Power and gas from deserts as option for a global energy transition

Prof. Dr. Michael Düren, Univ. Gießen

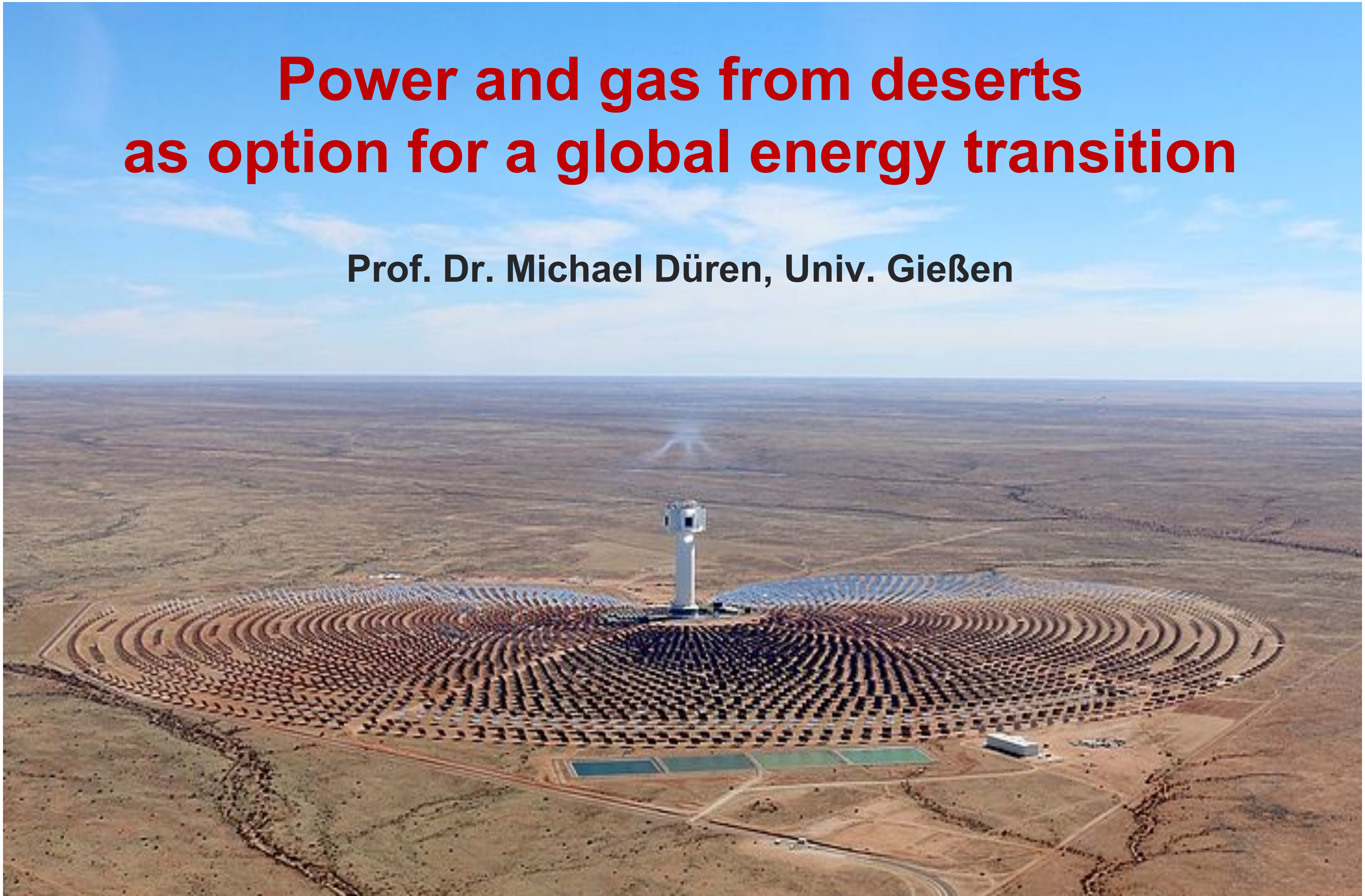

Photo: Hp.Baumeler via Wikimedia Commons

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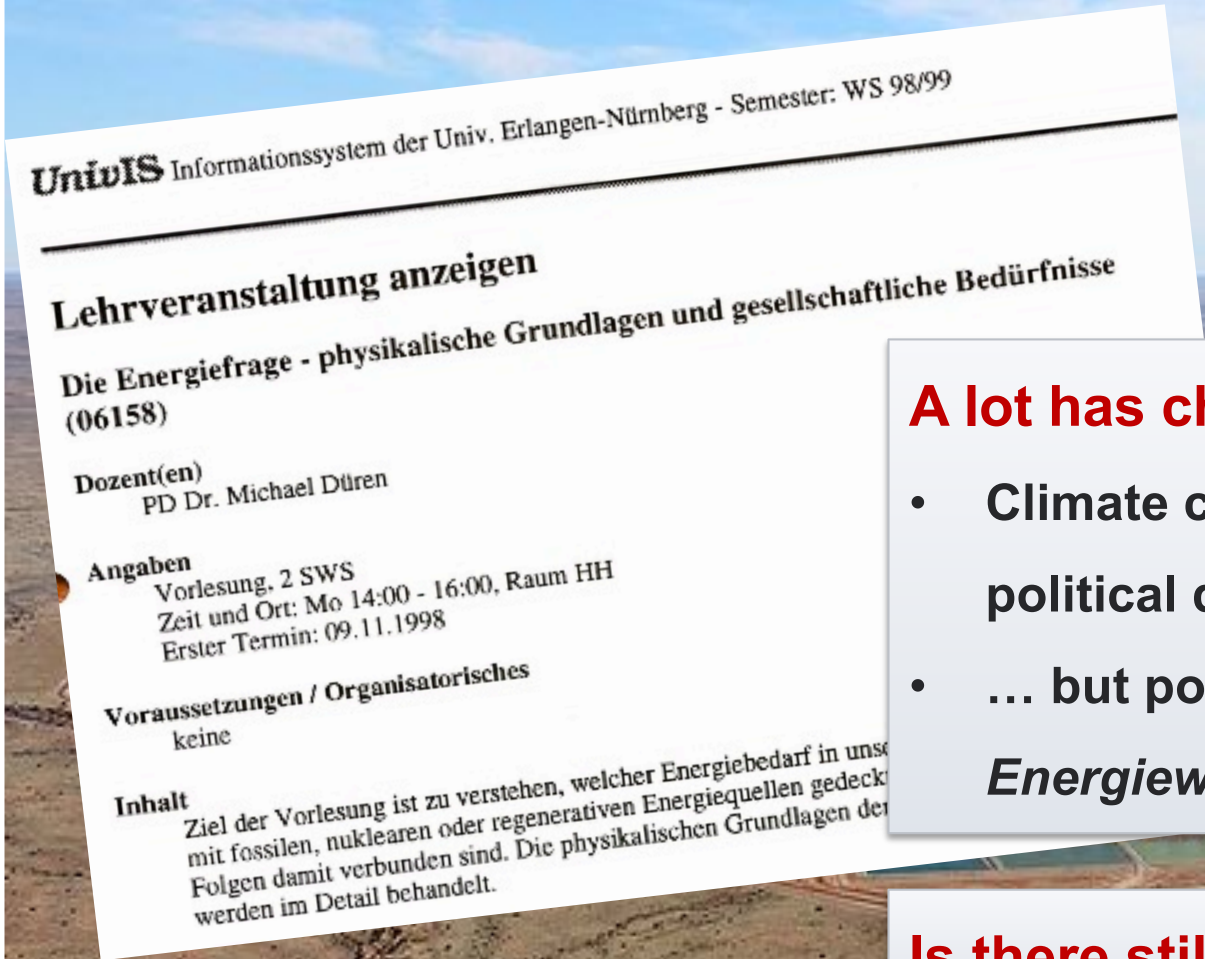
20 years ago, I gave my first lecture series about the “energy problem" at this university.


UnivIS Informationssystem der Univ. Erlangen-Nürnberg - Semester: WS 98/99

Lehrveranstaltung anzeigen

Die Energiefrage - physikalische Grundlagen und gesellschaftliche Bedürfnisse (06158)

Dozent(en)
PD Dr. Michael Düren

Angaben
Vorlesung, 2 SWS
Zeit und Ort: Mo 14:00 - 16:00, Raum HH
Erster Termin: 09.11.1998

Voraussetzungen / Organisatorisches
keine

Inhalt
Ziel der Vorlesung ist zu verstehen, welcher Energiebedarf in uns
mit fossilen, nuklearen oder regenerativen Energiequellen gedeck
Folgen damit verbunden sind. Die physikalischen Grundlagen de
werden im Detail behandelt.

A lot has changed since then!

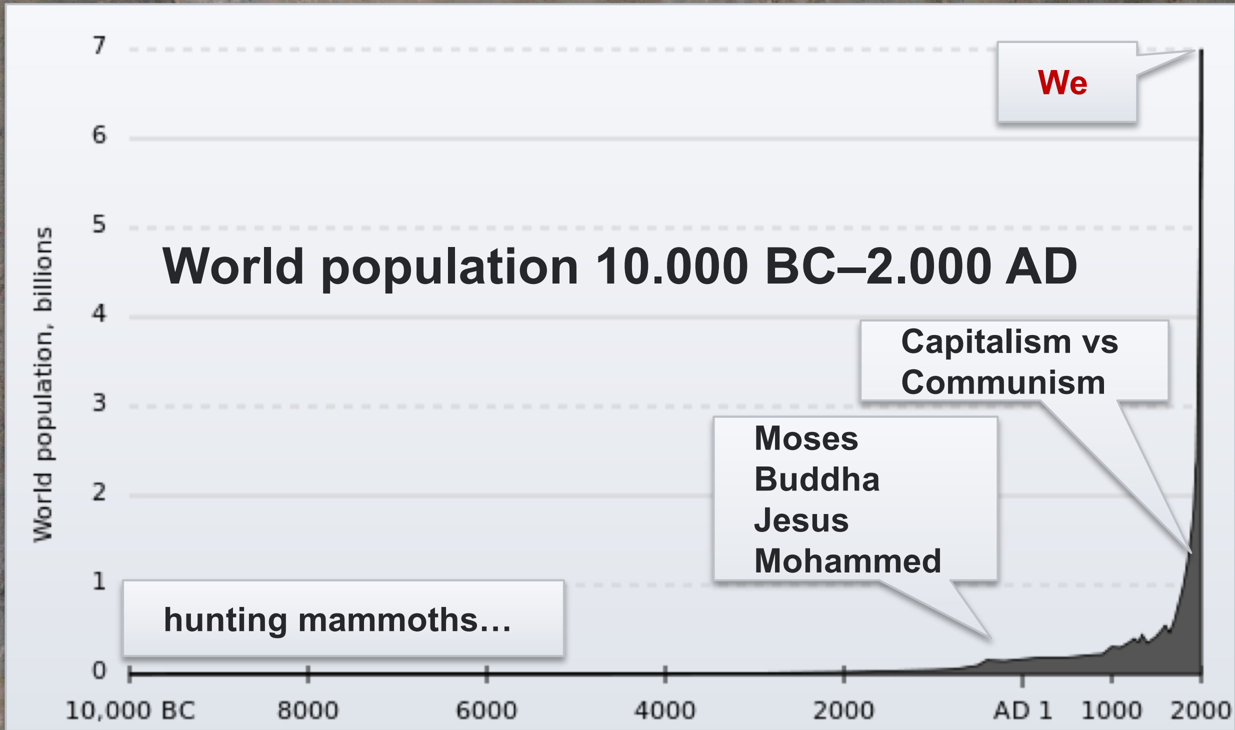
- Climate change is omnipresent in political discussions
- … but politics is still not able to plan the *Energiewende* in a global, strategic way

Is there still time for business as usual?

