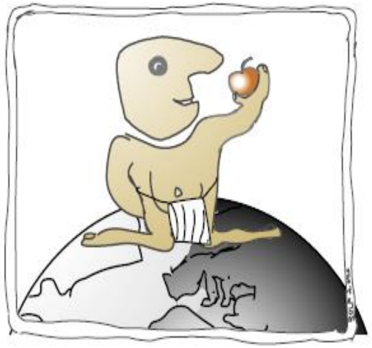
RENEWABLES

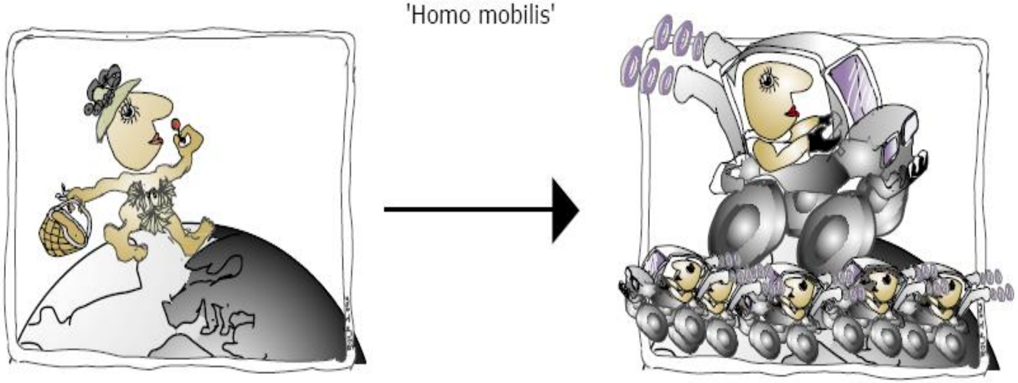
Miguel Centeno Brito
FCUL
Universidade de Lisboa

'Homo touristicus'

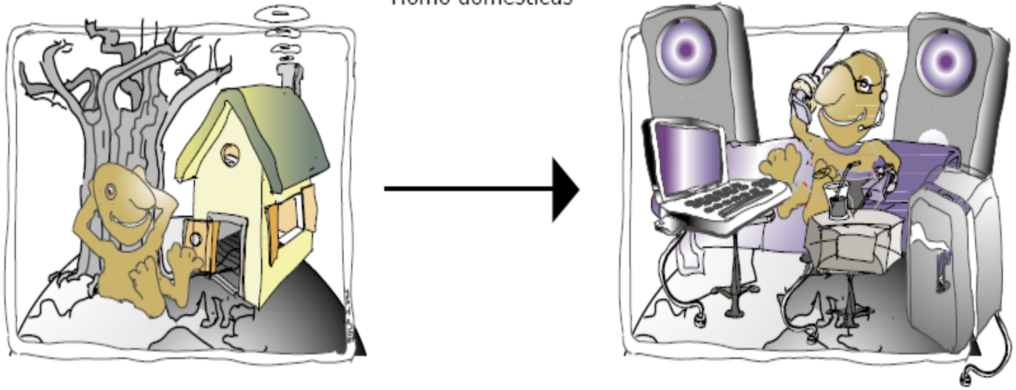
'Homo gastronomicus'

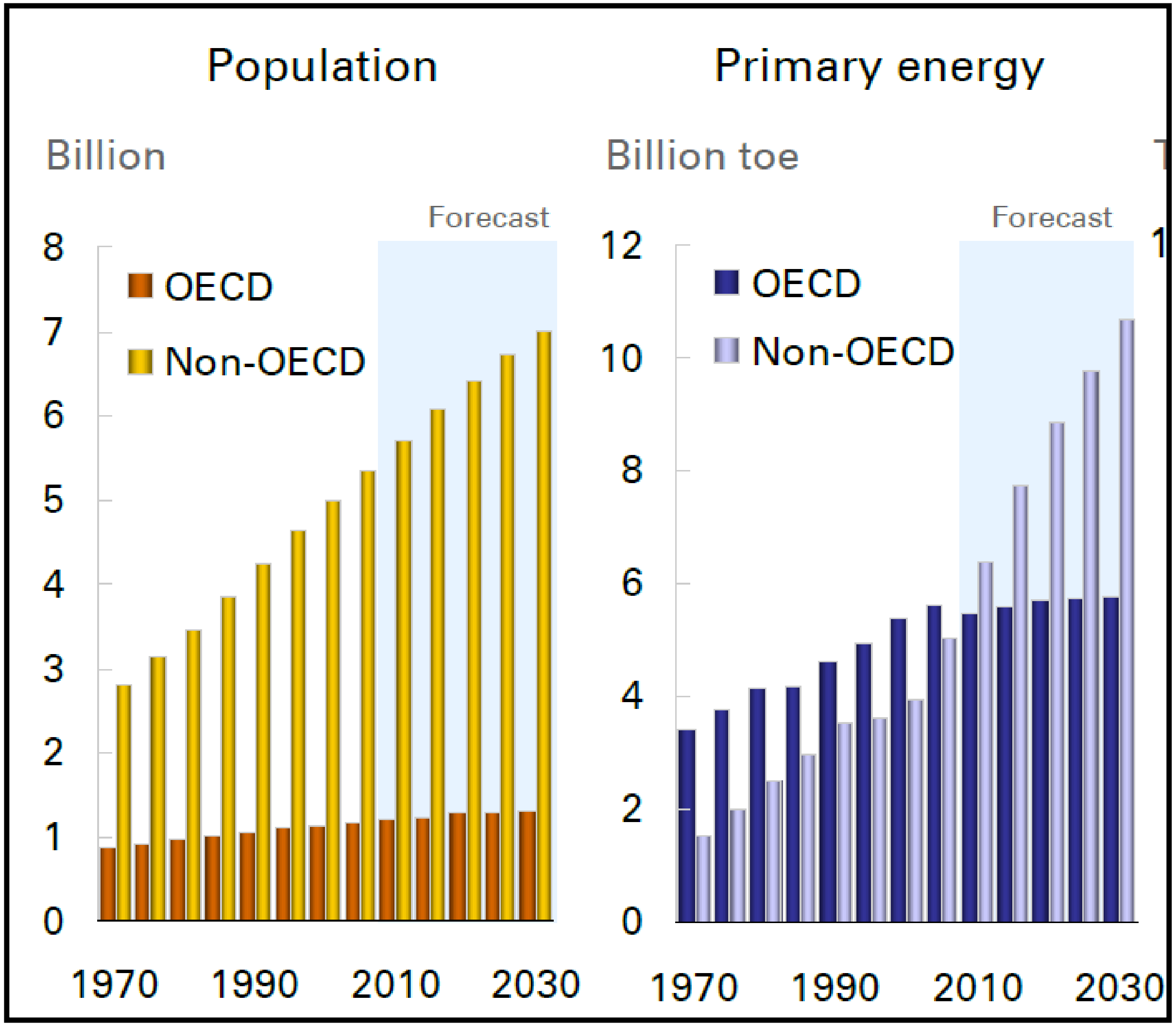


'Homo mobilis'

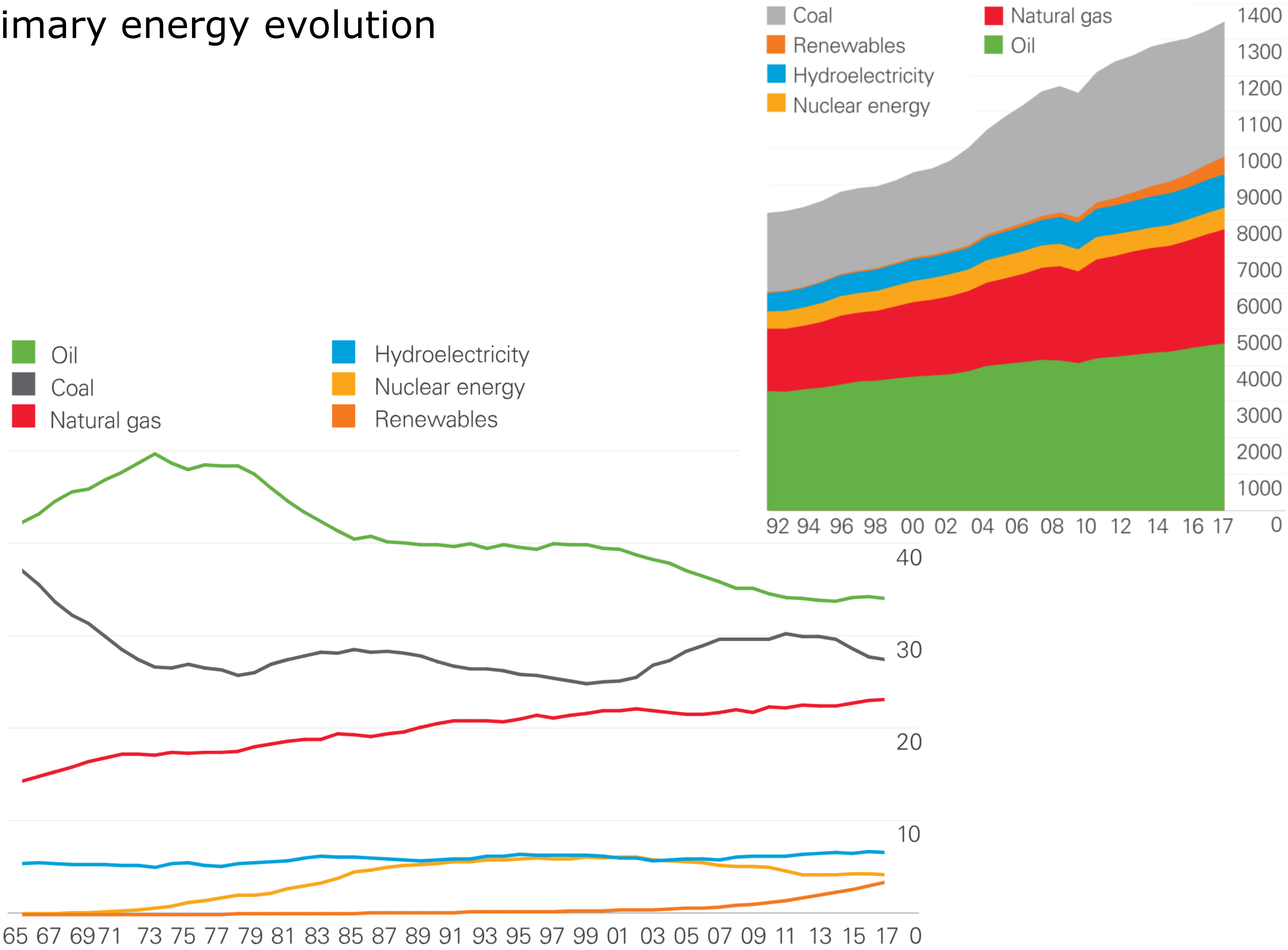


'Homo domesticus'

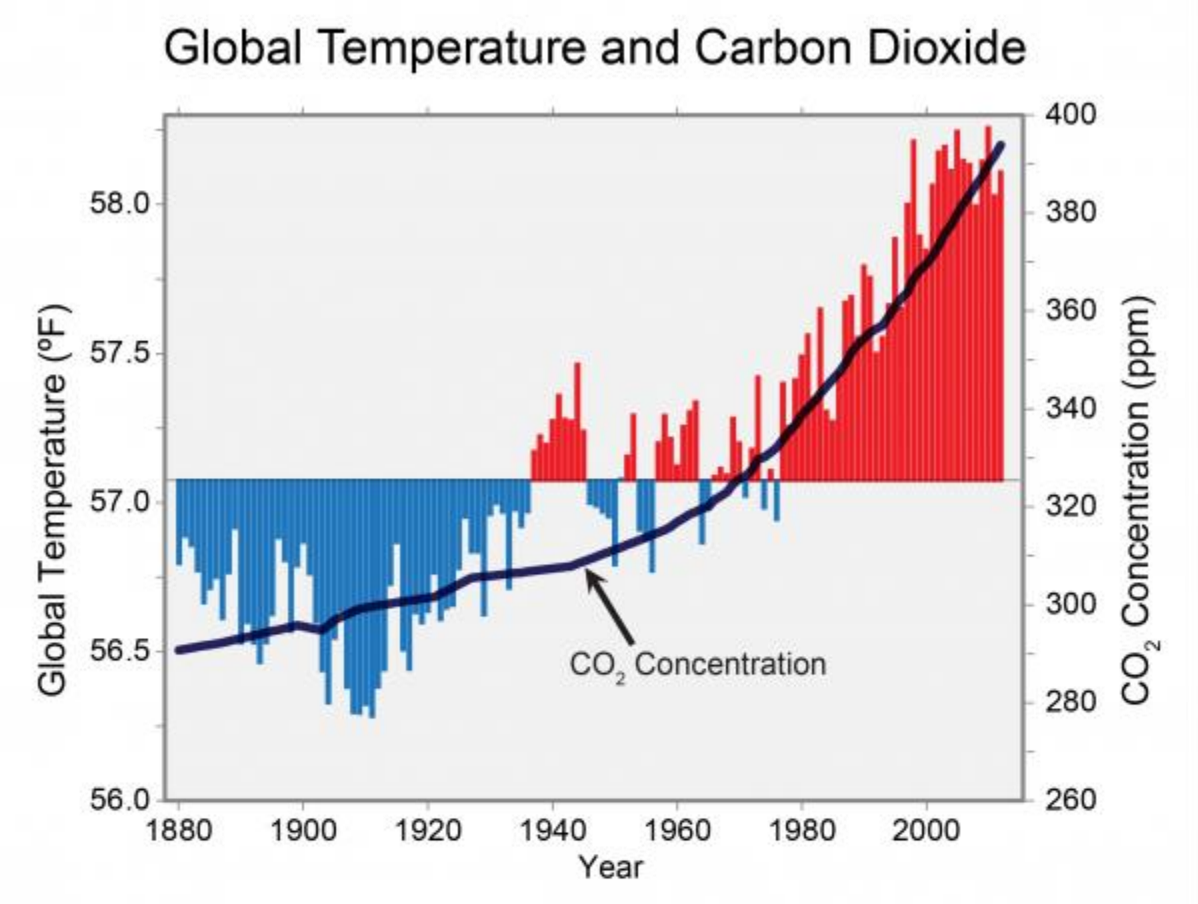



Population
Billion
Forecast
8
7
6
5
4
3
2
1
0
OECD
Non-OECD
1970
1990
2010
2030
Primary energy
Billion toe
Forecast
12
10
8
6
4
2
0
OECD
Non-OECD
1970
1990
2010
2030

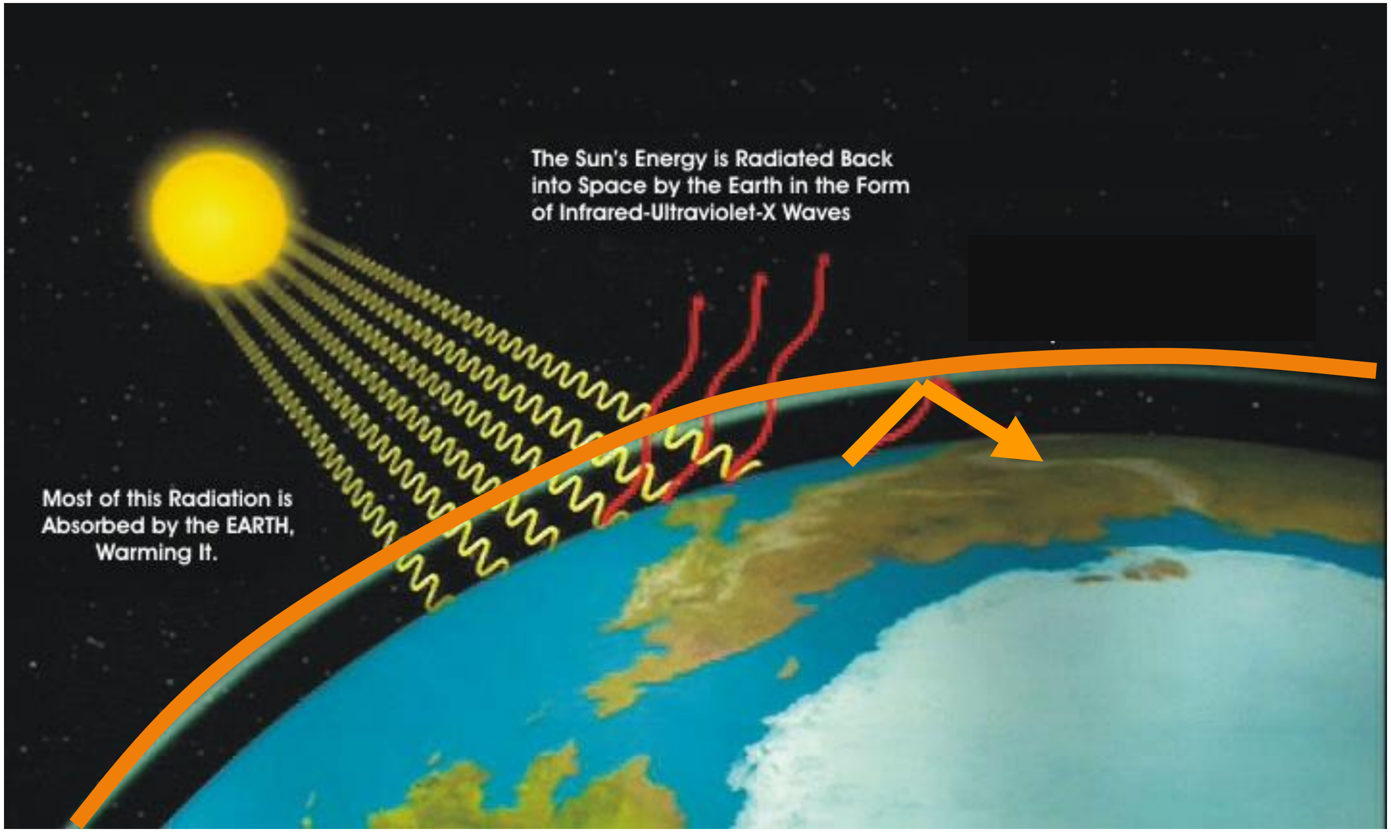
Primary energy evolution



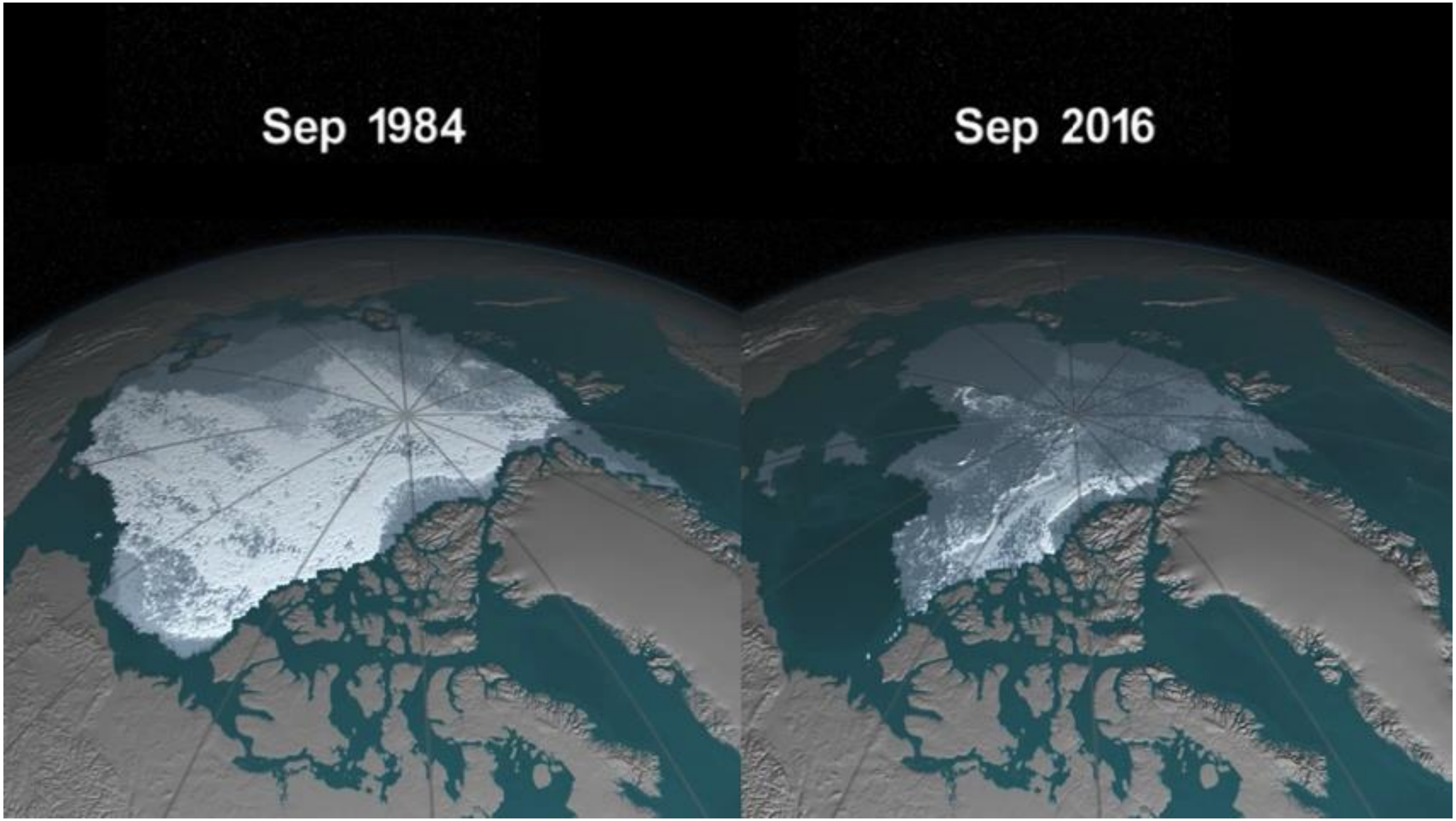
Global effects on environment



Global effects on environment



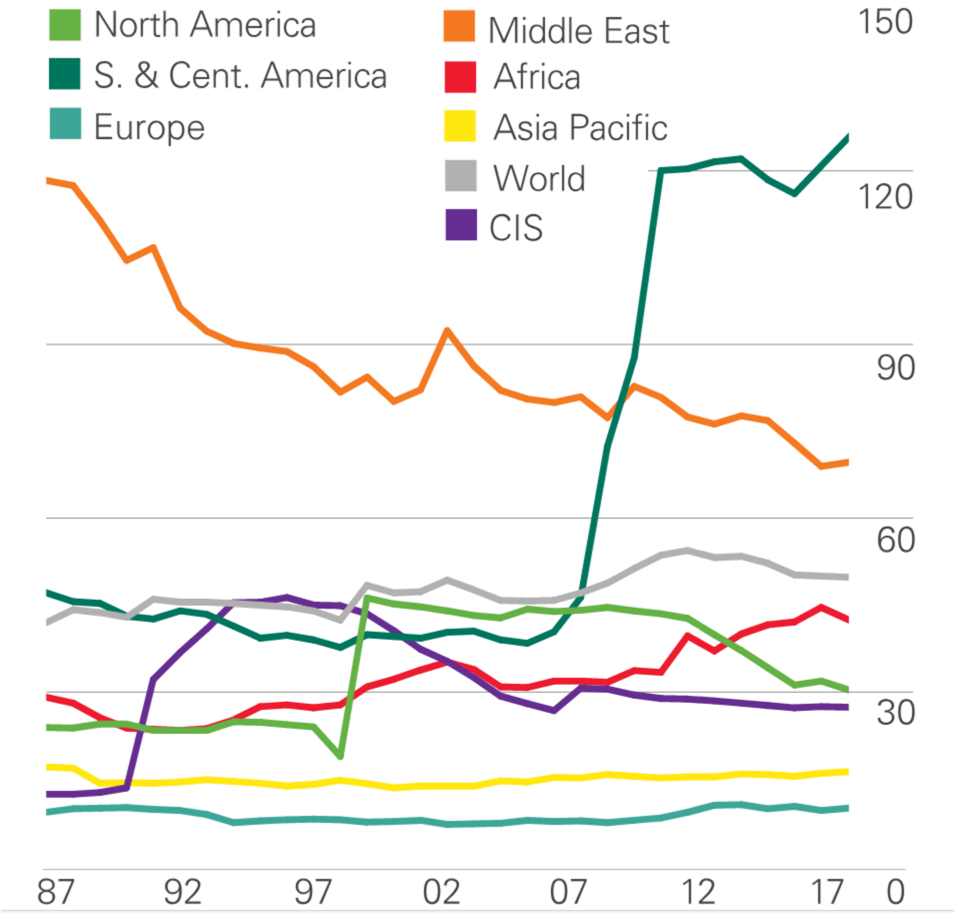
Global effects on environment



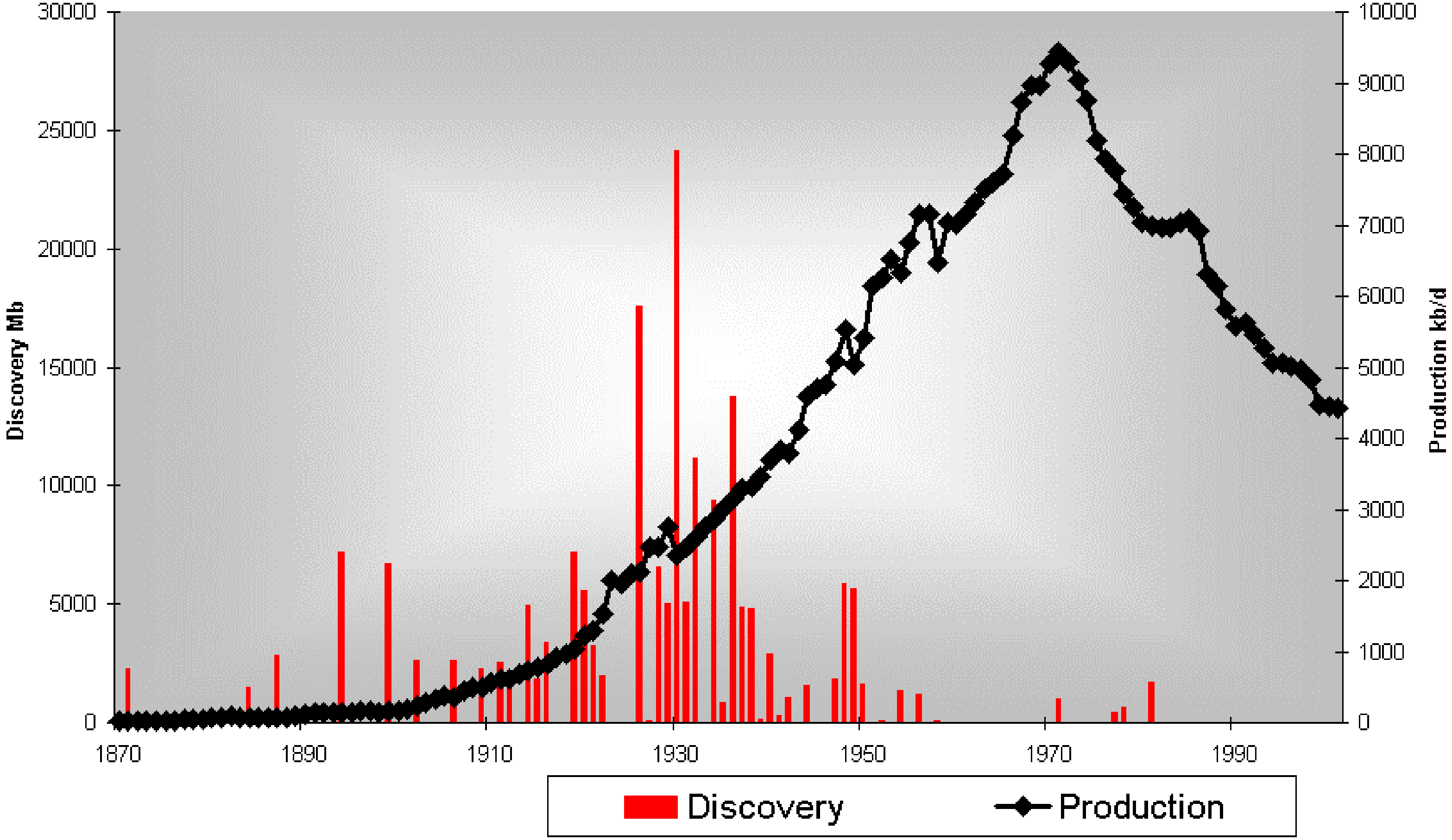
HESS

Declining reserves

Ratio reserves/current production



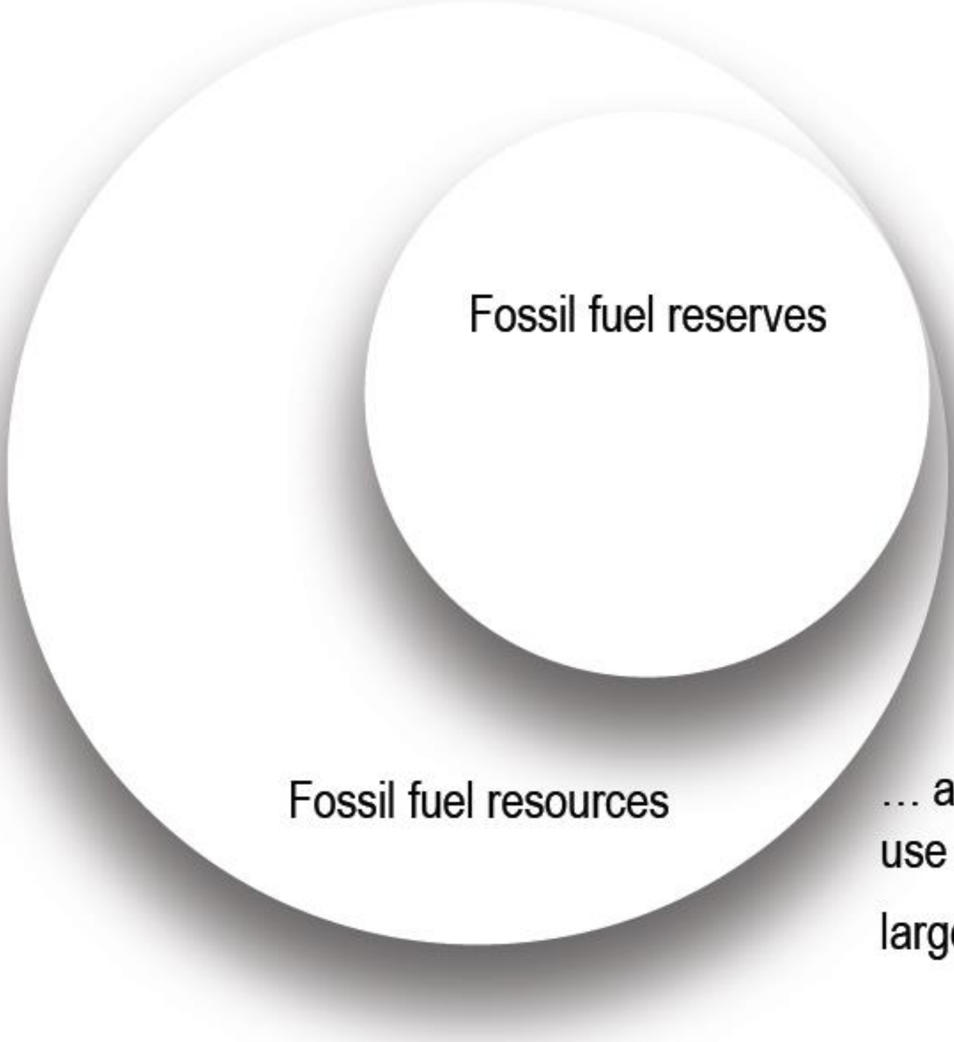
US-48


30000
25000
20000
15000
10000
5000
0
Discovery Mb
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Production kb/d
1870
1890
1910
1930
1950
1970
1990
Discovery
Production

End of fossil paradigm

- limited reserves
- consumption increase
- cost increase
- environmental impacts

The Energy Dilemma

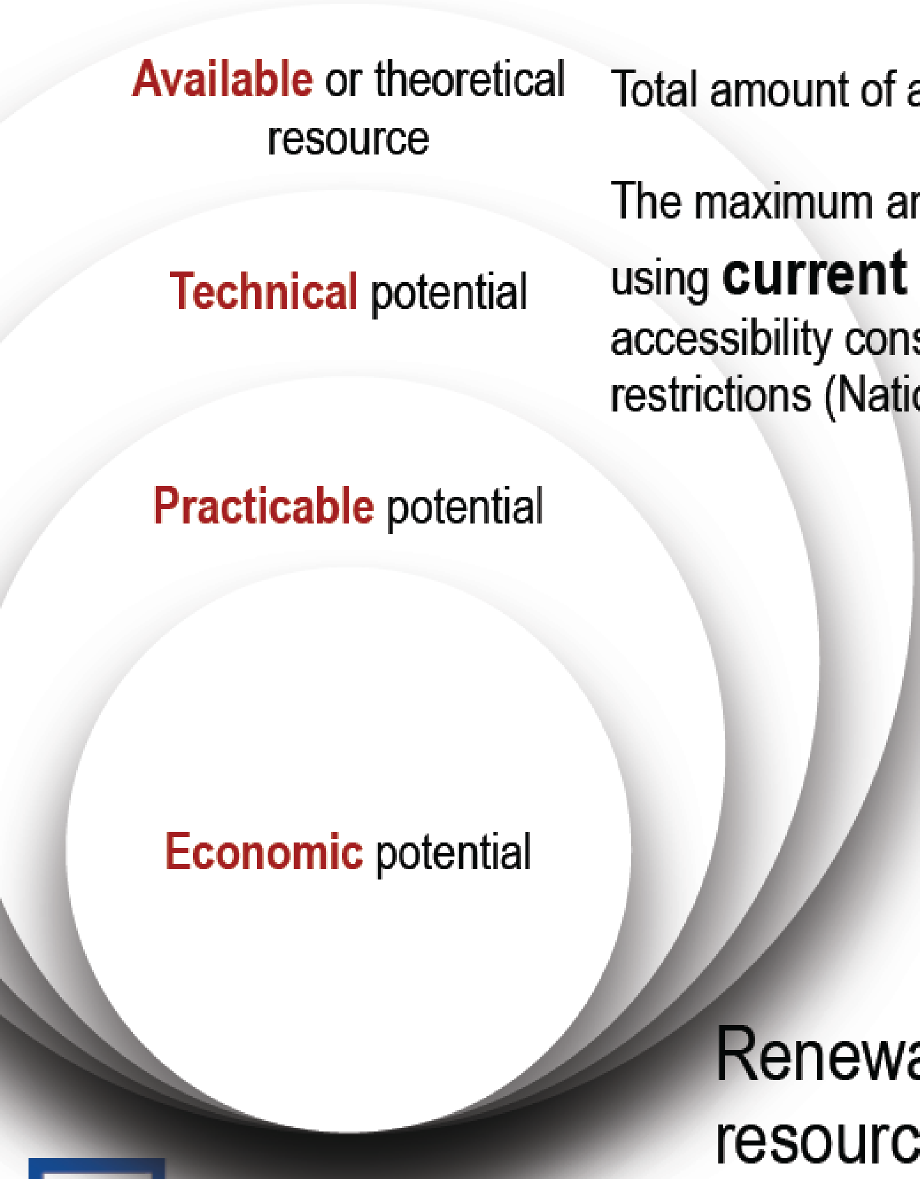


Fossil fuel reserves

… are that **known** and **currently** considered economic to extract within a whole range of *practical*, *legal* and *environmental* constraints.

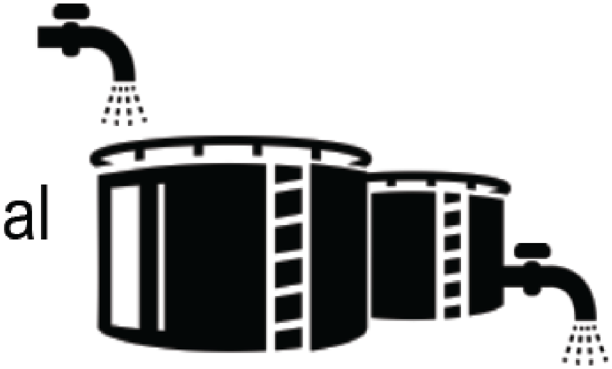
Fossil fuel resources

… are **stores** of energy, potentially available for use once extracted from the ground. They are large, but **finite**.

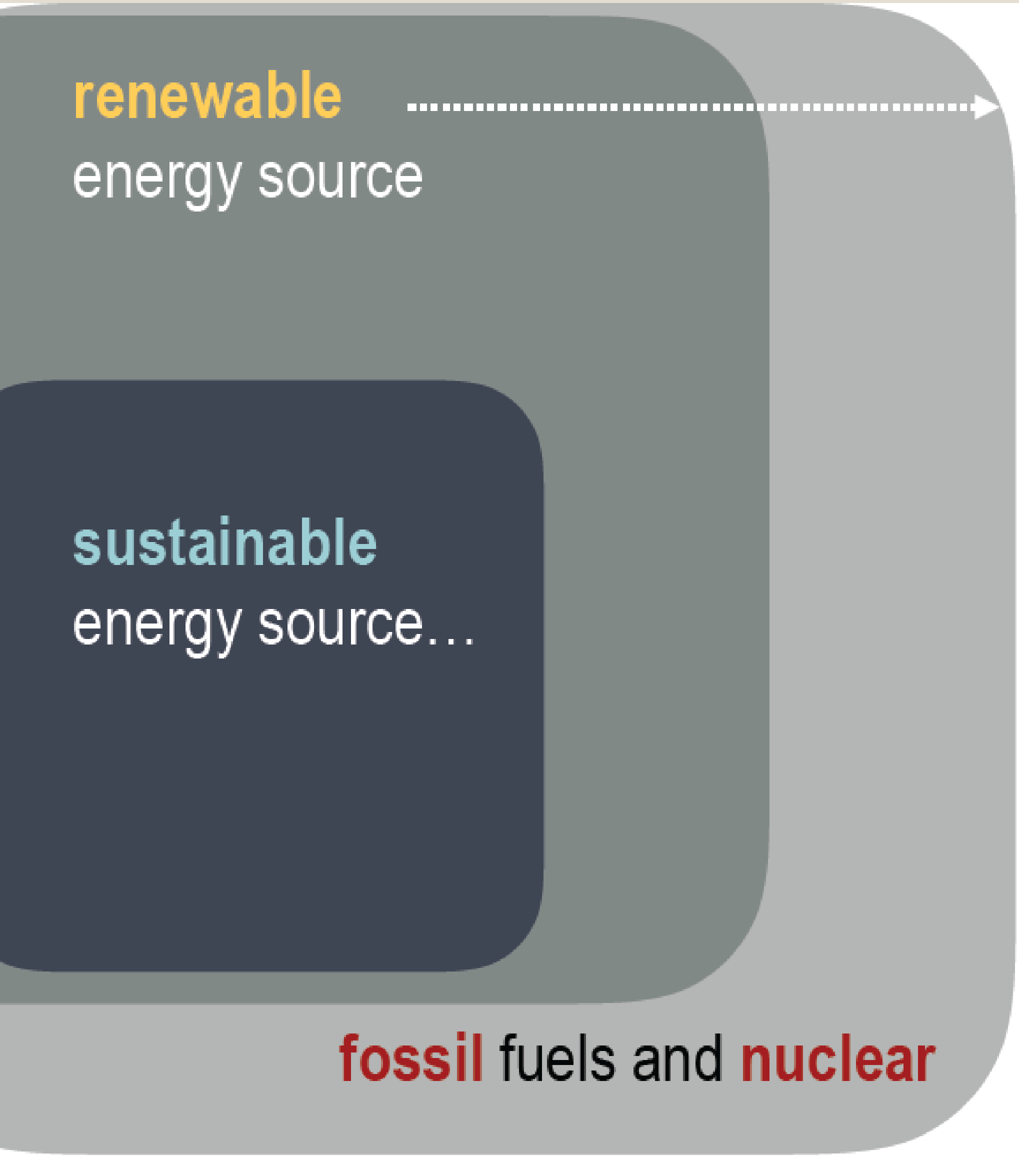


Available or theoretical resource	Total amount of annual energy **delivered** by the source.
Technical potential	The maximum amount of annual energy that could be **extracted** using **current** mature technology. It is also limited by basic accessibility constraints (roads, buildings, …) and other institutional restrictions (National Parks, …).
Practicable potential	The **technical** potential reduced by **constrains** on using or distributing energy and further **limitations** on land or technology use due to public acceptability.
Economic potential	The **technical** potential that is economically **viable**.

Renewable energy resources are potential **flows** of energy.



