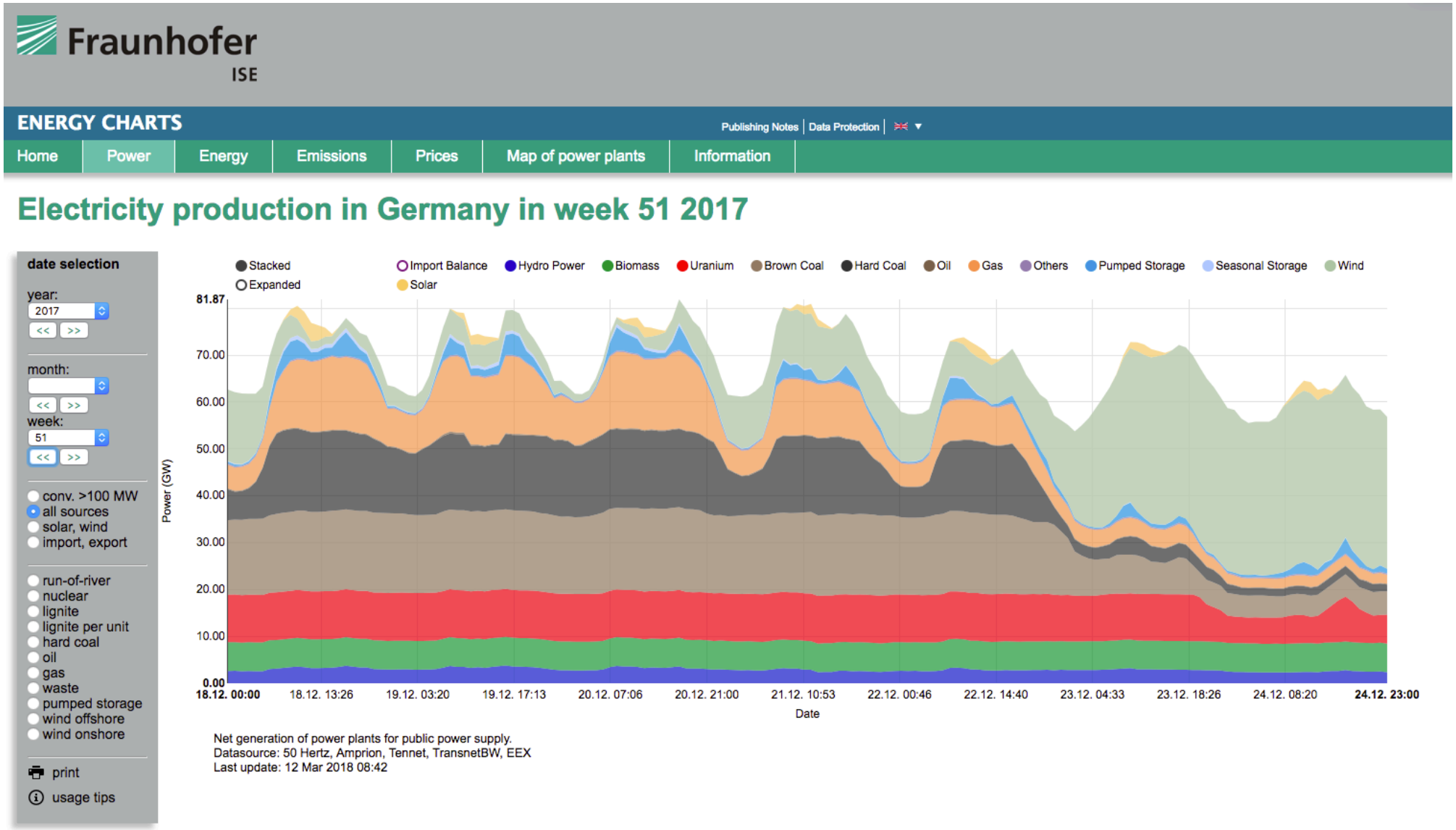
Only **solar** and **wind** energy have the potential to cover all our energy needs

- the sun radiates 1.3 kW per m^2, a part of it drives the wind
- solar ground irradiation in Southern Europe about 0.2 kW/m^2
- photovoltaic cells would deliver about 0.04 kW/m^2
- each person would need 125 m^2 of ground to get 5 kW

Main disadvantages of solar and wind energy:

- thinly distributed, difficult to concentrate
- not available at all times

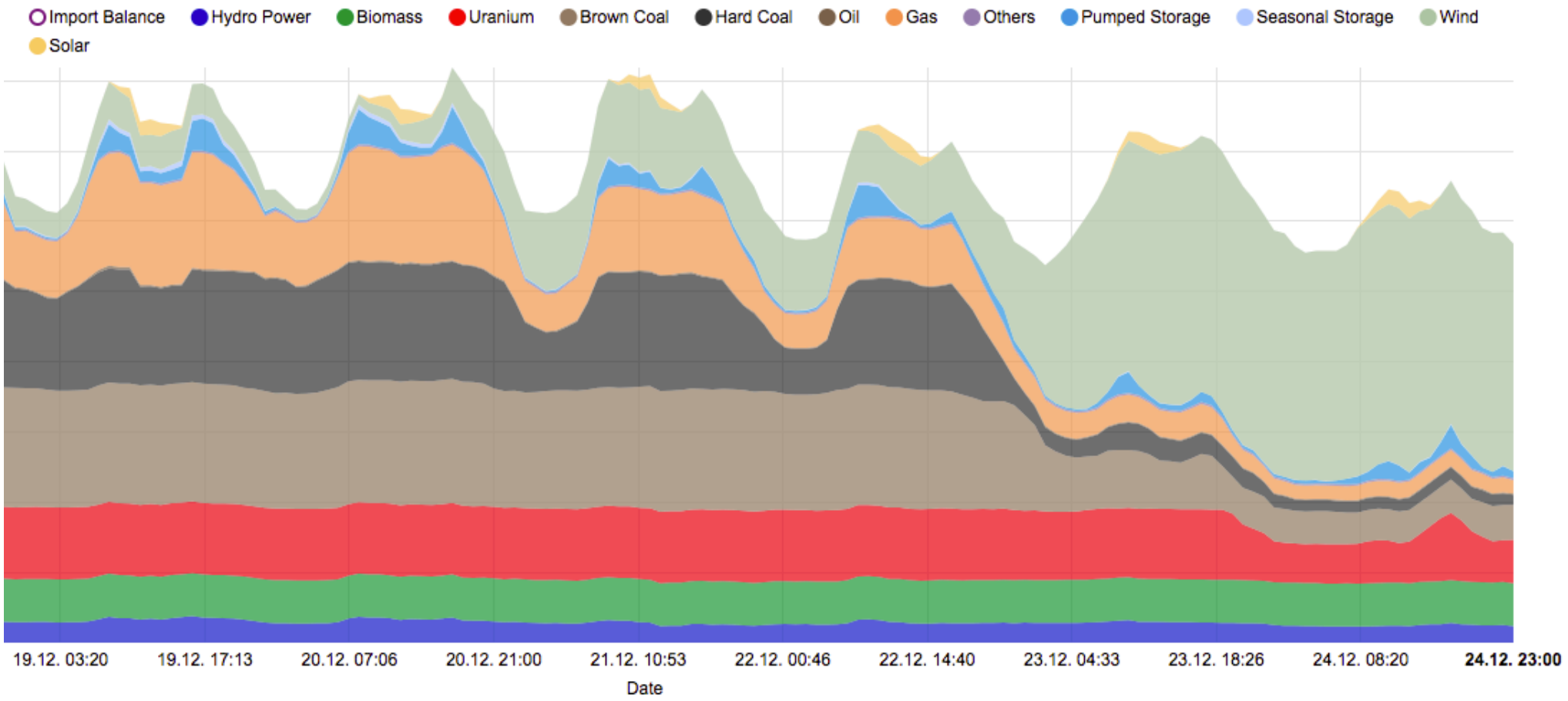
Electricity production in Germany last Christmas