Problem #1
Rise of world population

Foto: Hiery/Ante

Problem #1
Rise of world population



<u>It cannot continue this way:</u>

Poverty (and other cultural factors) have to be changed to reduce population growth

→ requires water, food & energy

Demographic-economic Paradox

Problem #2
Rising energy use

The (anatomically) modern human successfully used a 100% renewable energy system for 200 000 years

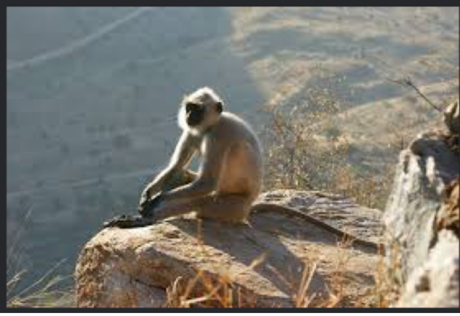
Bio mass

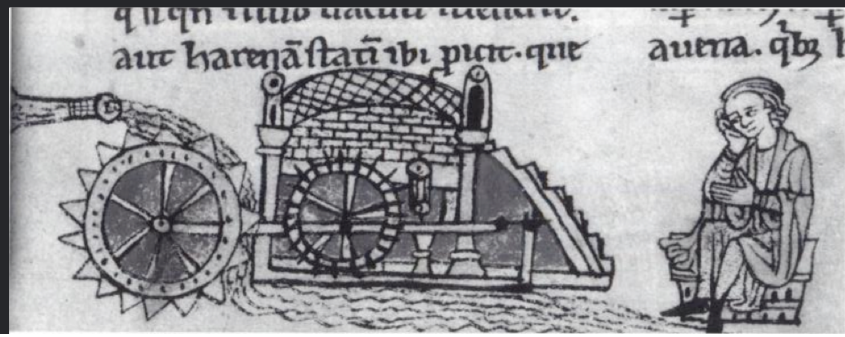
Solar Power
(heat, light)

Wind

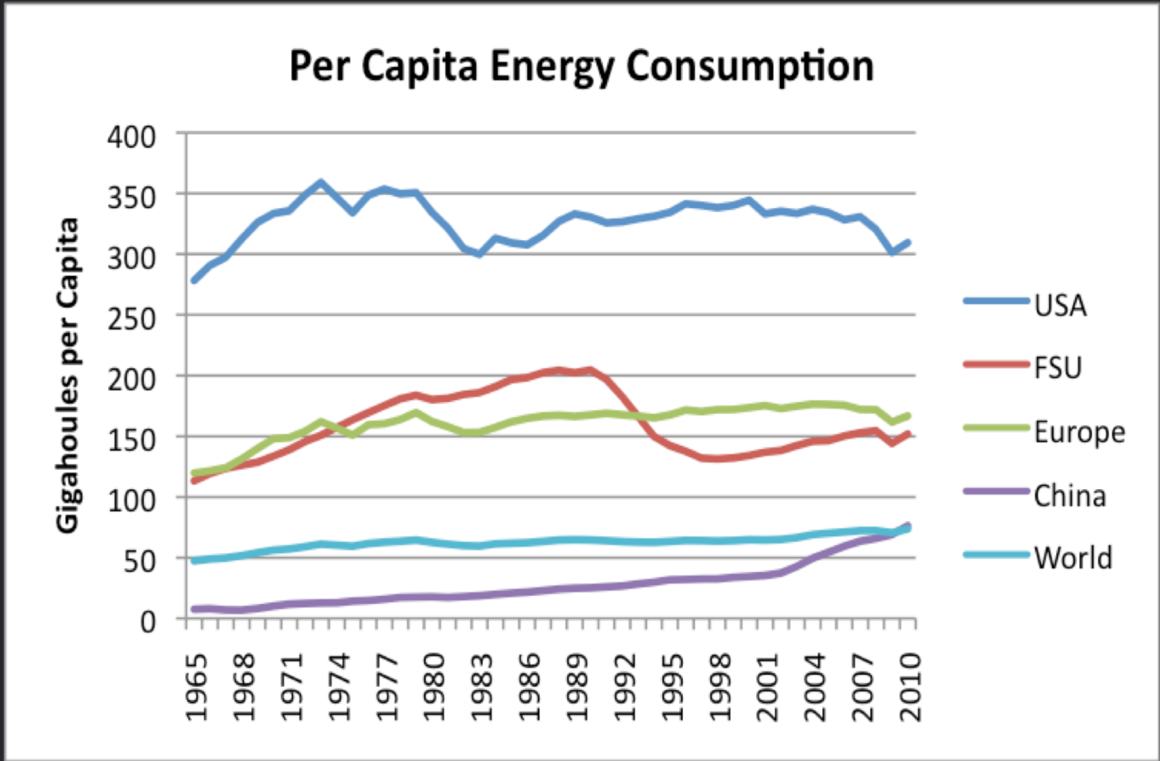
Geothermal

Water





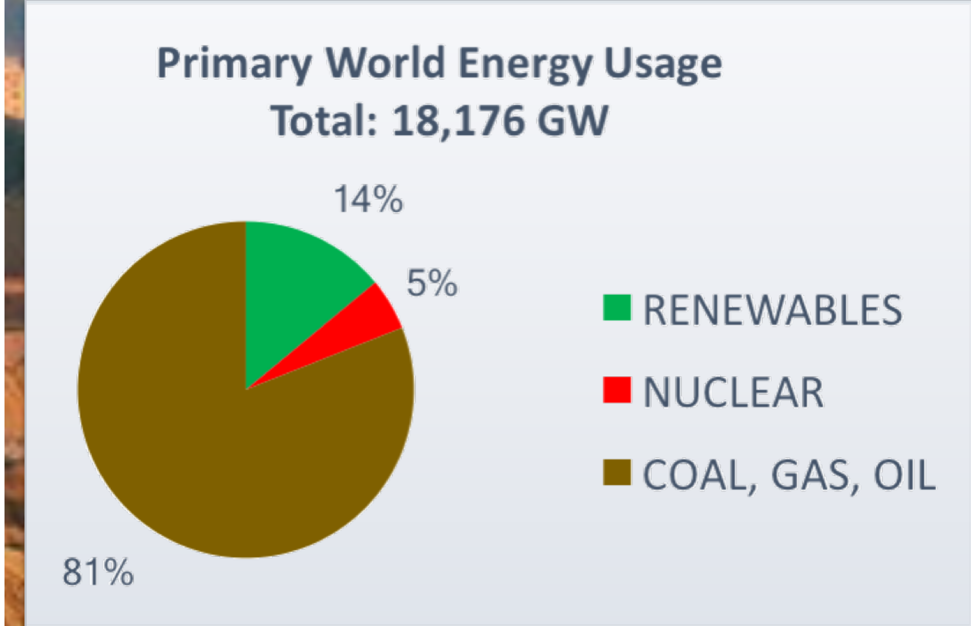
Problem #2
Rising energy use



per capita:

- Europe: 2 x world average
- USA: 4 x world average
- ~ constant in time
- rising in China, India, …
- world average:
  75 GJ/y = 2.5 kW
  = power of 1 boiling device

Rising energy consumption



- **Today's world energy usage corresponds to 18,000 nuclear power plants**
- **About 81% is fossil (35 Gt/y CO_2)**
- **Nuclear power is negligible (1,5%, nominally 5%)**