Ciências ULisboa

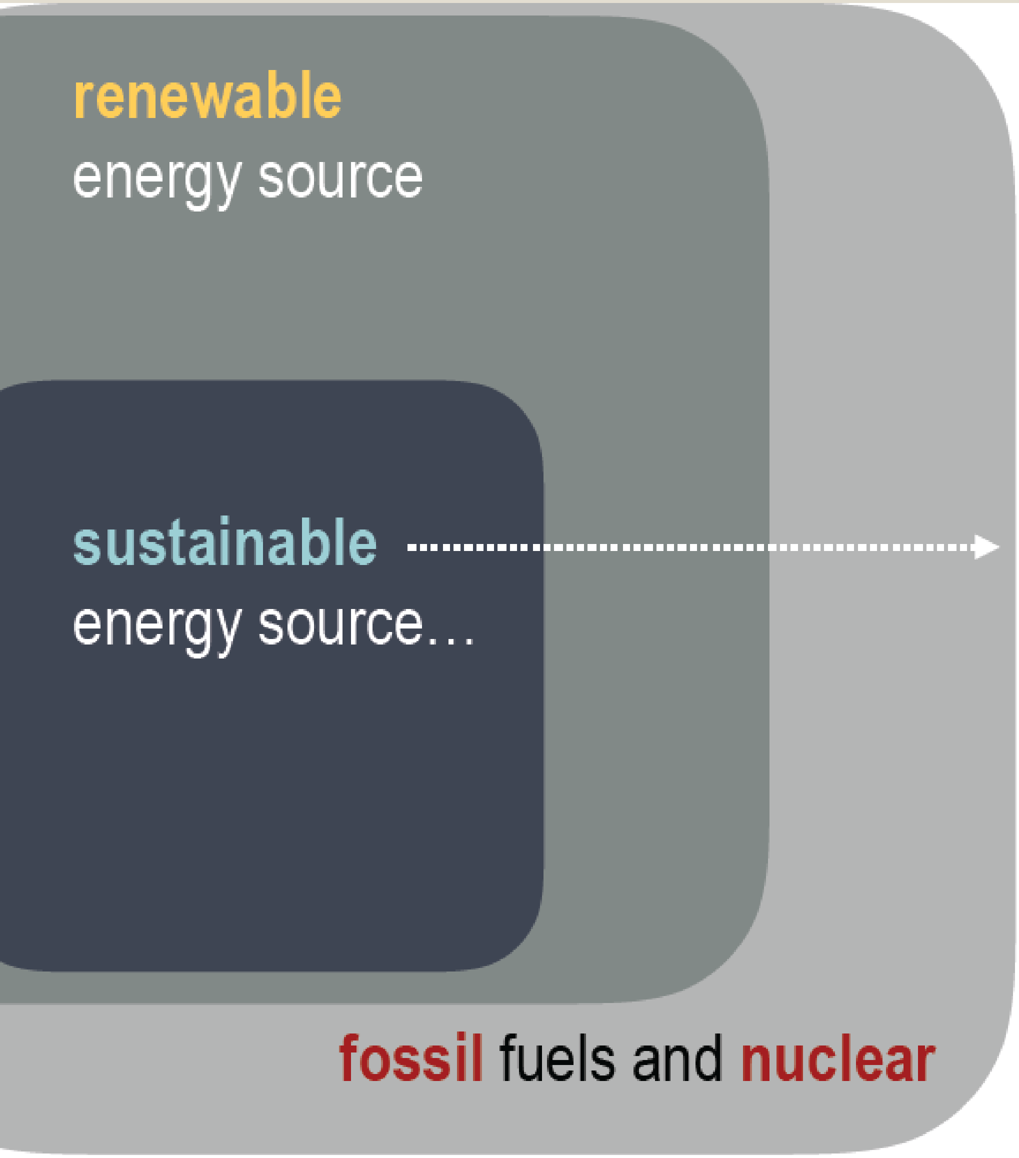


renewable energy source

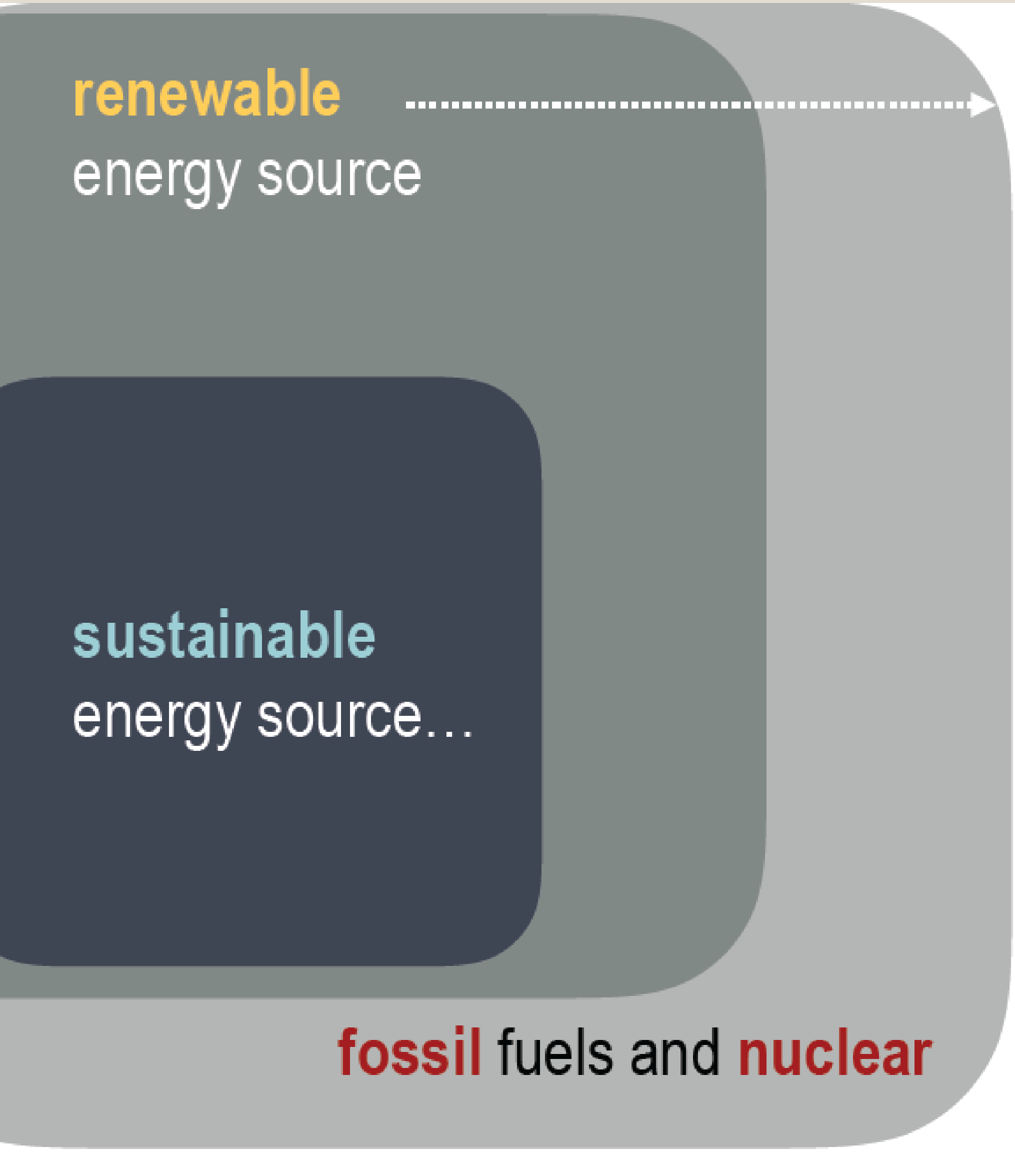
sustainable energy source…

fossil fuels and **nuclear**

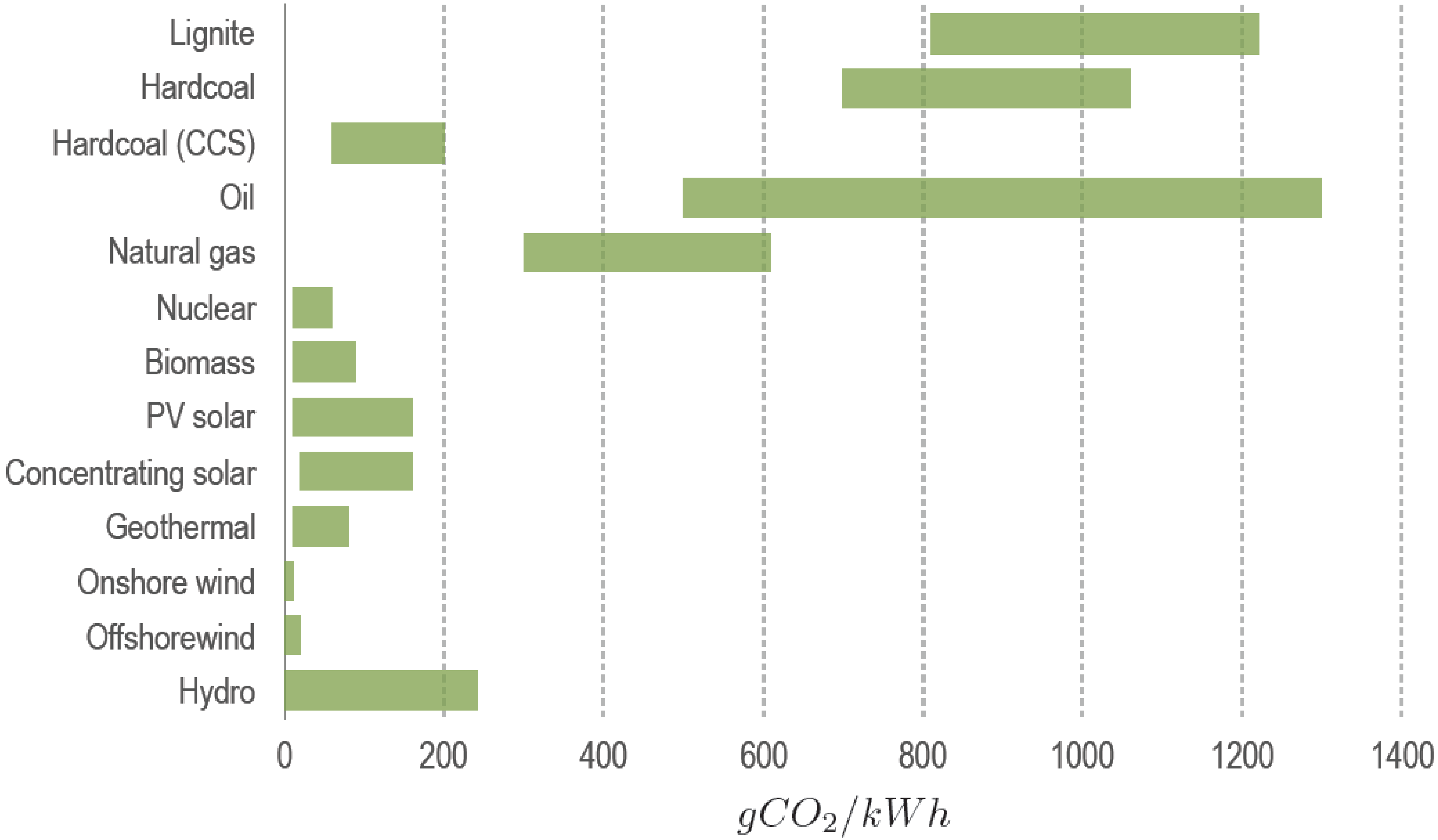
“energy flows which are replenished at the same rate as they are ‘used’”
(Sorensen, 2000)



- ✓ … is not substantially **depleted** by continued use;
- ✓ … does not entail significant pollutant **emissions** or other **environmental** problems;
- ✓ … does not involve the perpetuation of substantial health **hazards** or social **injustices**.



renewable energy source is *more* **sustainable** *than* fossil fuels and nuclear



Source: Adapted from Boyle G. Renewable Energy, Power for a sustainable Future. Oxford University Press, 2012.

1 litre biodiesel

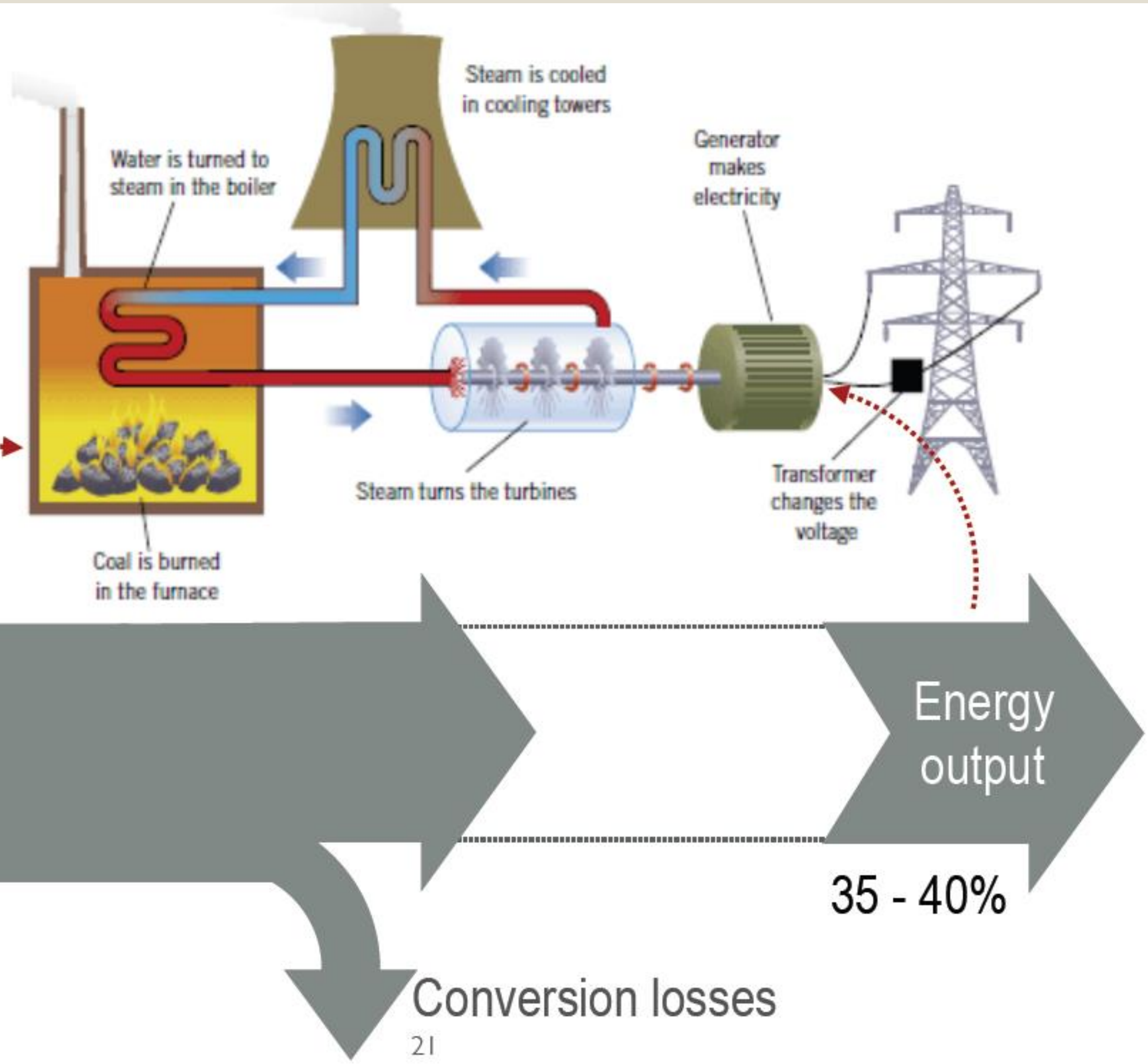
1 litre ethanol

~40%
1 litre Diesel
$3.1kgCO_2$

~25%
1 litre gasoline
$2.7kgCO_2$

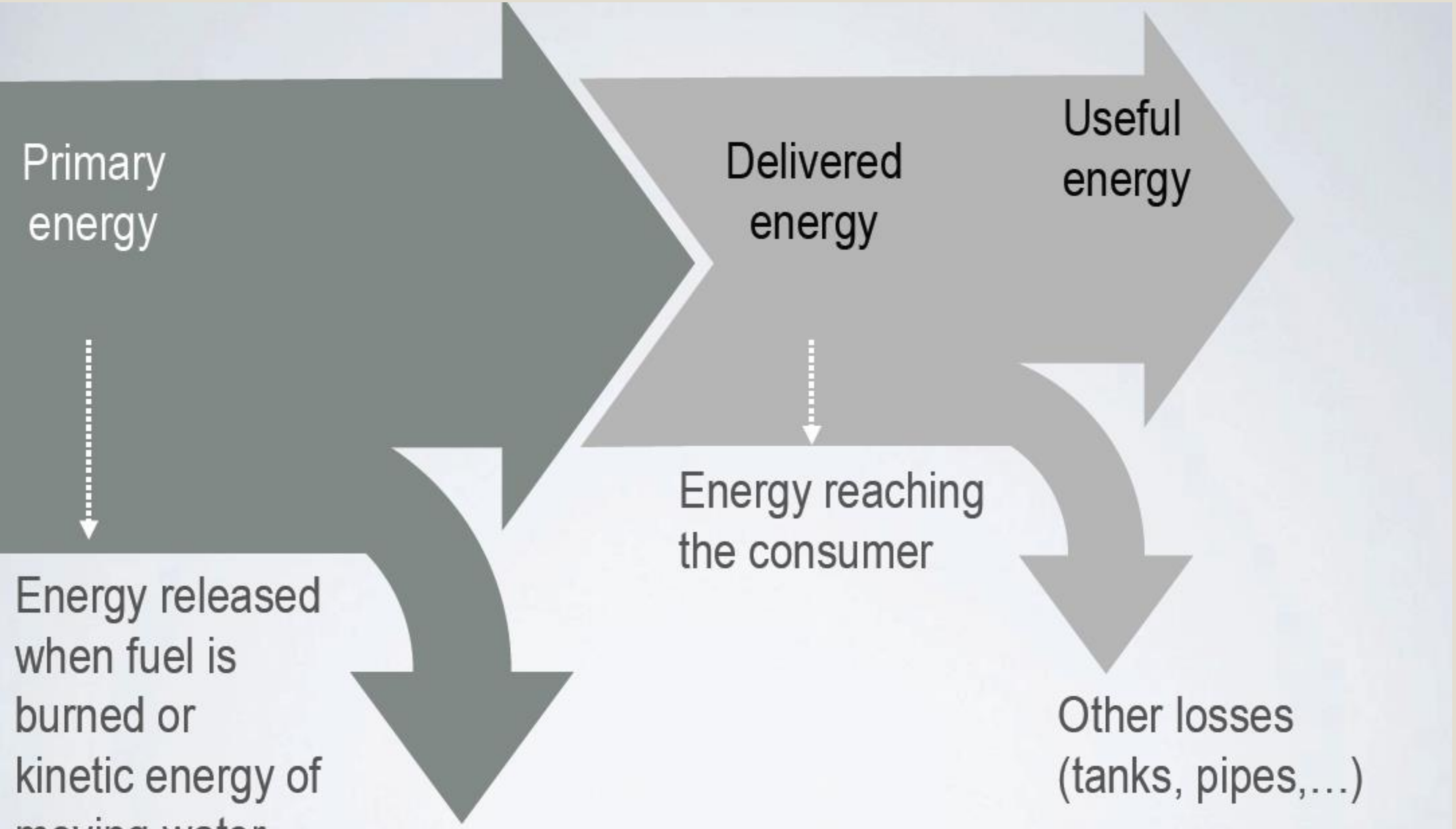
Ciências
ULisboa

The efficiency is physically limited by Carnot's theorem



35 - 40%

Conversion losses



Primary energy

Delivered energy

Useful energy

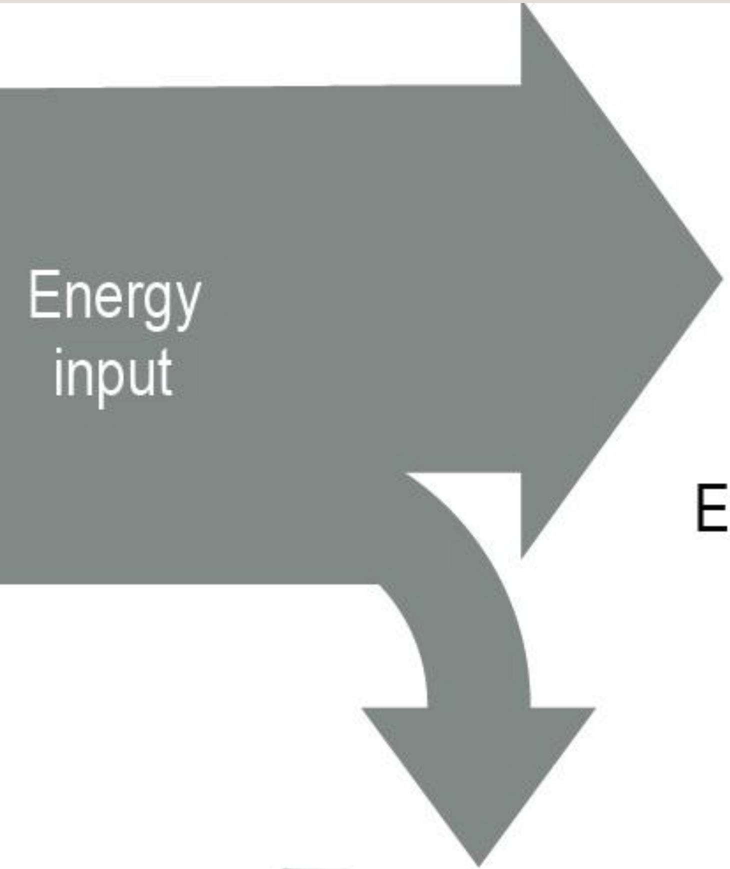
Energy released when fuel is burned or kinetic energy of moving water

Energy reaching the consumer

Conversion and transmission losses

Other losses (tanks, pipes,…)

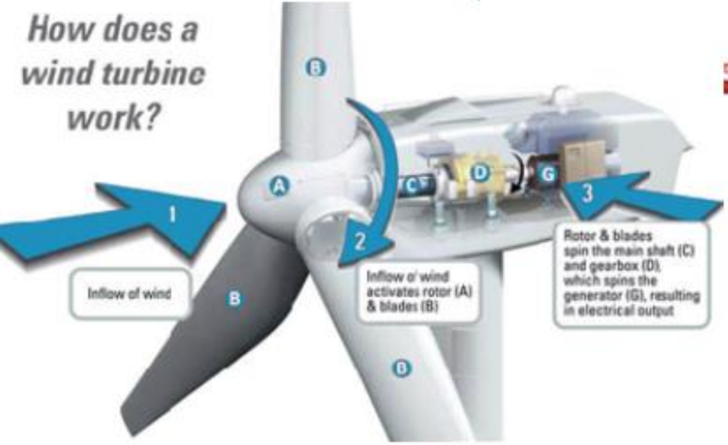
Ciências ULisboa

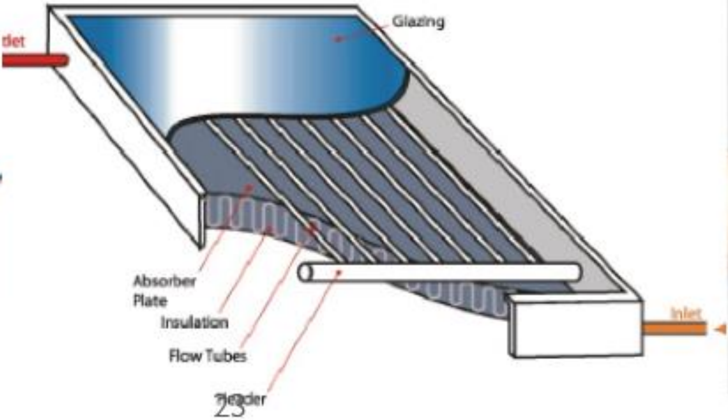


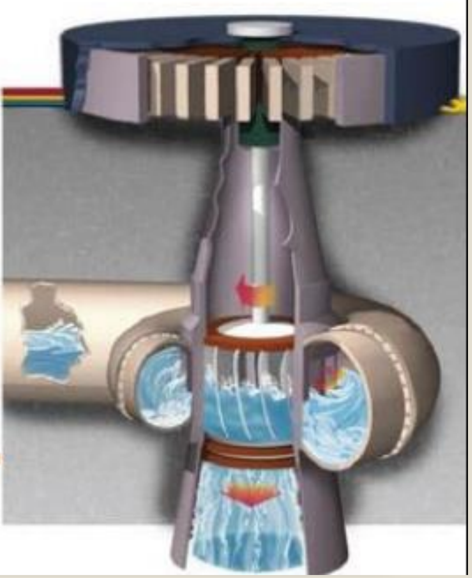
Energy input

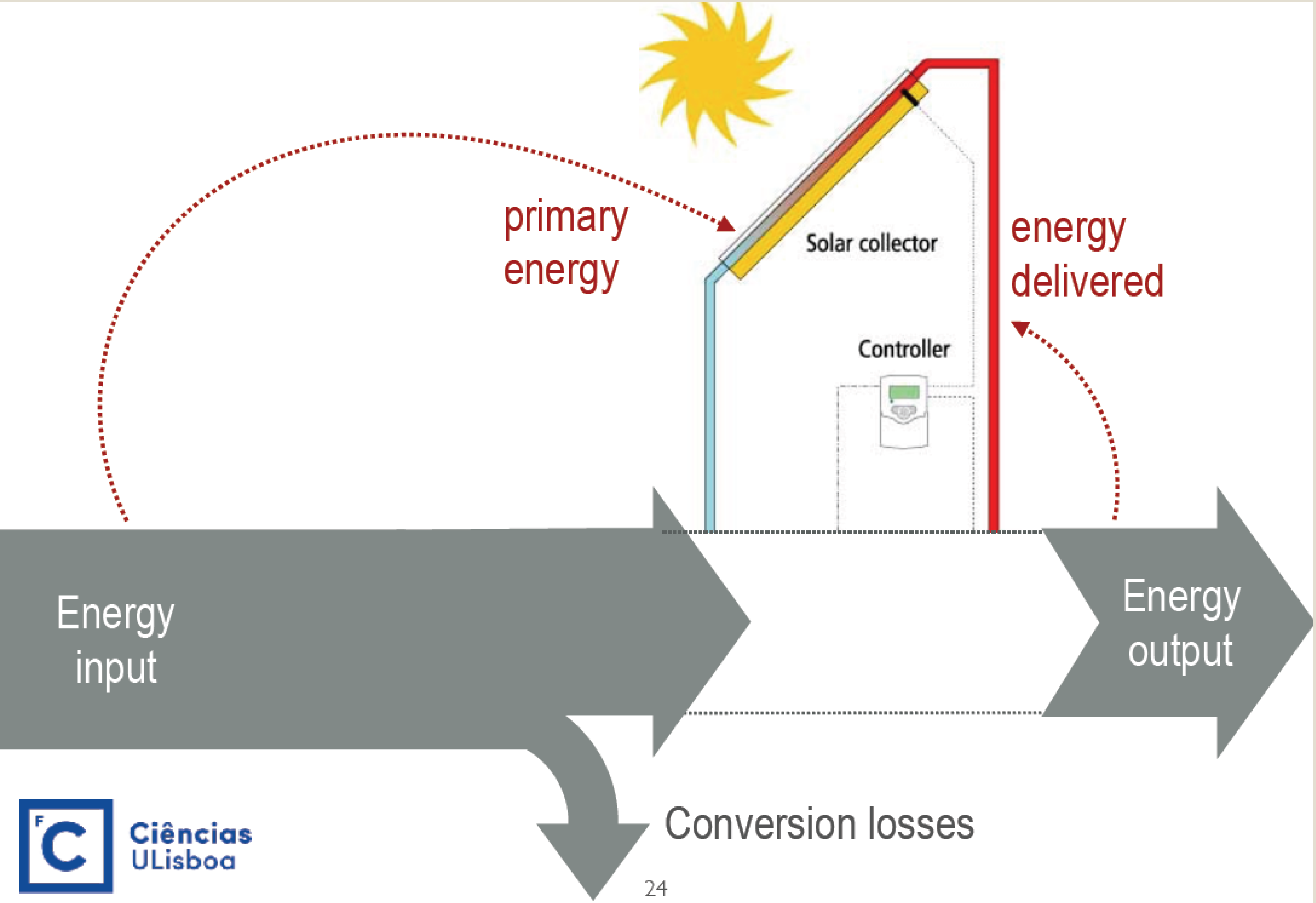
Energy output

Efficiency $\eta = \dfrac{\text{output}}{\text{input}}$









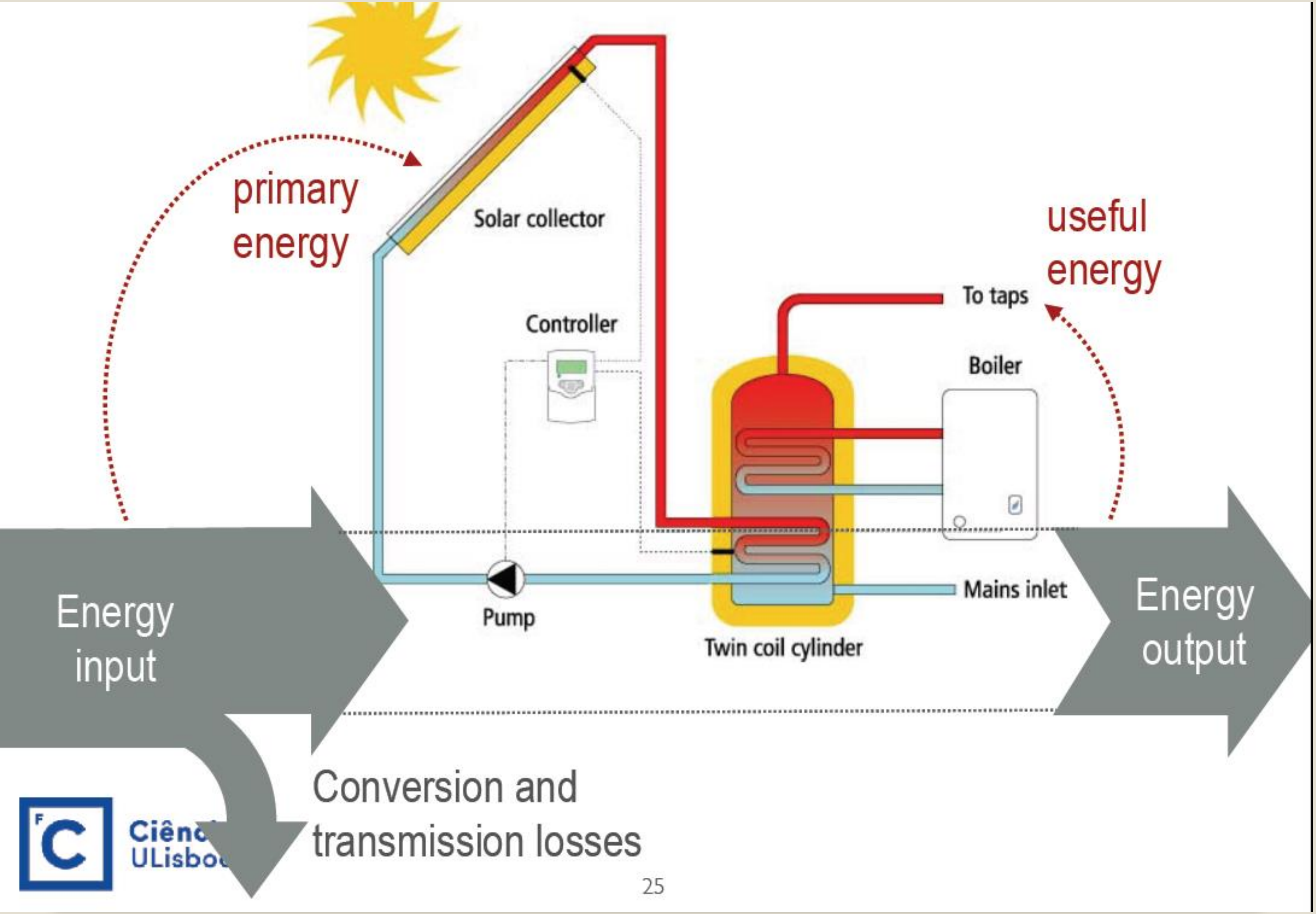
primary energy

energy delivered

Energy input

Energy output

Conversion losses



primary energy

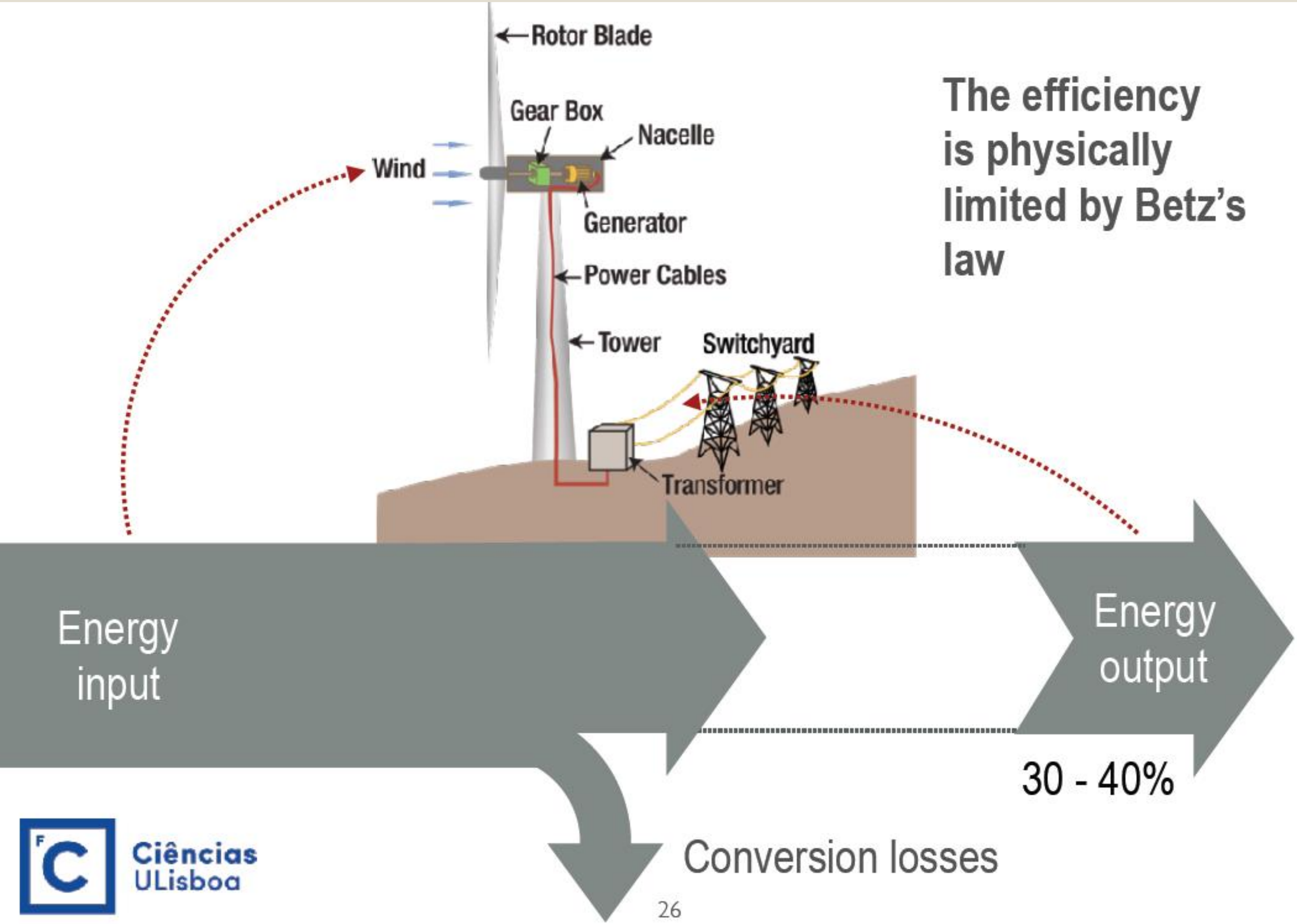
useful energy

Energy input

Energy output

Conversion and transmission losses

The efficiency is physically limited by Betz’s law

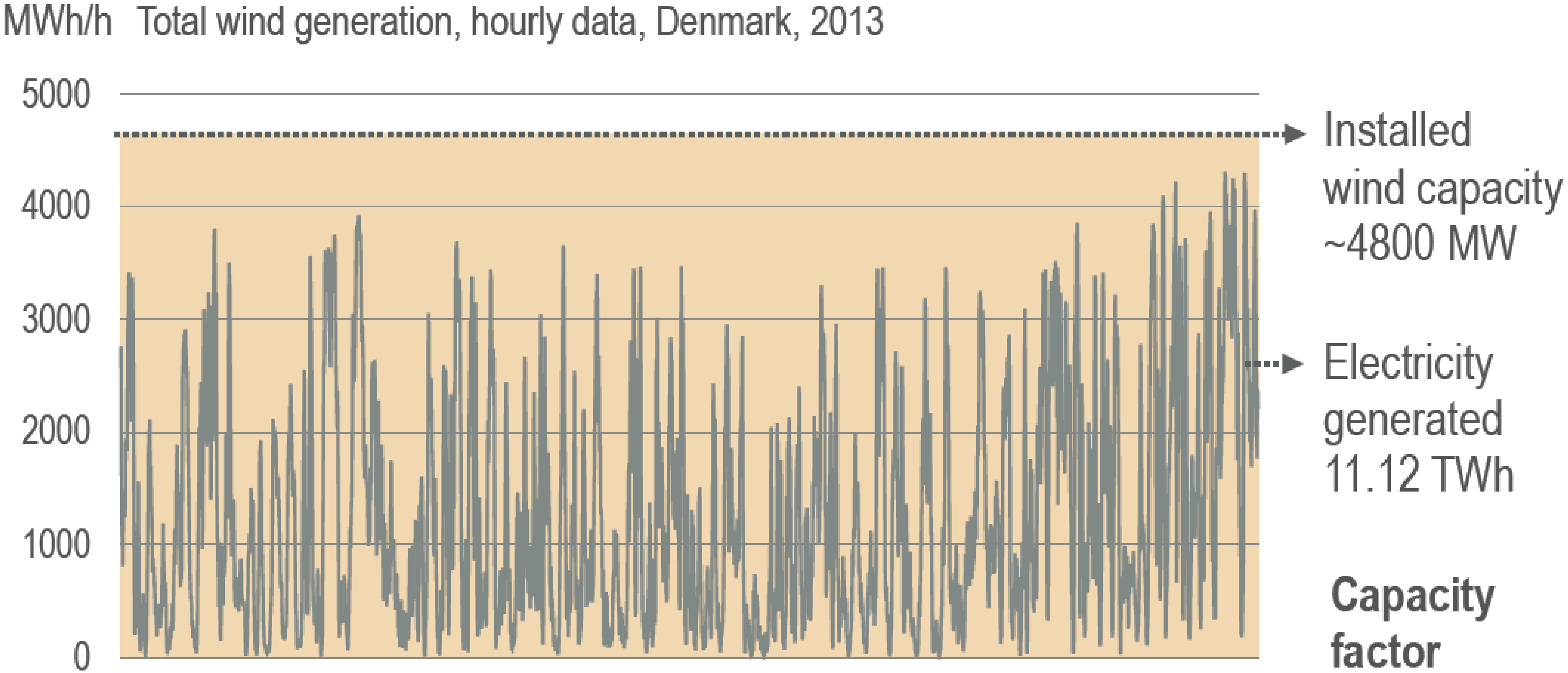


Energy input

Energy output

30 - 40%

Conversion losses

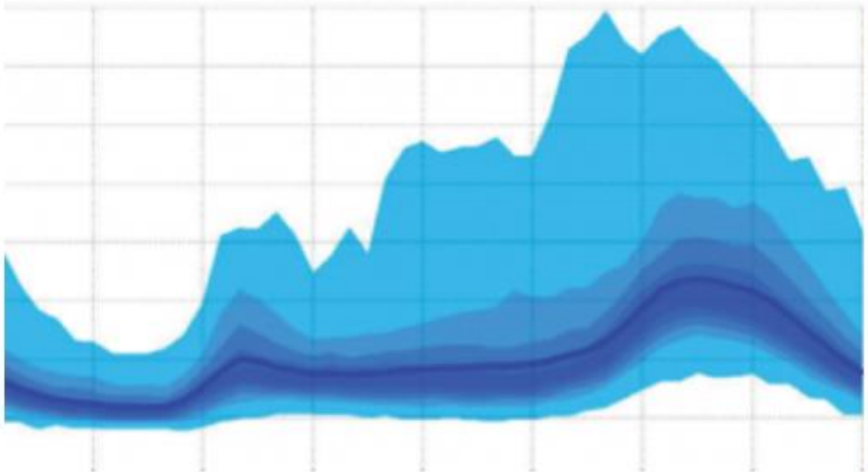


Source: http://pfbach.dk/firma_pfb/time_series/ts.php

Capacity factor 26%

Capacity factor decreases by

… resource privation;
… maintenance pauses;
… low demand.



load profile

maintenance

day/night

SOLAR ENERGY

SOLAR ENERGY APPLICATIONS

Solar radiation = electromagnetic energy

Direct use without transformation
e.g. Ilumination in buildings.