https://www.energy-charts.de/index.htm

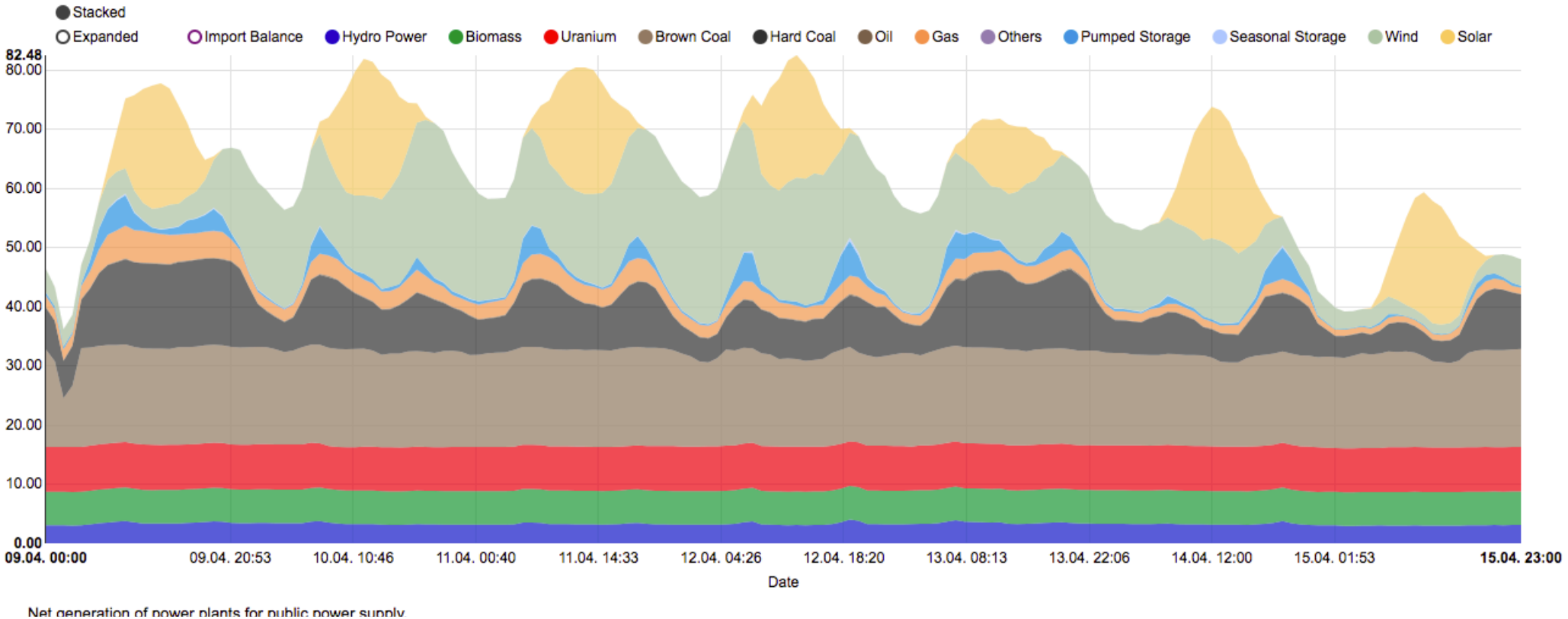
Electricity production in Germany last Christmas

More than 50% of electricity in Germany came from wind on Christmas eve!