1 GW = power of 1 nuclear reactor
18 000 GW = 160 000 TWh/year
18 000 GW / 7.5 billion people $= 2.4$ kW per person

Problem #3
climate change

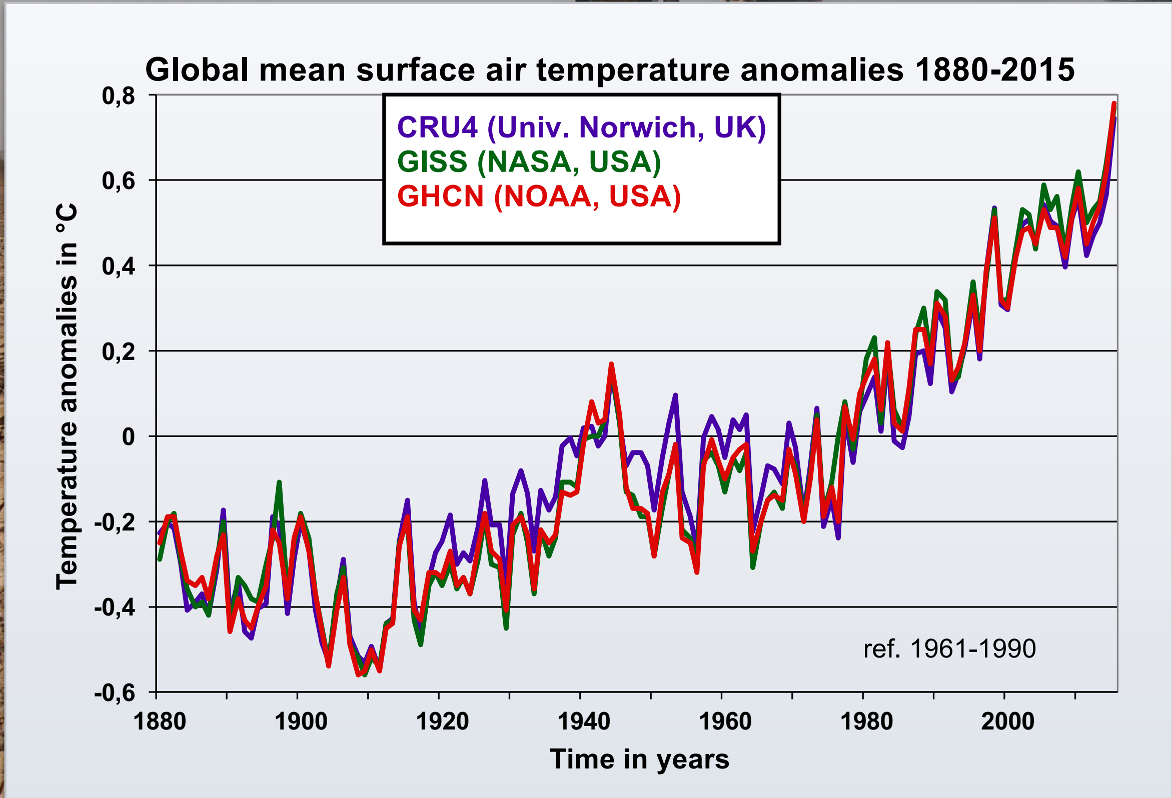


Foto: Hiery/Ante

Problem #3
climate change

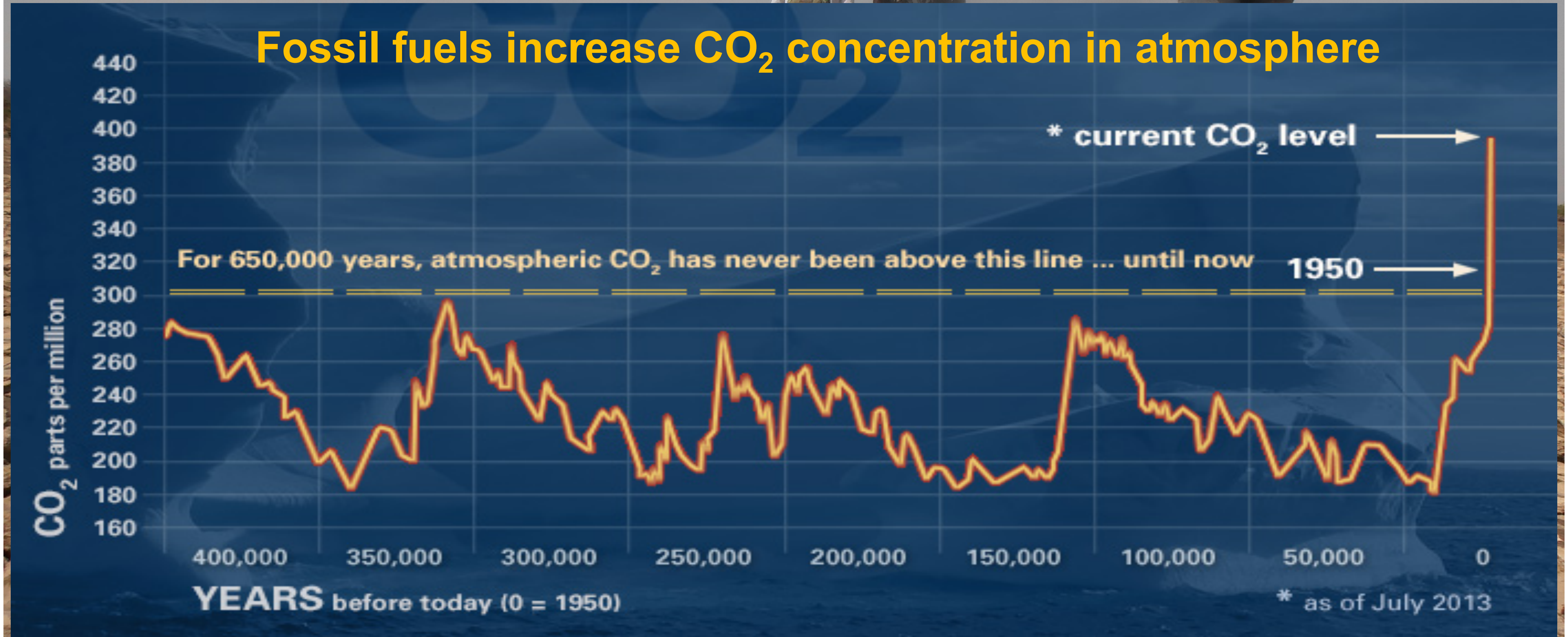
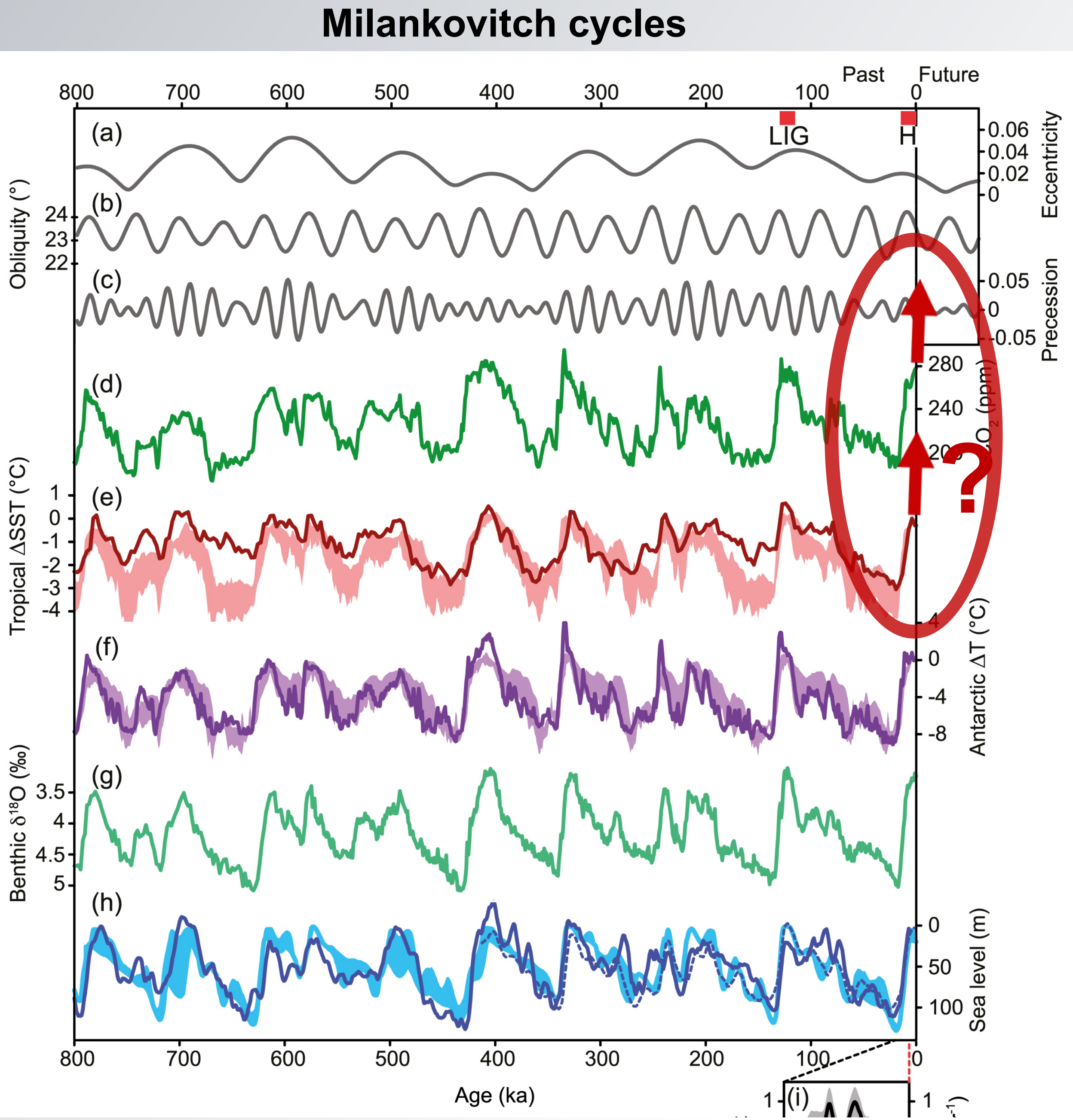


Foto: Hiery/Ante

The Scaring Self-Amplification of Climate Change



- Global temperature is in phase with, but not proportional to solar forcing. (time inversion symmetry!)
- Instead, increased solar irradiation is a trigger for a fast, self-amplified temperature jump.
- Global system needs typically 50,000 years to go back to "ground level"!
- Anthropogenic CO_2-boost may be a "super-trigger" to generate a new great temperature boost.

The earth system is a strongly coupled system!

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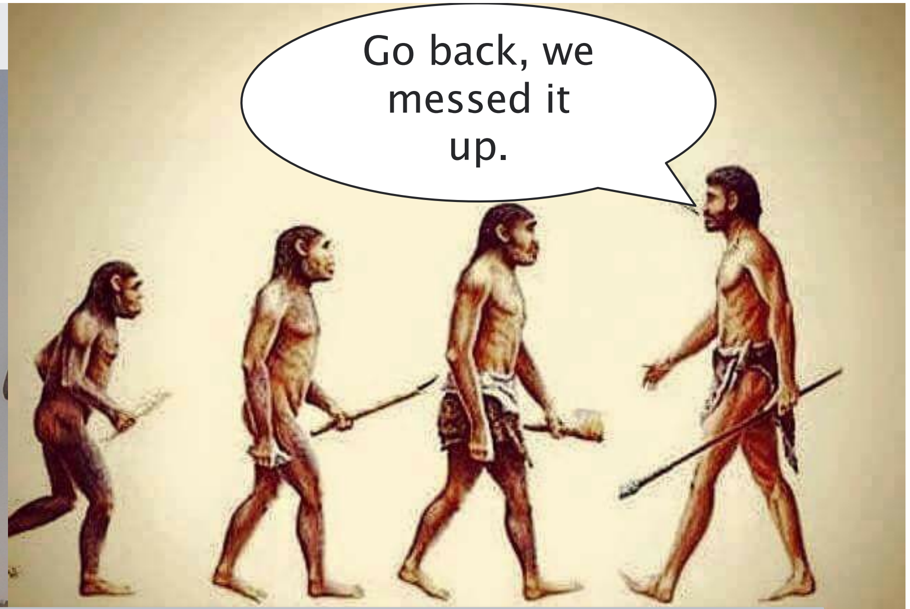
The only solution: energy transition



Extraordinary challenges to the future energy system:

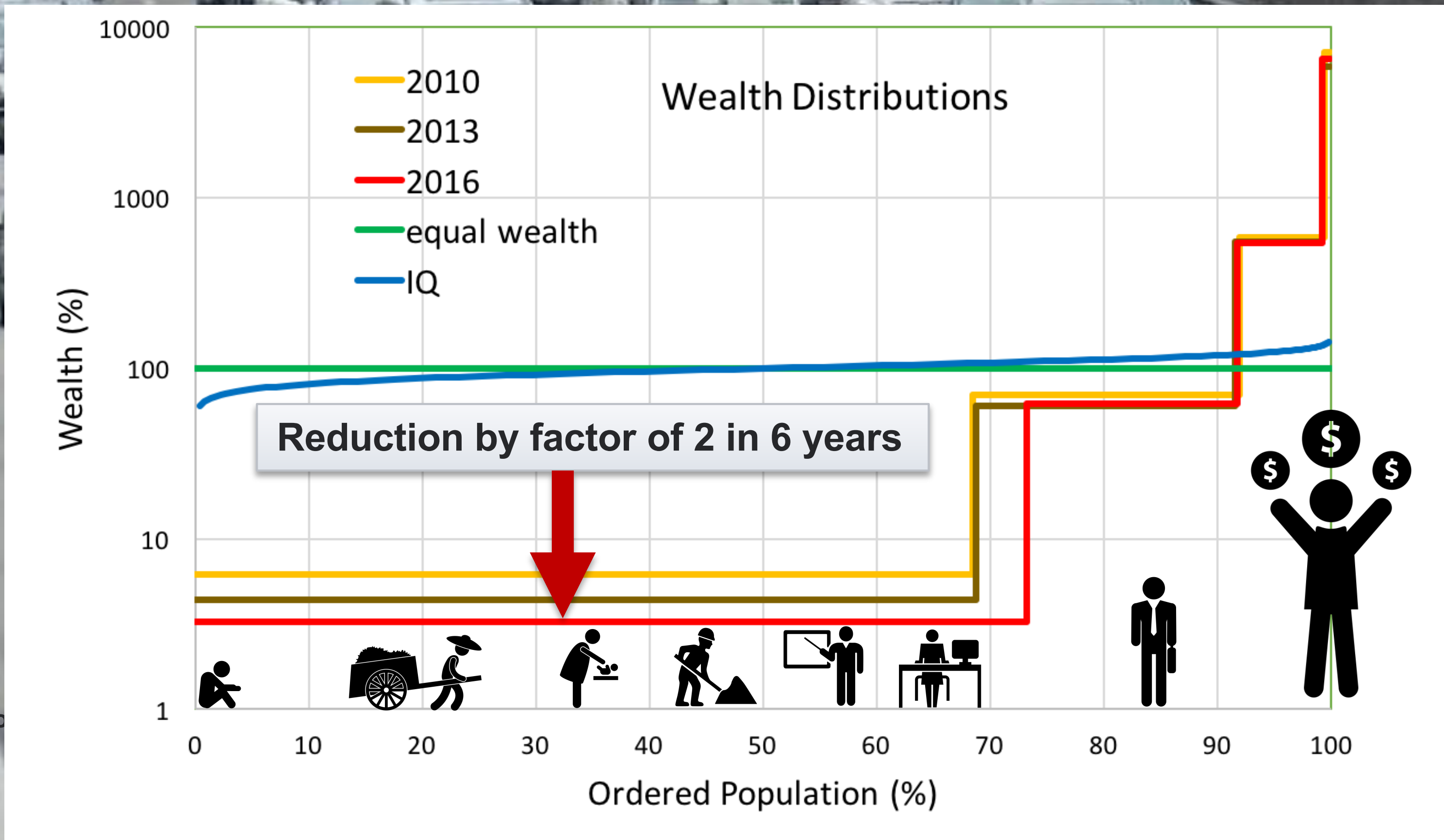
- Simple (human resources)
- Safe ⟷
- Infinite (renewable)
- ~~Cost-efficient~~ Viable (know-how + resources + jobs)

"money is relative"

Main rule:
do not use technologies that create more problems than they solve! (nuclear energy: terrorism and proliferation; fracking, CCS, …)

Problem #4
„Financial capitalism“

The global energy transition is a non-trivial challenge to the intelligence and ethics of the human species.
Is our economic system suitable for solving this problem?



Very few people control most of the „wealth“

The impact of 2/3 of the population is marginalized!

Transport of coal in the Gobi Desert: There are better ways to make use of deserts!