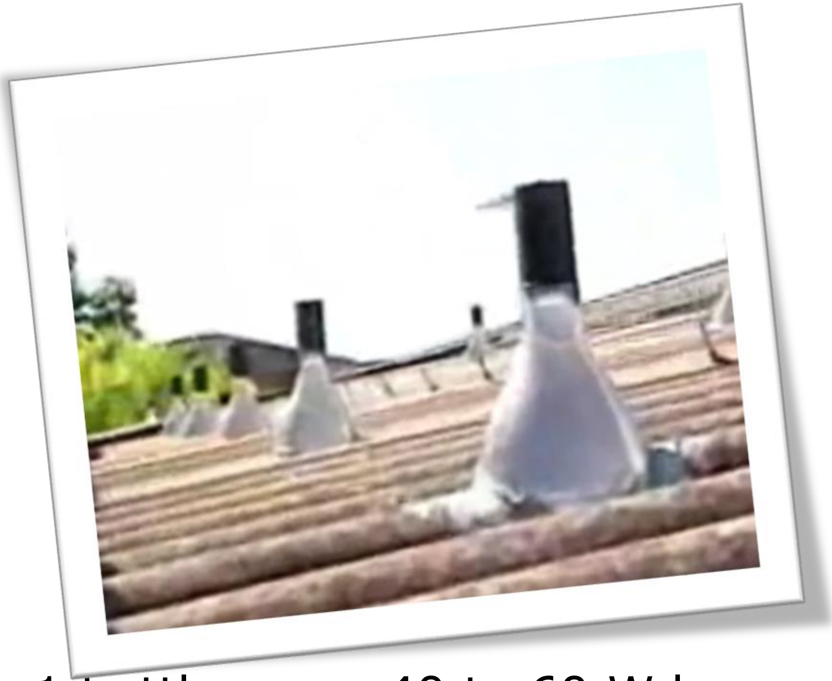
Use in other form by conversion:

- thermal, as heat
- photovoltaic, as electricity

APLICAÇÕES ENERGIA SOLAR

Radiação solar = energia electromag

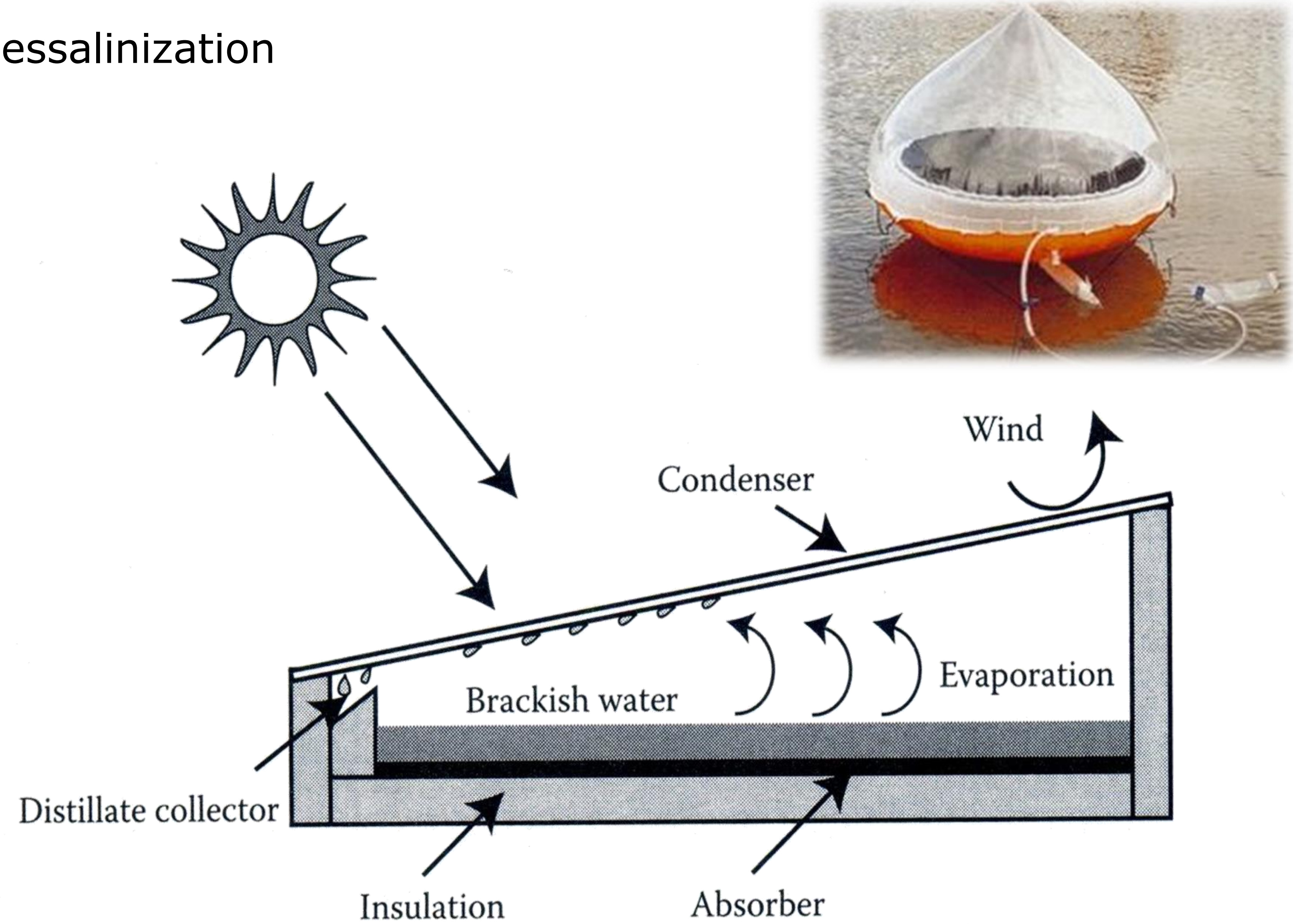
Direct use of solar energy without transformation
e.g. Buildings ilumination.



1 bottle ~ one 40 to 60 W lamp

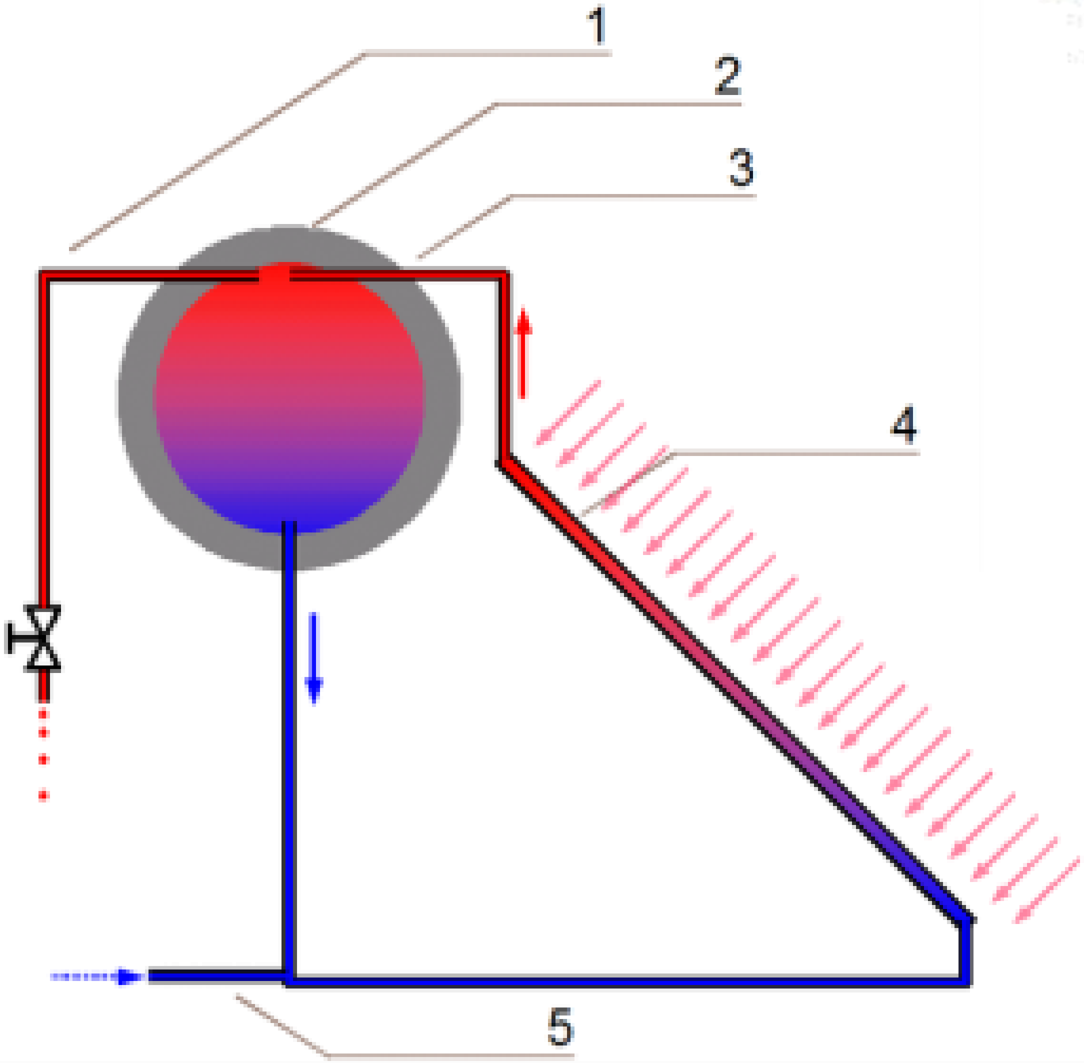

Air Circulation
Solar
Raditiation
Heat
Conduction
High
Thermal
Mass
South
Facing
Glazing
Air Cavity
Caption

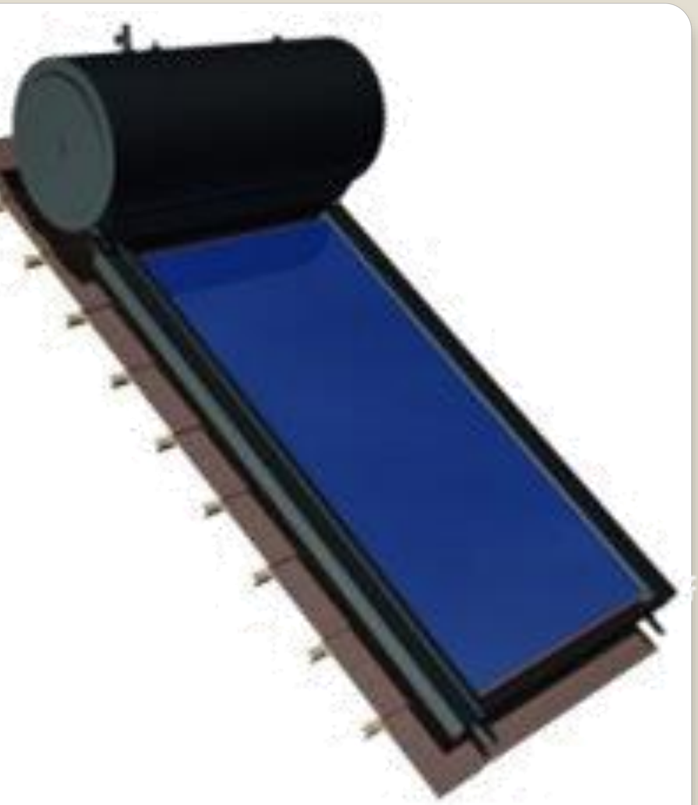
Dessalinization



Hot water production

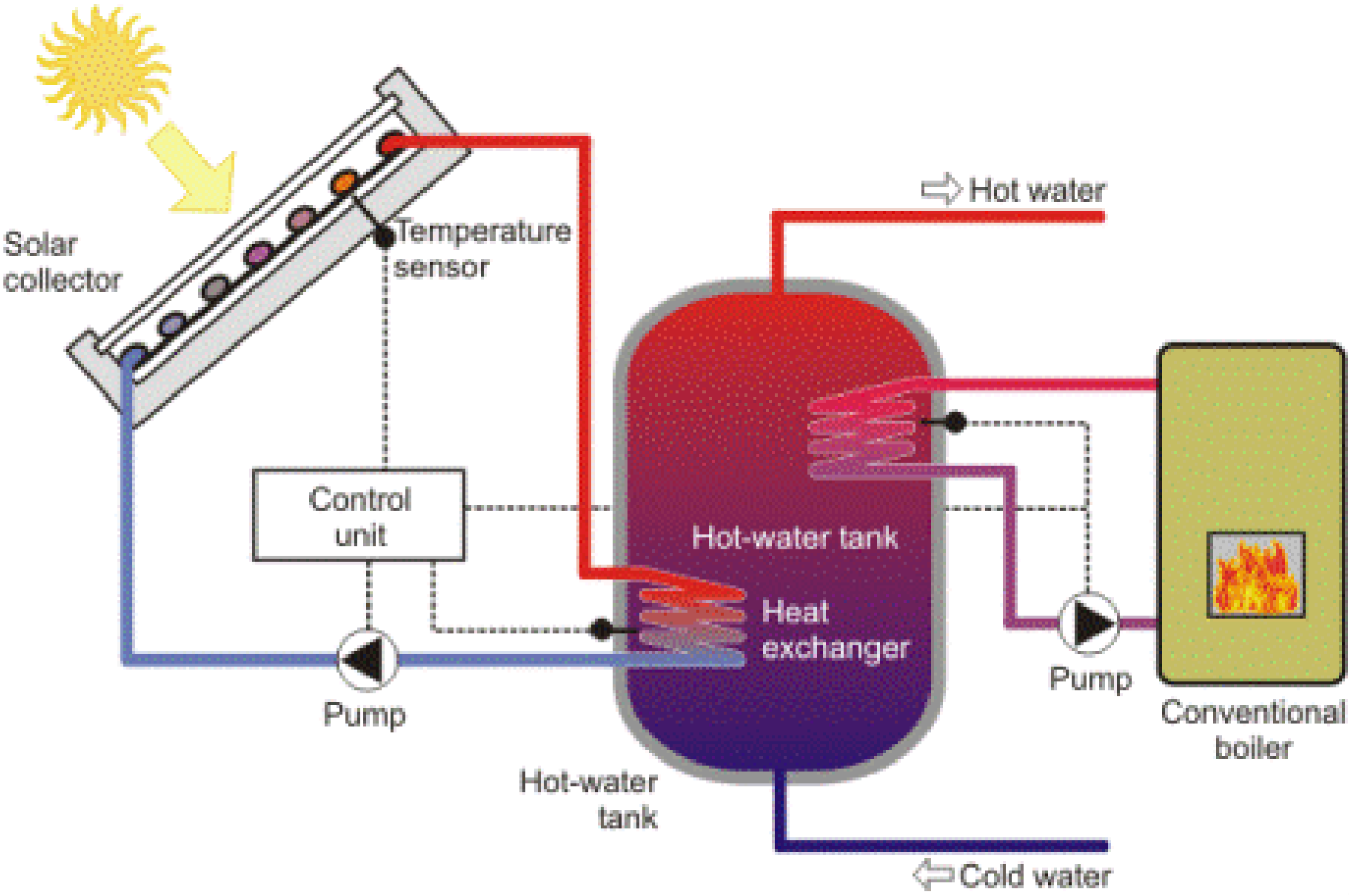
Convection flow

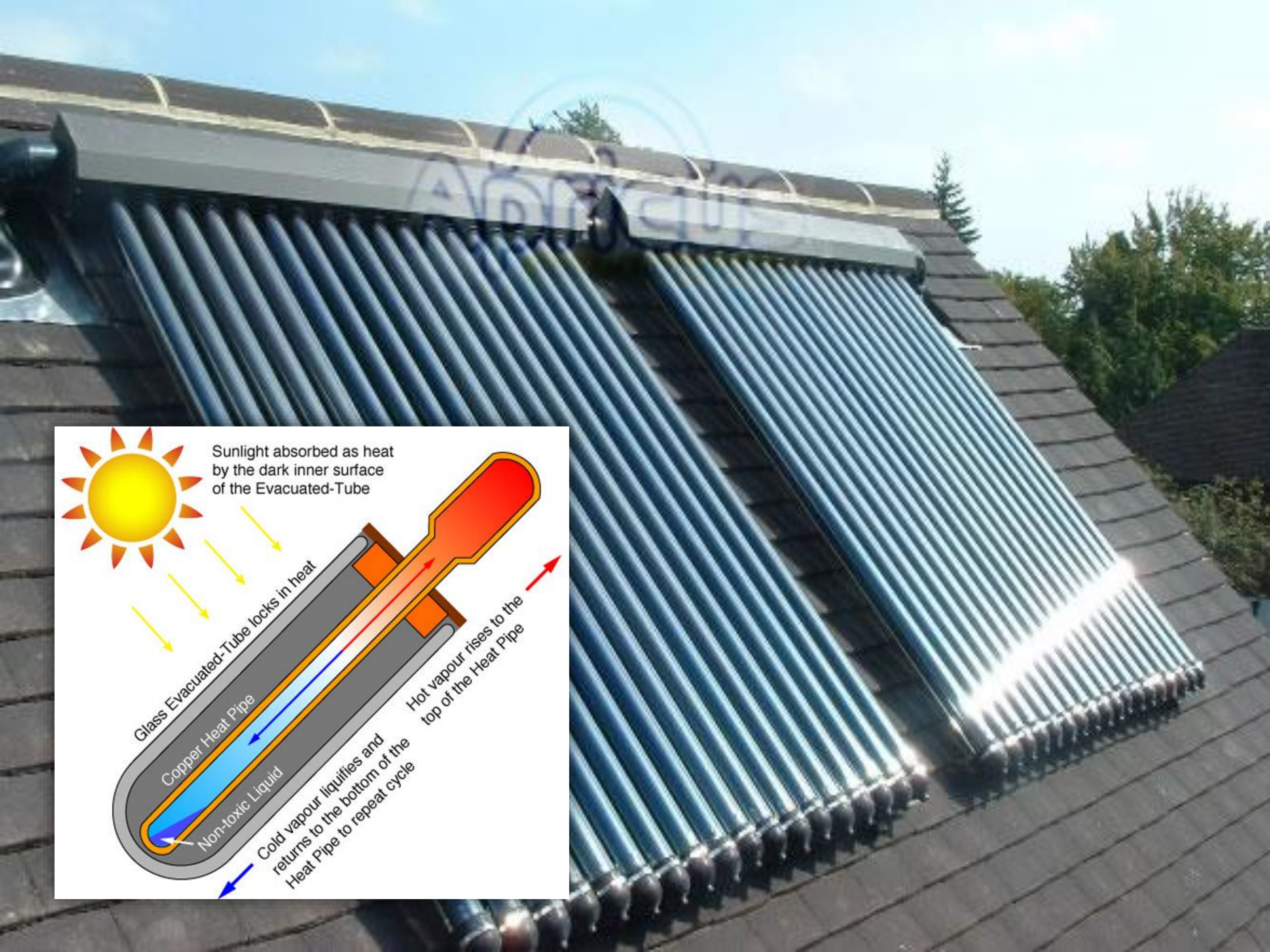




Hot water production

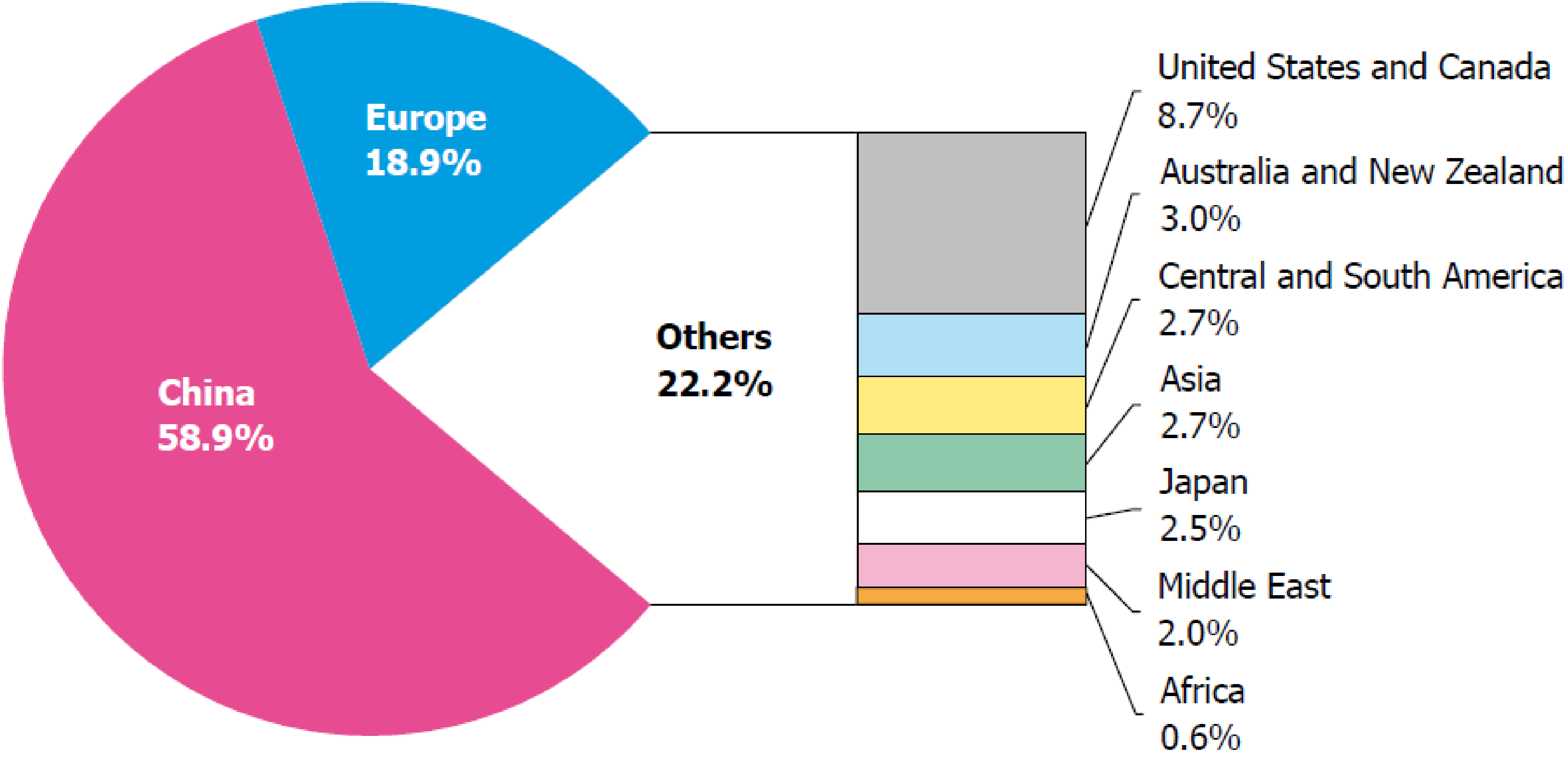
Forced flow



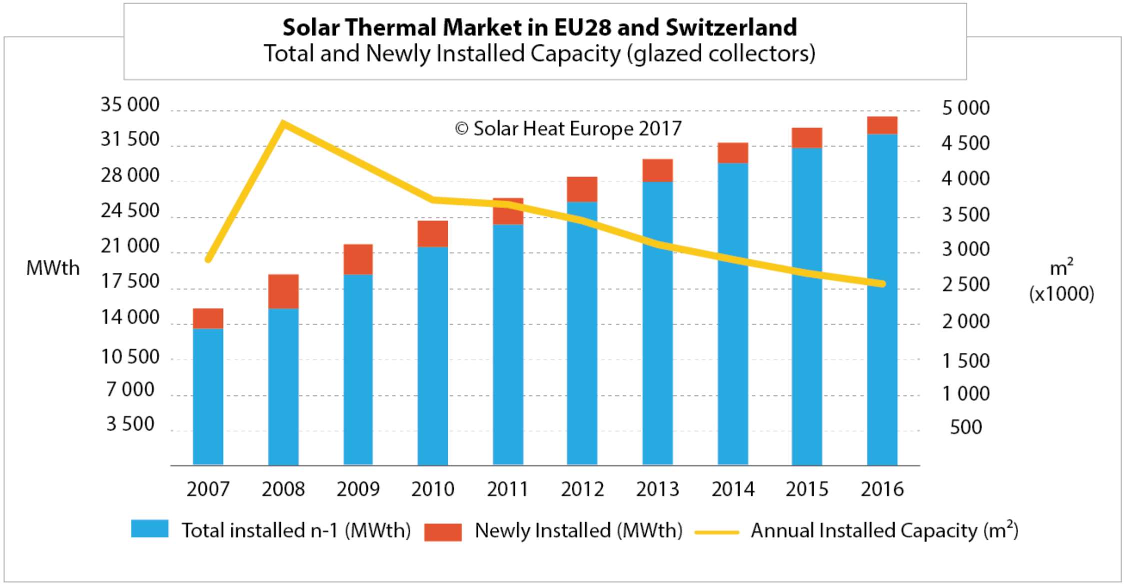

Sunlight absorbed as heat by the dark inner surface of the Evacuated-Tube
Glass Evacuated-Tube locks in heat
Copper Heat Pipe
Non-toxic Liquid
Hot vapour rises to the top of the Heat Pipe
Cold vapour liquifies and returns to the bottom of the Heat Pipe to repeat cycle

World market for solar thermal

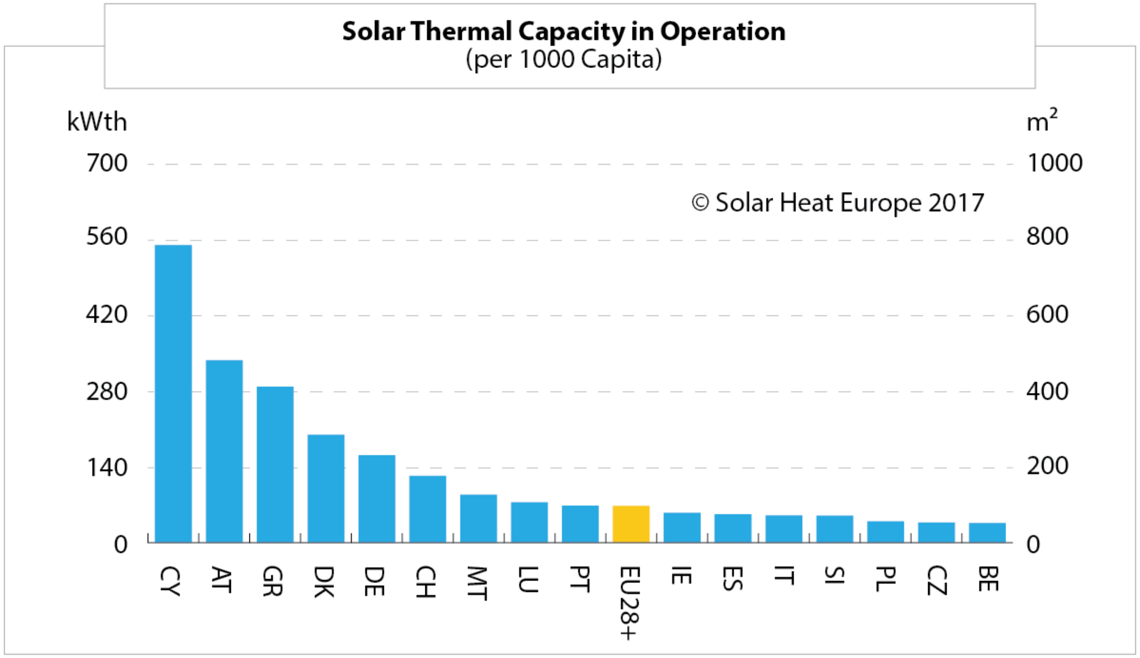
Installed capacity



Africa:	Namibia, South Africa, Tunisia, Zimbabwe
Asia:	India, South Korea, Taiwan, Thailand
Central + South America:	Barbados, Brazil, Chile, Mexico, Uruguay
Europe:	EU 27, Albania, Former Yugoslav Republic of Macedonia, Norway, Switzerland, Turkey
Middle East:	Israel, Jordan



Solar Thermal Market in EU28 and Switzerland
Total and Newly Installed Capacity (glazed collectors)



Solar Thermal Capacity in Operation
(per 1000 Capita)

Using the thermal path for electricity production

Electricity production using a thermal machine

Solar concentration

Diameter: 8.5m ($\sim 57 m^2$)

Focal distance: 4.5m

Concentration factor: 2500

Fluid (He) temperature: 650°C

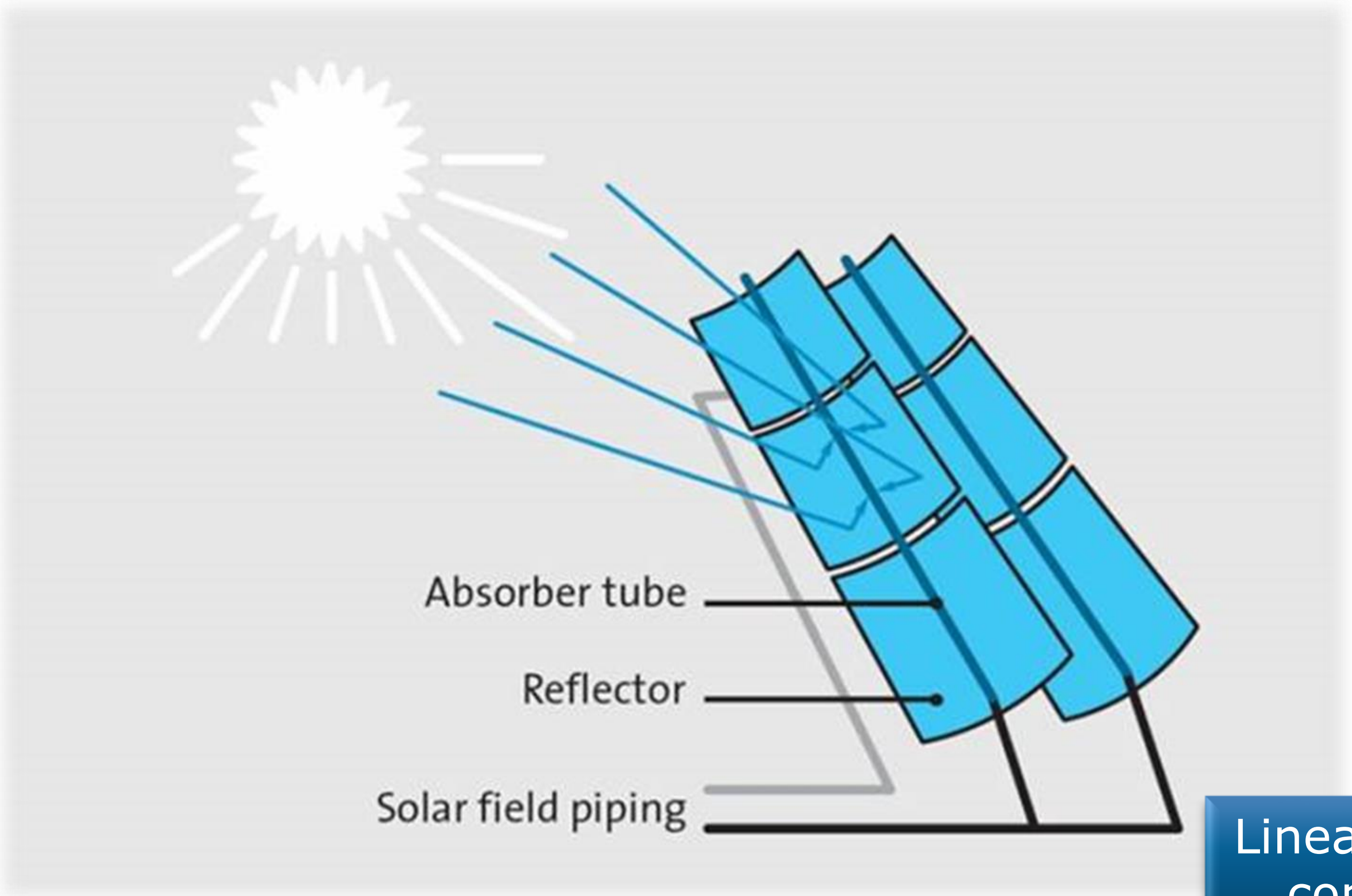
Pressure: 20-150bar

Power: 8.4kW

Focal parabolic concentrators

Electricity production using a thermal machine

Solar concentration



Linear parabolic concentrators

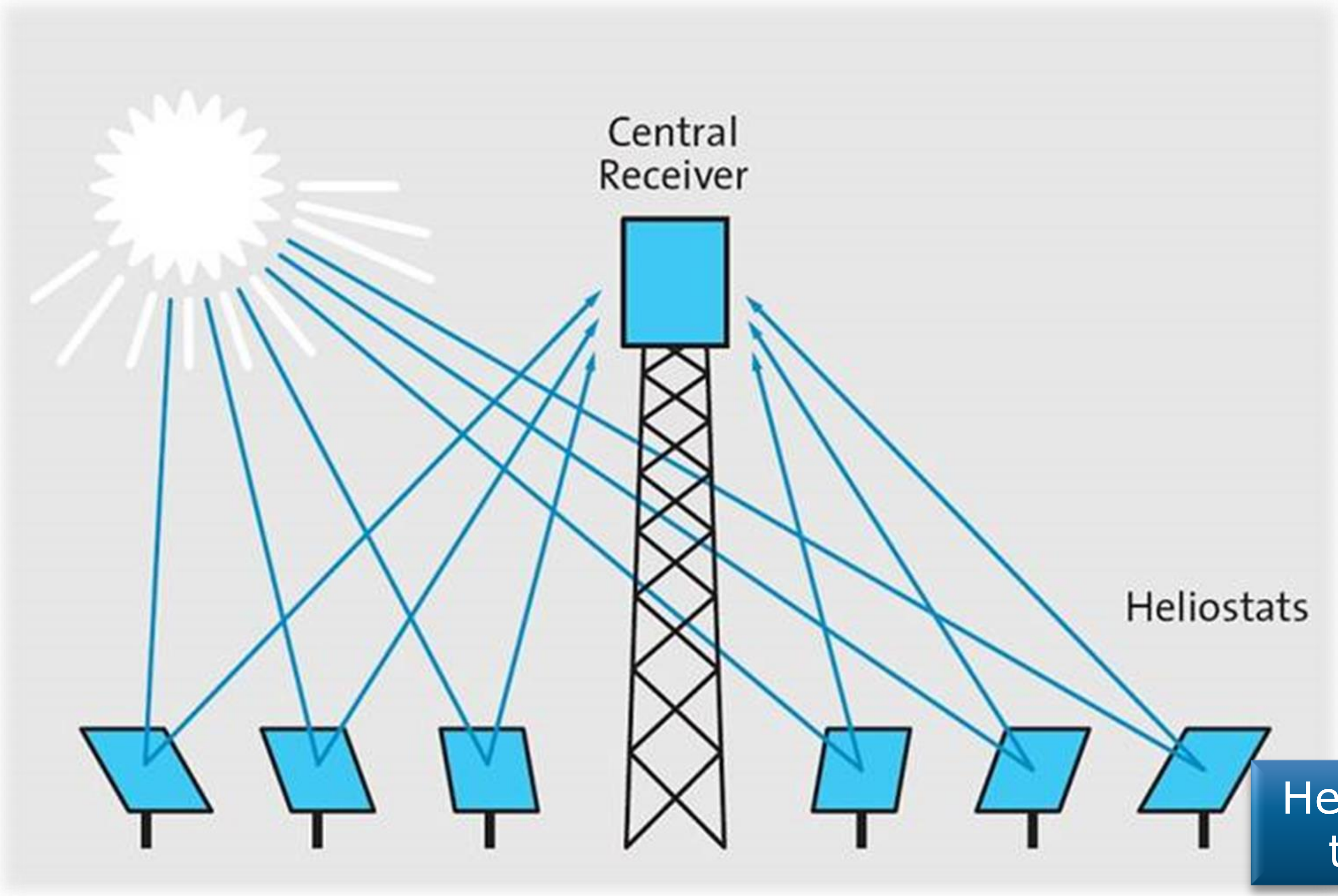
Electricity production using a thermal machine

Solar concentration

Linear parabolic concentrators

Electricity production using a thermal machine

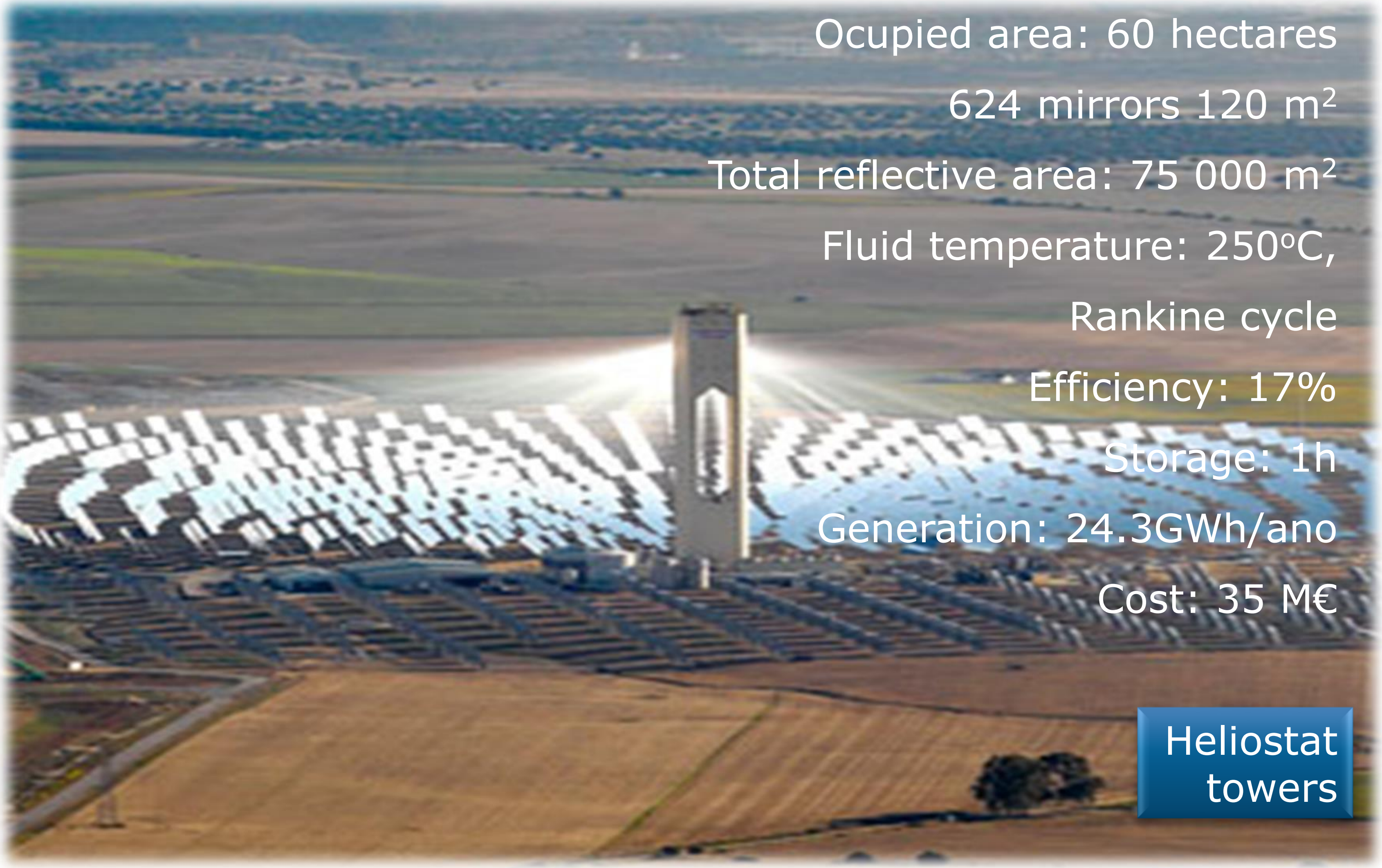
Solar concentration



Heliostat towers

Electricity production using a thermal machine

Solar concentration



Ocupied area: 60 hectares

624 mirrors 120 m^2

Total reflective area: 75 000 m^2

Fluid temperature: 250ºC,

Rankine cycle

Efficiency: 17%

Storage: 1h

Generation: 24.3GWh/ano

Cost: 35 M€

Heliostat towers

Using the photovoltaic path for electricity production

Average solar radiation in Portugal:

$1500\ kWh/m^2/ano$

Assuming a energy conversion efficiency of 15%:

$225\ kWh/m^2/ano$

Considering electricity consumption in 2010:

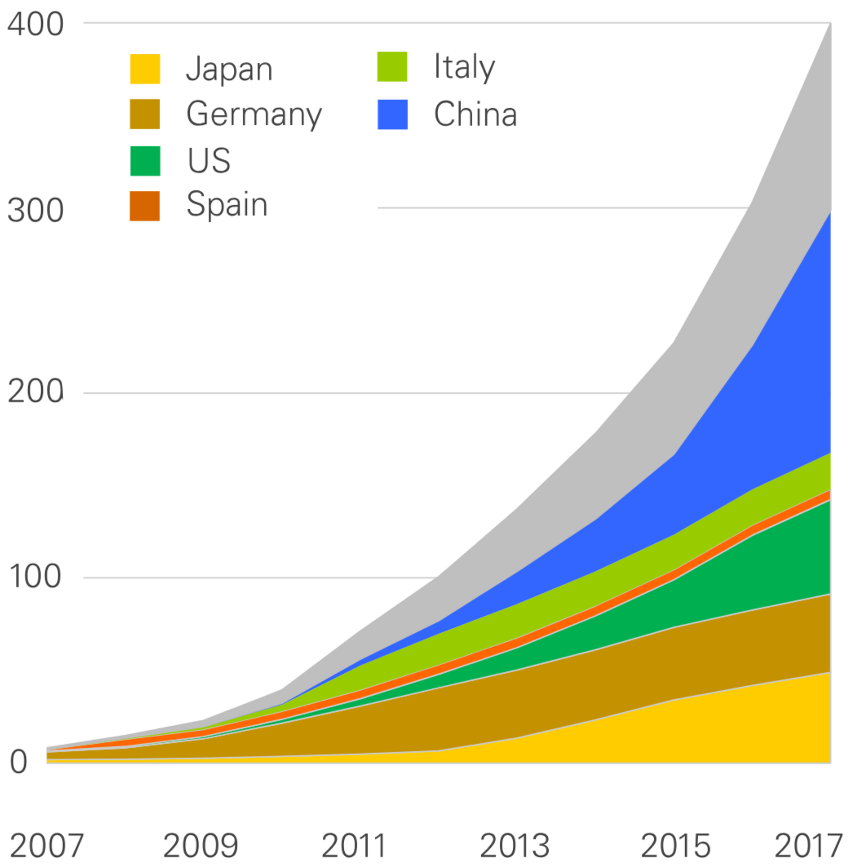
$5.0\ x10^{10}\ kWh/ano$

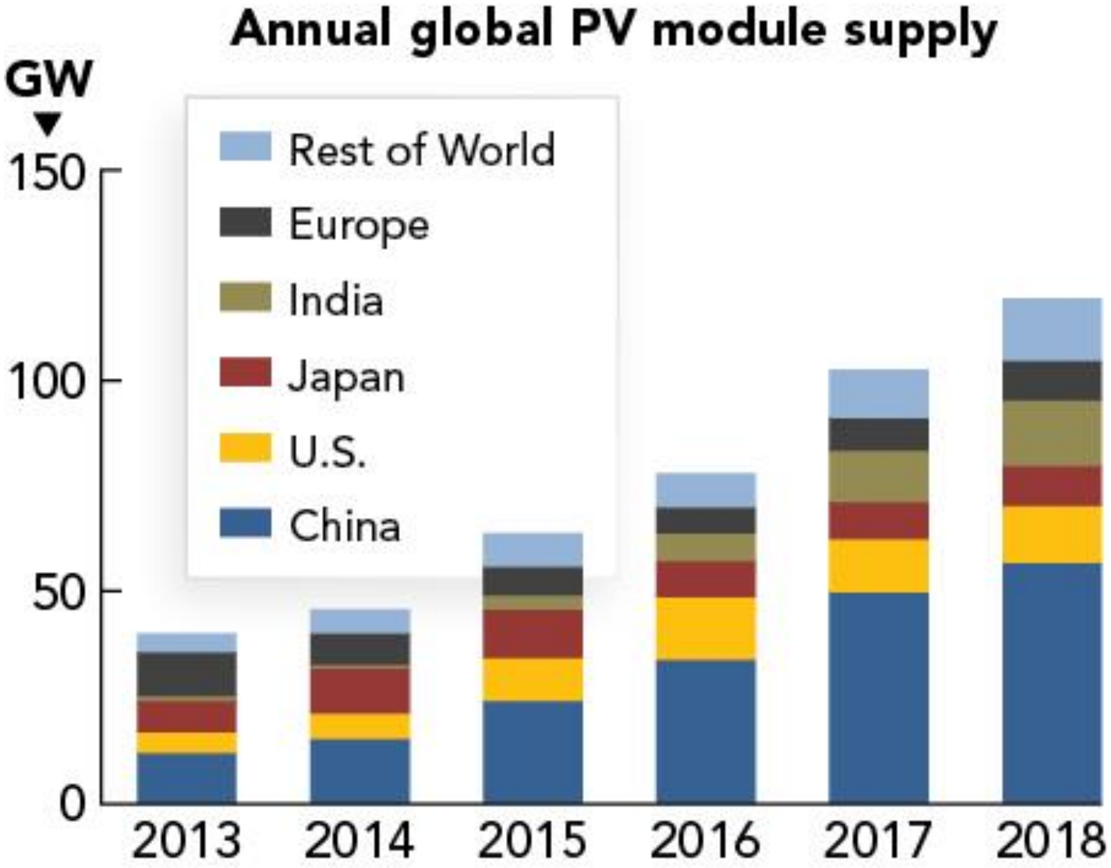
Total area needed to produce 100% electricity consumption in 2010:

$220\ km^2$ $22m^2/person$


16° W
Palheiro de Terra
Palheiro do Mar
Ponta do Risco
Ponta do Corgo da Areia
Pico dos Tornozelos
Pico da Atalaia
Selvagem Grande
Enseada da Atalaia
Enseada das Pedreiras
Ilhéu Sinho
Enseada das Cagarras
Pico do Inferno
Ponta do Inferno
Ponta de Leste
Oceano Atlântico
Atlantic Ocean
Ilhéus do Norte
Ilhéu Redondo
Ilhéu Comprido
Ilhéu Alto
Ponta do Norte
Selvagem Pequena
Ponta de Oeste
Pico do Veado
Canal da Selvagem Pequena
Ilhéu de Fora
Ilhéu Pequeno
Ponta de Leste
Ponta dos Garajaus
Ilhéu Grande
Ponta do Sul
Ilhéu do Sul
30° N

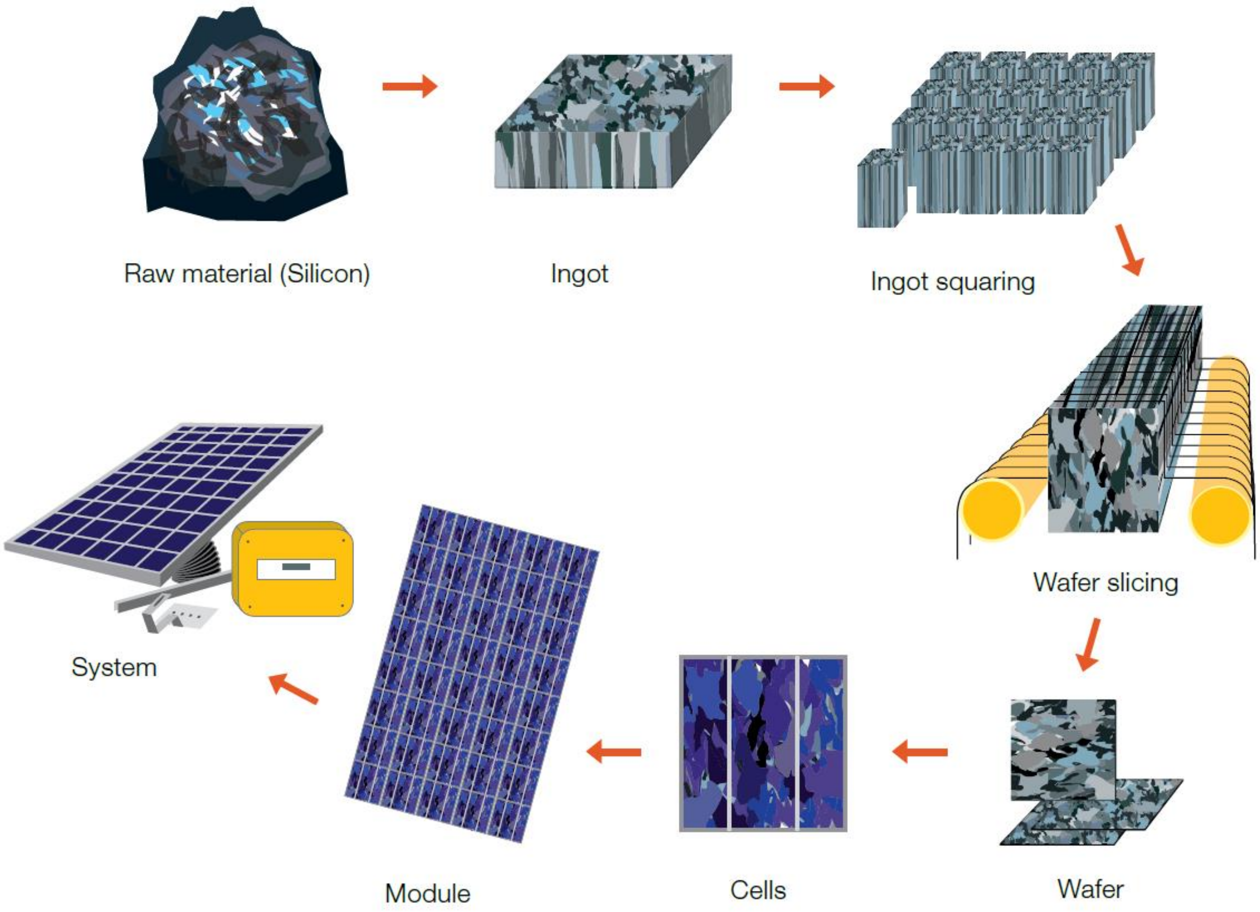
Solar PV installed capacity (GW)





Annual global PV module supply
GW
150
100
50
0
Rest of World
Europe
India
Japan
U.S.
China
2013
2014
2015
2016
2017
2018

Process flow to make a silicon solar cell (dominant PV technology)



Raw material (Silicon)

Ingot

Ingot squaring

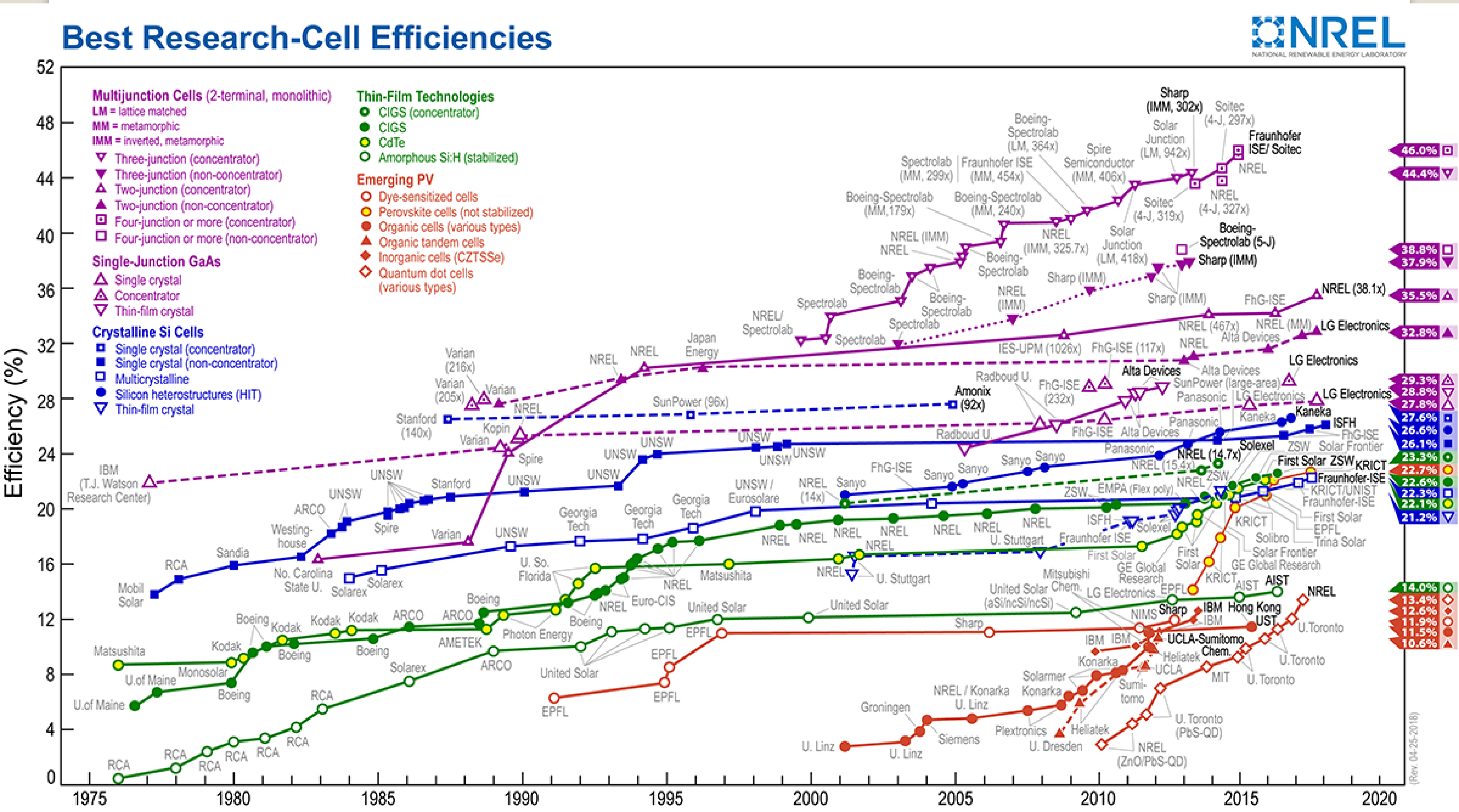
Wafer slicing

Wafer

Cells

Module

System



Best Research-Cell Efficiencies

- *Energy Payback time*
- *Energy yield*

$$Energy\ yield = \frac{Energy\ payback\ time}{Operational\ lifetime}$$

Typical values for module guaranty is 25 years
PV plants with 40 years have production values around 80% of the starting nominal values.

A PV module produces 20 a 50x the energy spent in manufacturing!

- *Payback time* energético

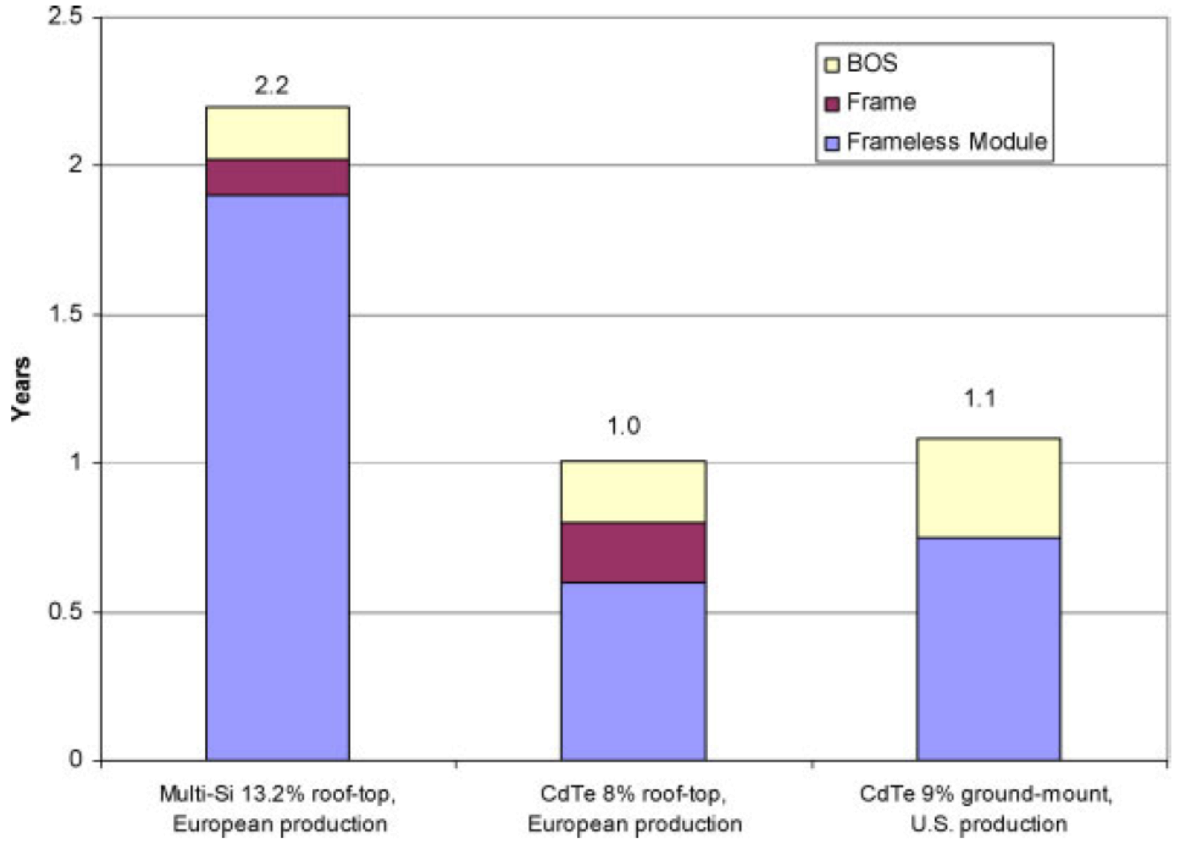
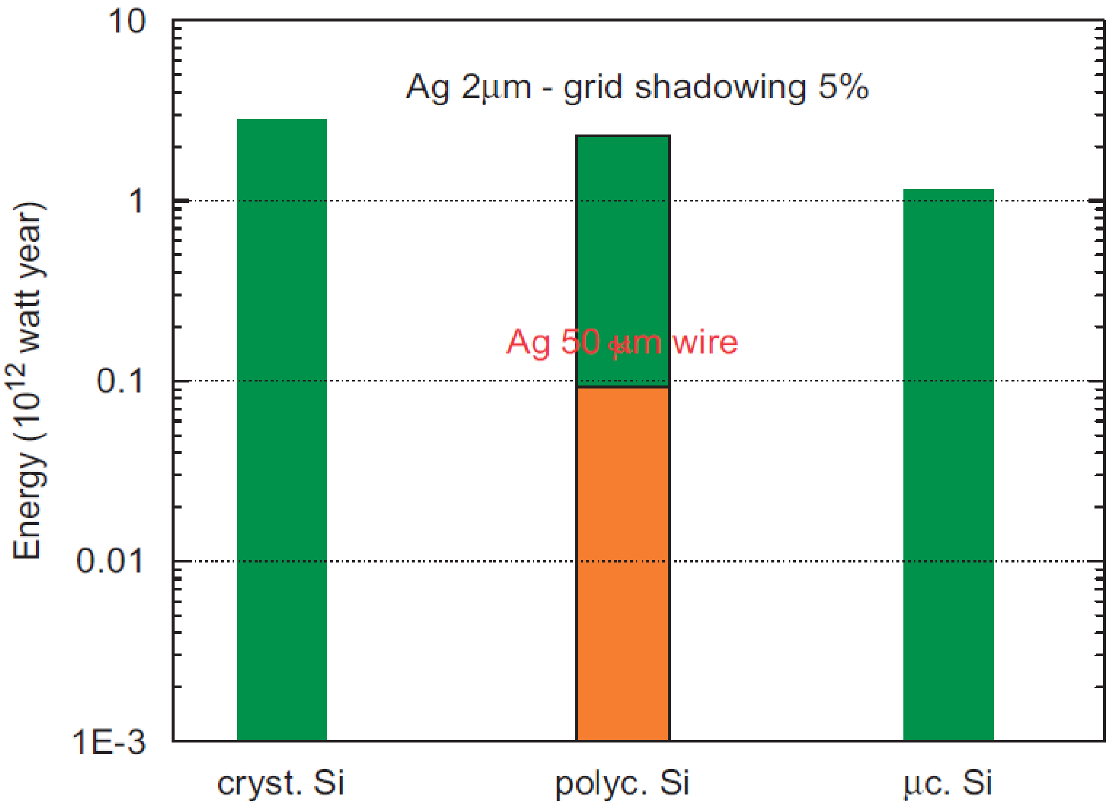


Figure 3. PV energy payback times of 2004 PV technologies for average southern Europe insolation (1700 kWh/m^2/yr), 75% performance ratio for roof-top installations, 80% performance ratio for utility ground-mount installations[4–7]

V. Fthenakis, E. Alsema, *Photovoltaics energy payback times, greenhouse gas emissions and external costs,* Prog. Photovolt: Res. Appl. 2006; 14:275–280

Feedstock limitations



Potential energy limits imposed by global silver (Ag) reserves for bulk-like silicon photovoltaic technologies. The orange shaded area represents limits reached using 50 mm-thick Ag ribbons. The green shaded area represents limits estimated using a 2 mm thick Ag electrodes and 5% grid shadowing.

A.Feltrin, A.Freundlich, *Material considerations for TW level deployment of PV*, Renewable Energy 33 (2008) 180–185

- Feedstock limitations

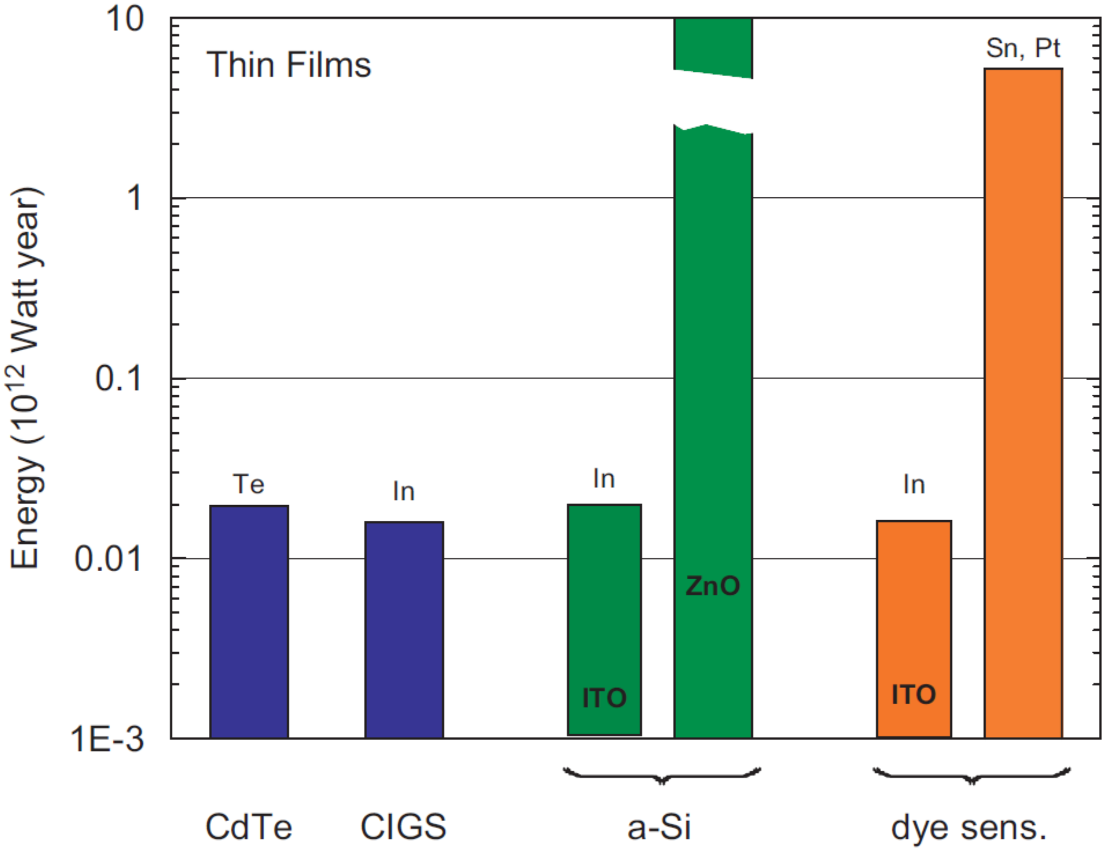


Fig. 4. Potential energy limits imposed for four different thin film photovoltaic technologies.

A.Feltrin, A.Freundlich, *Material considerations for TW level deployment of PV,* Renewable Energy 33 (2008) 180–185

- Feedstock limitations

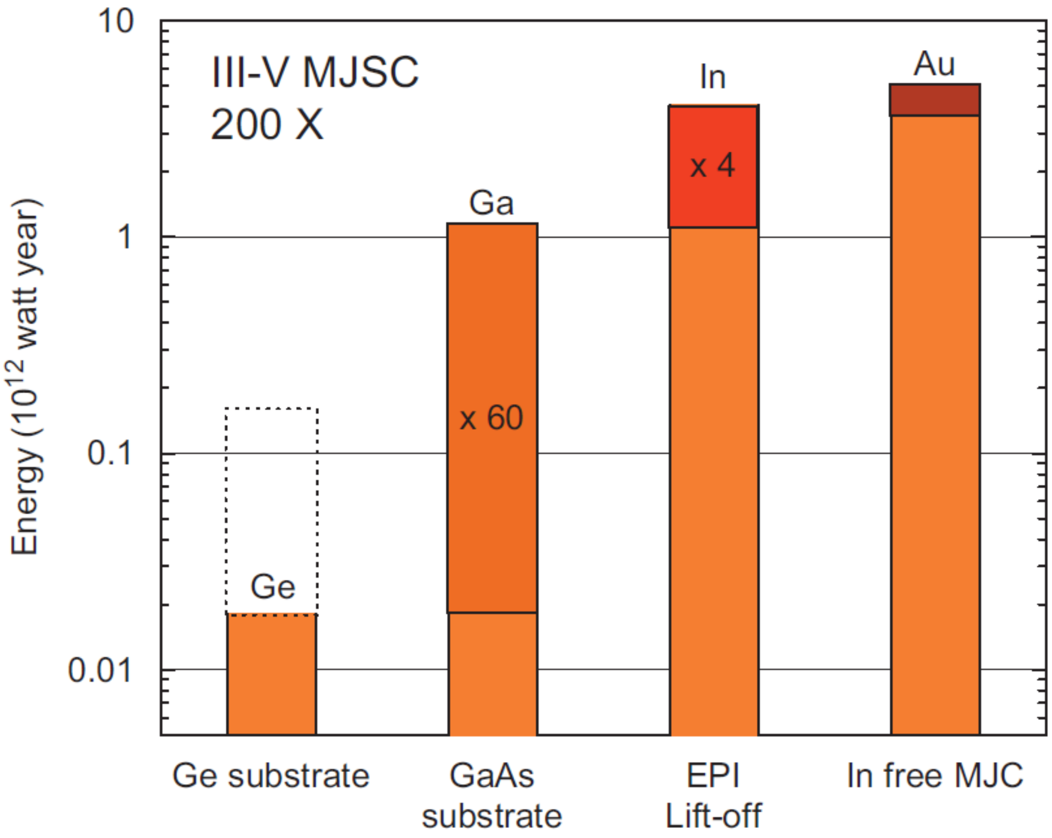
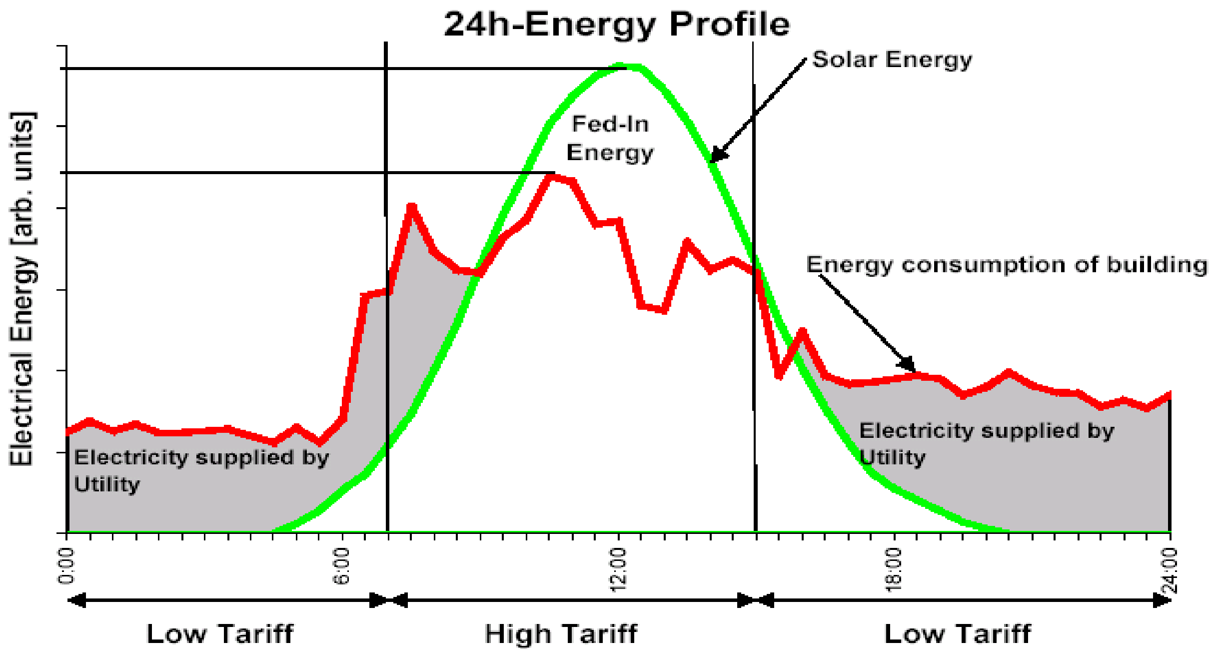


Fig. 5. Potential energy limits imposed to III–V multi-junction cells (200 sun concentrations). The third and fourth columns show the extrapolated potential of this technology if lift-off/cell exfoliation techniques are adopted.

A.Feltrin, A.Freundlich, *Material considerations for TW level deployment of PV,* Renewable Energy 33 (2008) 180–185

Variability in PV systems



Advantages:

Energy production aligned with peak consumption

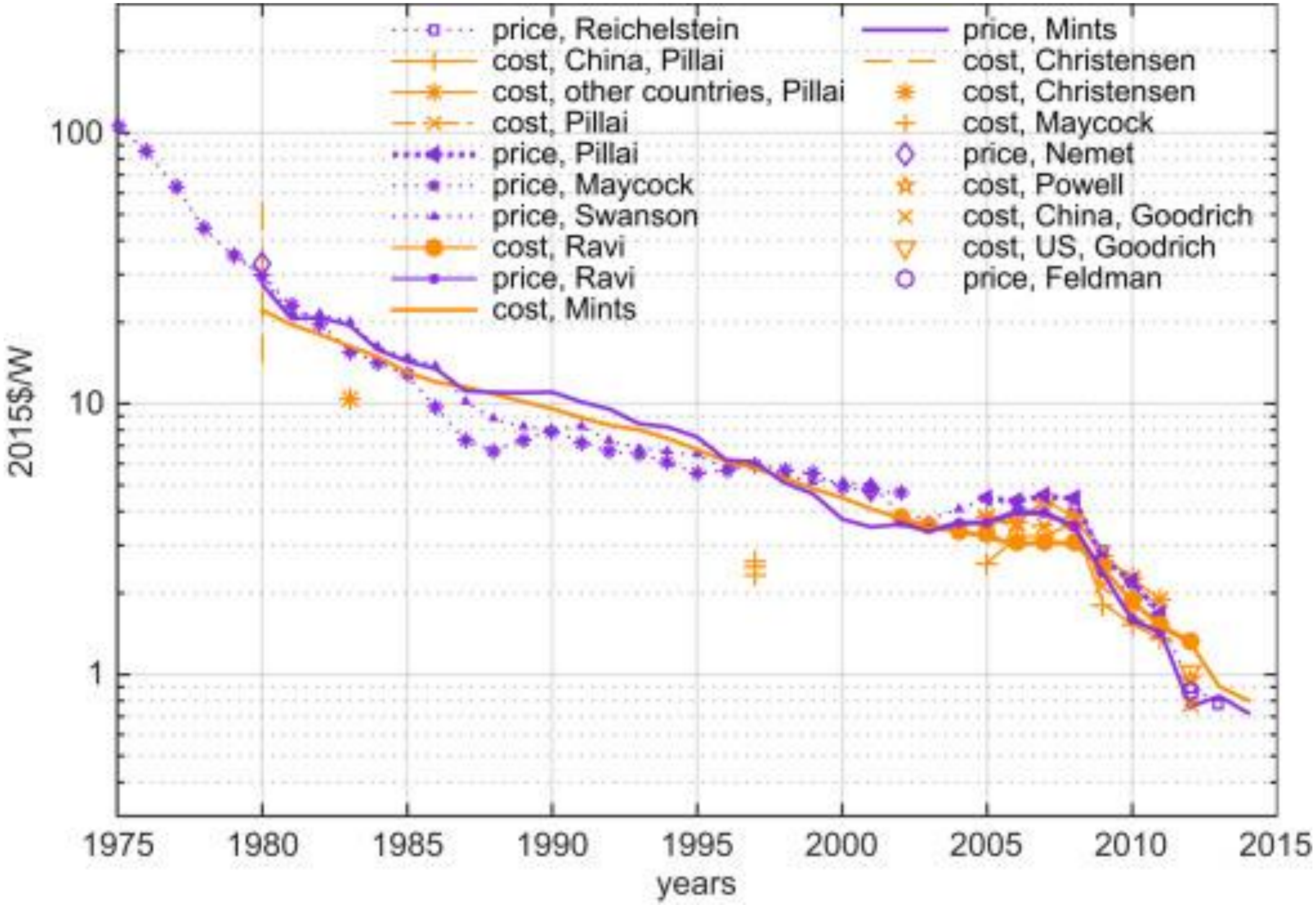
Energy produced where it is used

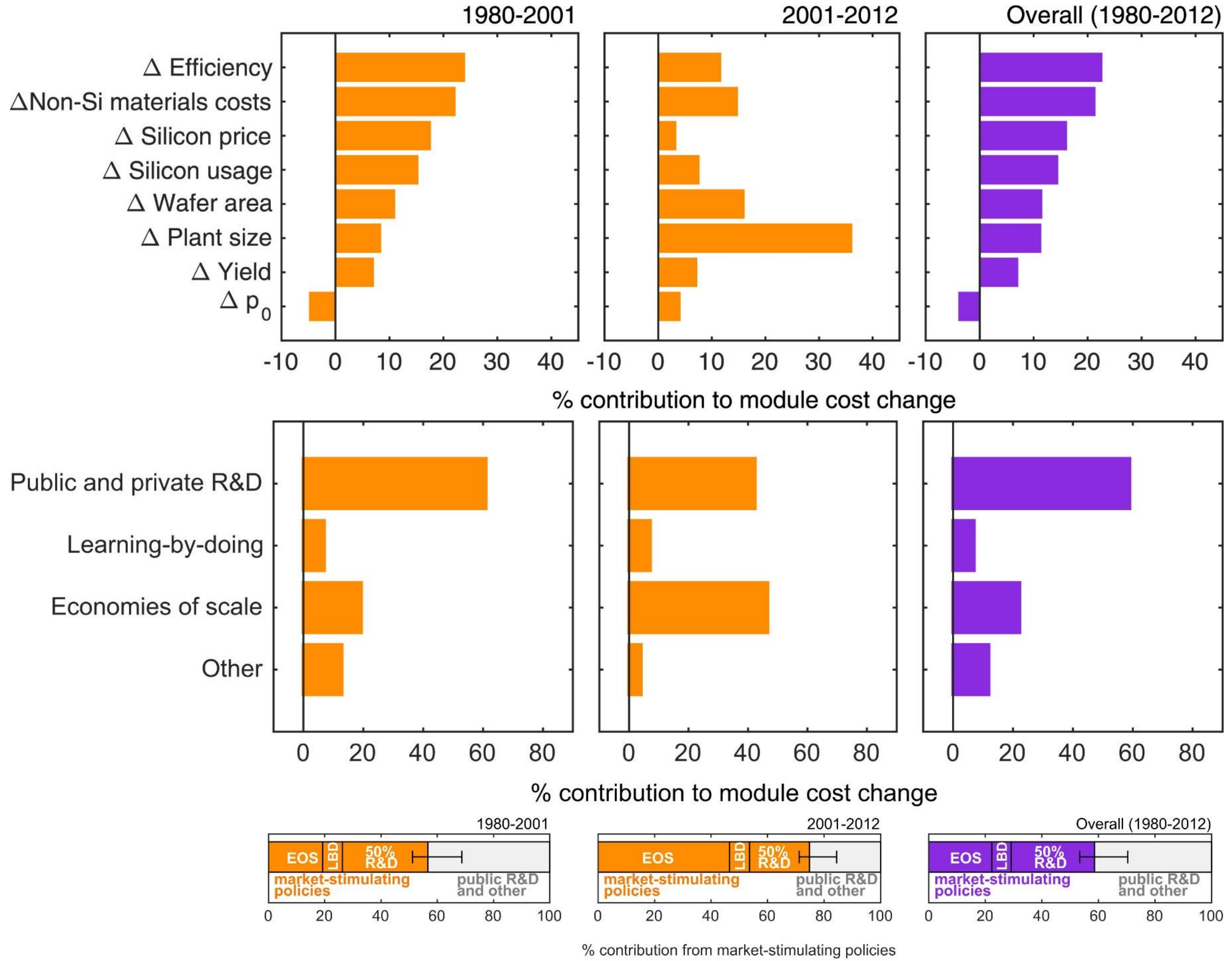
Disadvantages:

No production at night

Needed area

PV electricity cost



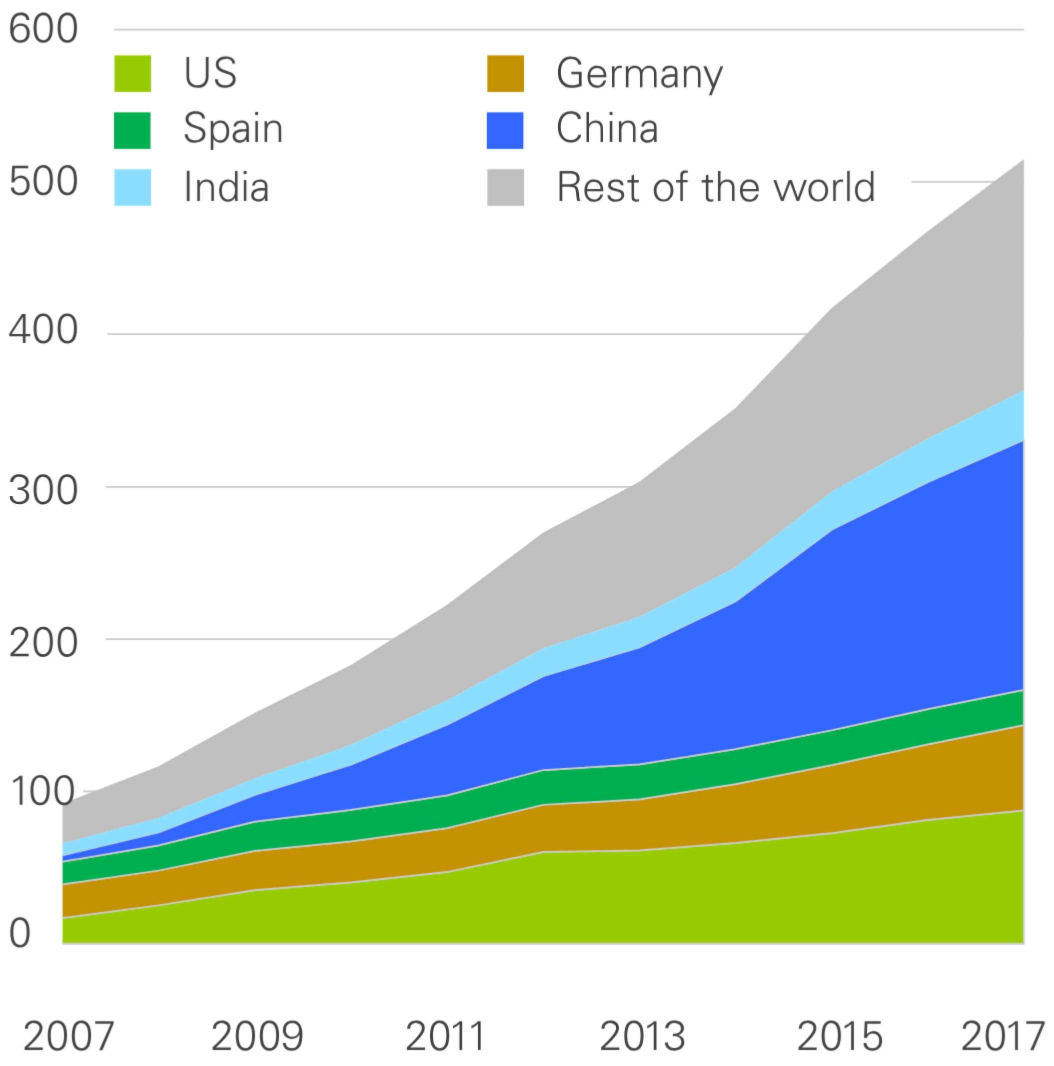

1980-2001
2001-2012
Overall (1980-2012)
Δ Efficiency
ΔNon-Si materials costs
Δ Silicon price
Δ Silicon usage
Δ Wafer area
Δ Plant size
Δ Yield
Δ p0
-10
0
10
20
30
40
% contribution to module cost change
Public and private R&D
Learning-by-doing
Economies of scale
Other
0
20
40
60
80
% contribution to module cost change
EOS
LBD
50% R&D
market-stimulating policies
public R&D and other
0
20
40
60
80
100
% contribution from market-stimulating policies

WIND ENERGY

It is an old technology...

... With an amazing restyling!