https://www.energy-charts.de/index.htm

Electricity production in Germany last week



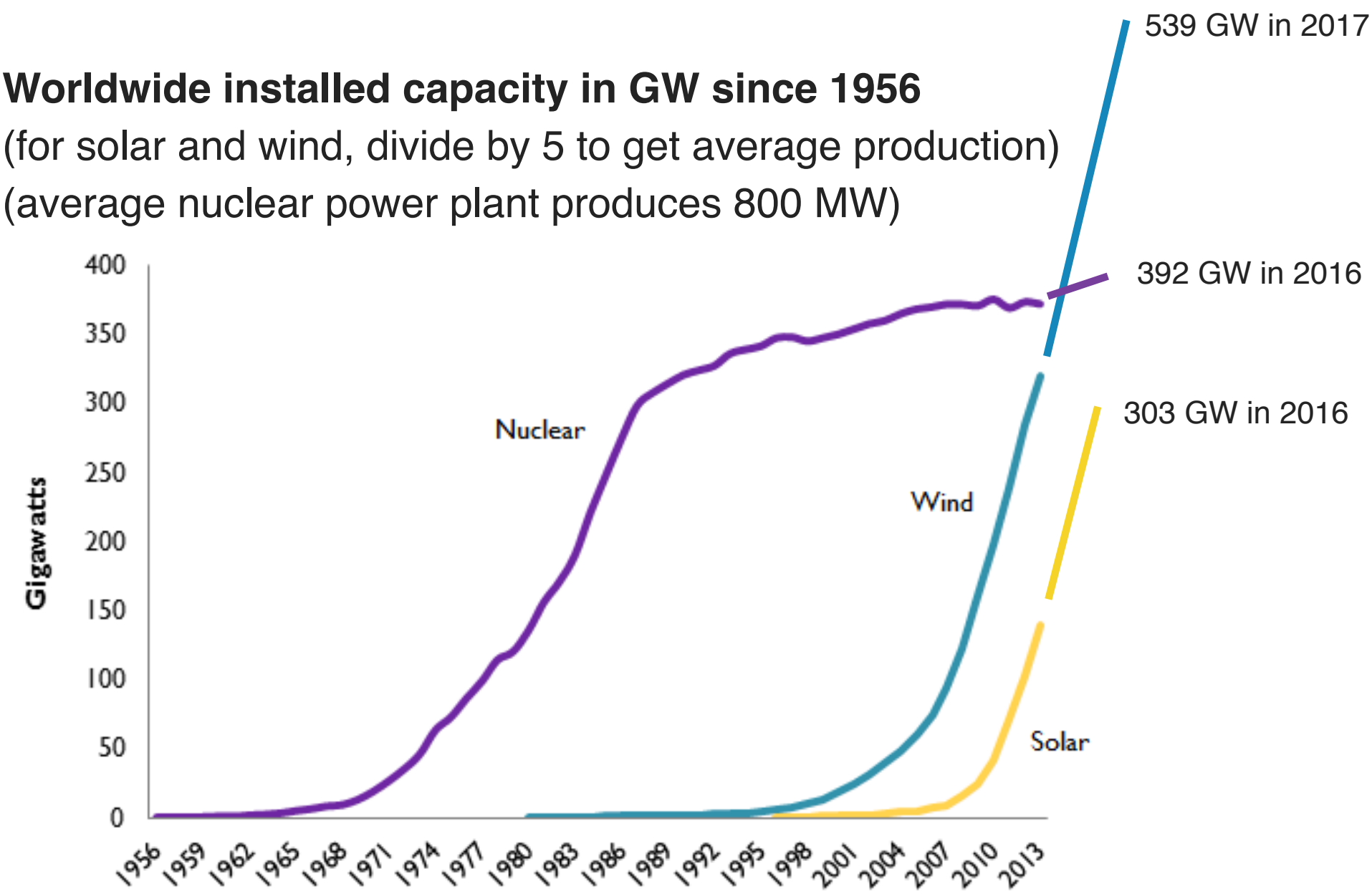
Net generation of power plants for public power supply

Worldwide, wind and solar power grow strongly and provide already as much electricity as 200 nuclear power plants

Worldwide installed capacity in GW since 1956

(for solar and wind, divide by 5 to get average production)

(average nuclear power plant produces 800 MW)



Sources: IAEA; Ochs and Ray; BP; Flavin

Installed Capacity and Capacity Factor of Energy Systems

Installed Capacity:
maximum power that can be delivered [Megawatt]

Capacity Factor:
average yearly production divided by installed capacity

Example:
A wind turbine of 5 MW installed capacity delivers 8760000 kWh of electricity in one year. What is its capacity factor?

1 year = 8760 hours, so average yearly production is
8760000 kWh / 8760 h = 1000 kW = 1 MW.

Thus, its capacity factor is 1 MW / 5 MW = 0.2 = 20 % (a typical value)

What is needed for 5 MW installed power ?