Mongolei

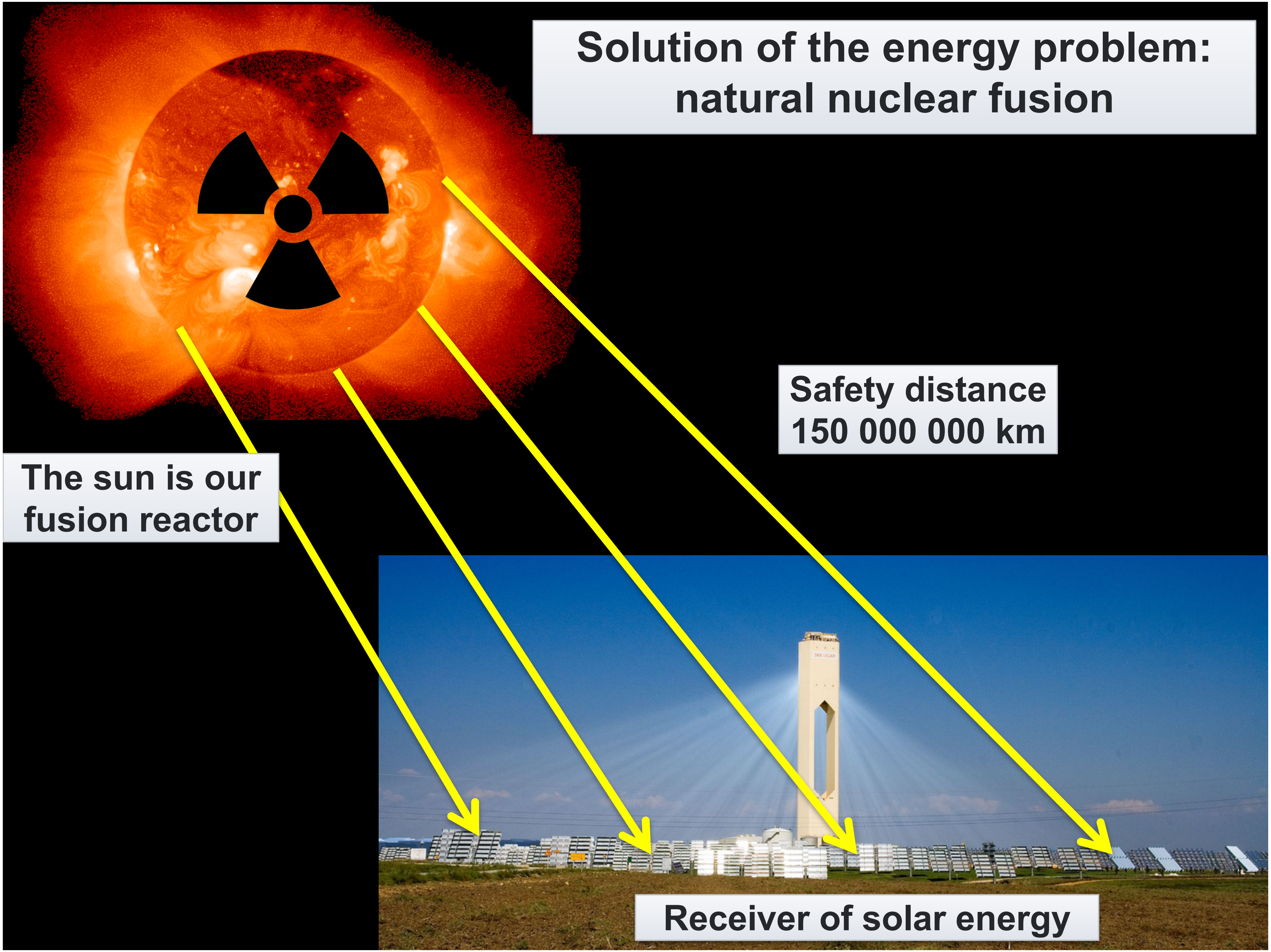
15. November 2017 14:06 Uhr

130 Kilometer - Das ist der wohl längste Stau der Welt

In der Wüste Gobi stauen sich Tausende LKW auf einer Länge von 130 Kilometern. Grund dafür ist das boomende Kohle-Geschäft zwischen der Mongolei und China. Doch nicht alle sind auf den Boom vorbereitet.

Drucken

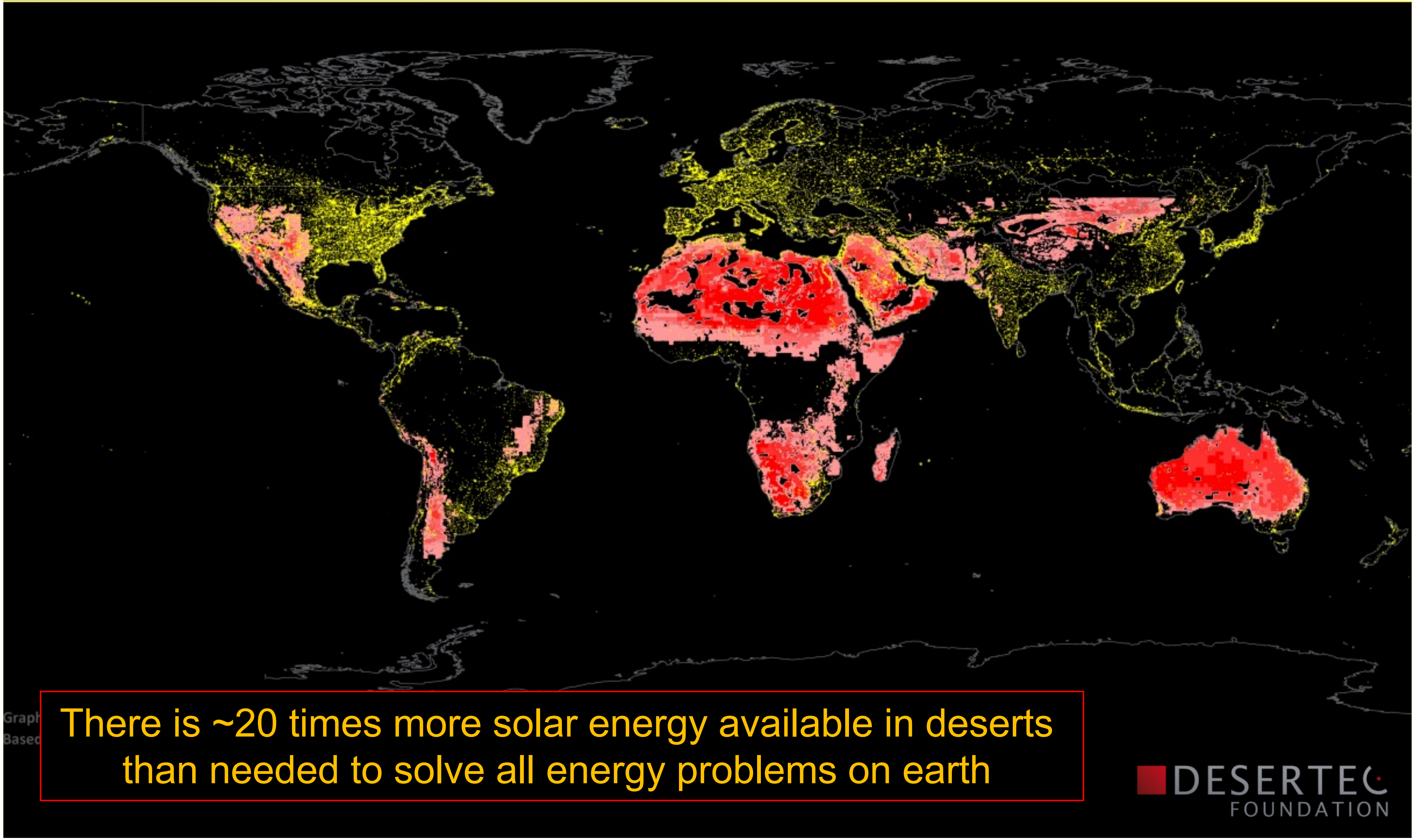
Stau in der Gegenrichtung - Diese LKW-Fahrer in der Mongolei müssen gute Nerven haben. Die Strecke durch die Wüste Gobi in Richtung China ist komplett verstopft. Auf 130 Kilometern stauen sich hier Tausende Kohlelaster. Das Geschäft mit dem begehr mehr...


Solution of the energy problem:
natural nuclear fusion
Safety distance
150 000 000 km
The sun is our
fusion reactor
Receiver of solar energy

There is abundant solar irradiation in deserts

Solar energy potential: ~340 000 GW_{el}

(all year average; day & night average, current technology, 4.5% land use factor)

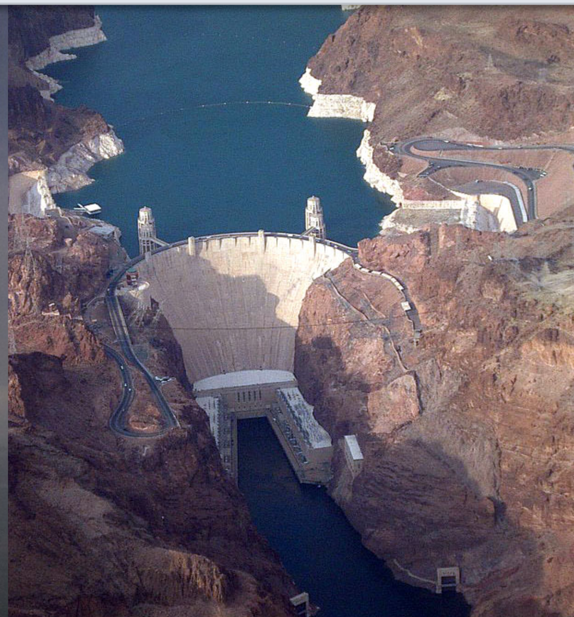


There is ~20 times more solar energy available in deserts than needed to solve all energy problems on earth

DESERTEC FOUNDATION

Technologies of choice:

- Mix of PV, wind power, solar thermal power, hydro, biomass, ...



Technologies of choice:

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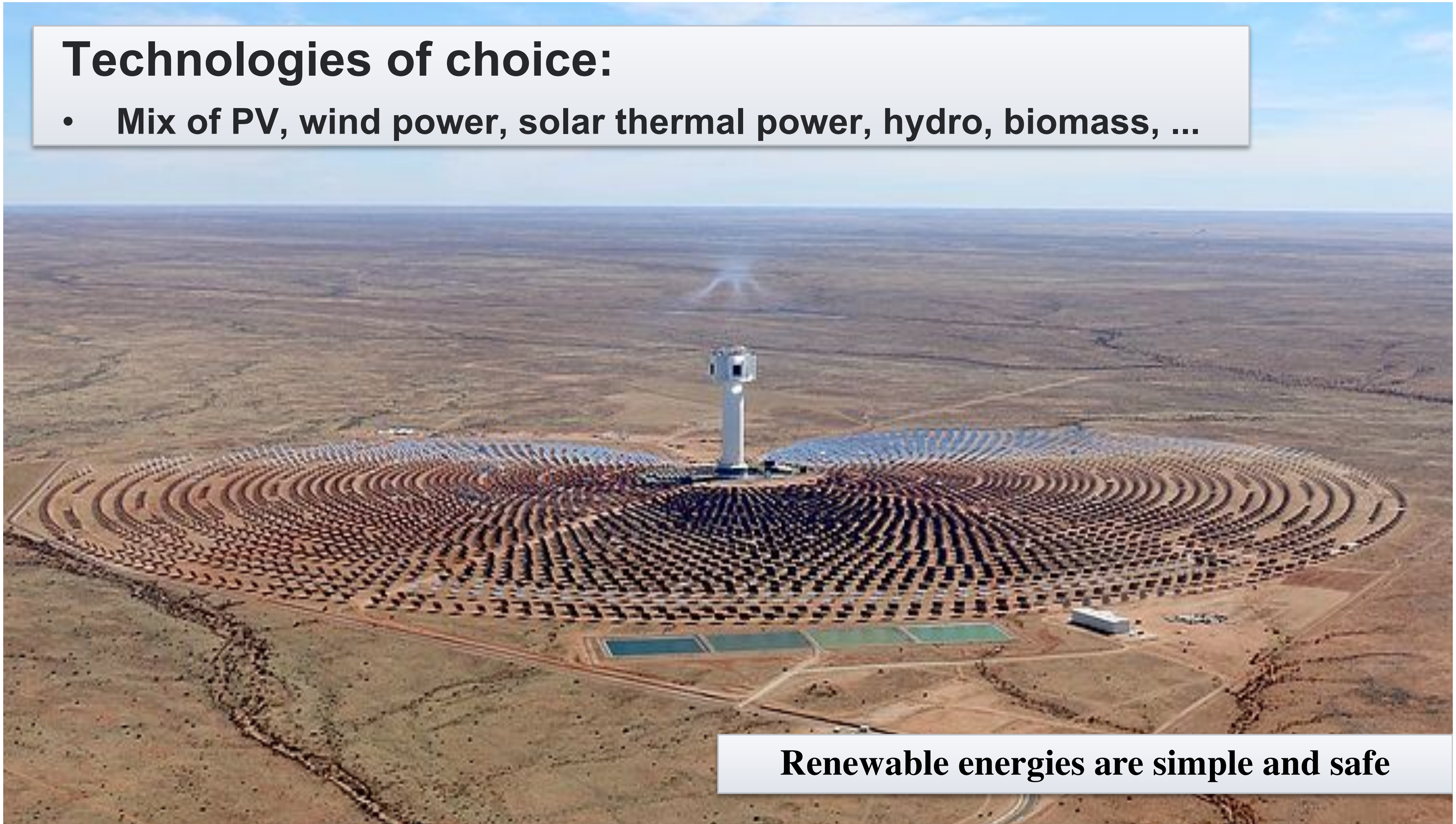