Evolution of installed capacity

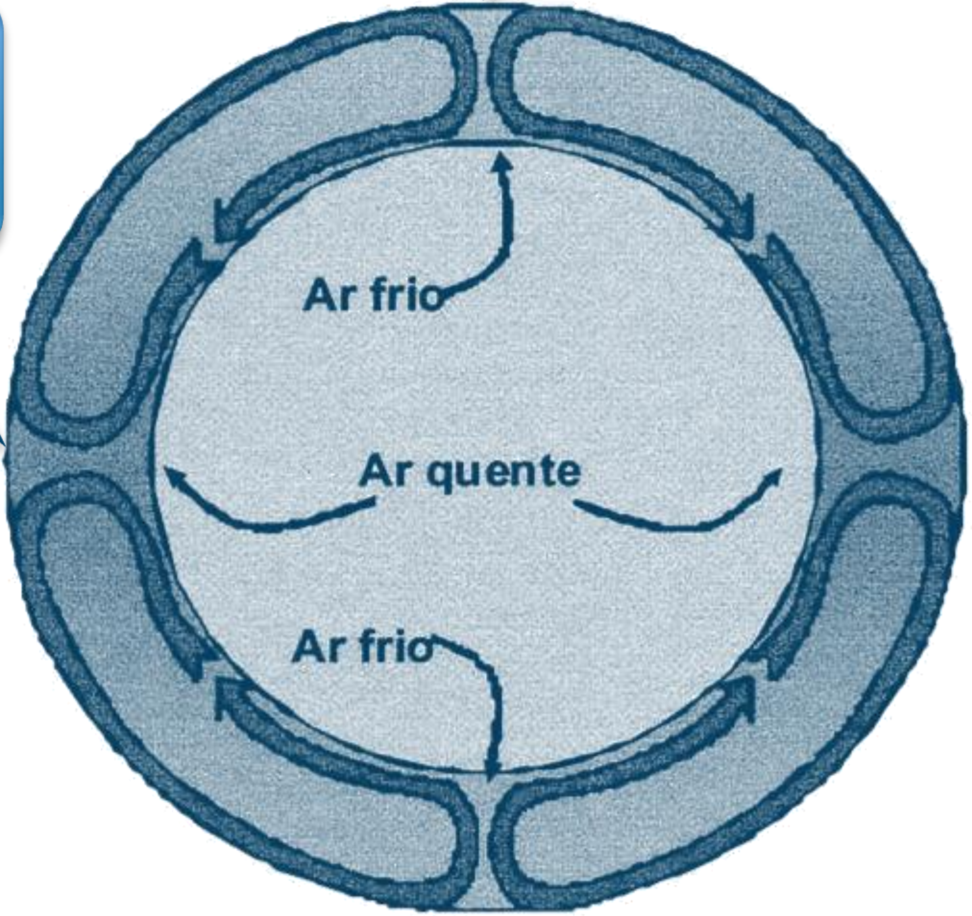


Wind resource

No Earth rotation

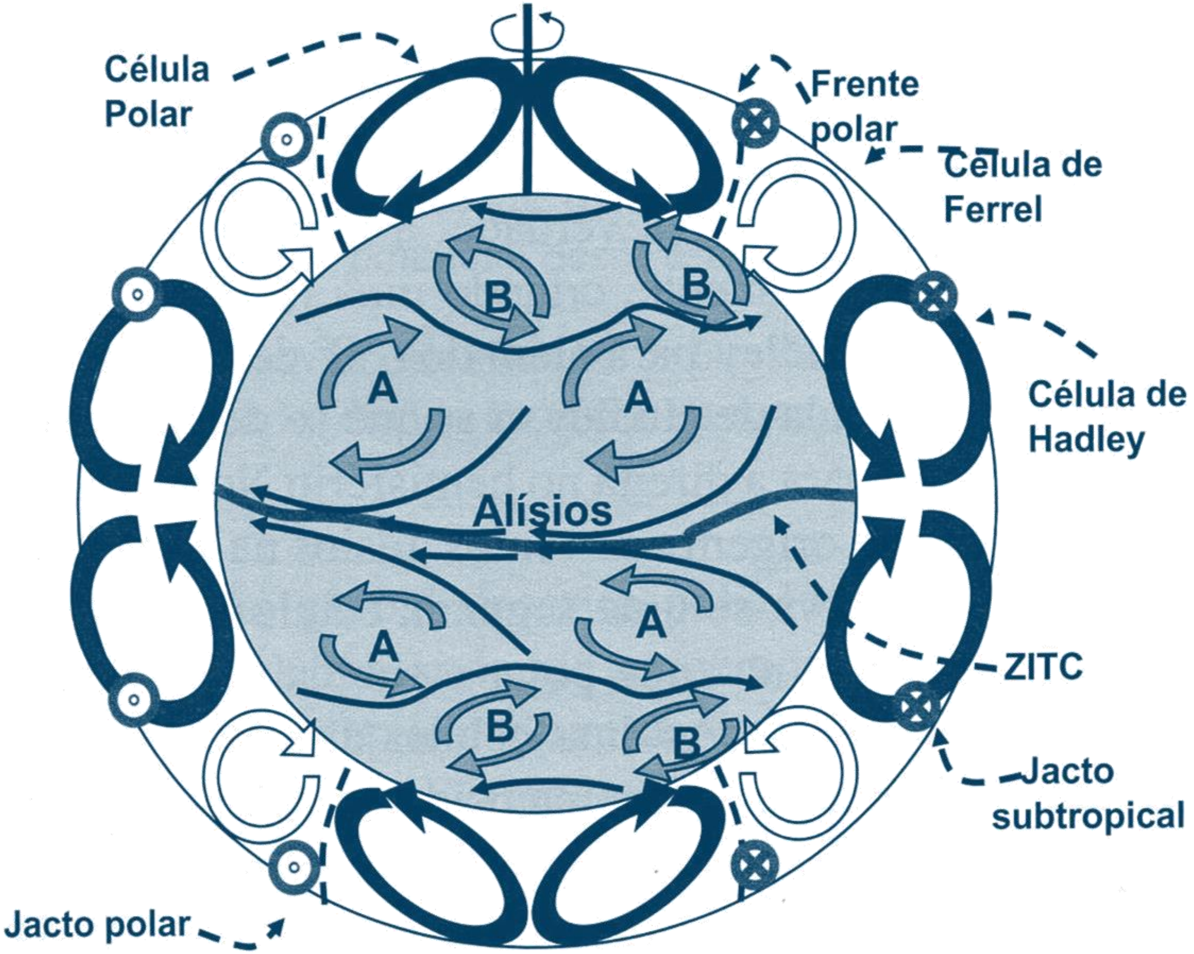
Convergence zone at high altitude, divergence zone at the surface

Convergence zone at the surface, divergence zone at high altitude



Wind resource

With Earth rotation (including Coriolis effect)



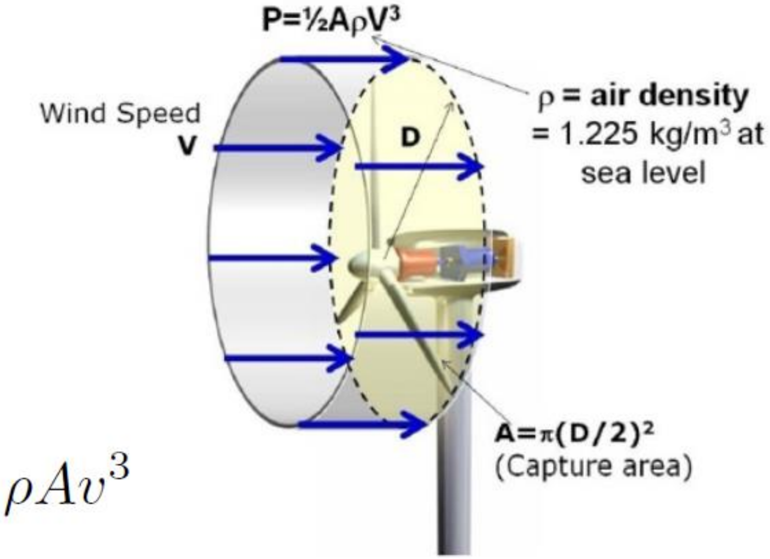
Although the ‘excitation’ is NS, the resulting wind is EW.

How much energy is there in the wind

$$E_c = \frac{1}{2}mv^2 = \frac{1}{2}(\rho A dx)v^2$$

$$P = \frac{dE_c}{dt} = \frac{1}{2}\left(\rho A\frac{dx}{dt}\right)v^2 = \frac{1}{2}\rho A v^3$$

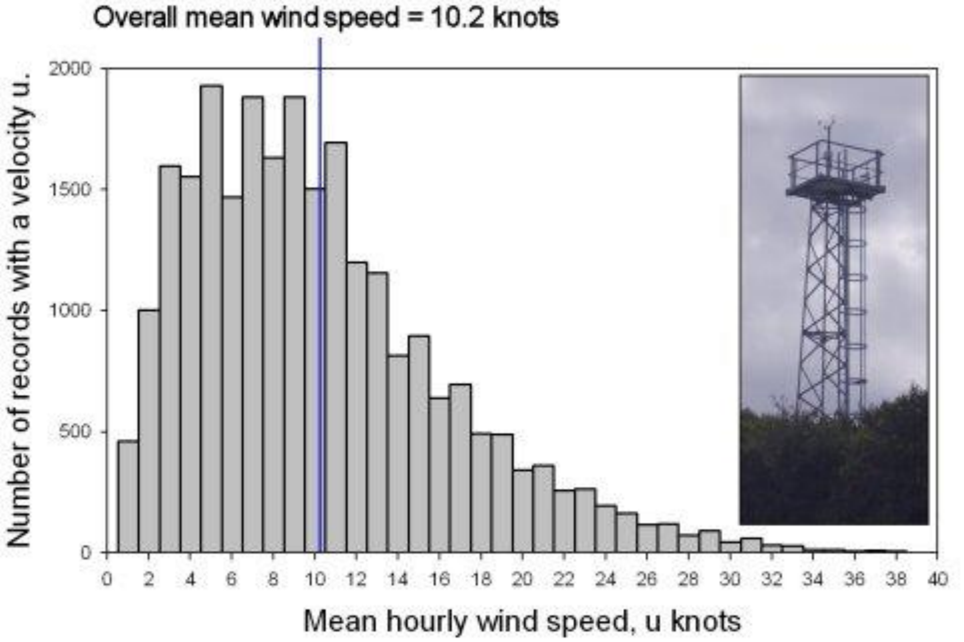
$$P_d = \frac{1}{2}C_p \rho A v^3$$



Wind speed distribuition

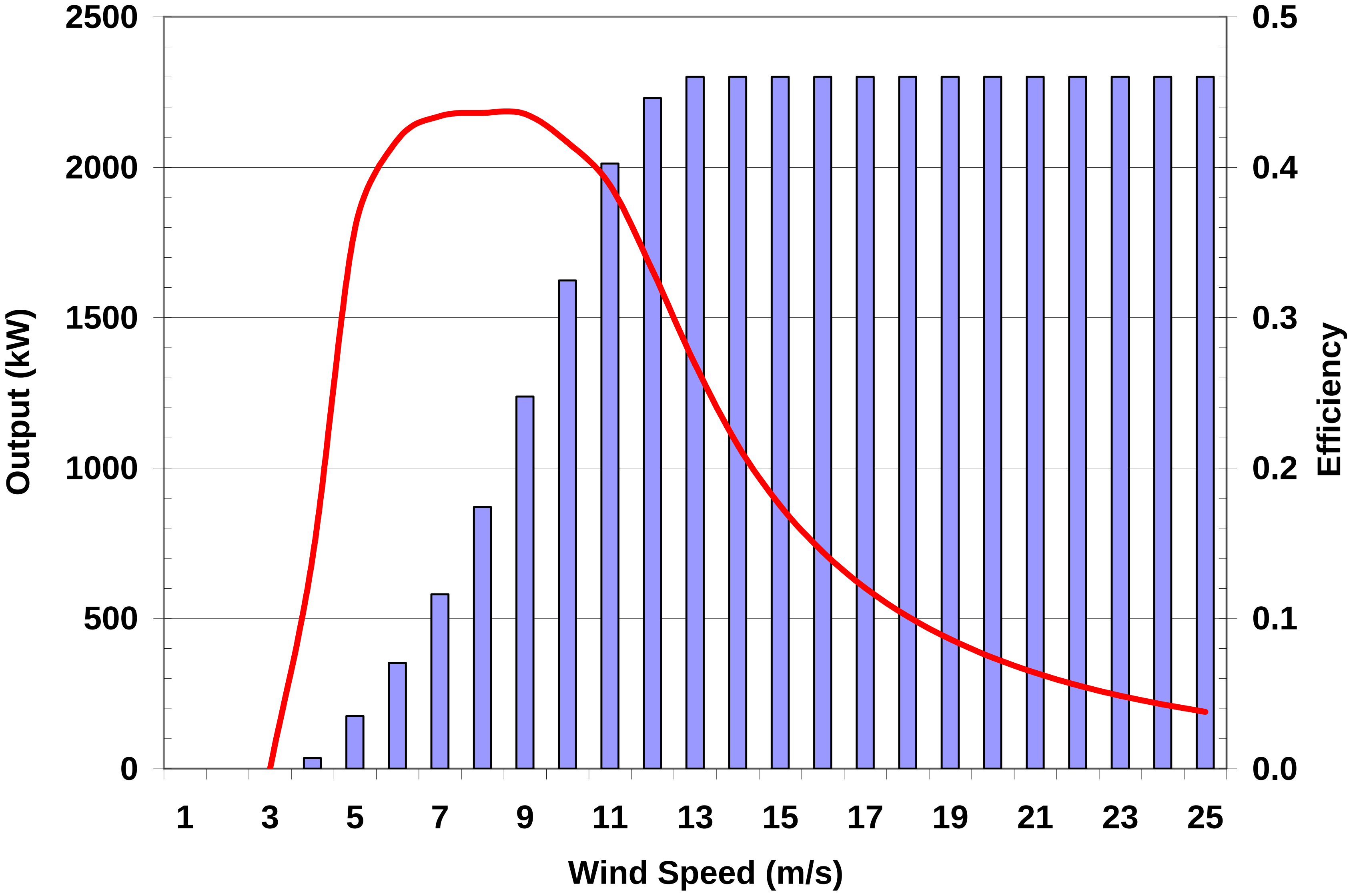
Weibull distribution

$$f(u)=\frac{k}{c}\left(\frac{u}{c}\right)^{k-1}e^{-(u/c)^k}$$



Histogram of hourly wind speeds at Plymouth, Mountbatten.
(Years 2005 to 2007 - 25,203 valid data points)

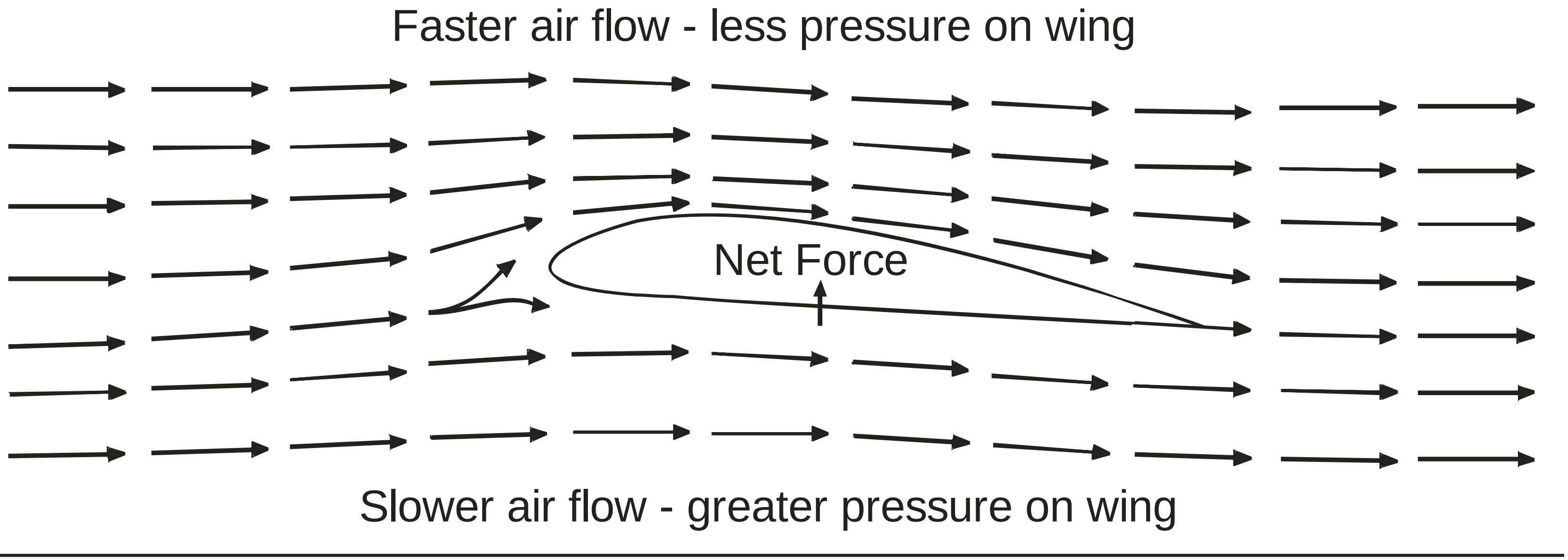
(adapted from Crown copyright data supplied by the Met Office)



The efficiency decreases with wind speed because power is limited to the generator rated power

How wind drives the rotor

The blade is like the aile in a plane. Pressure difference induces a force

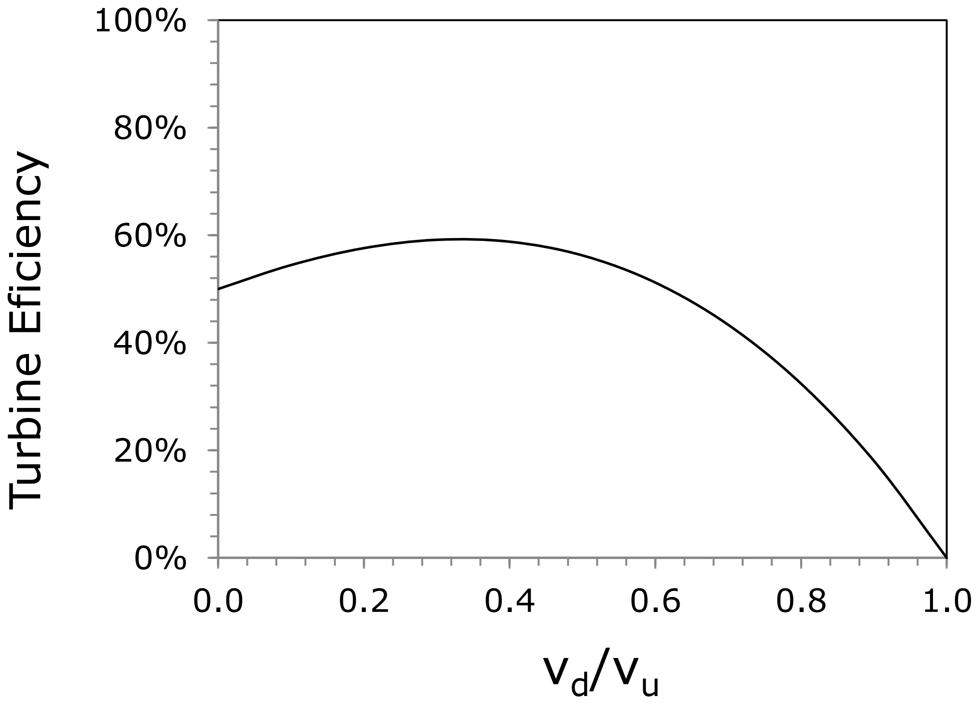


Faster air flow - less pressure on wing

Net Force

Slower air flow - greater pressure on wing

Wind turbine efficiency



no turbine can capture more than 16/27 (59.3%) of the kinetic energy in wind.

Practical utility-scale wind turbines achieve at peak 75% to 80% of the Betz limit

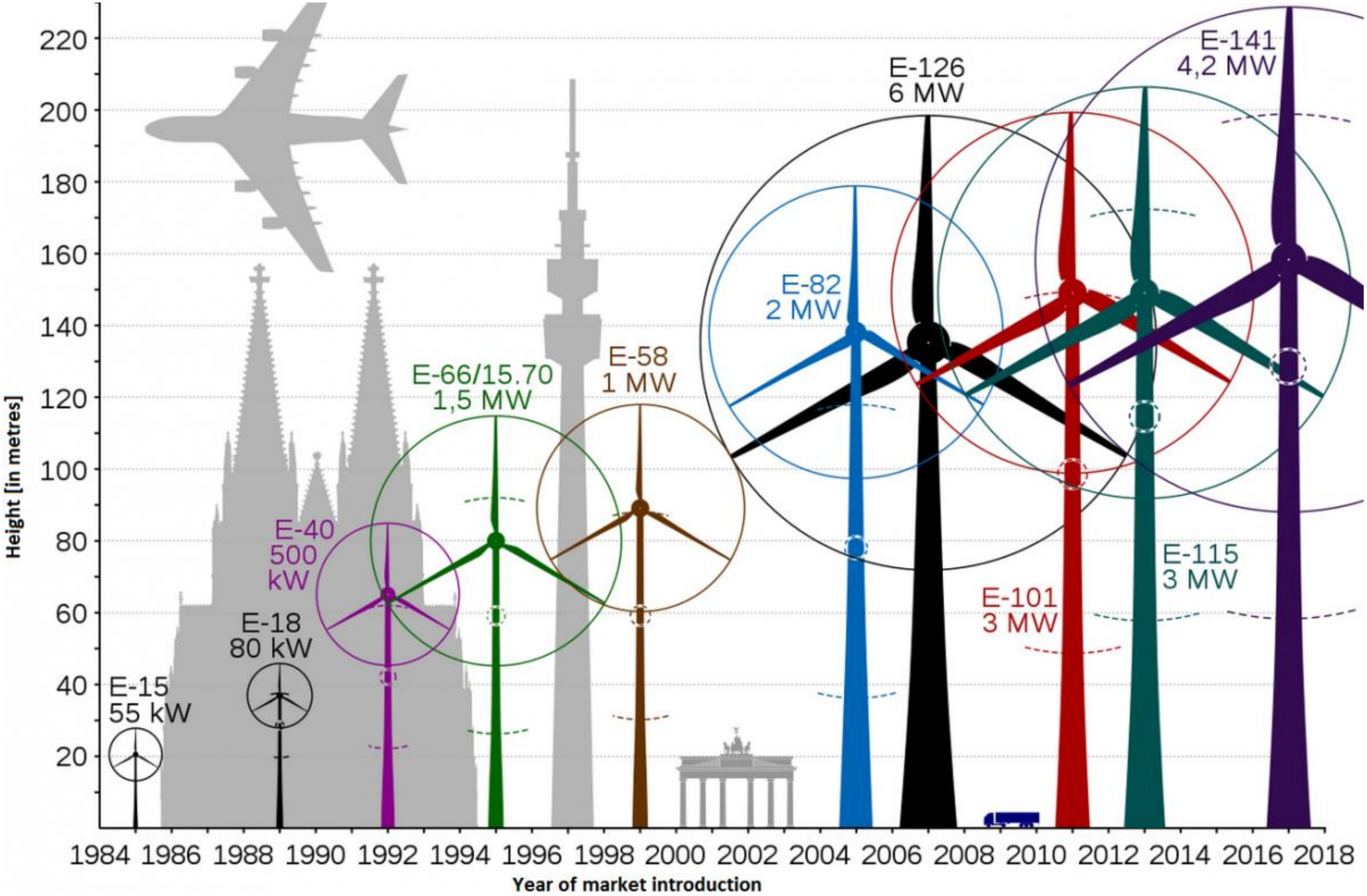
$$\rightarrow W_t = \left(\frac{1}{2} A\rho v_u^3\right)\frac{16}{27}$$

Betz limit

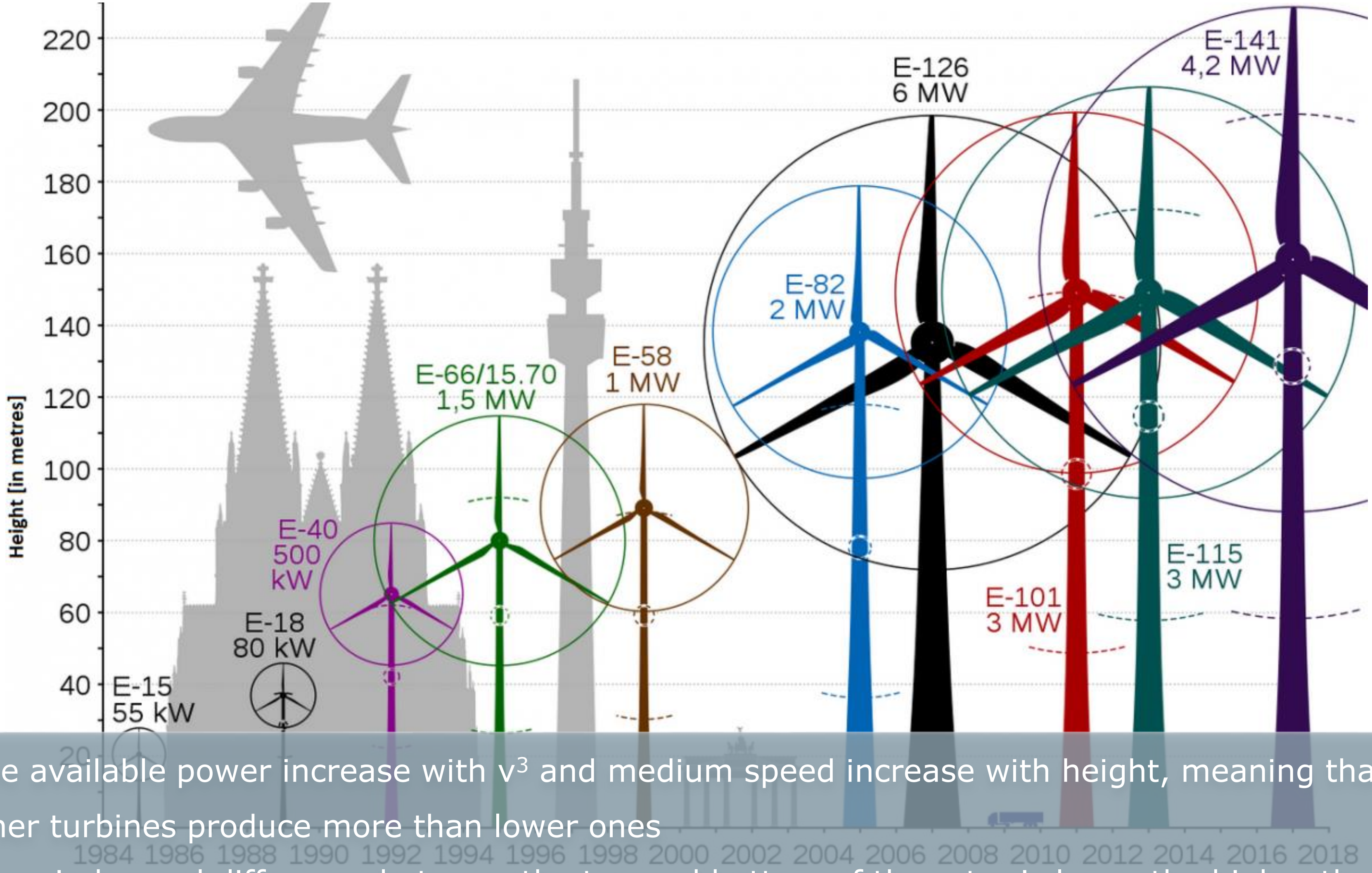
What’s the energy density in a wind farm

Wake effect – one turbine affects the performance of downwind turbines

Why bigger wind generators?



Why bigger wind generators?



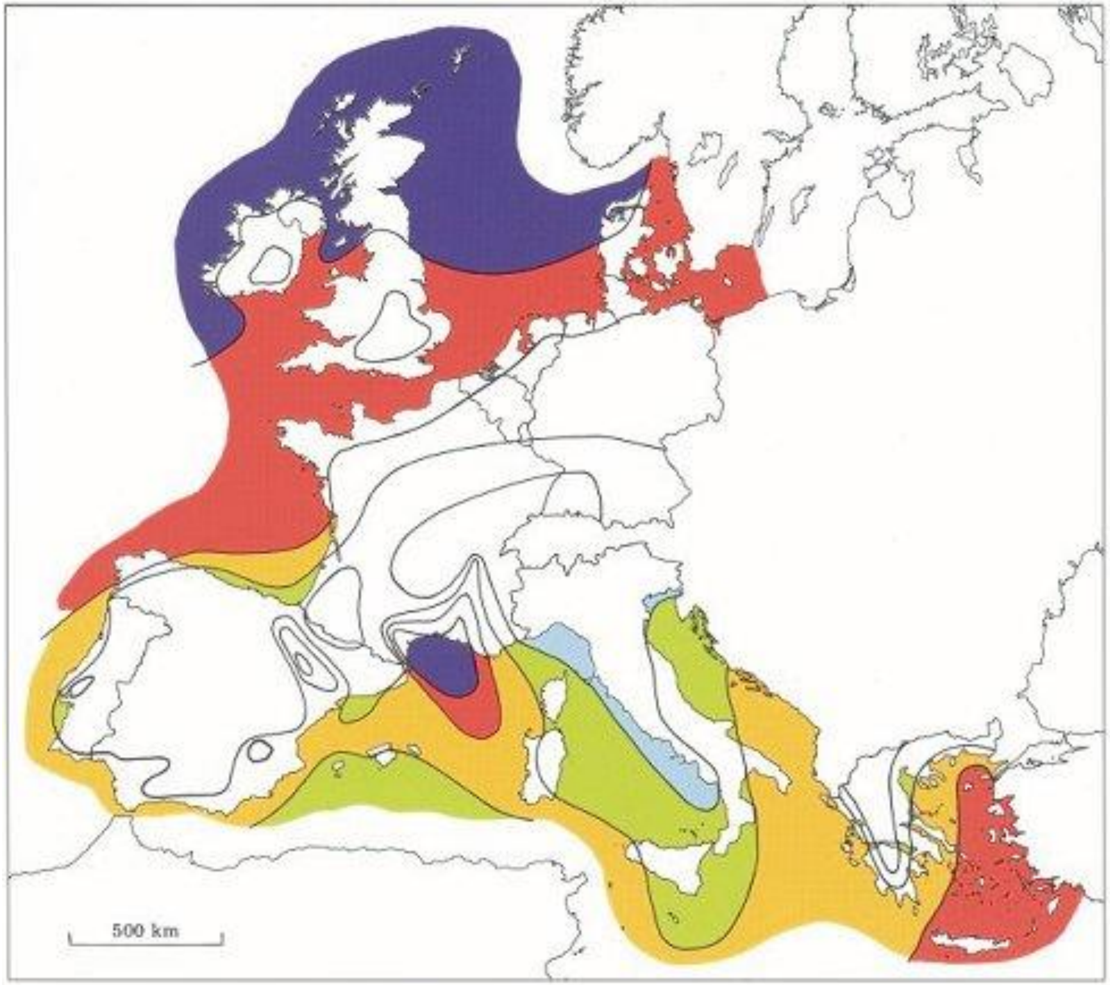
- The available power increase with v^3 and medium speed increase with height, meaning that higher turbines produce more than lower ones
- The wind speed difference between the top and bottom of the rotor is lower the higher the turbine is placed
- Turbulence decreases with height, so a better wind pattern distribuiton is obtained.

Offshore wind farms

- higher costs (2-3x)
- higher electricity production (2x)

Aditional costs for off-shore wind parks in Germany

Distance to shore	30km	50km	70km
Foundations	35-40%	45-50%	40-50%
Instalation	9-13%	11-19%	10-23%
Network connection	30-70%	44-83%	60-115%
Other expenses	7-24%	7-24%	7-24%
Total	**81-147%**	**107-176%**	**117-212%**



Wind resources over open sea (more than 10 km offshore) for five standard heights										
	10 m		25 m		50 m		100 m		200 m	
	m s^{-1}	Wm^{-2}	m s^{-1}	Wm^{-2}	m s^{-1}	Wm^{-2}	m s^{-1}	Wm^{-2}	m s^{-1}	Wm^{-2}
🟪	> 8.0	> 600	> 8.5	> 700	> 9.0	> 800	> 10.0	> 1100	> 11.0	> 1500
🟥	7.0-8.0	350-600	7.5-8.5	450-700	8.0-9.0	600-800	8.5-10.0	650-1100	9.5-11.0	900-1500
🟧	6.0-7.0	250-300	6.5-7.5	300-450	7.0-8.0	400-600	7.5- 8.5	450- 650	8.0- 9.5	600- 900
🟩	4.5-6.0	100-250	5.0-6.5	150-300	5.5-7.0	200-400	6.0- 7.5	250- 450	6.5- 8.0	300- 600
🟦	< 4.5	< 100	< 5.0	< 150	< 5.5	< 200	< 6.0	< 250	< 6.5	< 300


Vestas
WF1

Vertical axis wind generators

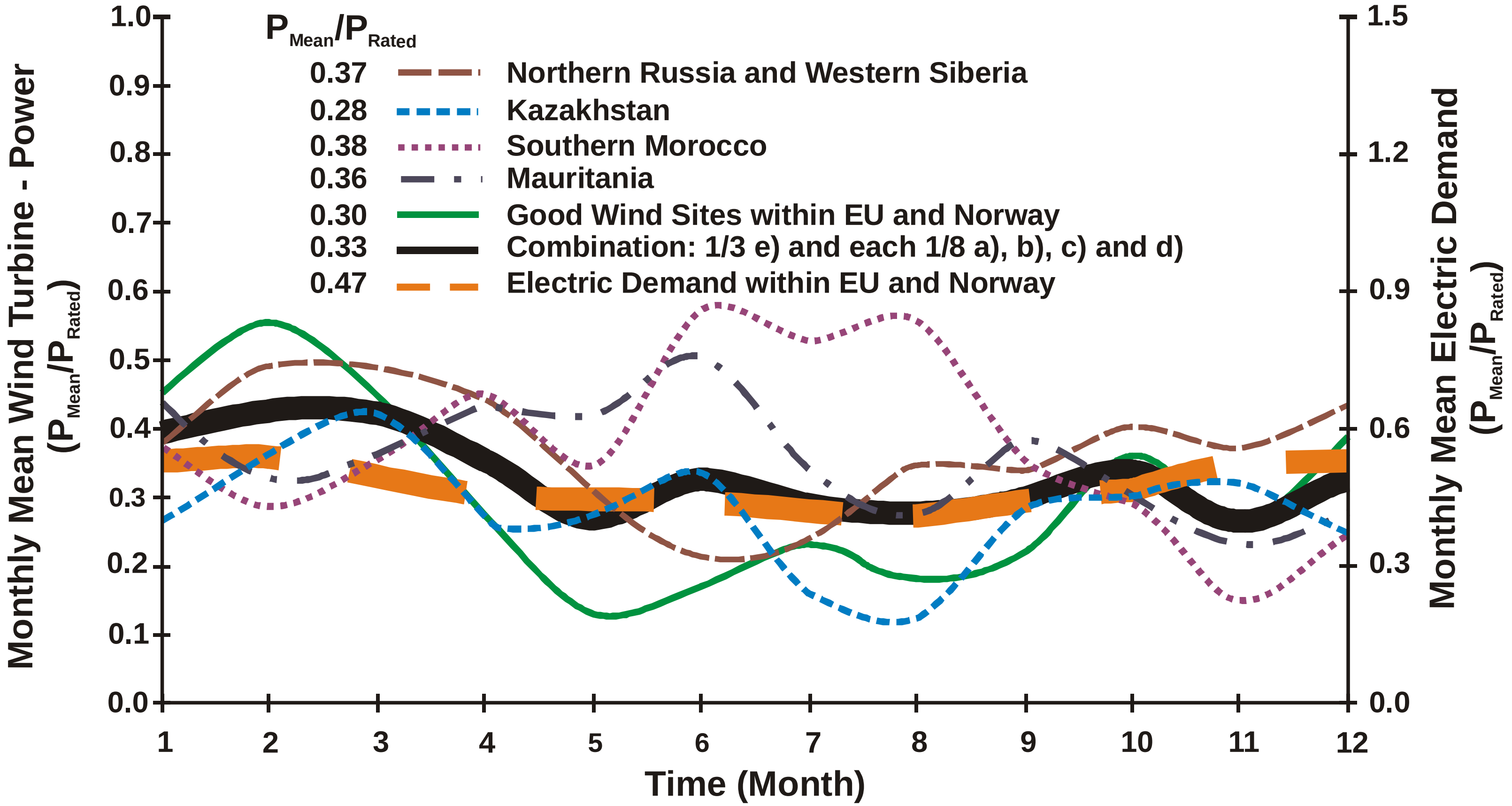
Omni-direccional

Lower efficiency

Not as high, so less wind available

Good in built environments

Wind **variability** makes it not completely predicatable in both production and demand response



Strengths

- ☐ No emissions during operational life
- ☐ No fuel consumption
- ☐ Low cost
- ☐ Fast deployment
- ☐ No water use

Challenges

- ☐ Mechanical & aerodynamic noise
- ☐ Birds and bats mortality
- ☐ Landscape visual impact
- ☐ Land use

Strengths

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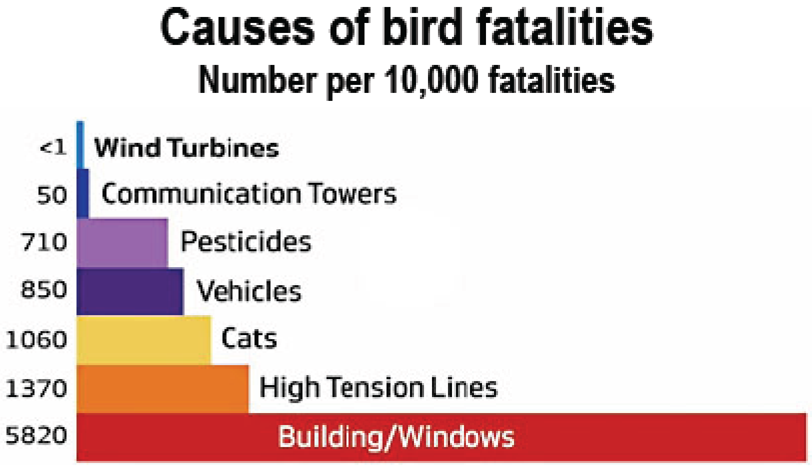
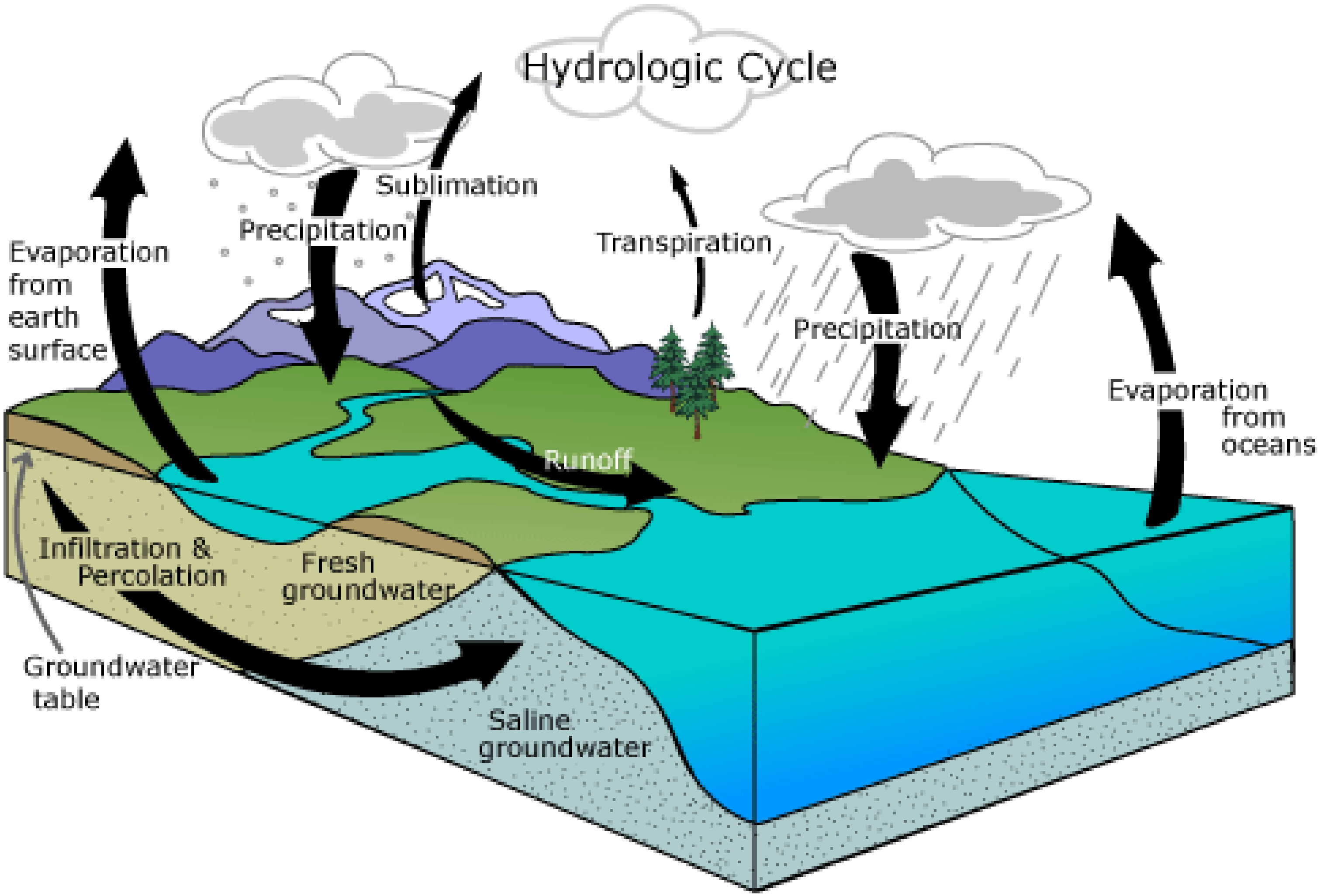
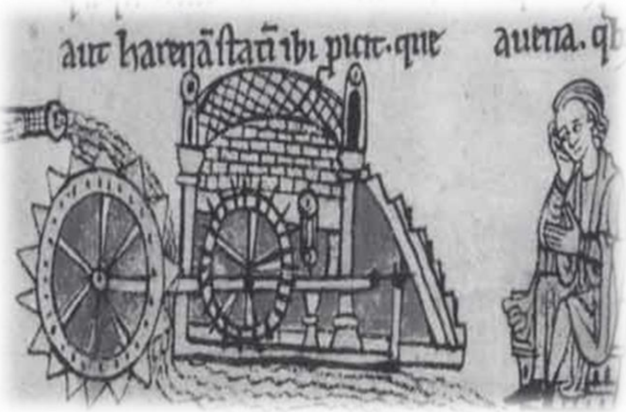
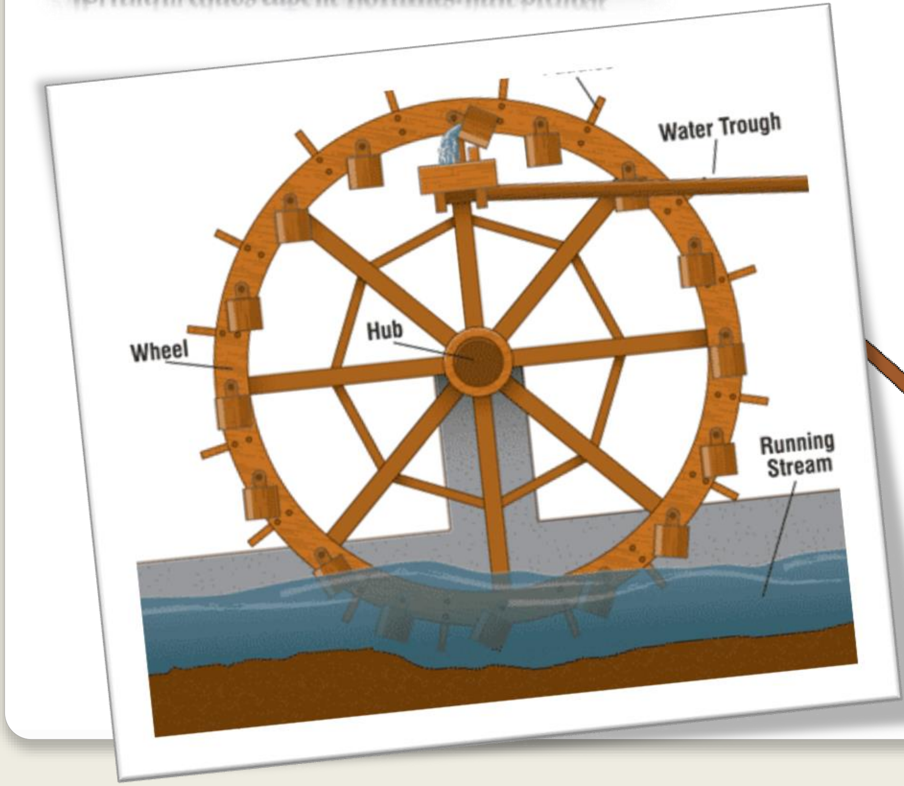