Solar in Southern Europe: area of 125 m x 200 m

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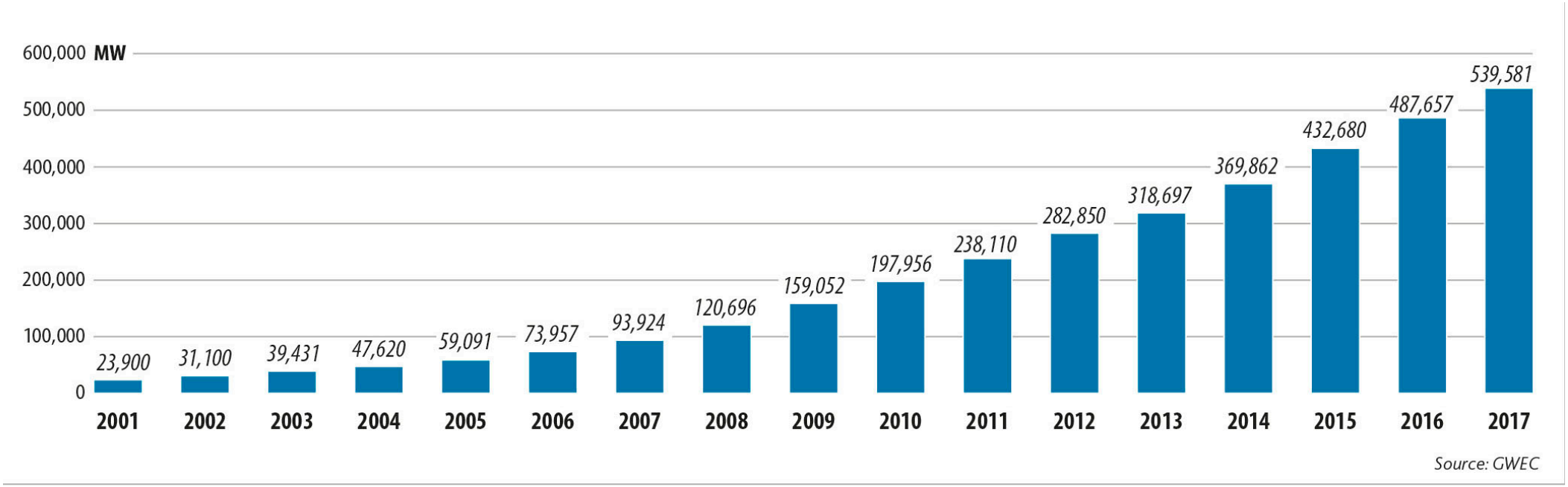
What is needed for 5 MW installed power ?

Solar in Southern Europe: area of 125 m x 200 m

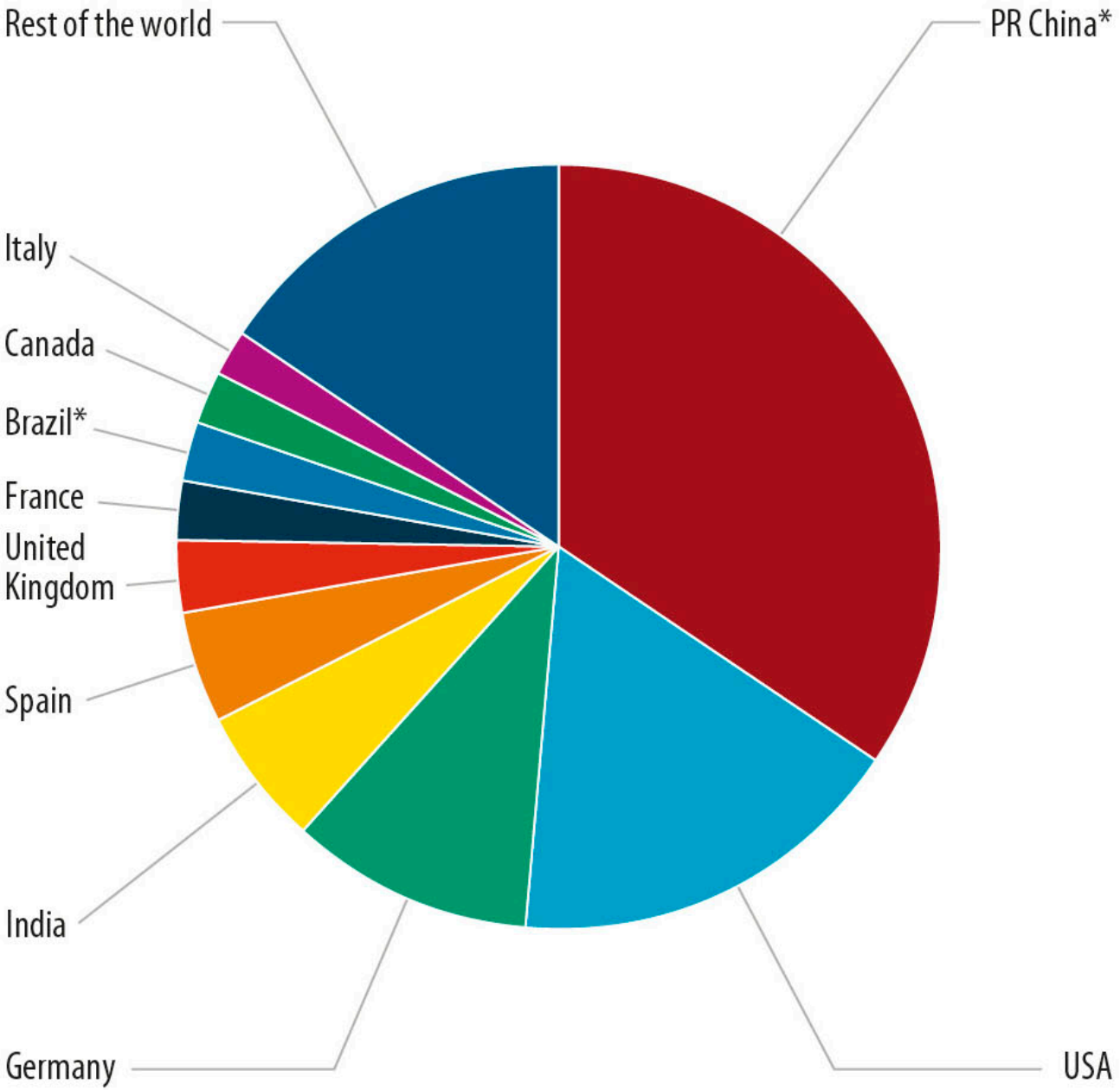
Wind in North Sea:
turbine of 150 m height