Renewable energies are simple and safe

Example:

- Solar tower with heat storage for power day and night
- Technology with a **high level of local value**
- **Future option: production of H_2, gaseous and liquid fuels?**

(Khi Solar One, South Africa)

Find the OPTIMUM Renewable Energy System

Energy production → Best sites and/or local

↓

Energy transport

↓

Energy storage

↓

Energy consumption

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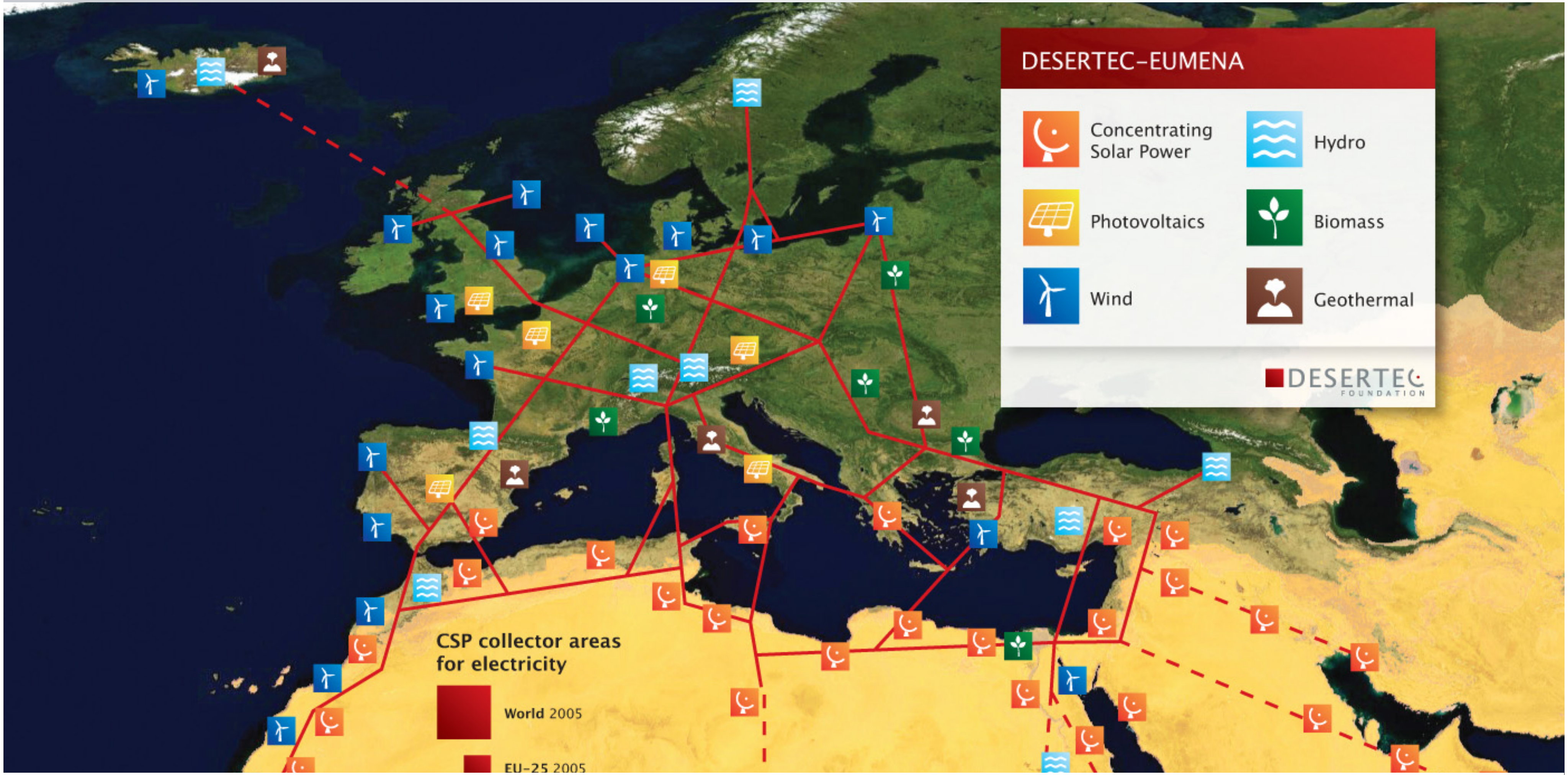
DESERTEC Concept: Produce renewables where the production is most cost effective

2008



Any technology (wind at coast; solar in deserts; large scale installations)
HVDC grid: to connect consumer and producer
& to average out fluctuations of producer and consumer

Political processes between European and North African countries are difficult today…

Nov. 2016

JOINT DECLARATION

on the establishment of a

Roadmap for Sustainable Electricity Trade

Between Morocco and the European Internal Energy Market

between

The Federal Republic of Germany

The French Republic

The Kingdom of Spain

The Portuguese Republic

and

The Kingdom of Morocco

This Joint Declaration has been executed at Marrakech during COP22 on the 17th November 2016 written in seven (7) originals.

The Federal Republic of Germany

Signed by Mr. Rainer Baake

State Secretary at the Federal Ministry for Economic Affairs and Energy

The French Republic

Signed by Ms. Ségolène Royal

Minister of Environment, Energy and the Sea, responsible for international relations on climate

The Kingdom of Spain

Signed by Mr. Álvaro Nadal

Minister of Energy, Tourism and Digital Agenda

The Portuguese Republic

Signed by Mr. Jorge Seguro Sanches

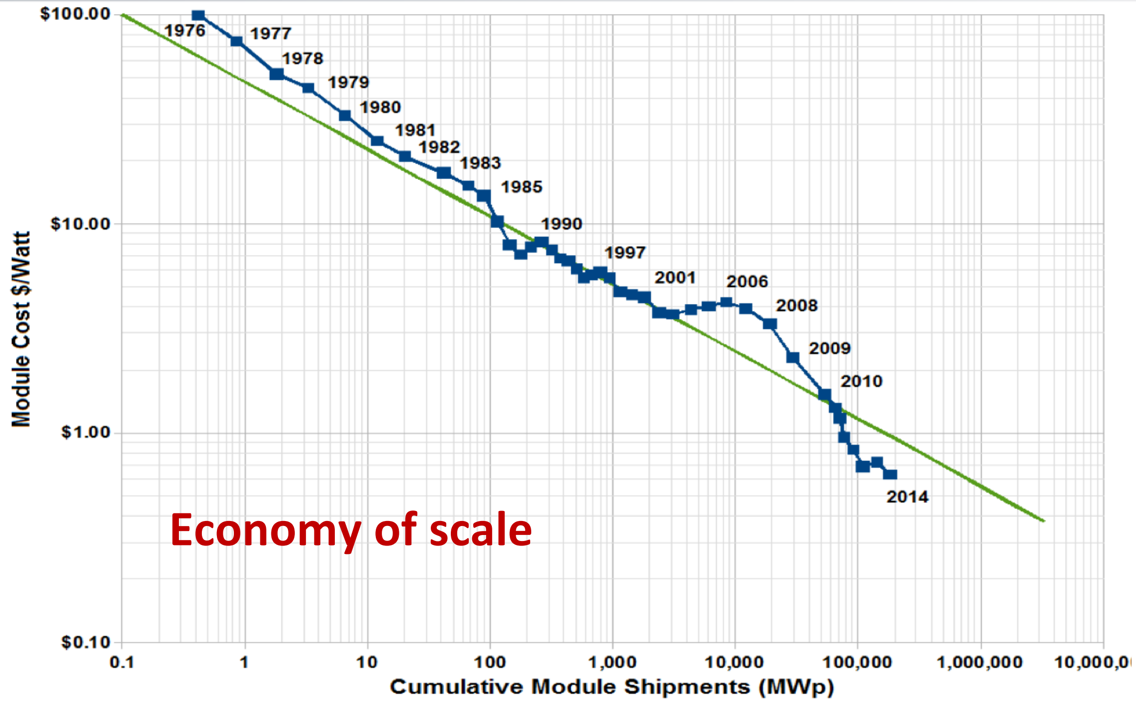
Secretary of State for Energy

The Kingdom of Morocco

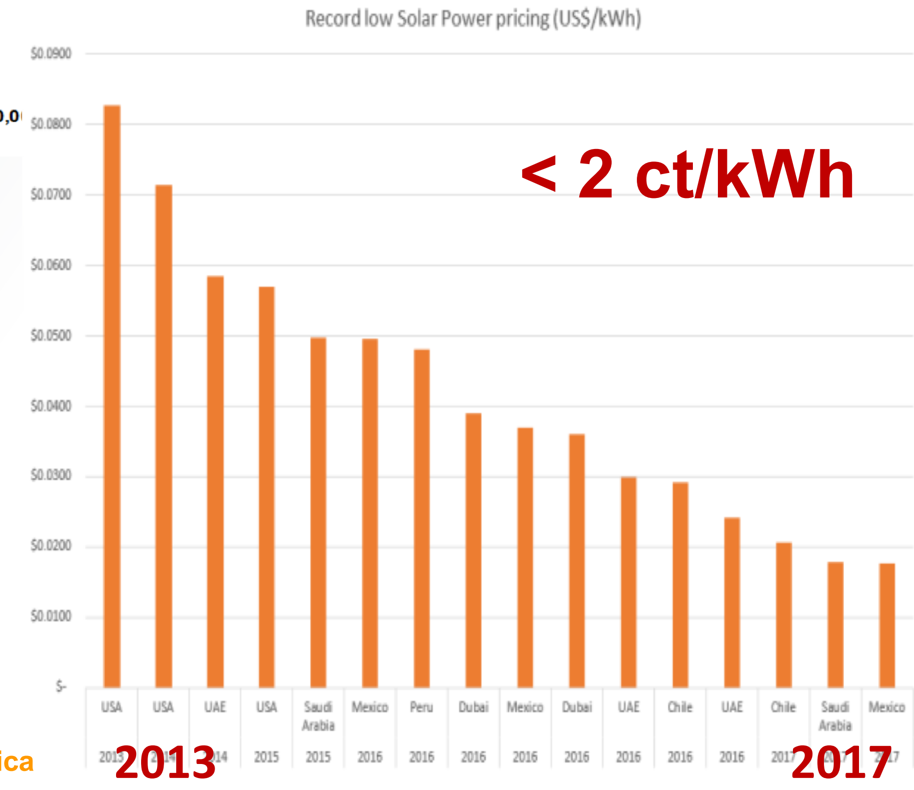
Signed by Mr. Moulay Hafid El Alami

Minister of Industry, Trade, Investment and the Digital Economy *and* Acting Minister of Energy, Mines, Water and Environment