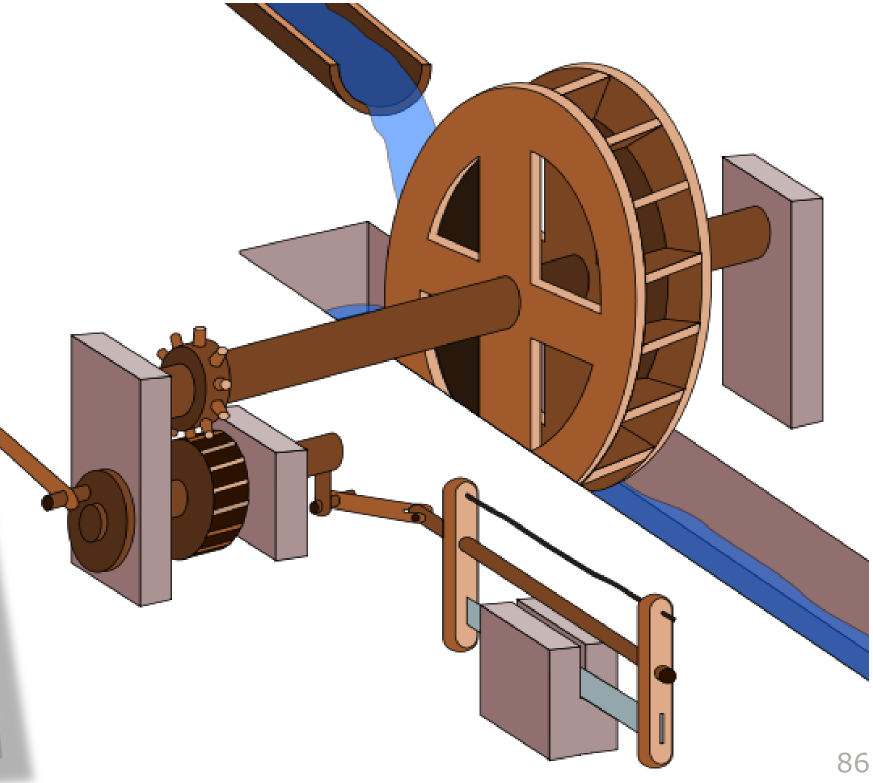
Hydro


Hydrologic Cycle
Sublimation
Precipitation
Evaporation from earth surface
Transpiration
Precipitation
Evaporation from oceans
Runoff
Infiltration & Percolation
Fresh groundwater
Groundwater table
Saline groundwater

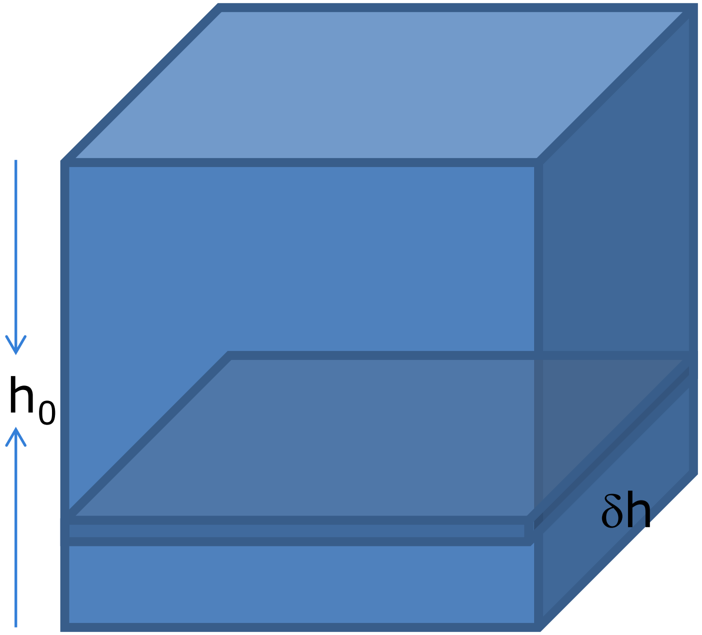

ſinus & aſellus aſedendo dictuſ. qi aſe
duſ. ſed hoc nomen qđ magiſ equiſ co
uenïebat: ideo hoc animal ſumpſit. q
priuſqm equos caperent homines. hunc preſider


aut harenā ſtatī ibi picit. que
auena. q


Water Trough
Hub
Wheel
Running Stream



HYDRO ENERGY



$$dE_p = (dm)gh = (\rho A\,dh)$$

$$E_p = \int_0^{h_0} dE_p\,dh = \int_0^{h_0} \rho A g h\,dh$$

$$= \rho A g\,\frac{h_0{}^2}{2} = \rho\left(Ah_0\right)g\,\frac{h_0}{2}$$

$$\boxed{E_p = \frac{1}{2}\rho V g}$$

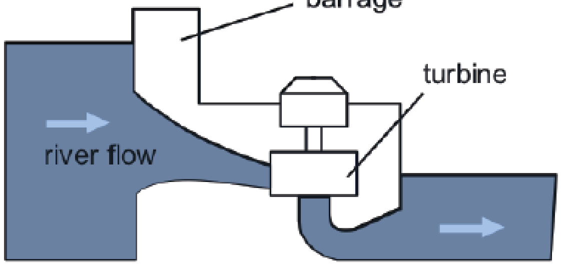
e.g. Alto Rabagão

Área 2200ha;

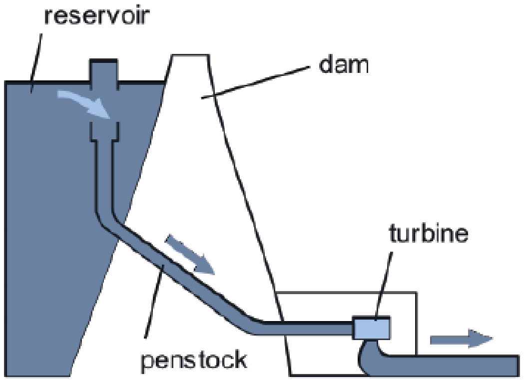
Head 130m;

Annual generation115 ×10^6 kWh

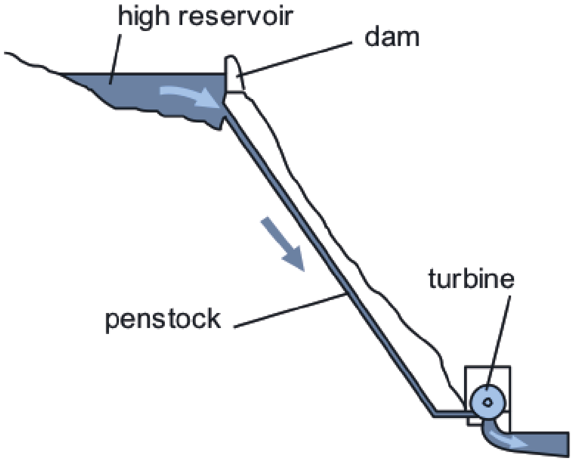
TYPES OF HYDRO SYSTEMS



Low head
2 - 20 m

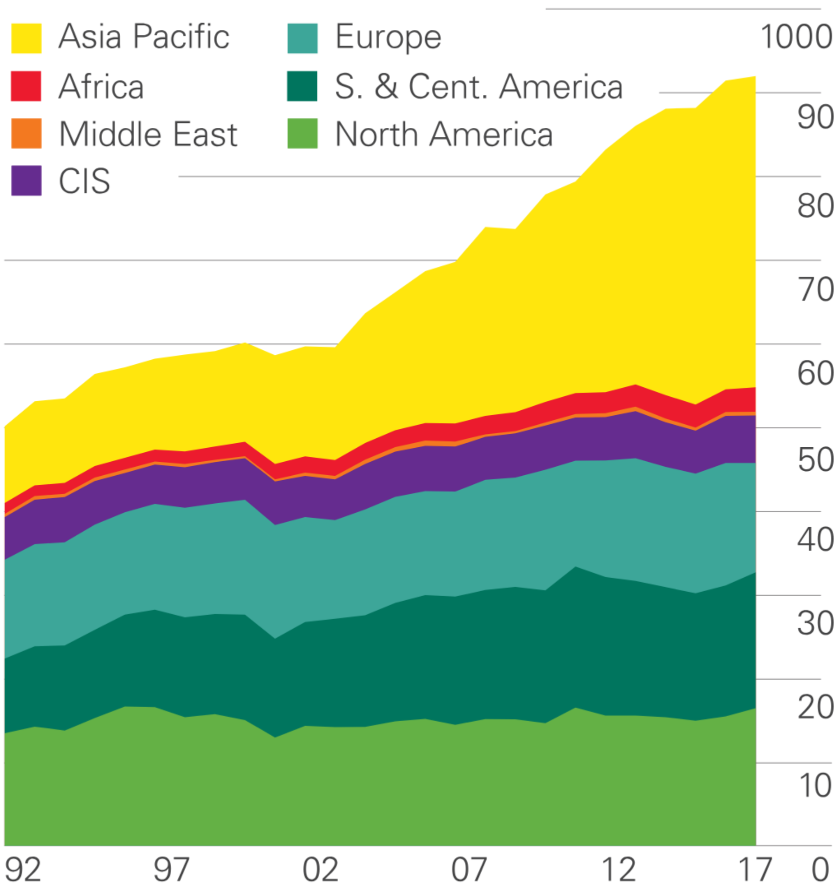


Medium head
2 - 20 m



Large head
>150 m

Hydro consumption (million tones oil equivalent)



POSITIVE IMPACTS

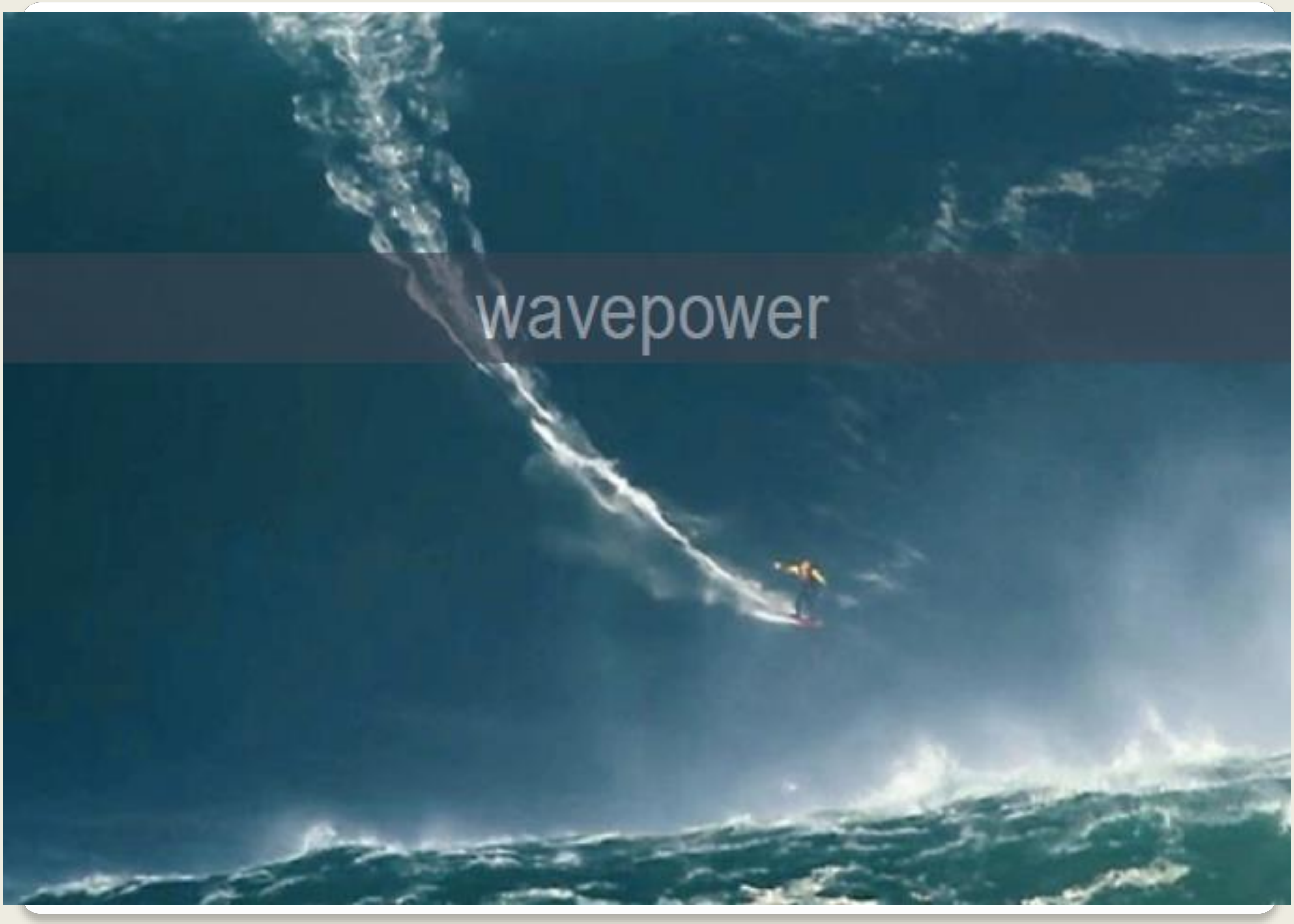
- Energy cost (low levelized cost)
- Energy security (and dispatchable)
- Enables coupling with wind power (1MW pumping/ 3.5MW wind power)
- Use of water for drinking and agriculture and flood control
- No emissions (no fuel, no water use) during operation

NEGATIVE IMPACTS

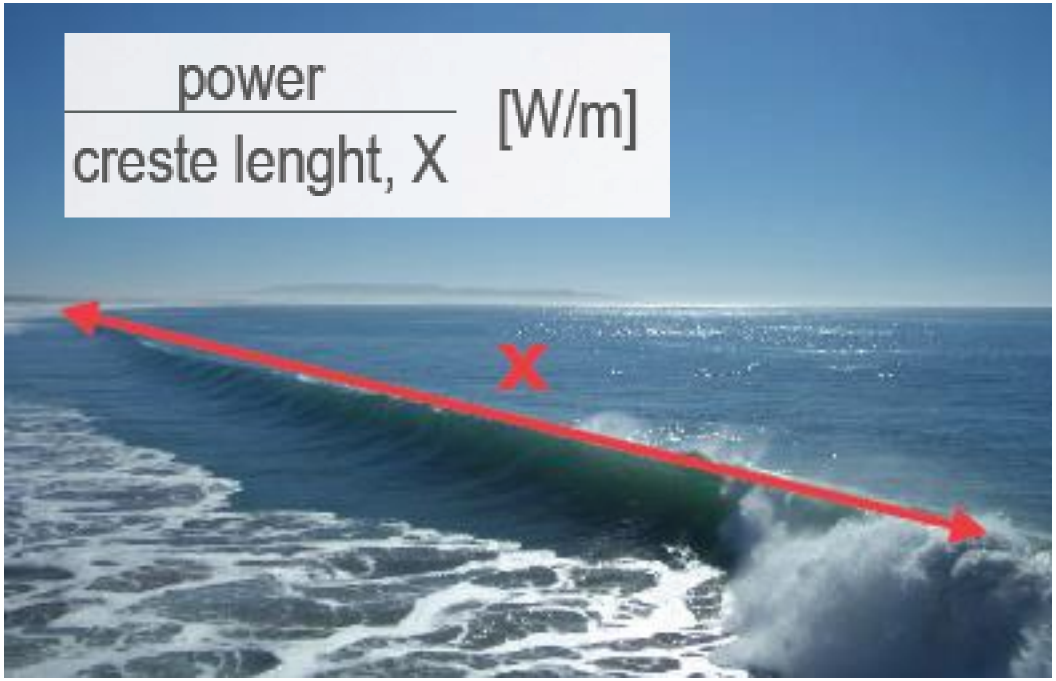
- Modification of landscape and ecosystems
- Methane emissions
- Population displacement
- Possible disease transmission
- (Accidents: Banqiao, 170,000 dead 1975)

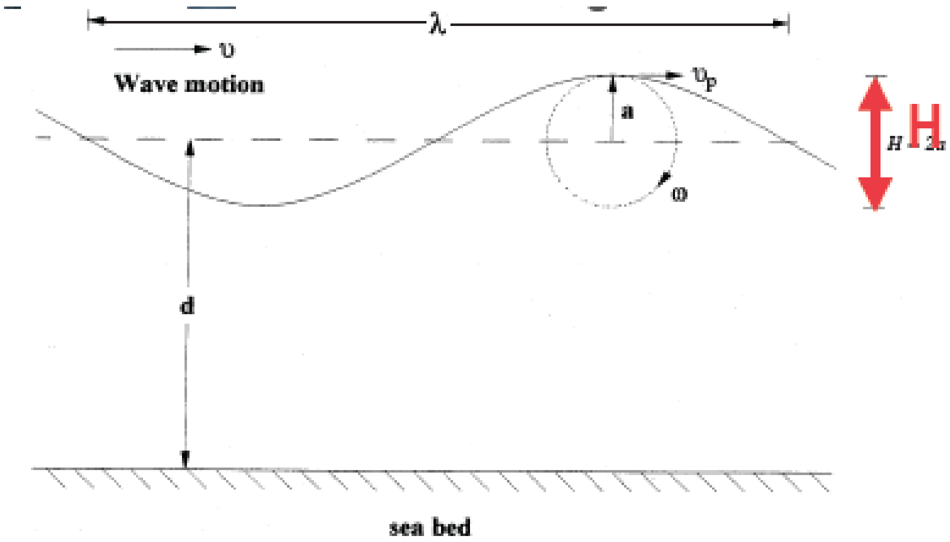
OCEAN

wavepower



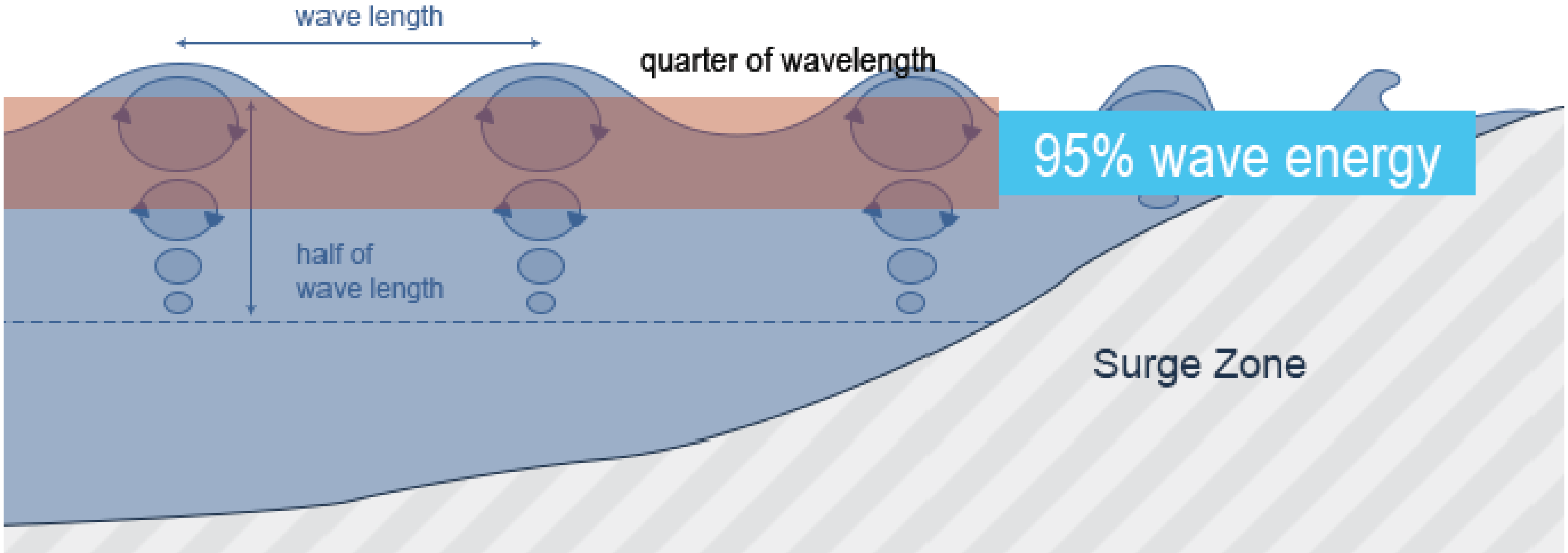
$$\frac{\text{power}}{\text{creste lenght, X}} \quad [\text{W/m}]$$





$$P = 0.5 H_s^2 T_e \quad [\text{kW/m}]$$

H_s	significant wave height, the average of the highest one third of the waves
T_z	average of zero crossing upwards movements



quarter of wavelength

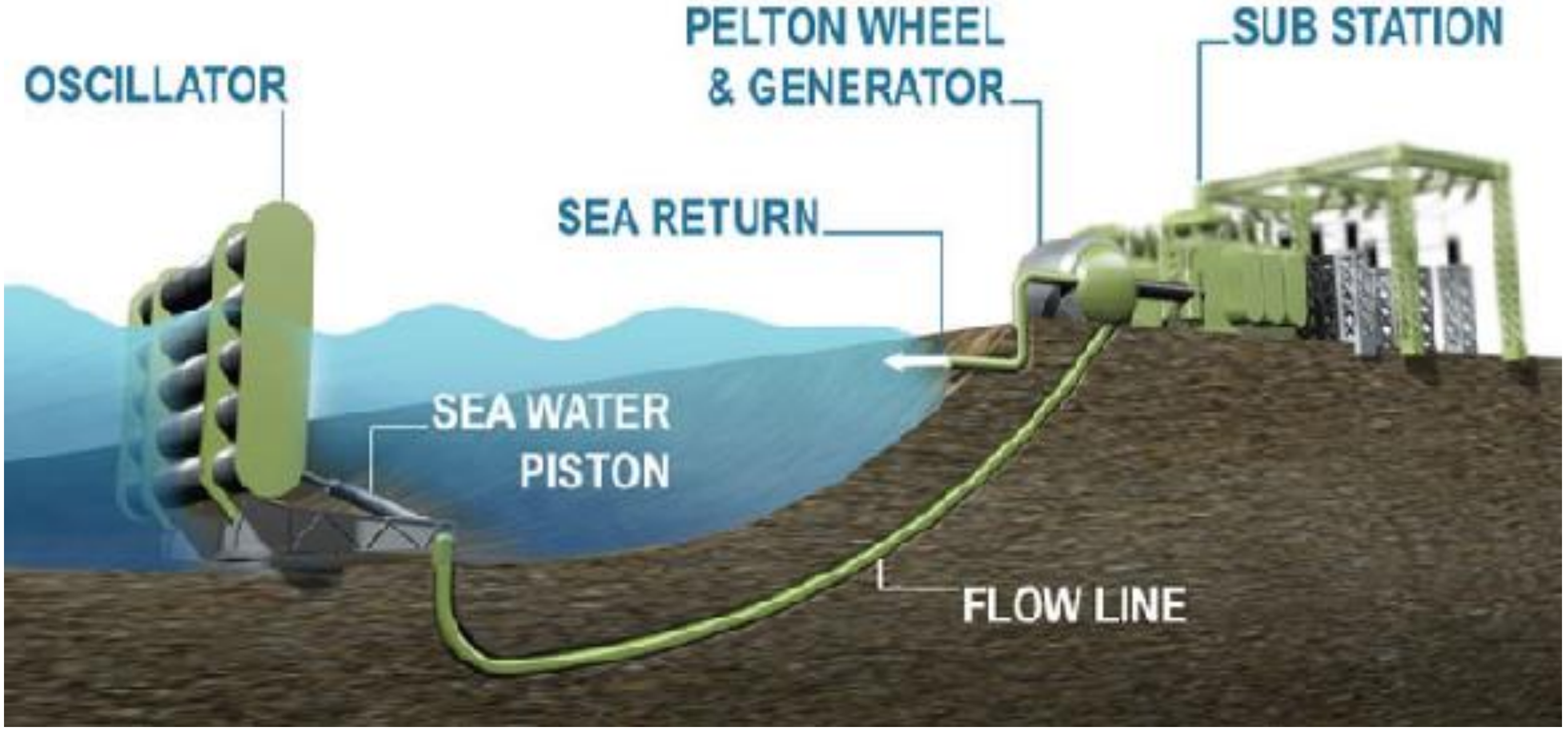
95% wave energy

WAVE ENERGY

On shore

WAVE ENERGY

Near shore



WAVE ENERGY

Floating

WAVE ENERGY

Floating

WAVE ENERGY

Energy density?

Pelamis

750kW

700 tons (including 350 ton ballast)

Then ~**500kg/kW**

Offshore wind

Turbine + foundation

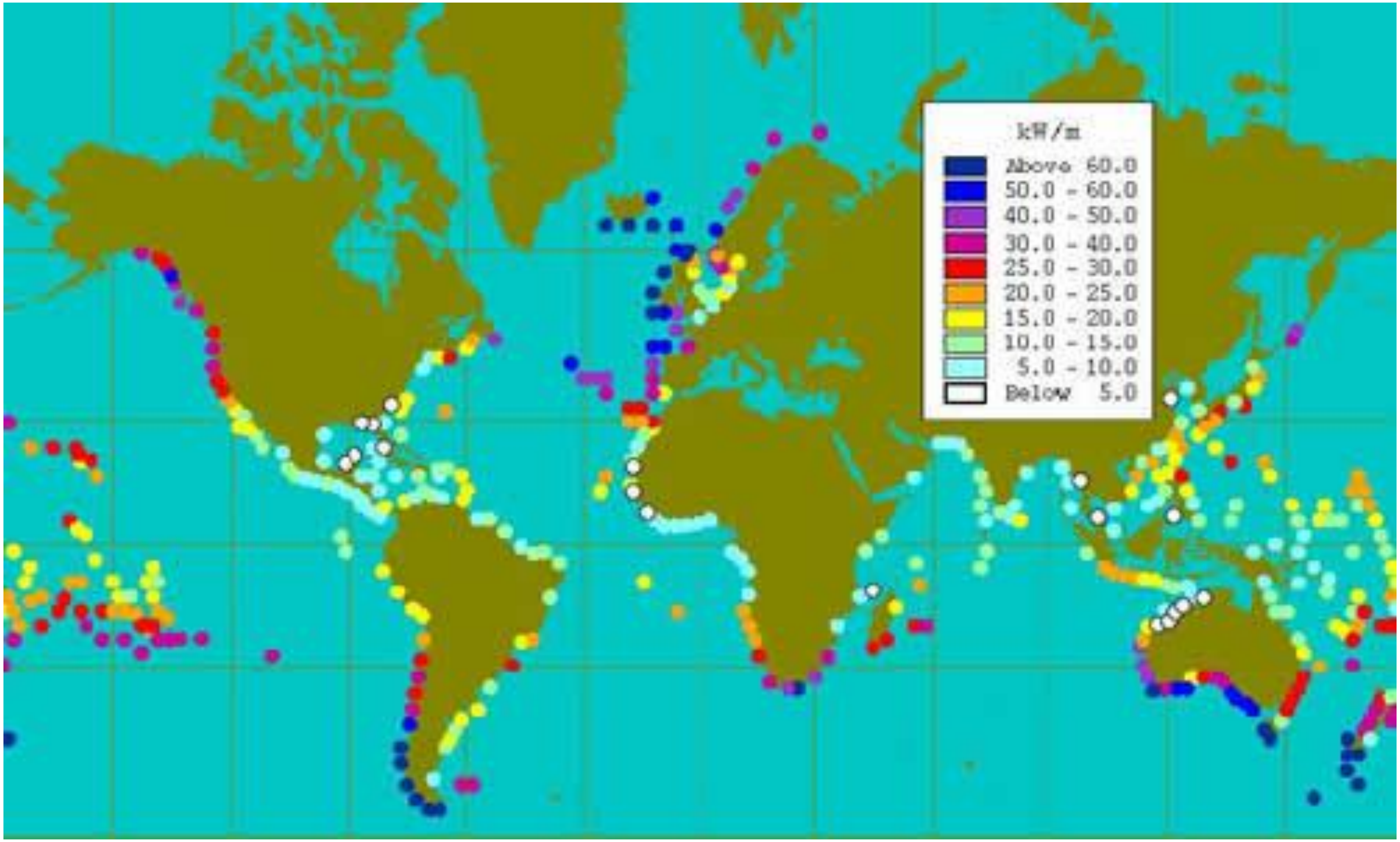
3MW weights about 500 tons

Then ~**170 kg/kW**

Difficult to imagine it might be viable.

Offshore wind would be much easier.

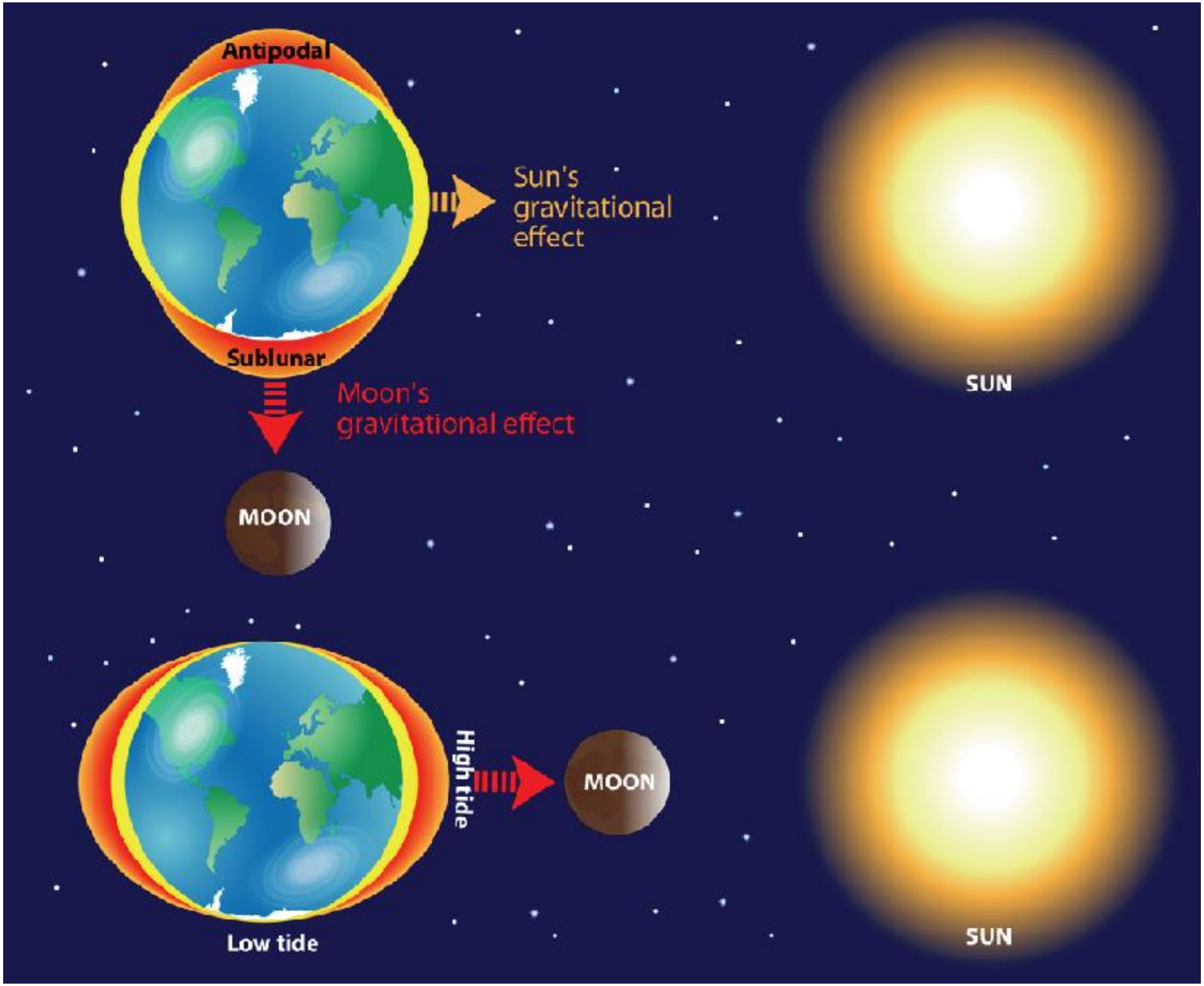
Electricity transport might be cost prohibitive. Potential decreases near shore…

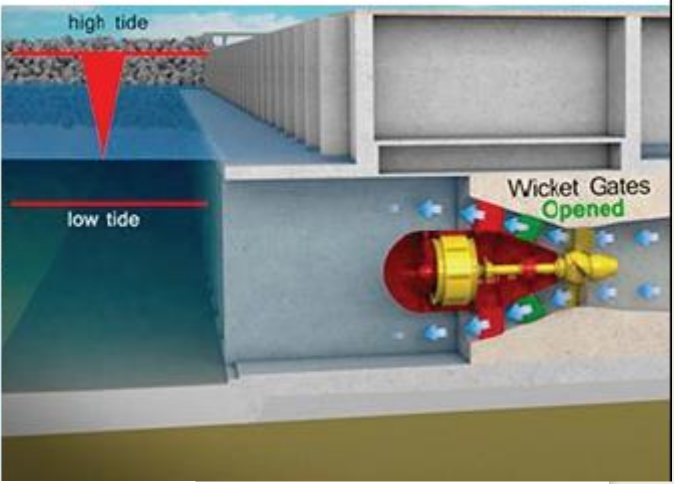


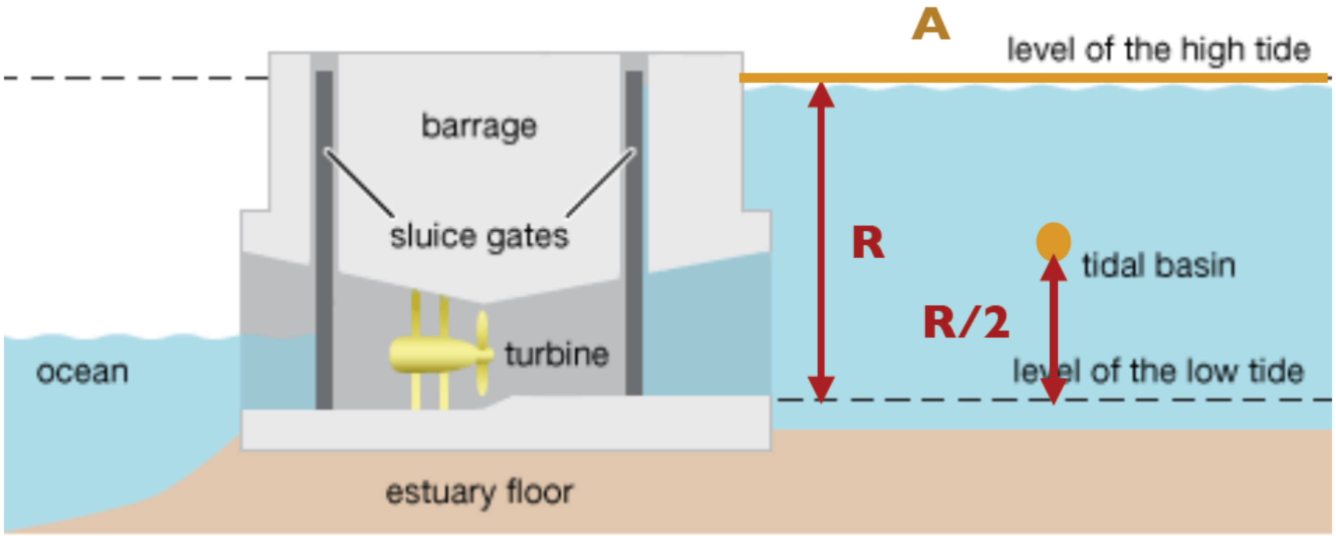
Portuguese coast: 500km @ 40 kW/m

25% efficiency -> 5GW = **0.5 kW/person** (but no more surfing…)

tidal power


Antipodal
Sublunar
Sun's gravitational effect
SUN
Moon's gravitational effect
MOON
High tide
MOON
Low tide
SUN