Worldwide installed wind power capacity 2001-2017



23x more since start of the millennium, 10% growth last year

Worldwide installed wind power capacity by country



[GWEC]

Wind Energy Systems Lecture Overview

Contents:

- Introduction
- Global Wind Energy Resource
- Aerodynamic Principles of Wind Turbines
- Design of Modern Wind Turbines
- Control of Modern Wind Turbines
- The Electrical System of Wind Turbines
- Alternative Concepts and Airborne Wind Energy

Organization:

- 2 x 2h slots per week
- blackboard lectures + some slides (uploaded the same day)
- interactive exercise sessions every 2nd week (same slot, same room)
- slots: Tuesday and Wednesday from 14:00-16:00 (under discussion)
- extra offer: “Fluid dynamics film series” each Wed. at 17:00

Introduction of Teachers and Audience

- Moritz Diehl
  - studied physics and mathematics in Heidelberg (D) and Cambridge (UK) in 1993-1999
  - PhD in numerical methods for optimal control in Heidelberg in 2001
  - professor for optimization in engineering at KU Leuven (B) in 2006-2013
  - since 2013 head of Systems Control and Optimisation Laboratory at IMTEK, Freiburg
  - interested in modelling and control of sustainable energy systems, in particular (airborne) wind energy

- Rachel Leuthold
  - studied aerospace and wind energy at MIT (US) and TU Delft (NL) in 2009-2016
  - works towards PhD in airborne wind energy in Moritz Diehl's team
  - co-organized the Airborne Wind Energy Conference AWEC 2017 in Freiburg last october

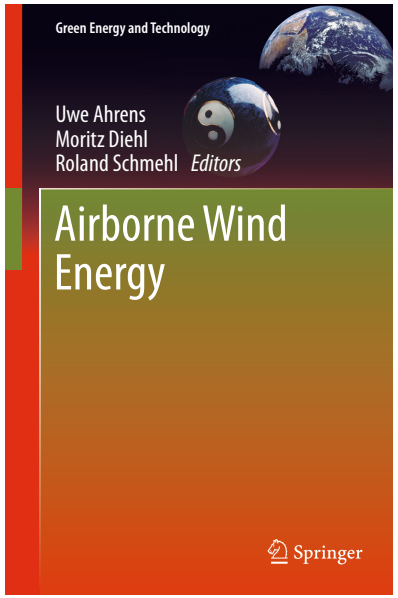
- Audience: Students from different master programs
  - Sustainable Systems Engineering (SSE)
  - Renewable Energy Engineering and Management (REM)
  - Embedded Systems Engineering (ESE)
  - Microsystems Engineering (MSE/MST)
  - Computer Science
  - Other ?

Literature

"Wind Energy Handbook"
by T. Burton, N. Jenkins, D. Sharpe, E. Bossanyi,
2nd edition, Wiley, 2011

“Wind Energy Explained - Theory, Design and Application”
by J. Manwell, J. McGowan, A. Rogers,
2nd editions, Wiley, 2009

“Airborne Wind Energy”
by U. Ahrens, M. Diehl, R. Schmehl (eds.)
Springer, 2013



Video in Freiburg from 17. April 2018

A Quiz Question

The the five wind turbines on Freiburg's ground are located on Rosskopf and Schauinsland, have each a height of 133 m and a nominal capacity of 1.8 MW.

They deliver together 10.2 GWh per year.

What is their capacity factor?