Power generation: Cost of PV

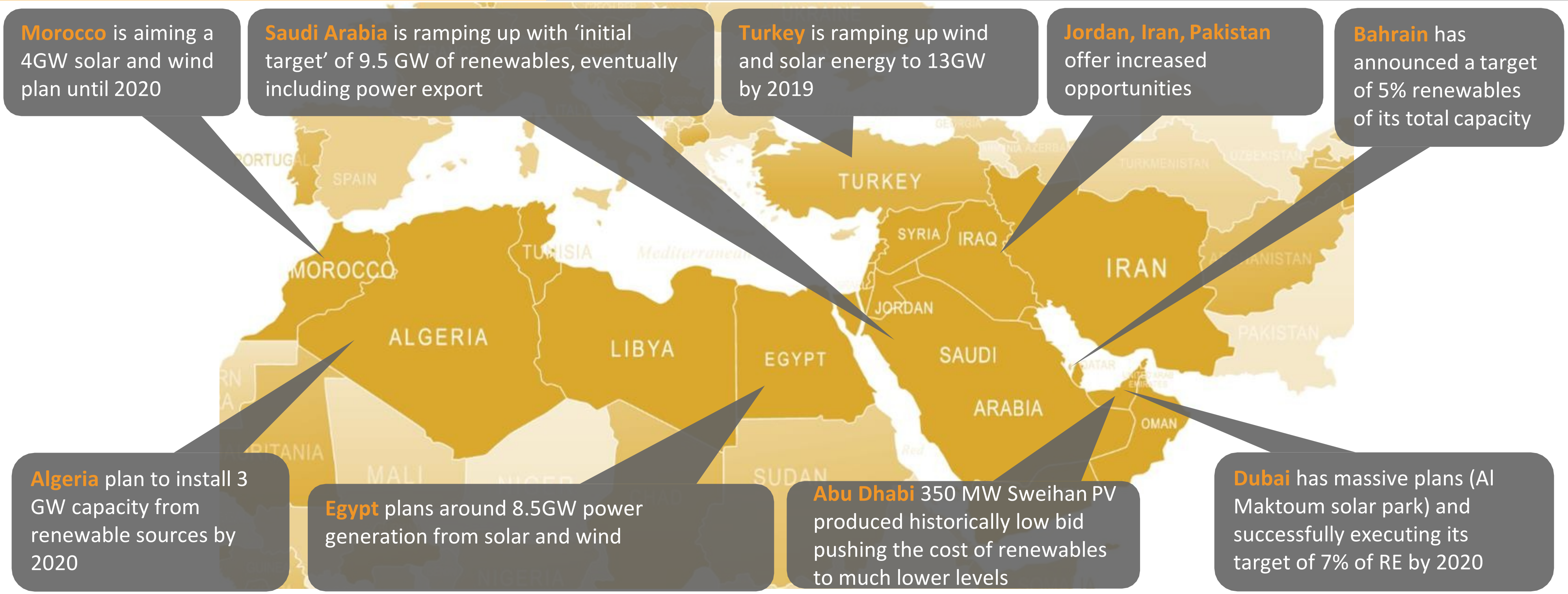


Solar Power pricing



Source: Clean Technica

Today most MENAT countries heading for renewables; 9.2 GW RE in operation

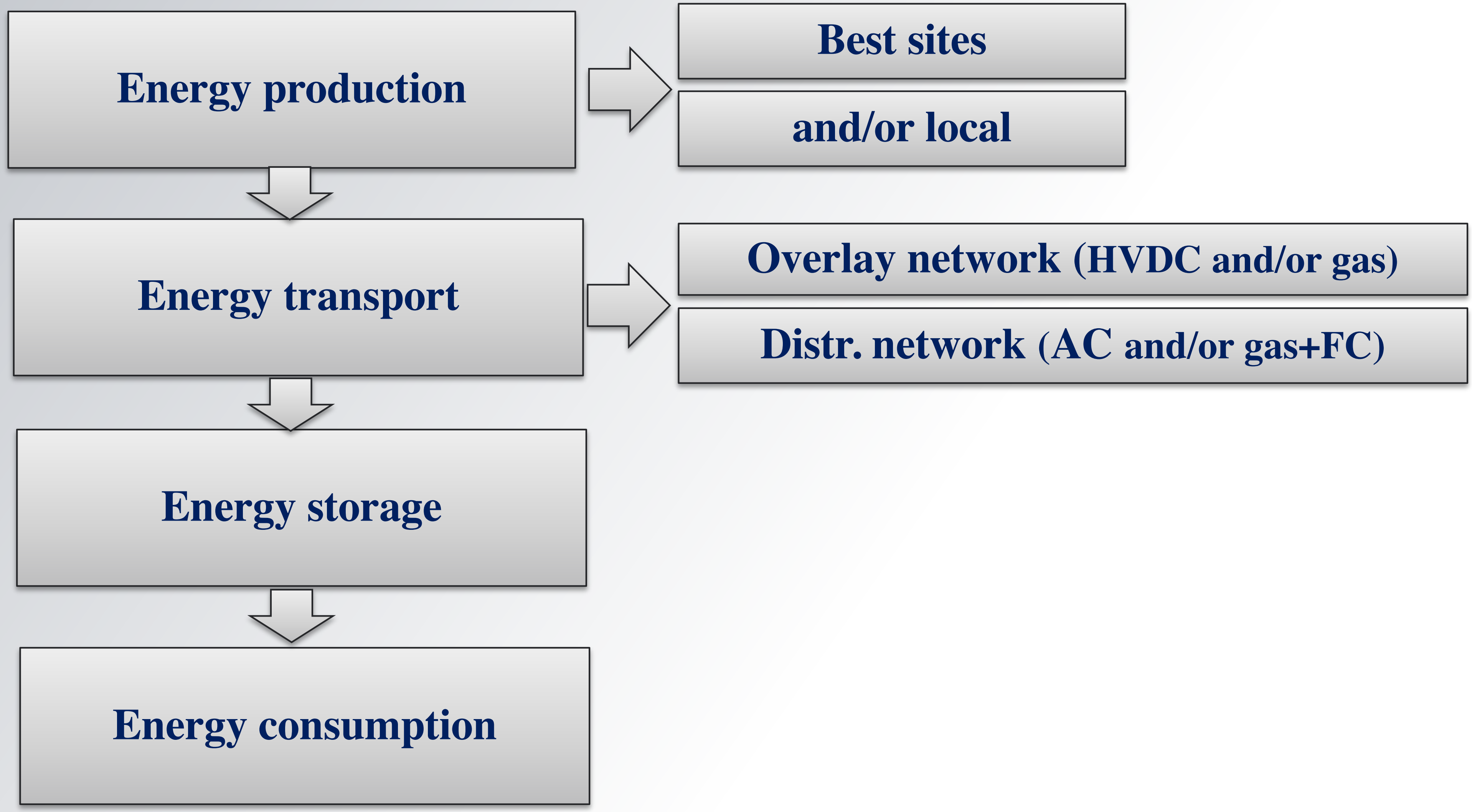


9.2 GW includes all solar and on-shore wind installations in the MENAT region

<u>Current Aspects of Dii:</u>

- **MENA will quickly improve and become less emitting and very cheap**
- **in future cases of grid connections to Europe and/or hydrogen transport.**
- **a cable connection to India is under study (State Grid of China and GCCIA)**
- **the role of storage (cooling, heat, power) in the value chain**
- **PV based desalination**
- **the role of modern cities in the power value chain**

Find the OPTIMUM Renewable Energy System



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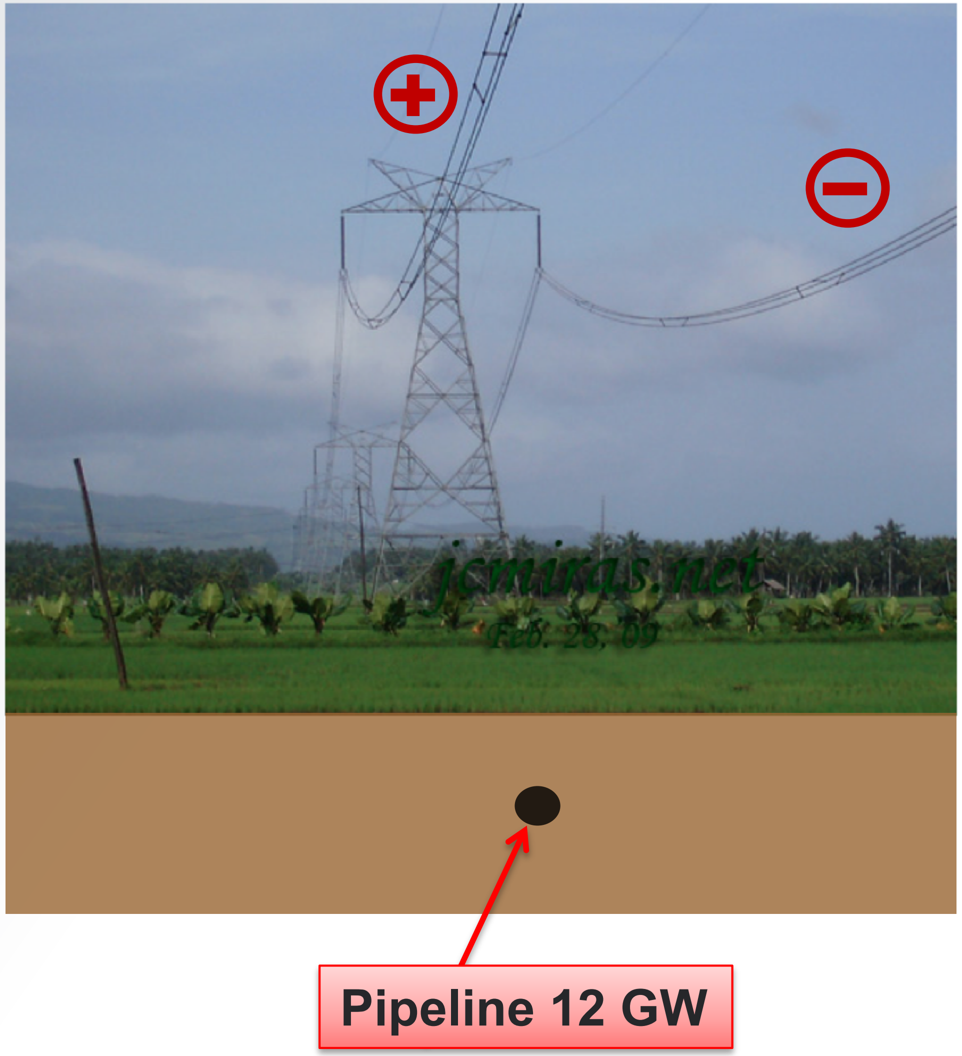
Energy exchange network “Overlay grid”

HVDC grid:

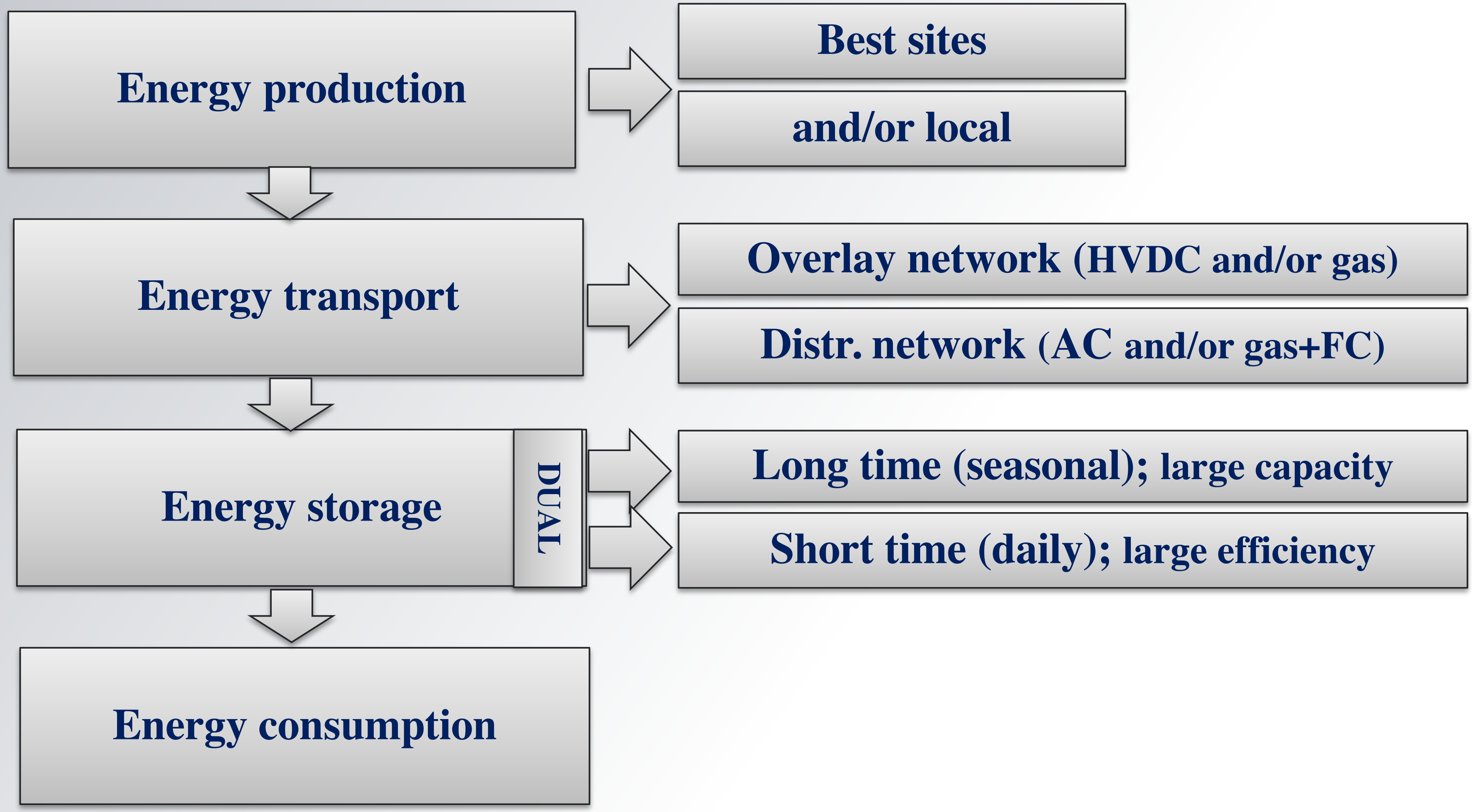
- Cheap: <1 ct/kWh / 1000 km (cheaper than storage)
- Efficient: <3.5% loss / 1000 km
- Useful: average out intermittency generated by weather conditions (required size: >1000 x 1000 km^2)