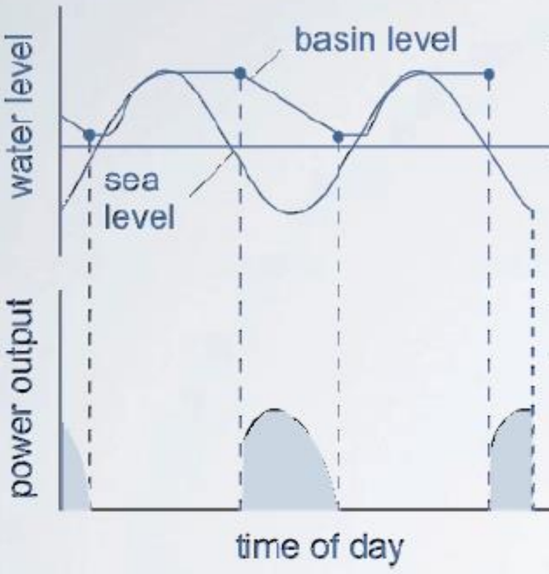




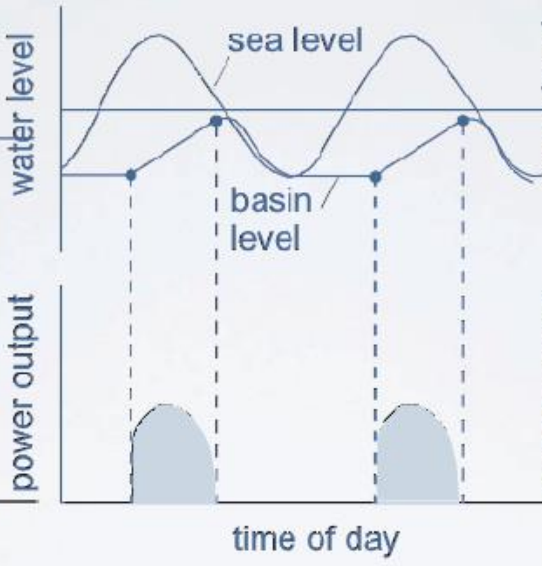
$$T = \frac{24.8}{2} h$$

$$E = \rho A R g \cdot R/2$$

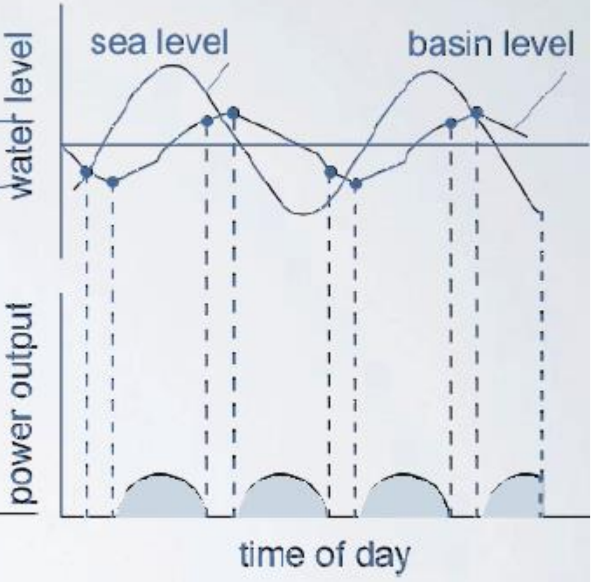
$$P_{max} = \frac{\Delta E}{\Delta T} = \frac{\rho g A R^2}{2T}$$



flood generation

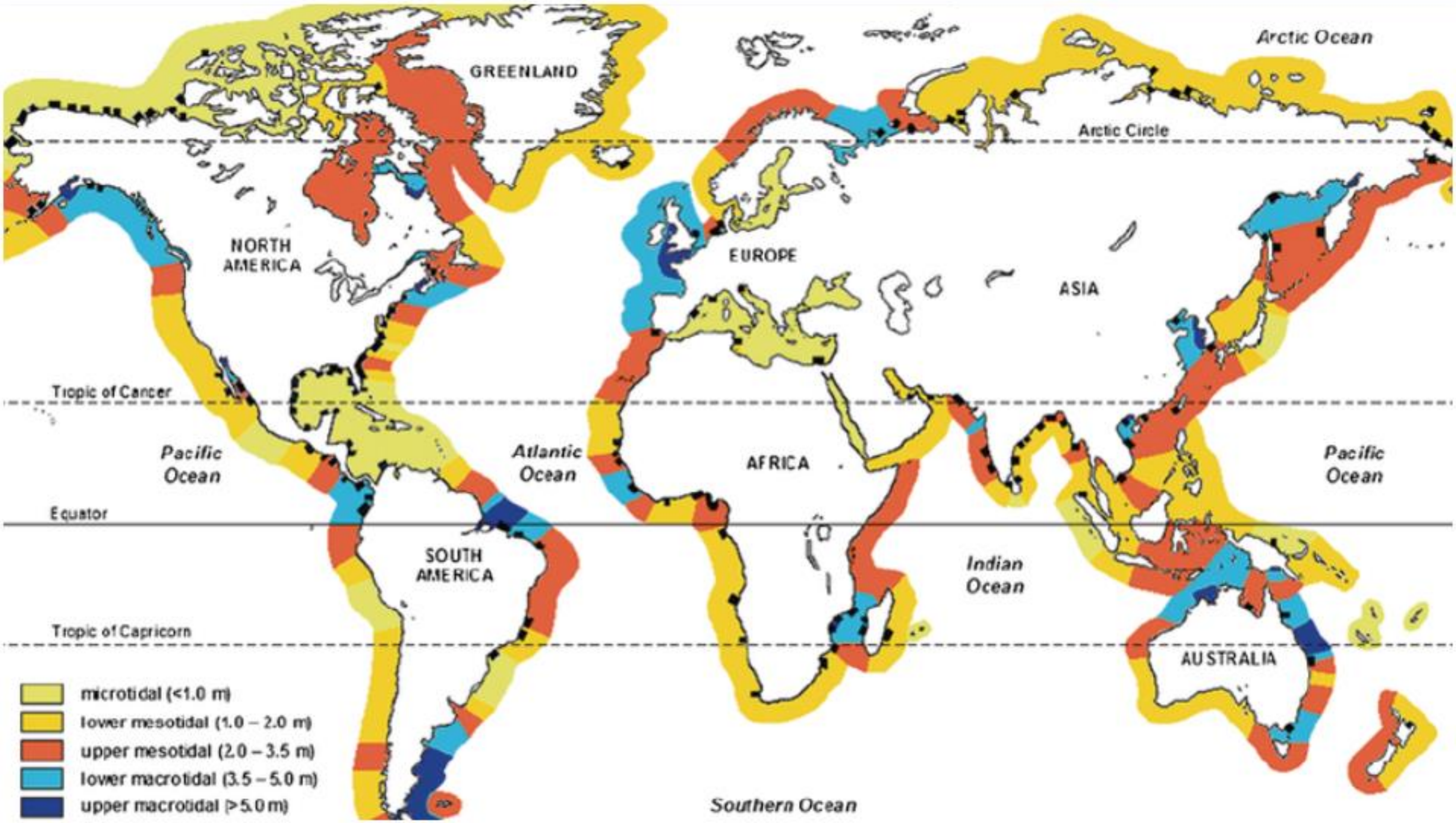


ebb generation

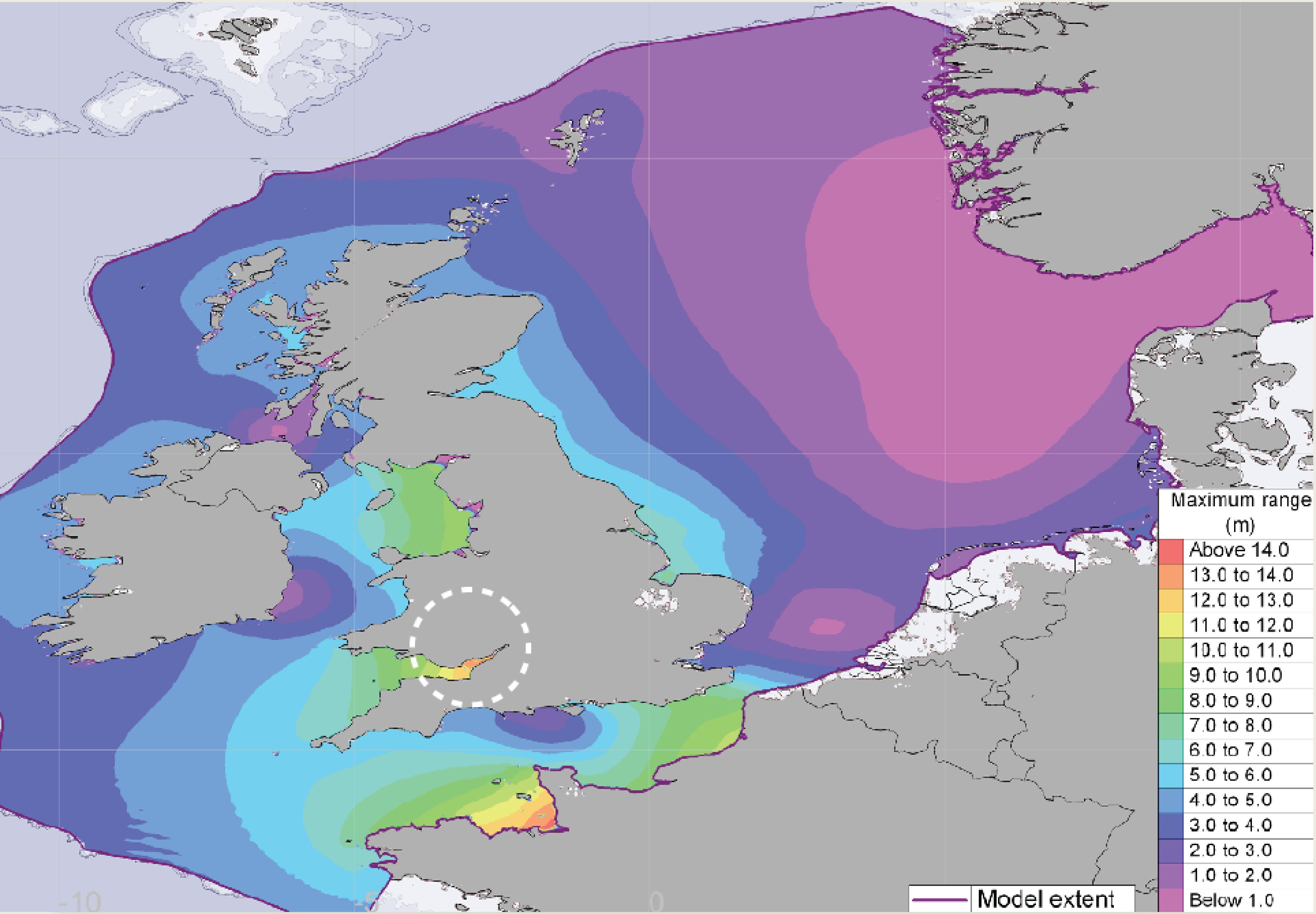


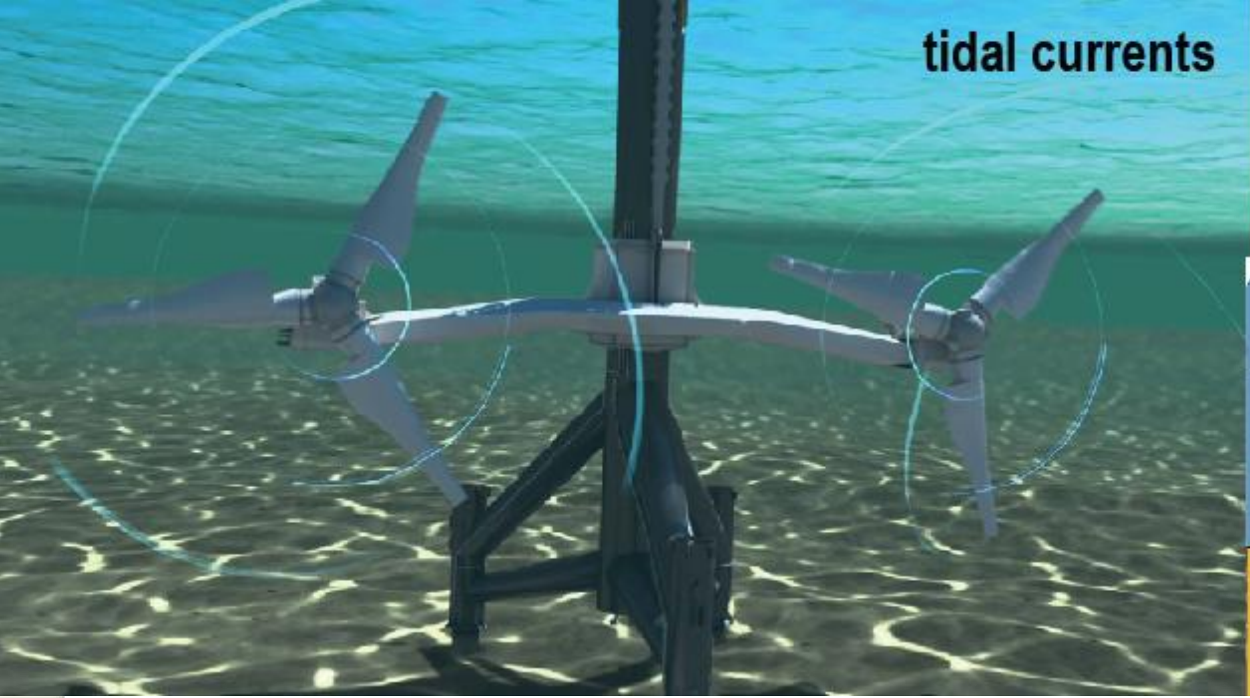
ebb and flood generation

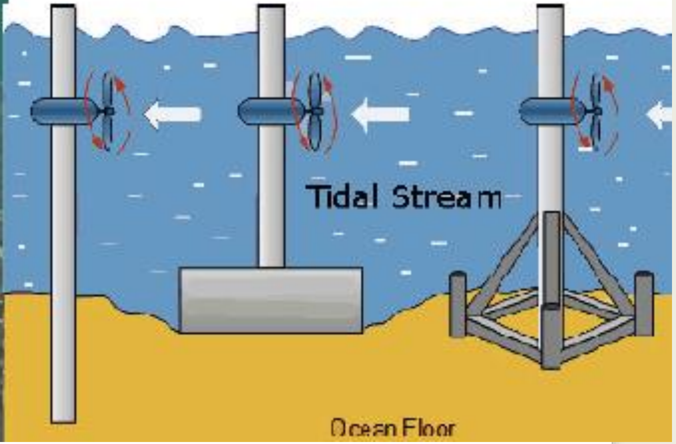
Ciências
ULisboa

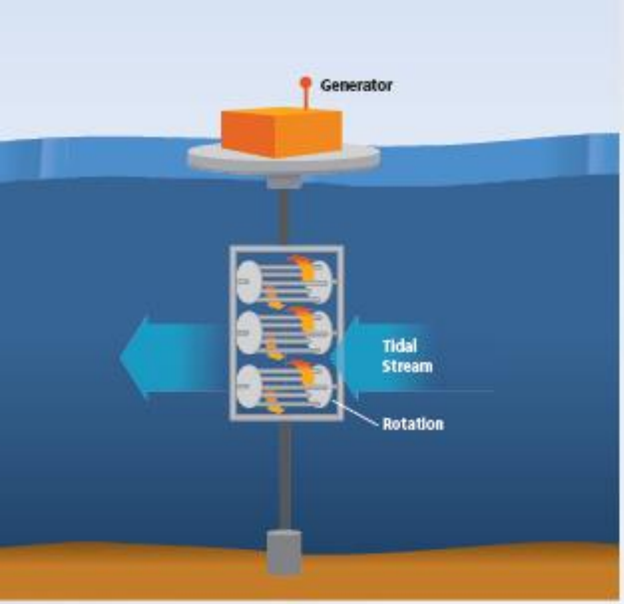


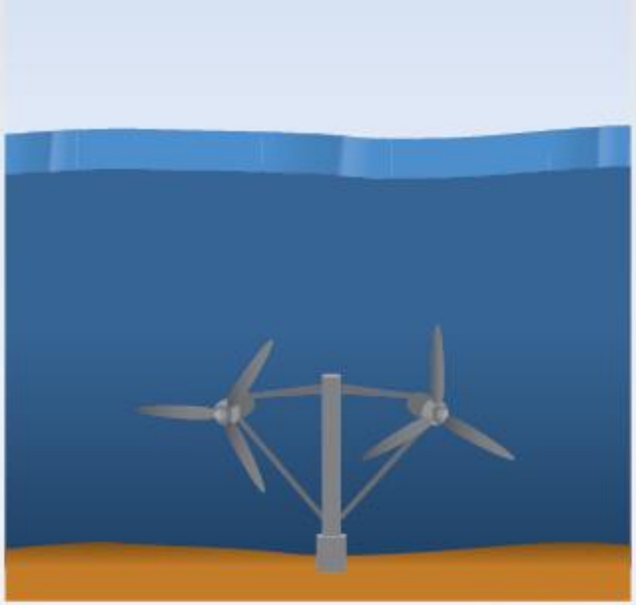
Ciências ULisboa

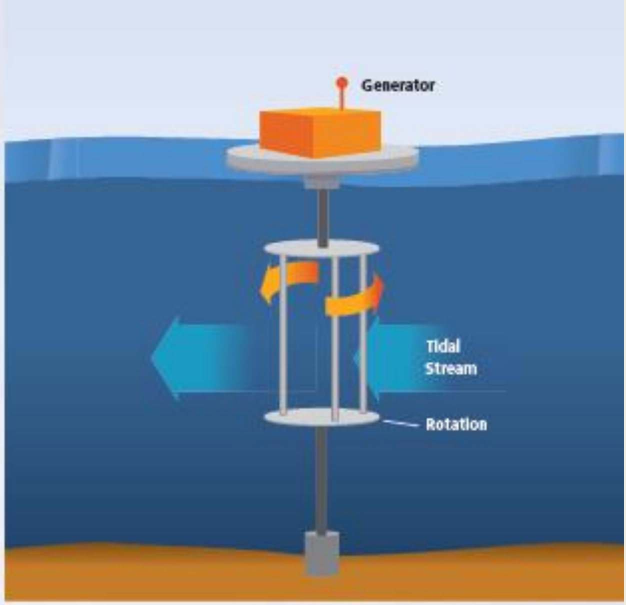

Maximum range (m)
Above 14.0
13.0 to 14.0
12.0 to 13.0
11.0 to 12.0
10.0 to 11.0
9.0 to 10.0
8.0 to 9.0
7.0 to 8.0
6.0 to 7.0
5.0 to 6.0
4.0 to 5.0
3.0 to 4.0
2.0 to 3.0
1.0 to 2.0
Below 1.0
Model extent
-10
-5
0


tidal currents


Tidal Stream
Ocean Floor







$$\rho_{water} \simeq 830\rho_{air}$$

same power rate

same diameter

$$v_{water} \simeq 0.1 v_{air}$$

same speed

$$D_{water} \simeq 0.035 D_{air}$$

Geothermal

dry and wet steam

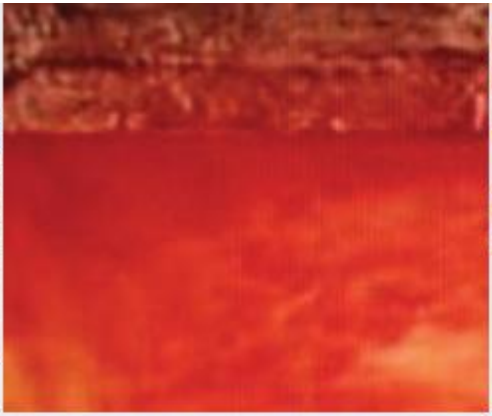
water or steam at high pressure and temperature (>180°C) at depth of 4 km

130 EJ

geopressurized brines

high pressure water with salts and methane (150-180°C)

540 EJ



hot rocks

Hot rocks (>200°C) poor of fluids at depths of 4-8 km

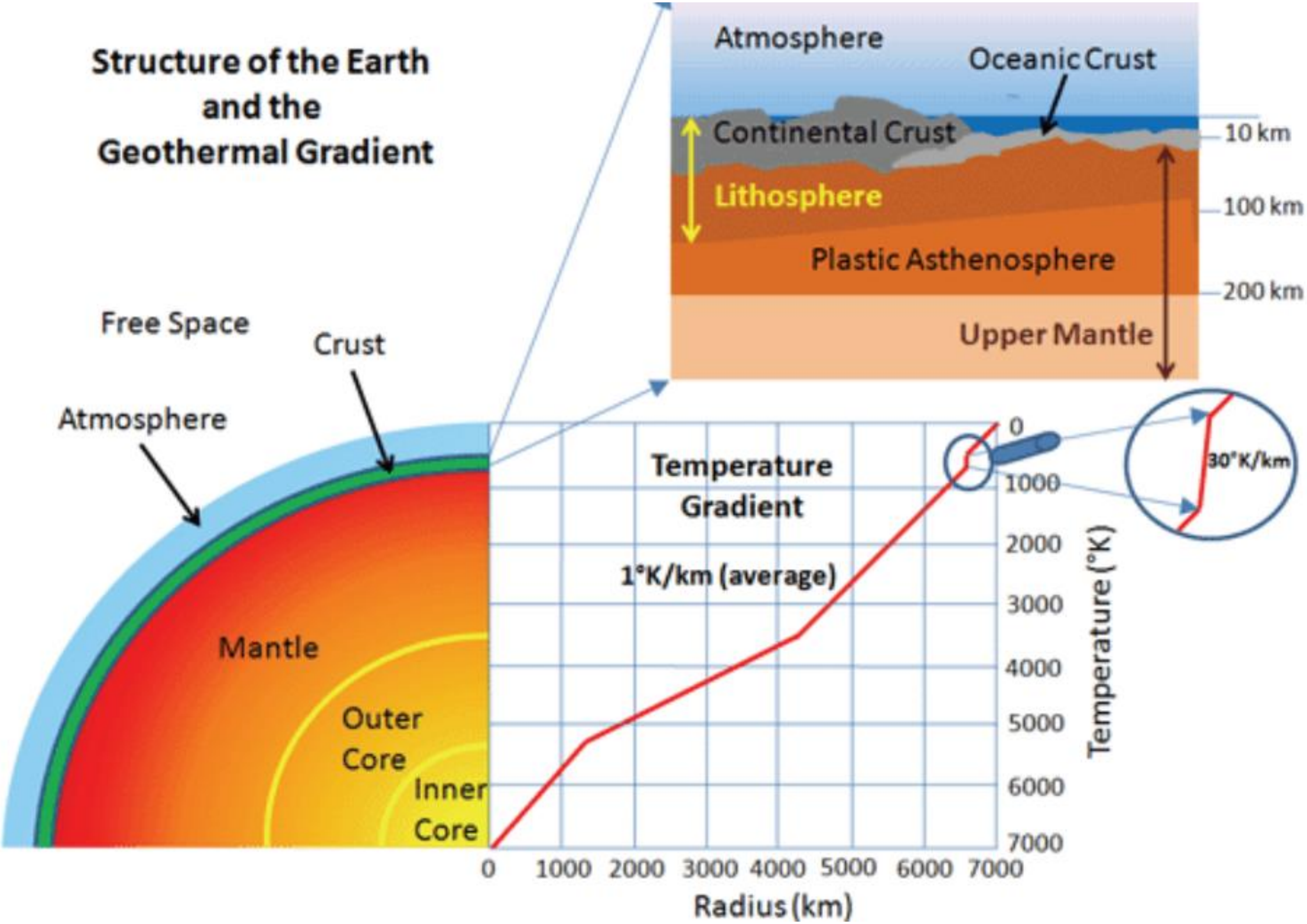
105 000 EJ

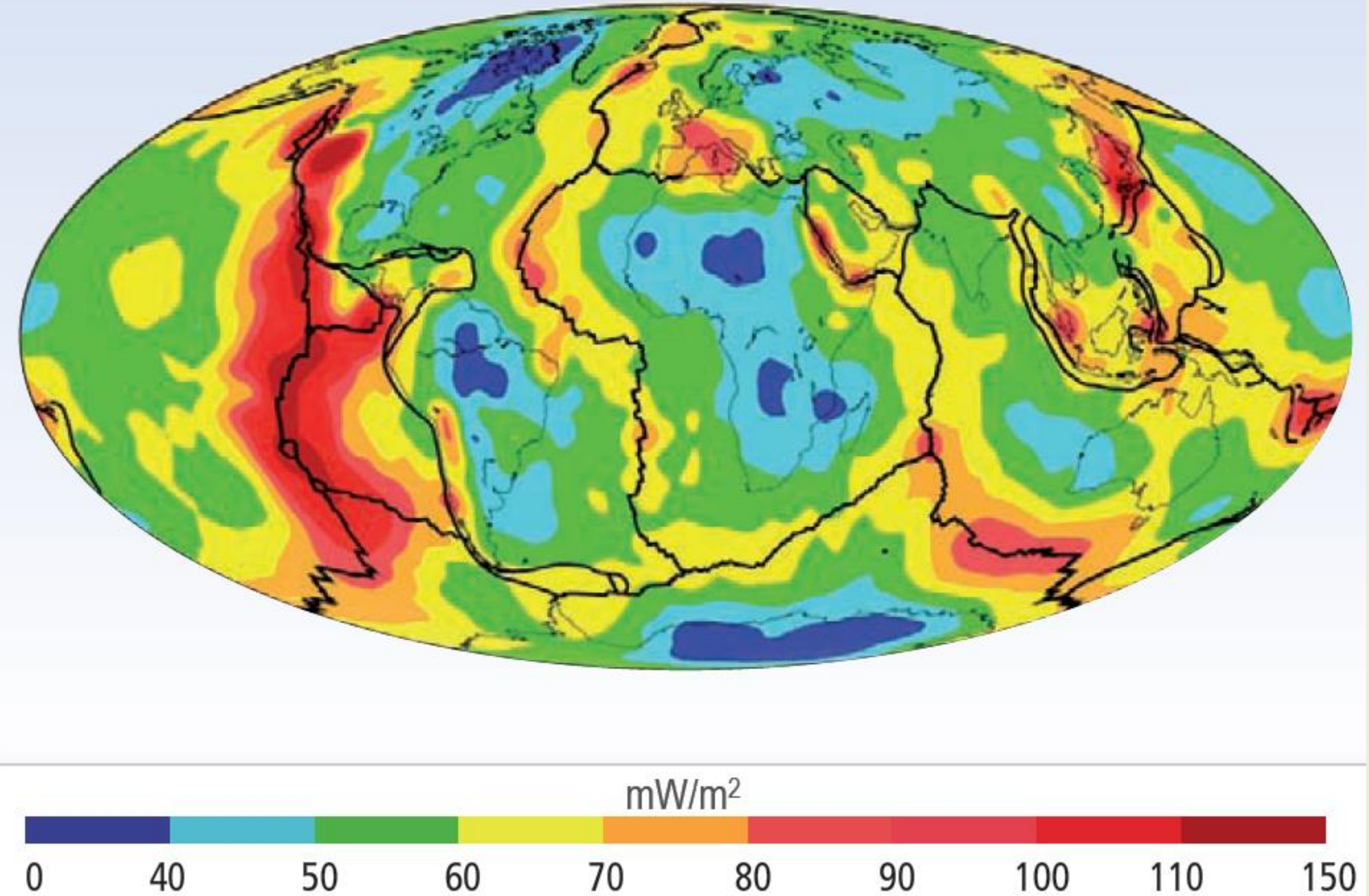
magma

Magma (>650°C) close to the surface by vulcano activity.

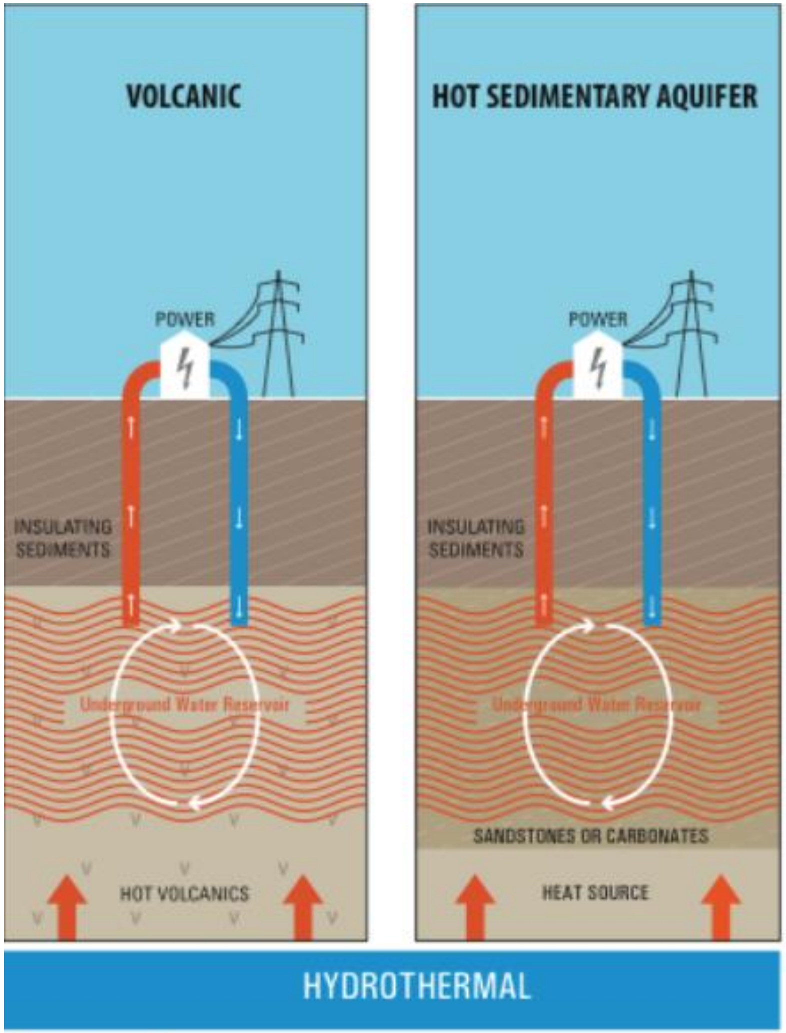
5 000 EJ

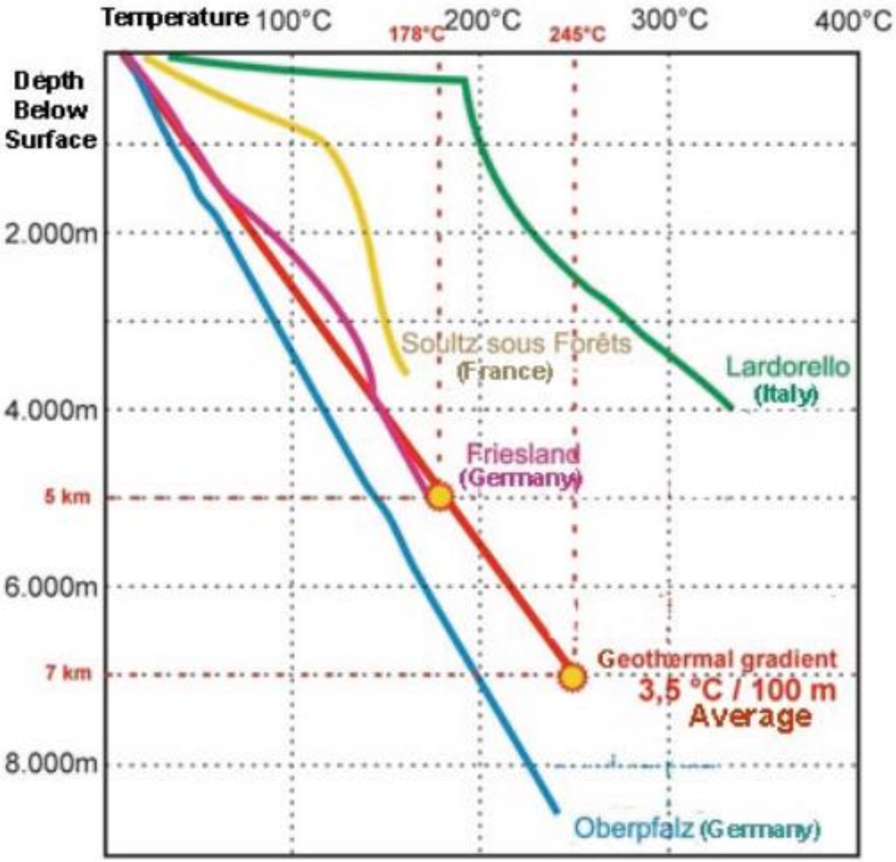
Structure of the Earth and the Geothermal Gradient



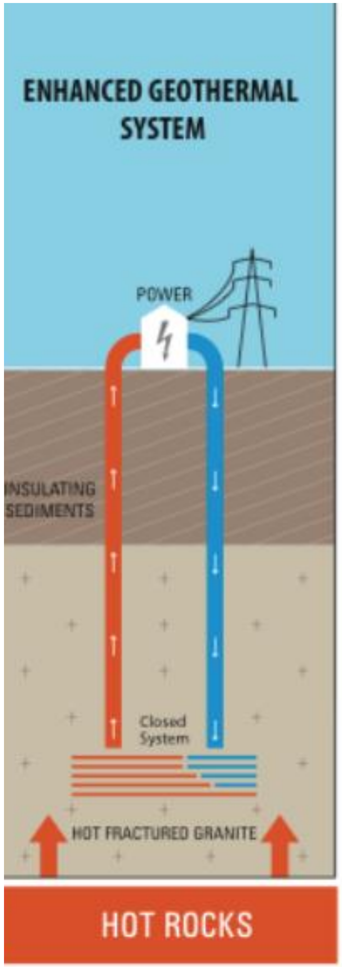

mW/m2
0
40
50
60
70
80
90
100
110
150

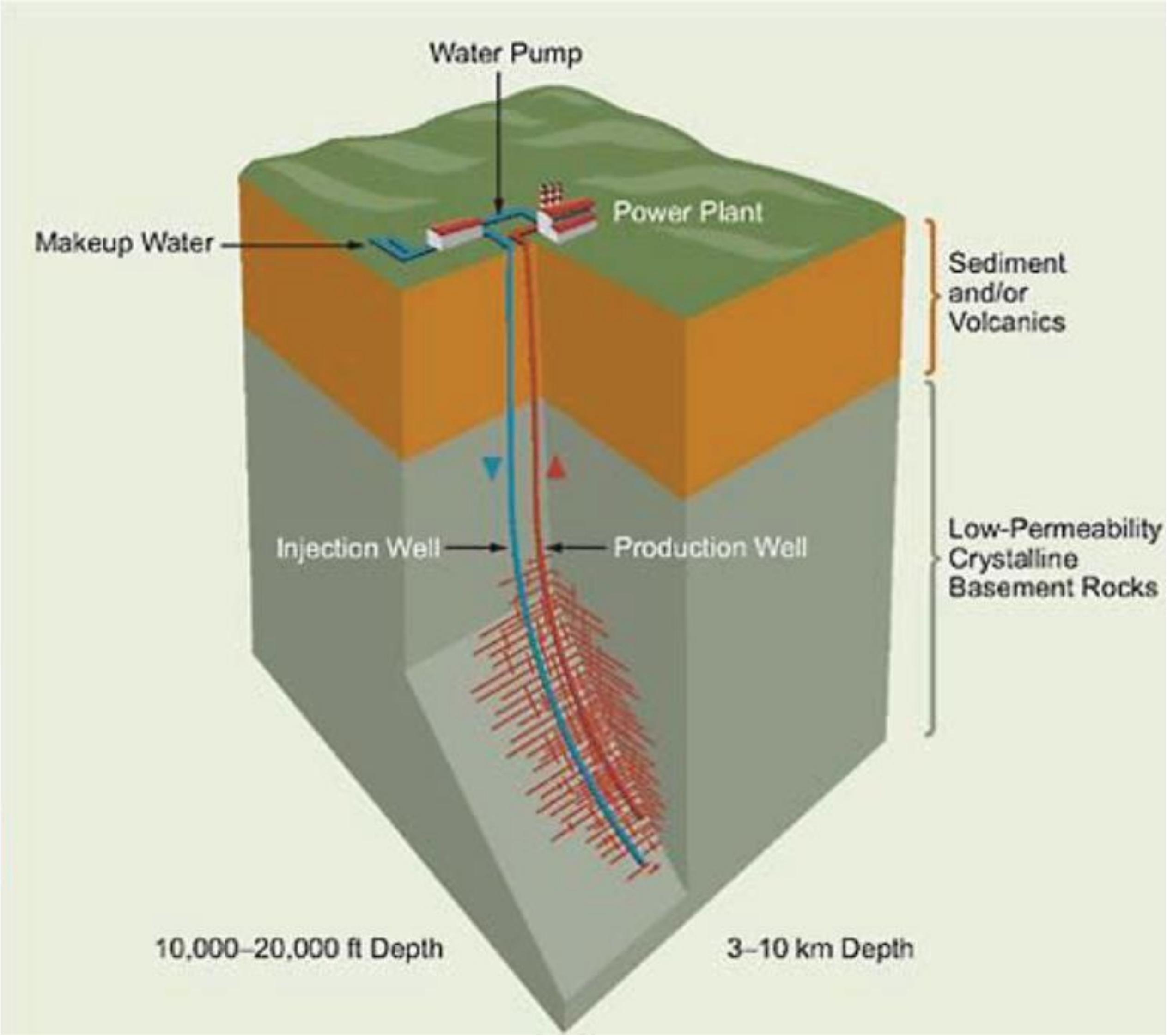
hydrothermal

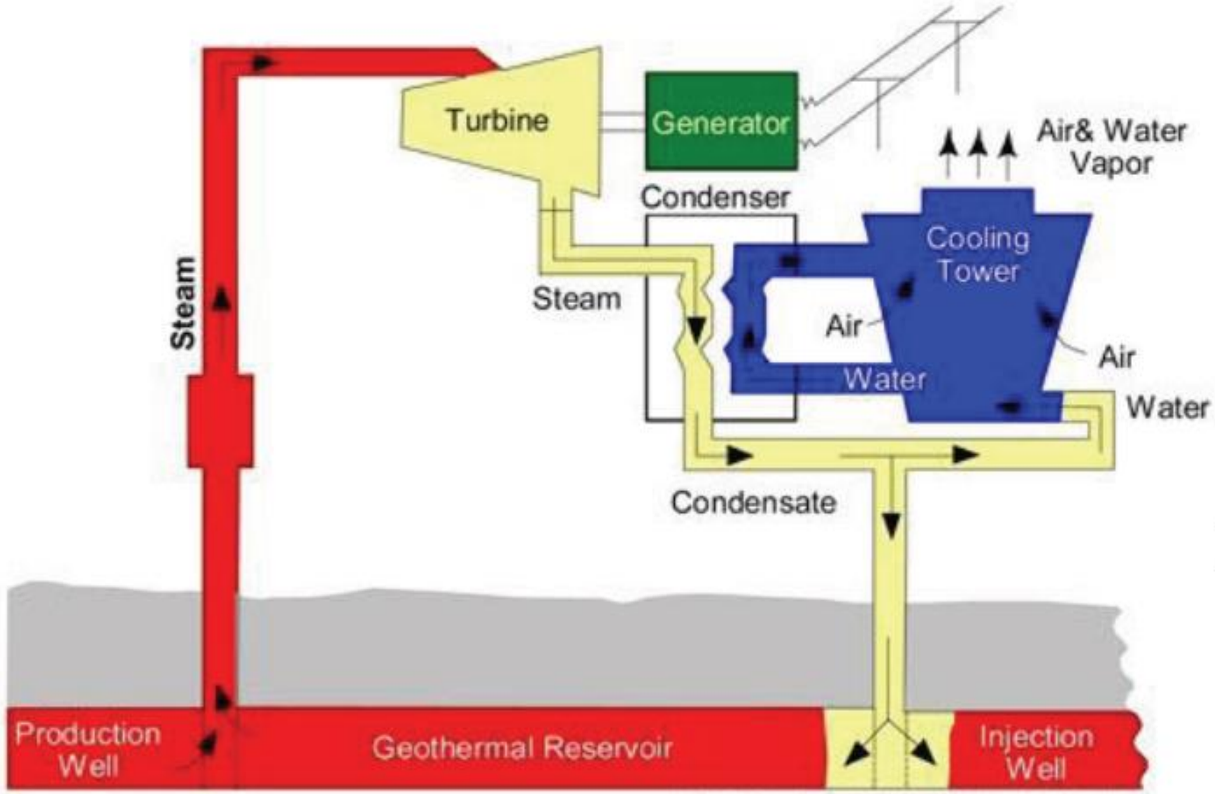




enhanced geothermal system





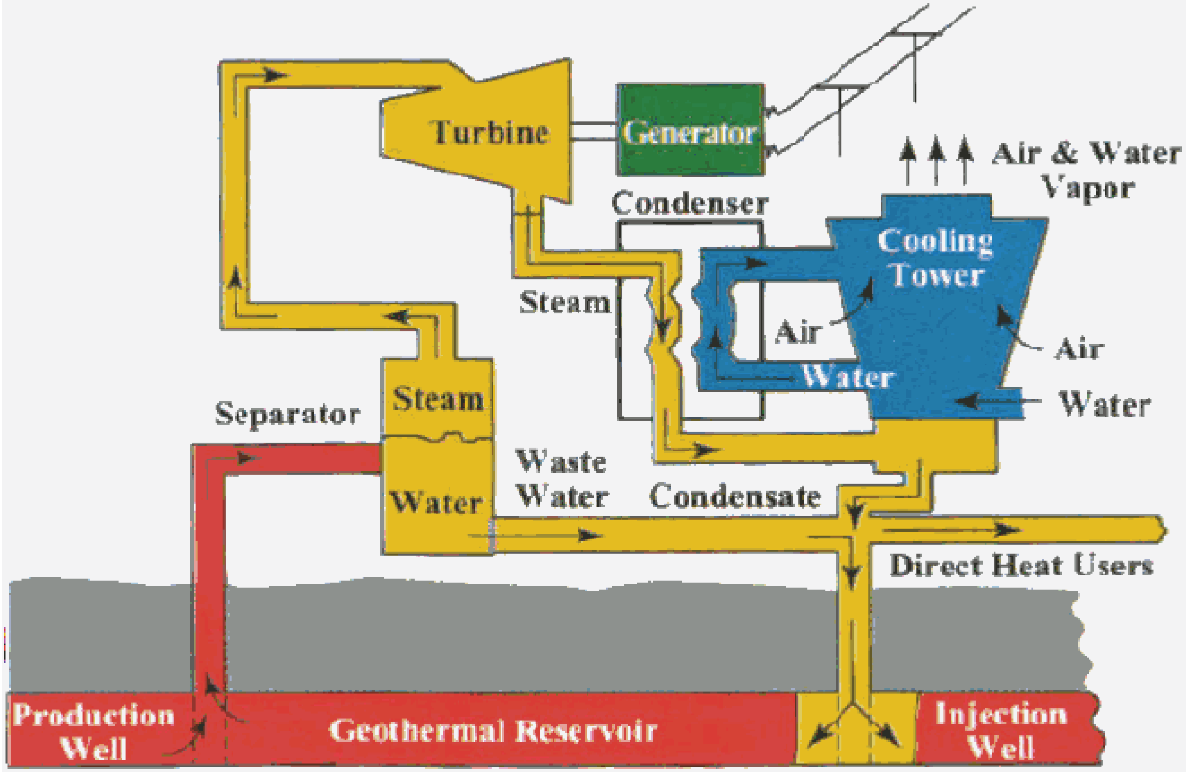


Modified from Geo-Heat Center

water vapor
(>350ºC, 8-9 atm)

Maximum efficiency
30%

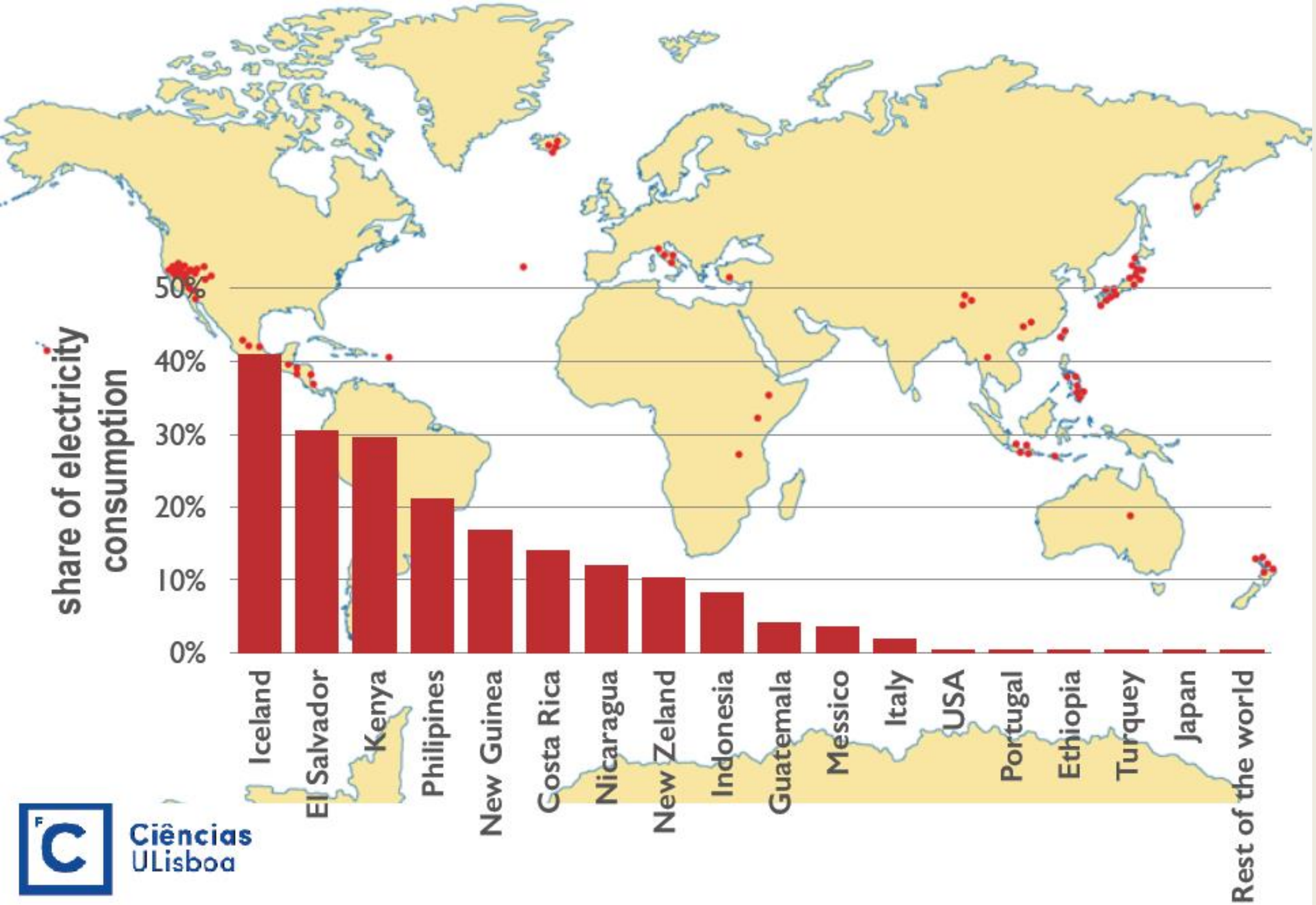
6.5 kg fluid/kWh



vapor and water mixture

(155-165ºC)

8 kg fluid/kWh



Ciências
ULisboa

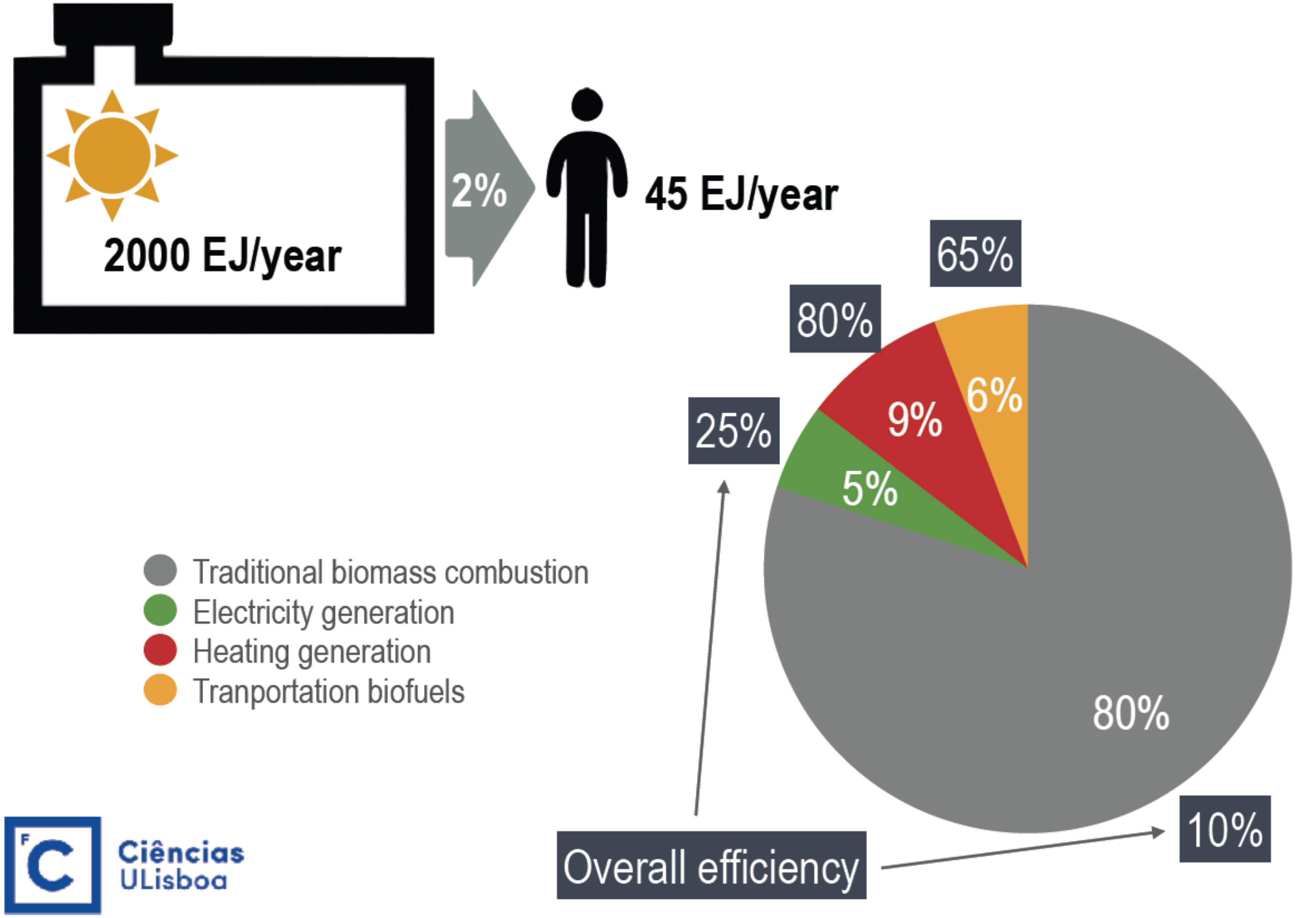
São Miguel, Açores

Ribeira Grande, 13 MW

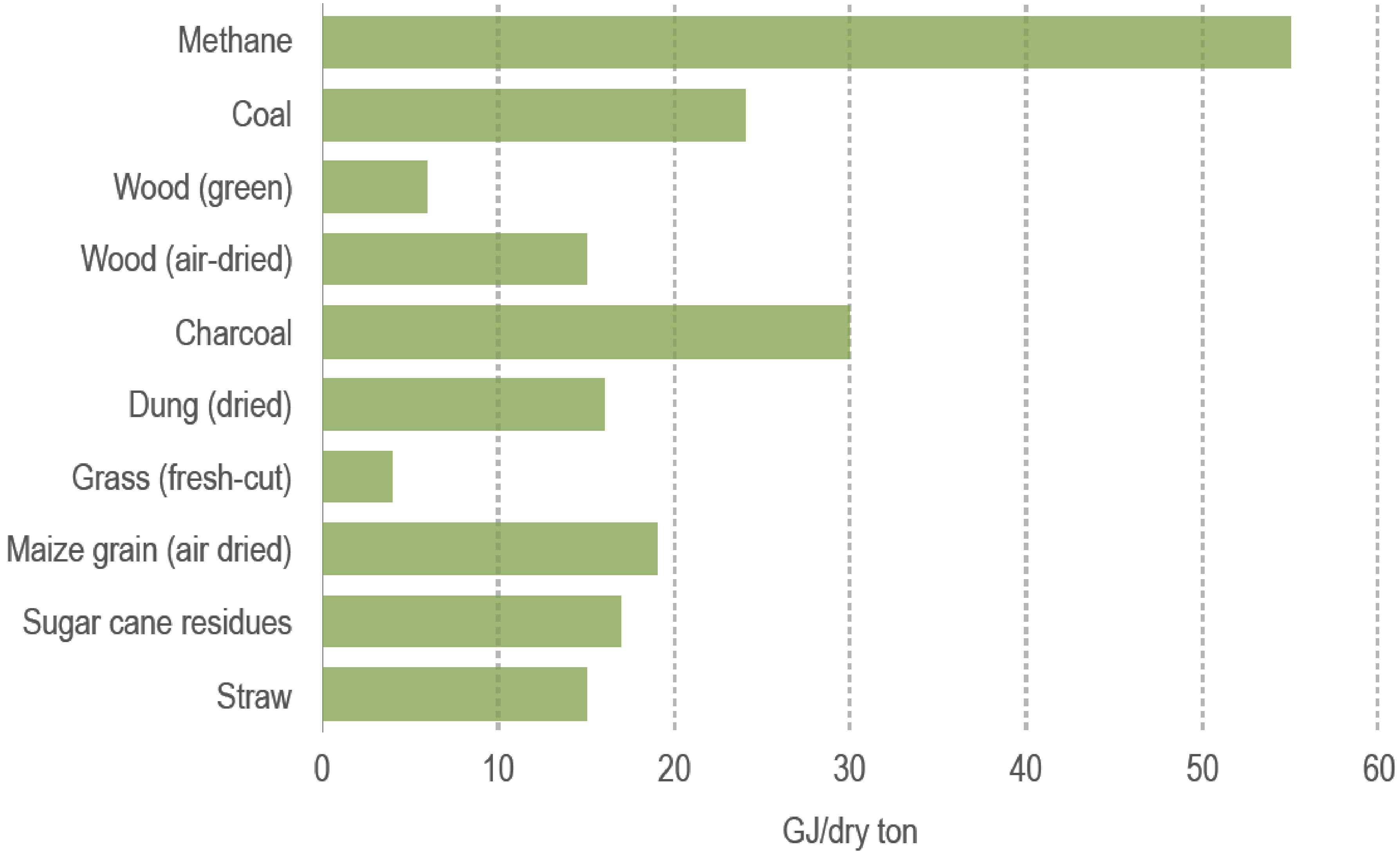
Pico Vermelho, 10 MW

Bioenergy

Sun's radiation + water + carbon dioxide ⇨ carbon hydrates + oxygen



Ciências ULisboa

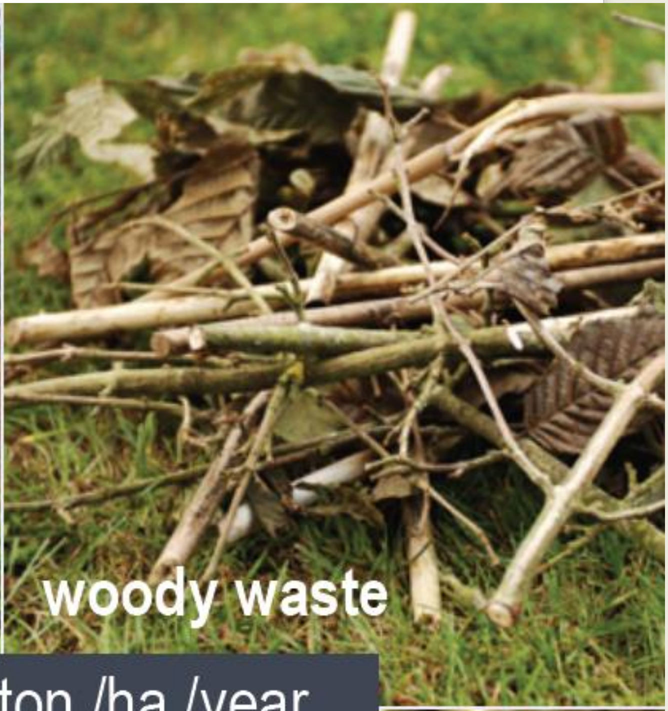


Source: Adapted from Renewables 2013, Global Status Report.
Gas CCGT and Conventional Coal ~ 0.07€/kWh / Nuclear ~0.10€/kWh

Photosynthetically active radiation	**~50%**
Absorbed by growing leaves	**~85%**
Converted into stored chemical energy	**21-27%**
Plant metabolism	**~60%**
Overall efficiency	**5-7%**

woody biomass


trees


woody waste

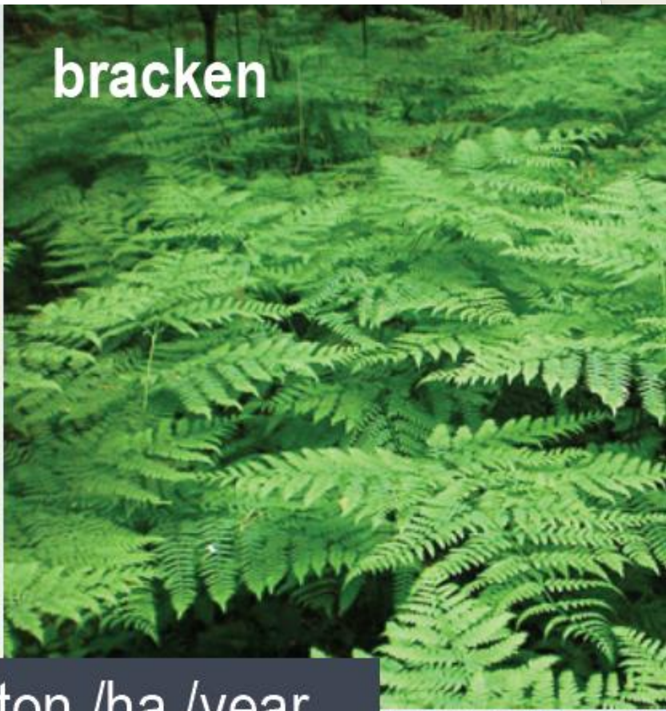
10 - 20 dry ton /ha /year


copses


pellets

cellulosic biomass


miscanthus

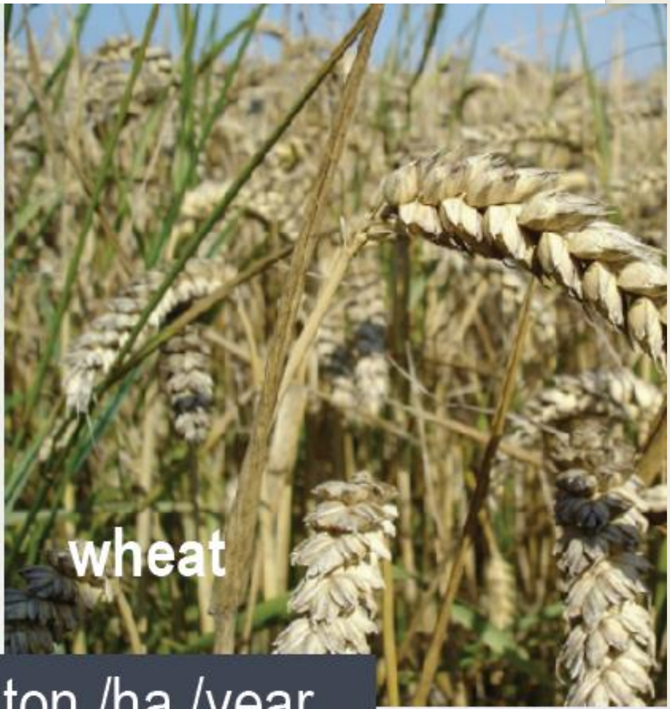

bracken

10 - 60 dry ton /ha /year

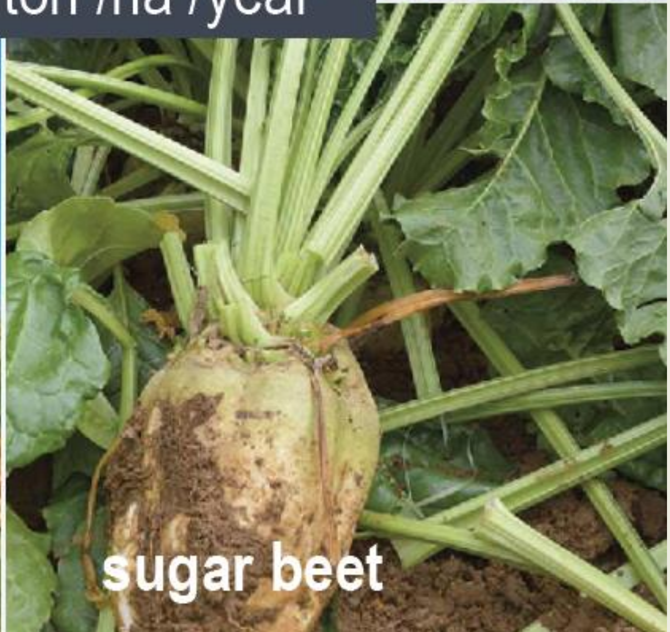

water hyacinth


gunnera

starchy/sugar crops

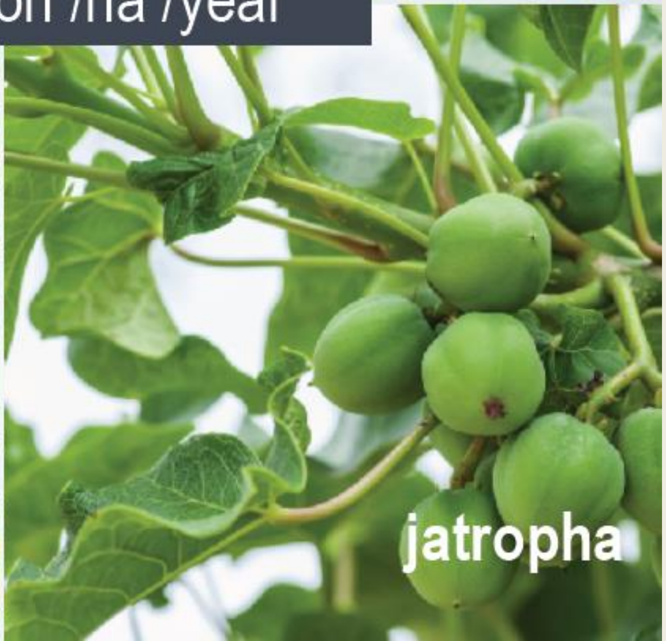


10 - 35 dry ton /ha /year



oily crops

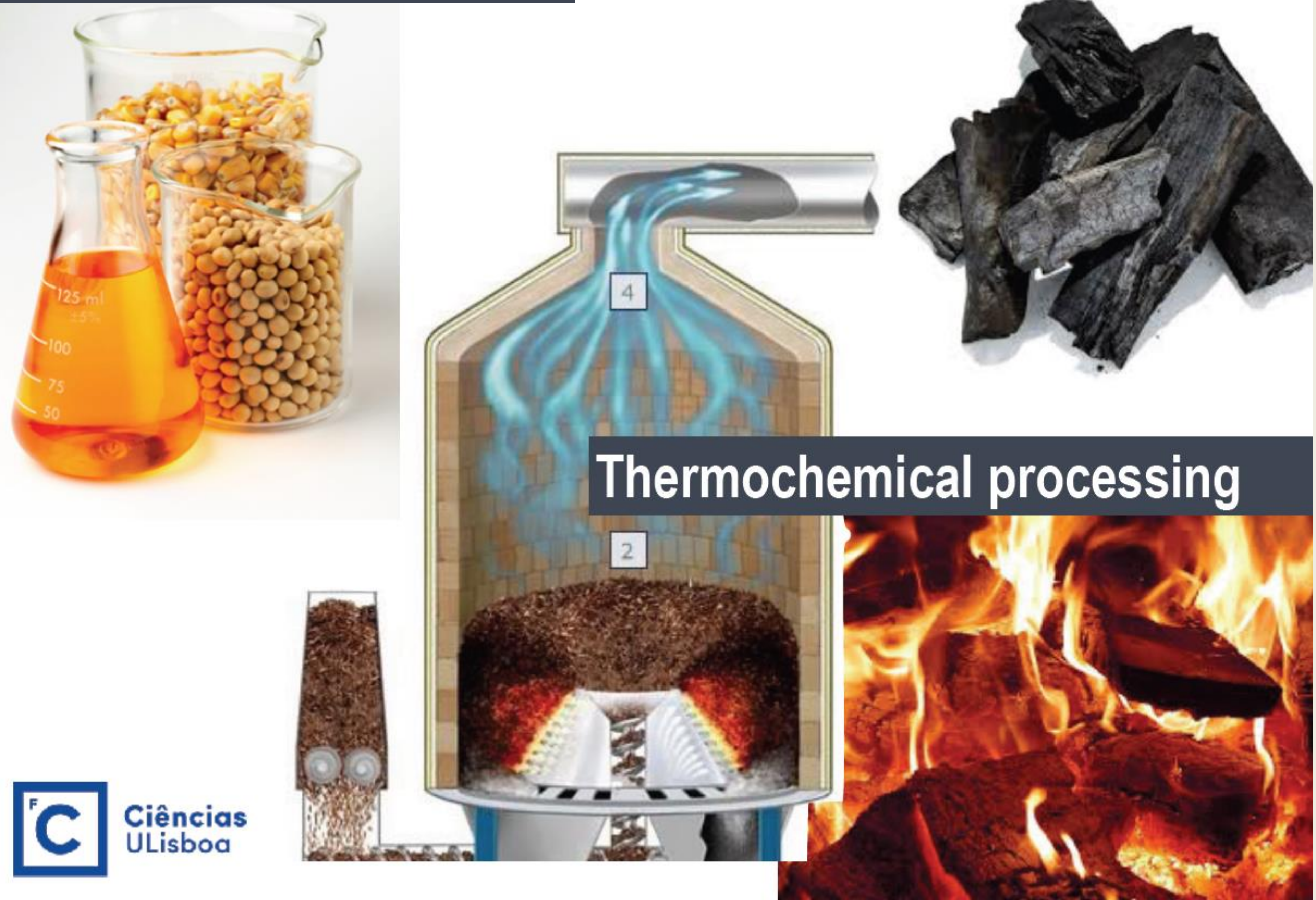
8 - 15 dry ton /ha /year



biomass processing

Physical processing

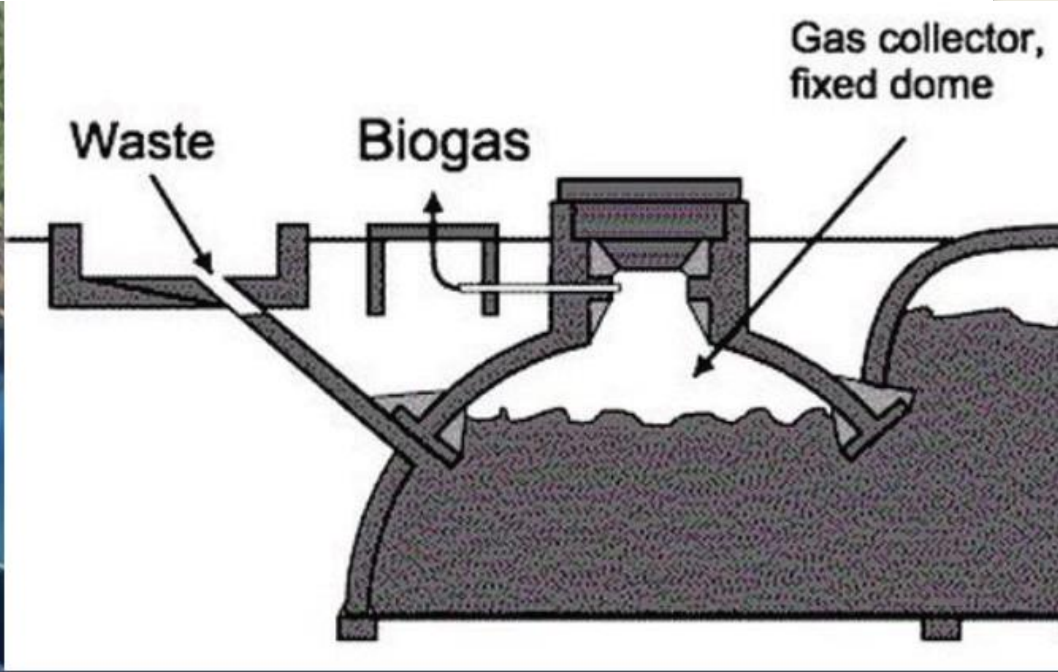
biomass processing



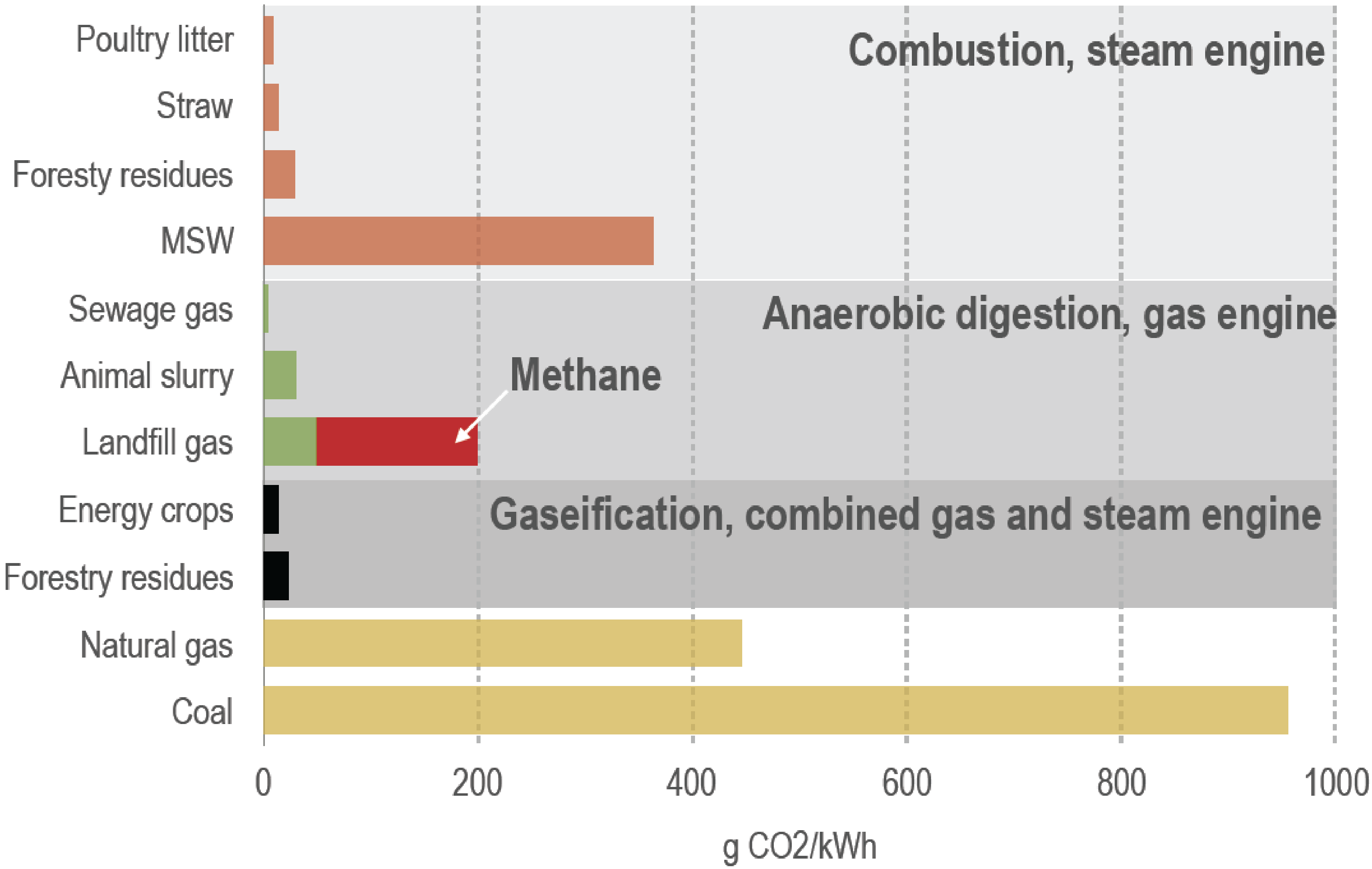
Thermochemical processing

Ciências
ULisboa

biomass processing

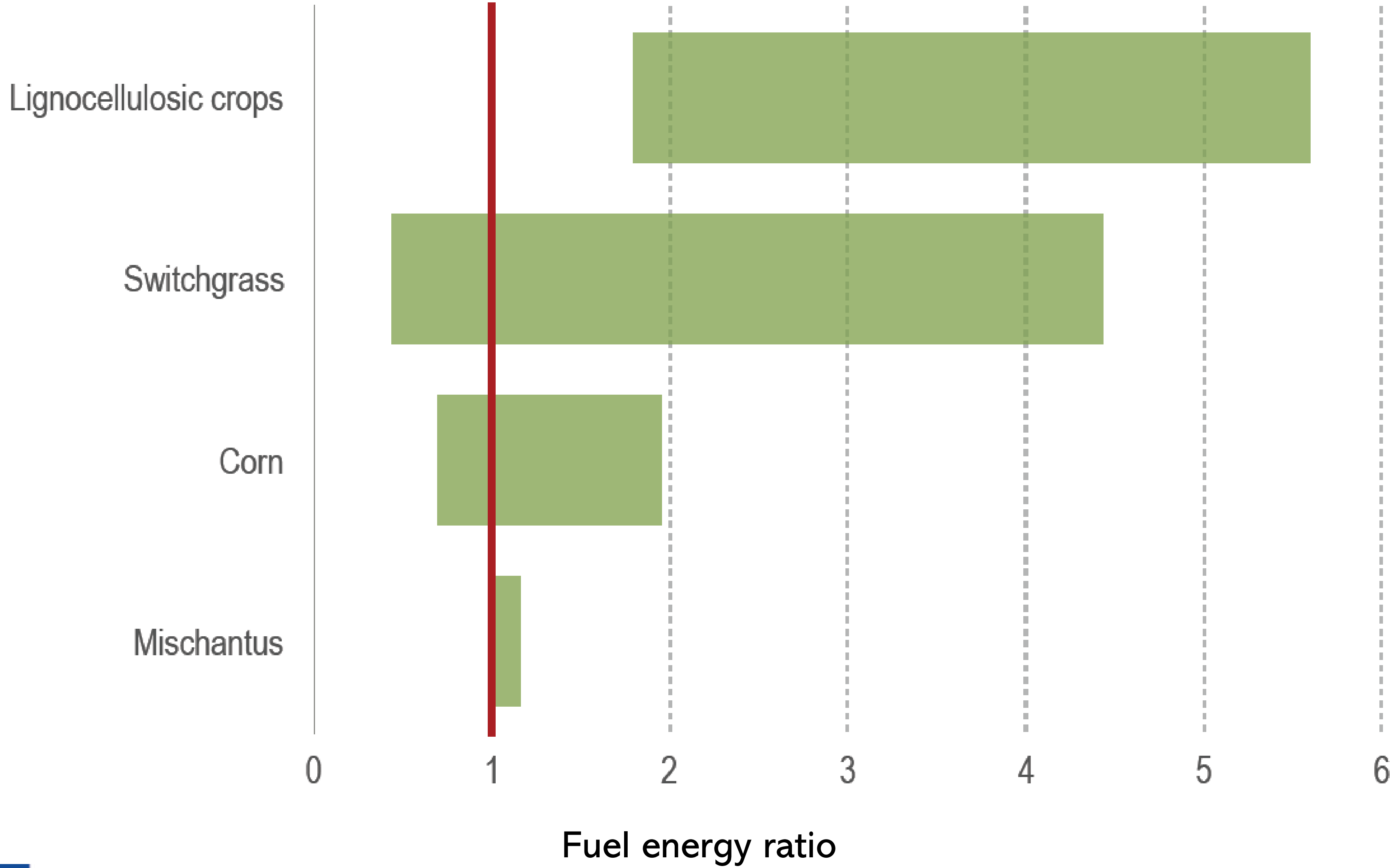


Biochemical processing



Ciências ULisboa

Source: Adapted from Boyle G. Renewable Energy, Power for a sustainable Future. Oxford University Press, 2012.



Source: Adapted from Boyle G. Renewable Energy, Power for a sustainable Future. Oxford University Press, 2012.

Environmental impacts

❑ Land and water use

❑ Food vs fuel competition

❑ Use of pesticides and herbicides

❑ Loss of biodiversity

❑ Decrease of soil fertility

❑ Emissions associated to deforestation

Strengths

❑ Biofuel storage

❑ Versatility

(heating, electricity, transport)

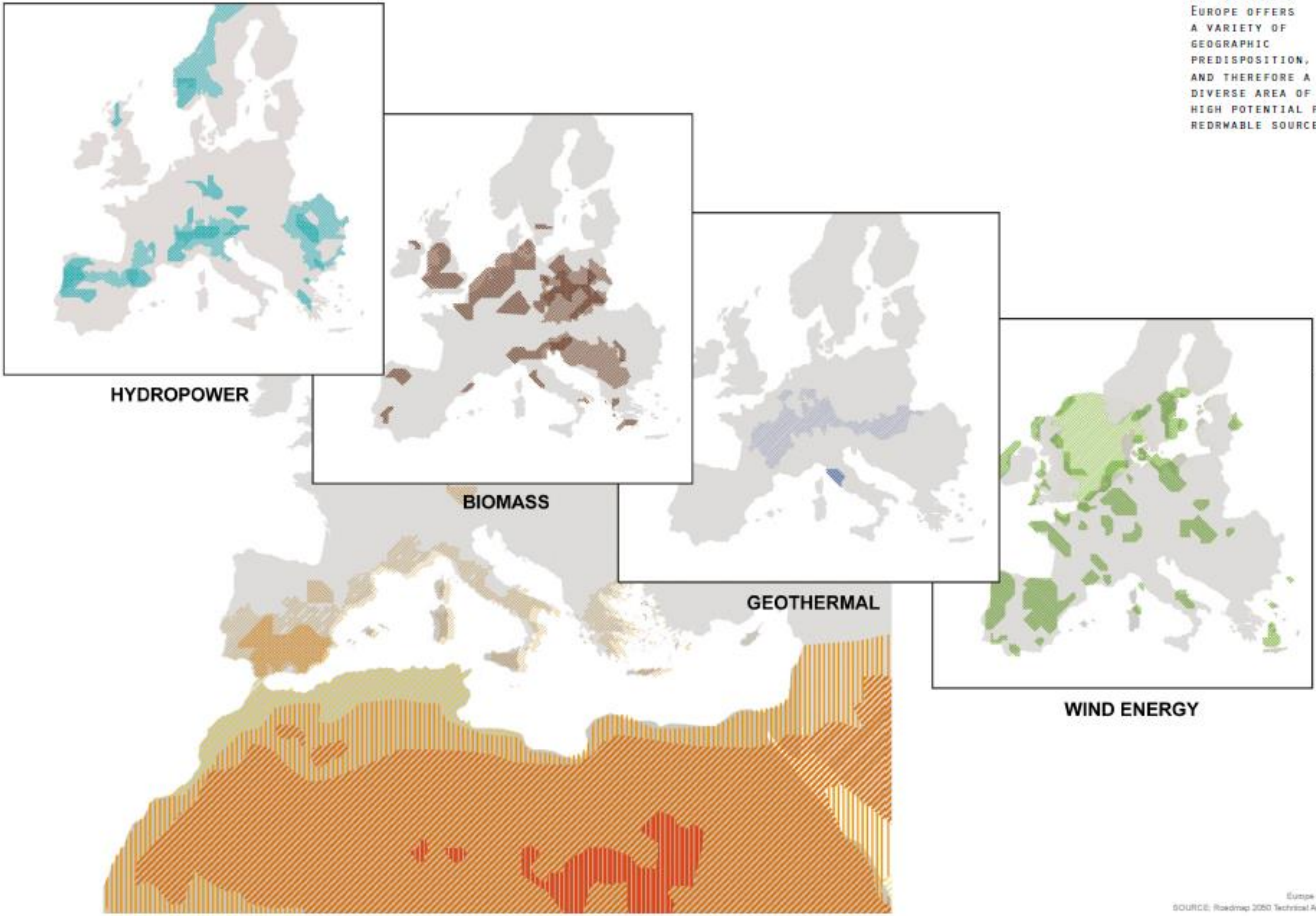
(Loss of Biodiversity, 2014)

What is
the best
renewable
energy?


NORTH HYDROPIA
ISLES OF WIND
TIDAL STATES
GEOTHERMALIA
C.C.S.R.
VRANIA
ENHANCED GEOTHERMALIA
CENTRAL HYDROPIA
EAST HYDROPIA
BIOMASSBURG
WEST HYDROPIA
SOLARIA
Boundaries:
Biomassburg
C.C.S.R. (Carbon Capture & Storage Republic)
Enhanced Geothermalia
Geothermalia
Hydropia
Isles of Wind
Solaria
Tidal States
Vrania
Map of
ENEROPA
Scale 1 : 20000000
Meridian of Greenwich

RENEWABLE ENERGY RESOURCE MAPPING

AN INTEGRATED
EUROPE OFFERS
A VARIETY OF
GEOGRAPHIC
PREDISPOSITION,
AND THEREFORE A
DIVERSE AREA OF
HIGH POTENTIAL FOR
REDRWABLE SOURCES.

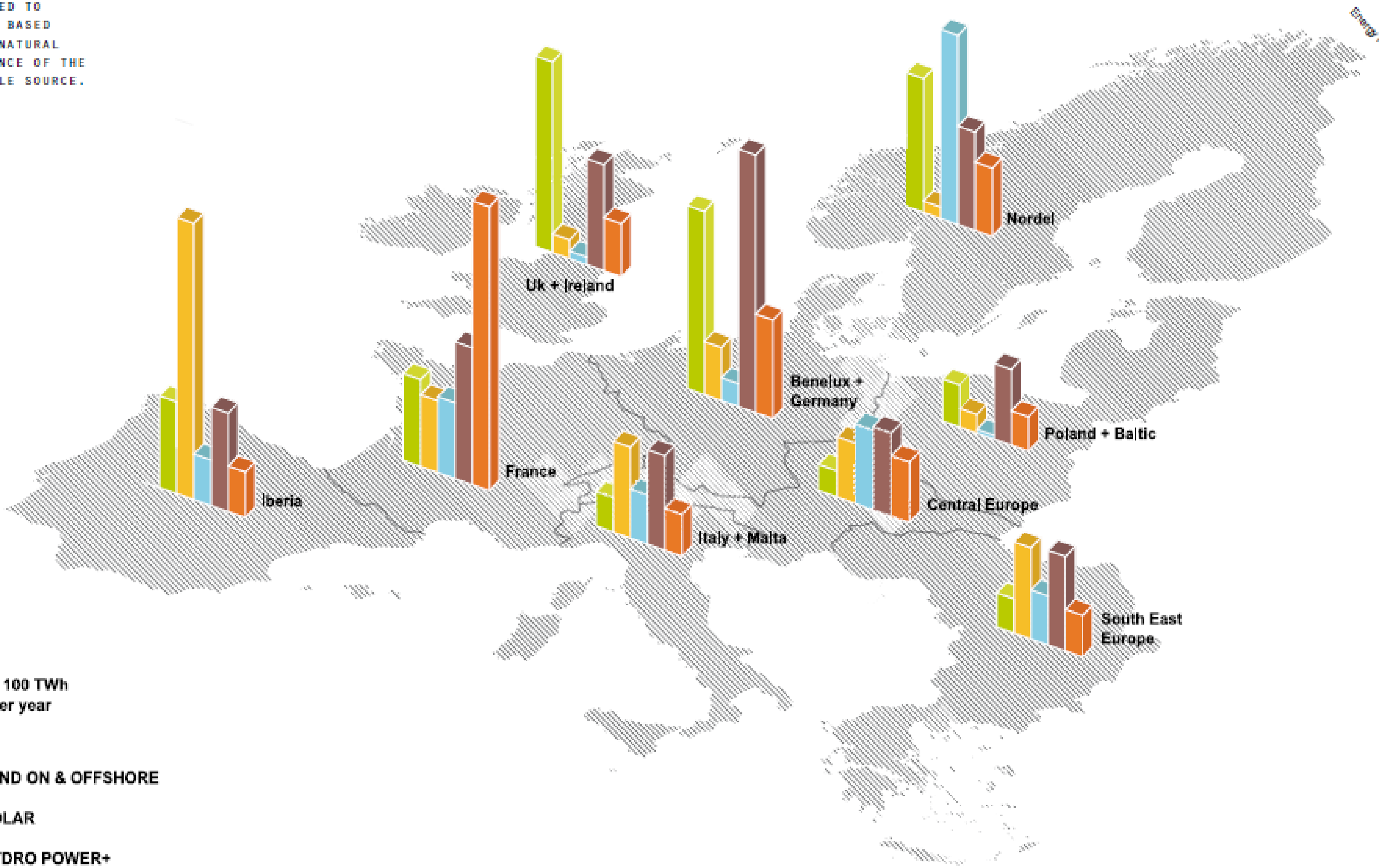


Forms of

Europe offers
SOURCE: Roadmap 2050 Technical Analysis

ENERGY RESOURCES IN 2050 (HIGH RES PATHWAY)

RENEWABLE TECHNOLOGIES ARE ALLOCATED TO REGIONS BASED ON THE NATURAL OCCURRENCE OF THE RENEWABLE SOURCE.



▯ = 100 TWh per year

🟩 WIND ON & OFFSHORE

🟨 SOLAR

🟦 HYDRO POWER+ GEOTHERMAL

🟫 CCS AND BIOMASS

🟧 NUCLEAR

BERGHEIM IN ENEROPA


Isles of Wind

SOLARIA

TIDAL STATES

BIOMASSBURG


HYDROPIA
Hydropia

THANK YOU

Miguel Centeno Brito