Alternative: **Gas grid:**

- ~5x cheaper; existing infrastructure
- no environmental impact
- **But** larger losses @ conversion to electrical power (e.g. fuel cells)



Find the OPTIMUM Renewable Energy System



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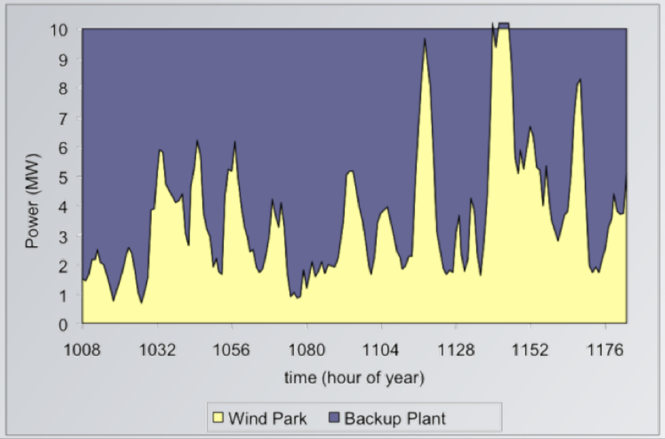
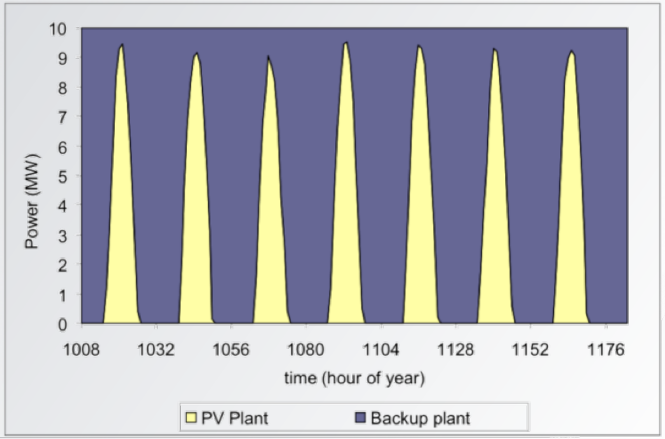
How to handle intermittency of renewables?

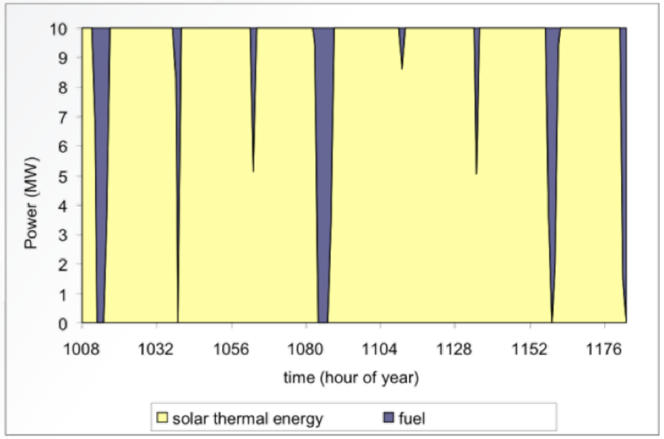
Wind



PV



CSP



- Overlay grid for averaging out production and consumption

- Short-term storage (daily cycles) with high efficiency: batteries, pump storage, CSP heat storage

- Long-term storage (few cycles per year) with large capacity: H_2, synthetic gaseous or liquid fuels, biofuels, solid biomass
  - Intermediate option: natural gas

Dual storage concept!

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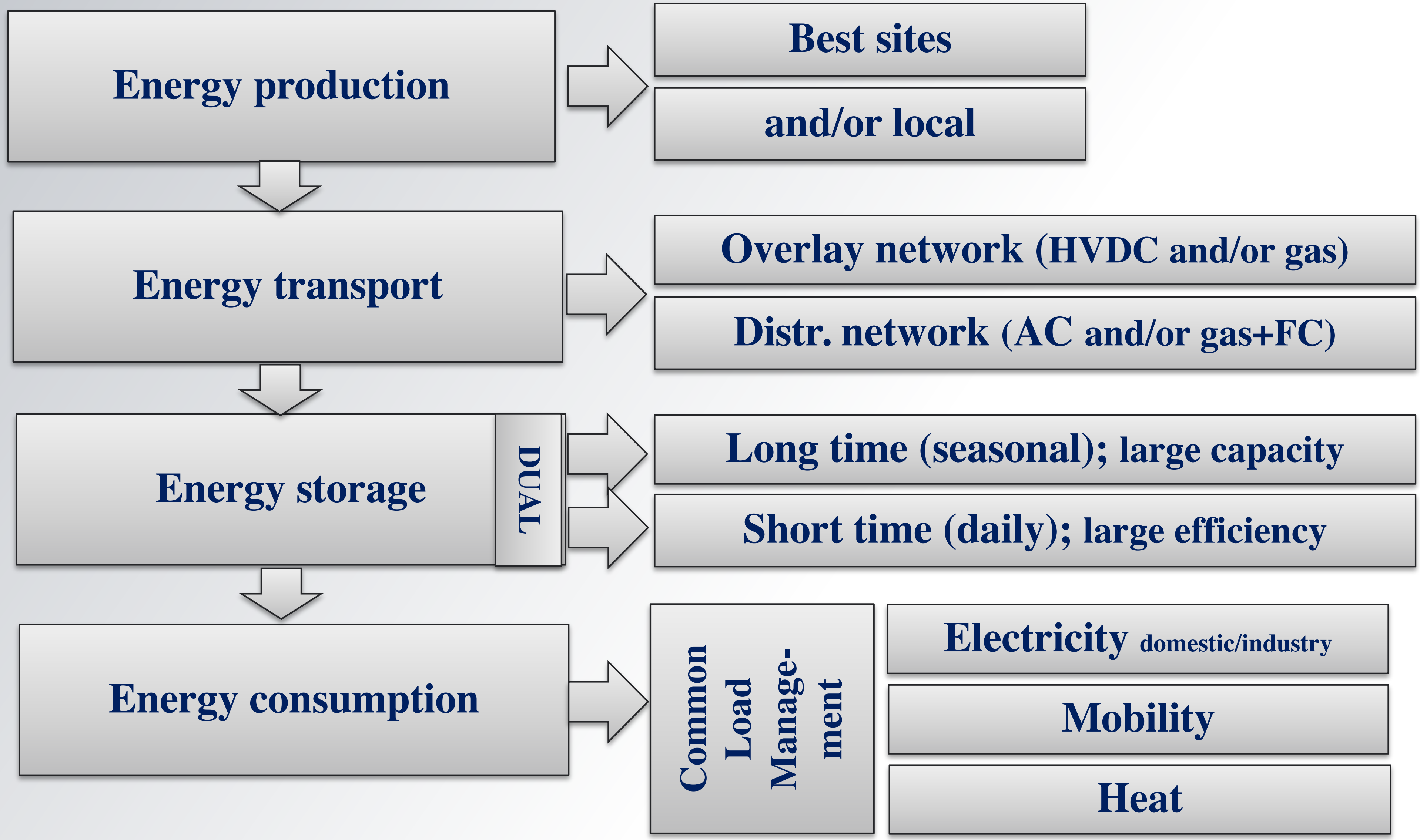
The long-term storage serves also as strategic reserve and as backup power for failures or blackouts

How to handle intermittency of renewables?

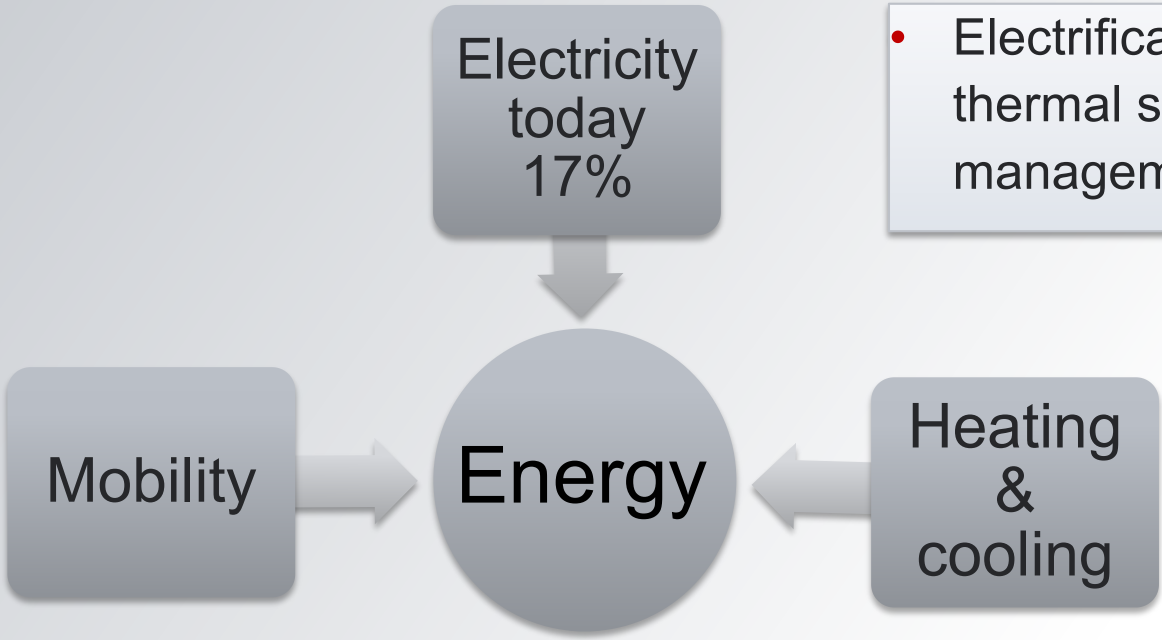
Storage Type	Short-Term	Long-Term
Technology	Batteries, pump storage, demand controlled hydro, CSP-heat storage, …	Gas storage
Capacity C	Large: Cover electricity consumption of 1-2 days	Huge: Cover electricity consumption of a few months or more
Max. Power Input (Charging)	Very Large: Cover surplus peak power of solar and wind	Medium: Charging (power-to-gas) is done at times of low power consumption or high renewable surplus or from short-term storage In addition: Direct charging by biogas, whenever available
Max. Power Output (Discharging)	Very Large: Cover peak power consumption, stabilize grid	Large: Cover average daily power consumption (but not peak power) Discharge by combined cycle power stations (base load), fuel cells and/or gas turbines (peaks)
Efficiency η	High: ~80-100%	Medium: ~30-45%
Cycle Time T_C	Short: several days (2-10)	Long: one or several years (1-5)
Energy Loss / Year $(1-\eta)/\eta * C/T_c$	Moderate: ~0…50 C/y	Moderate: ~0.2…2.3 C/y

Dual storage concept!

Find the OPTIMUM Renewable Energy System



"Energiewende": People often neglect mobility and heat



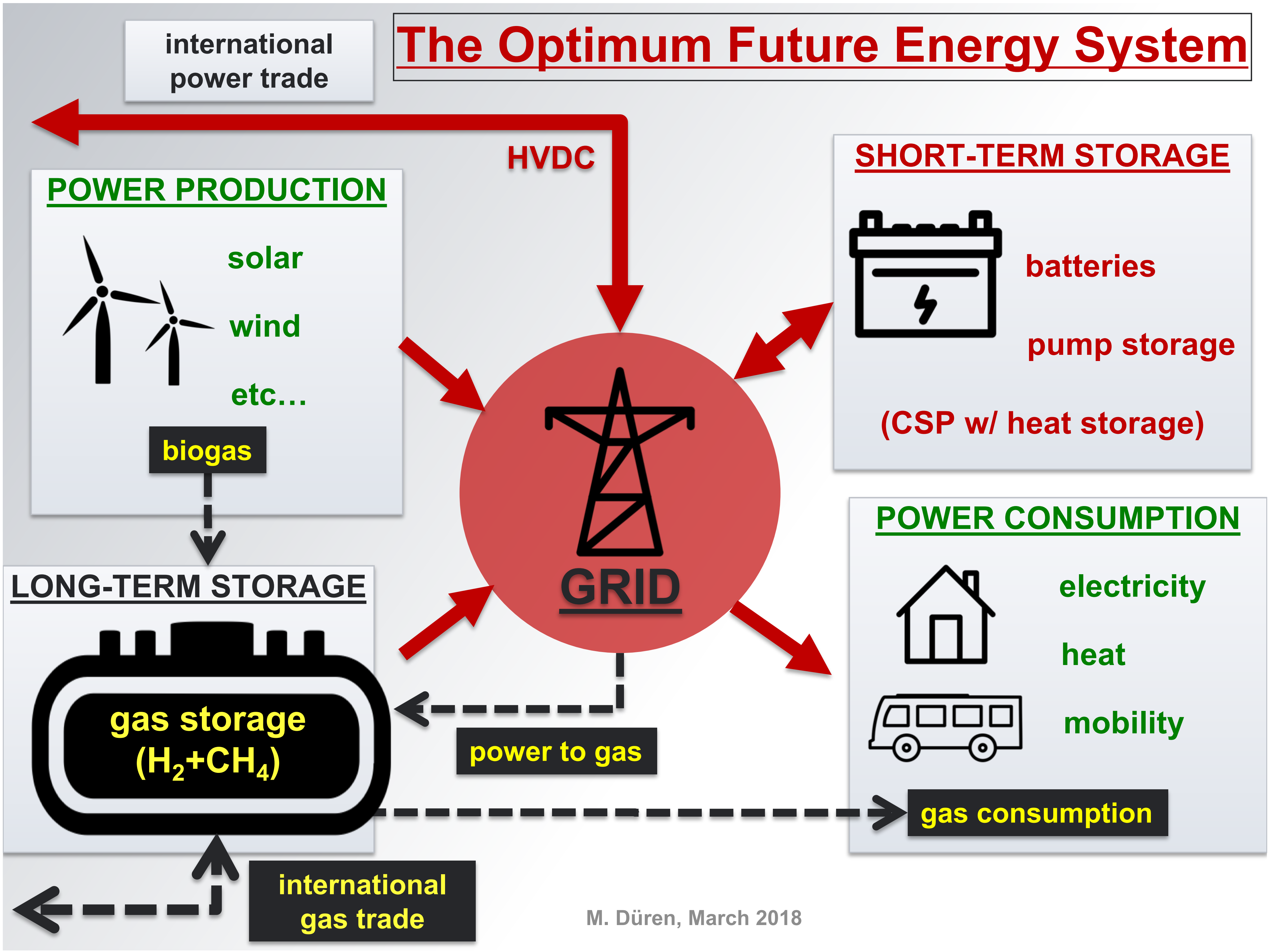
- Electrification of mobility and thermal sectors will make load management much more efficient.

Batteries,
Bio fuels,
Synthetic fuels,
CH_4, H_2, CH_2O_2

Insolation and heat pumps

- Electric engines are much more efficient than combustion engines

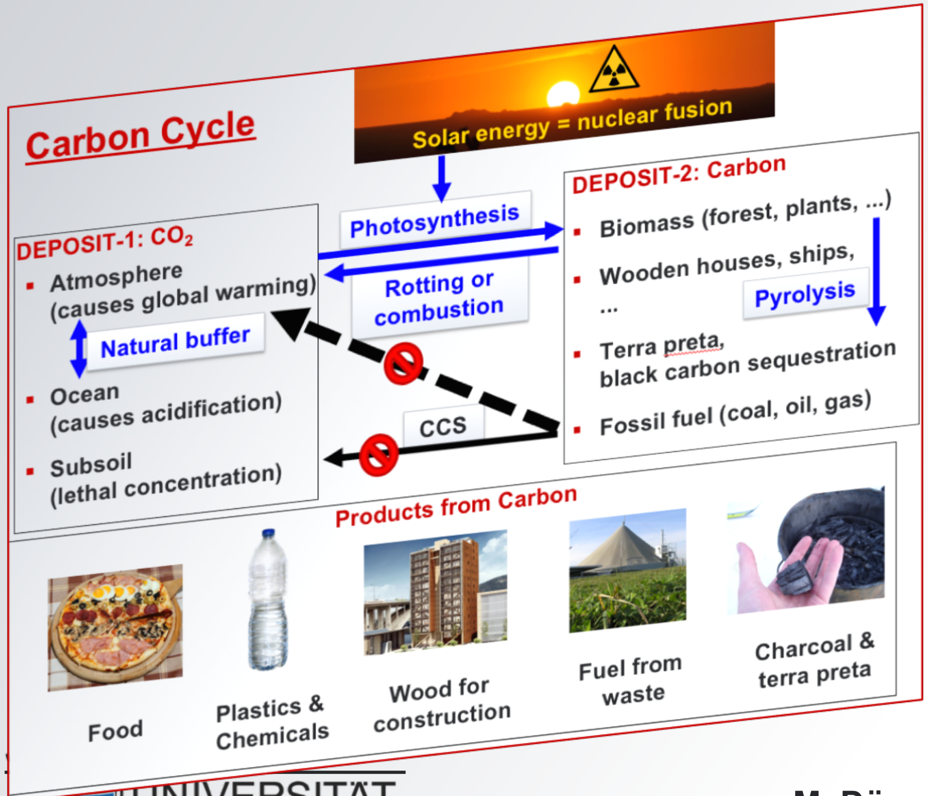
- Heat pumps have efficiencies of ~400-500%. (They produce 4x more thermal energy compared to the energy they need for operation)

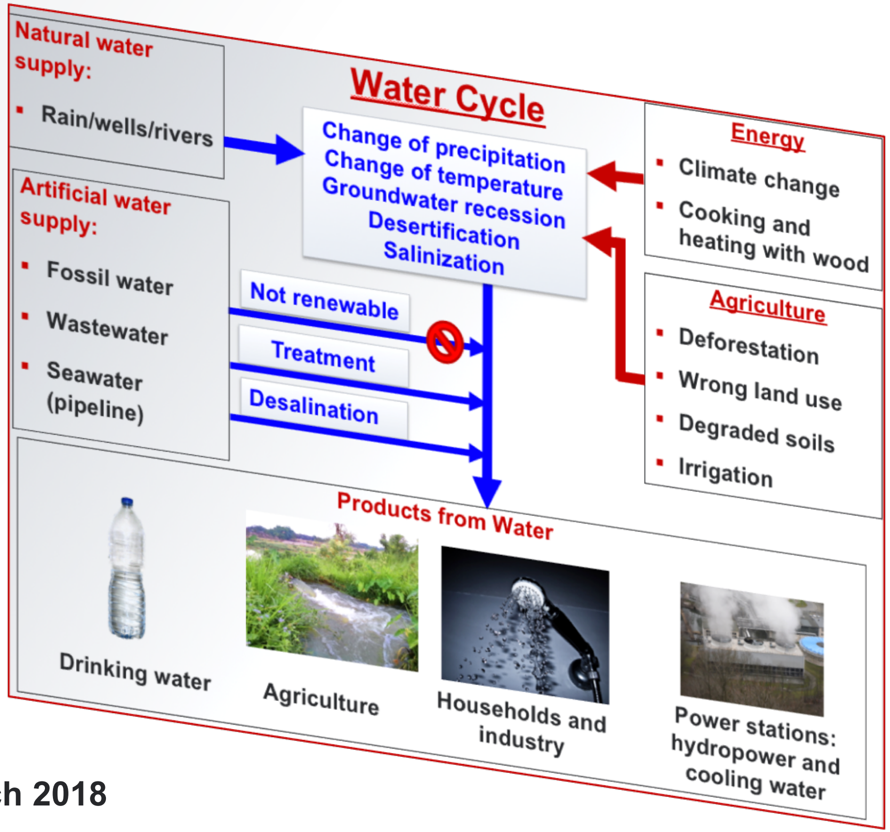

The Optimum Future Energy System
international power trade
HVDC
POWER PRODUCTION
solar
wind
etc…
biogas
SHORT-TERM STORAGE
batteries
pump storage
(CSP w/ heat storage)
GRID
LONG-TERM STORAGE
gas storage
(H_2+CH_4)
power to gas
POWER CONSUMPTION
electricity
heat
mobility
gas consumption
international gas trade
M. Düren, March 2018

What I could not cover:

- A **renewable energy system** has to be integrated into an overall sustainable system, including the **global water and carbon cycles**

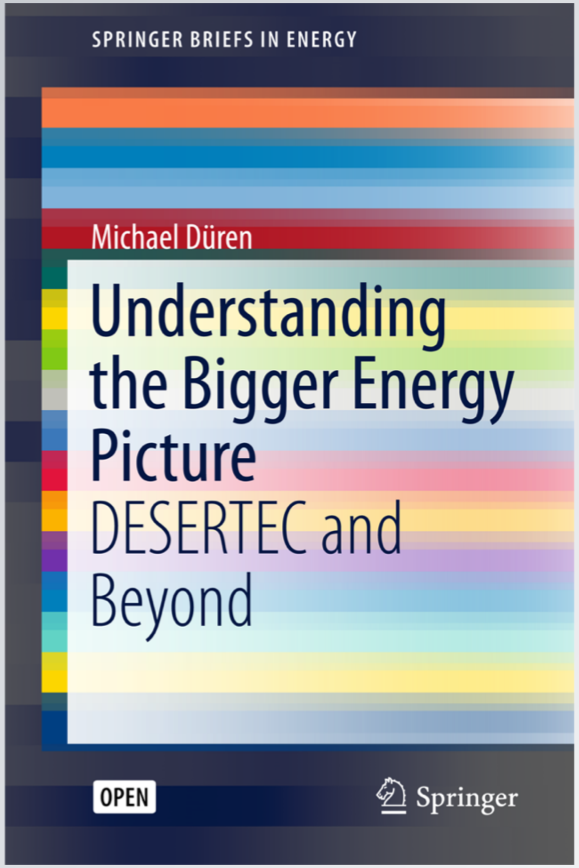
- Using **pyrolysis**, biomass can be used to make **deserts and drylands** fertile again (terra preta) and this way, allow for a safe **black carbon sequestration (negative CO_2 footprint)**





Understanding the Bigger Energy Picture

DESERTEC and Beyond



Book available:

Online: pdf und eBook: €0.00

Softcover: €21.39

https://dx.doi.org/10.1007/978-3-319-57966-5

THANKS FOR LISTENING!

PS: Thanks to Andreas Huber (Desertec) and Paul van Son (Dii) for udates!

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SPARES

Rule: Do not use technologies that produce potentially more problems than they solve

Nuclear:

significant fraction of nuclear power means:
- thousands of nuclear power stations
- in all regions of the world

Nuclear power is needed by nations that build or want to build nuclear bombs

Immense long term risk: **Terrorism and war zones**

Example: Saporoschje/Ukraine, 200 km away from the battlefield: The largest nuclear power plant of Europe with 6 reactors and nuclear storage facilities

Carbon sequestration: Wooden houses

Example: hybrid houses of wood and concrete save up to 90%(?) CO2 emissions and store carbon for ~100 years

→ negative CO_2 footprint

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Black carbon sequestration:

Example: „Terra Preta“ is a anthropogenic soil produced by the Indians in the Amazon basin. The recycling of bio-mass treated by pyrolysis makes the otherwise relatively infertile Amazonian soil fertile.

The storage of charcoal in the soil reduces the green house effect:

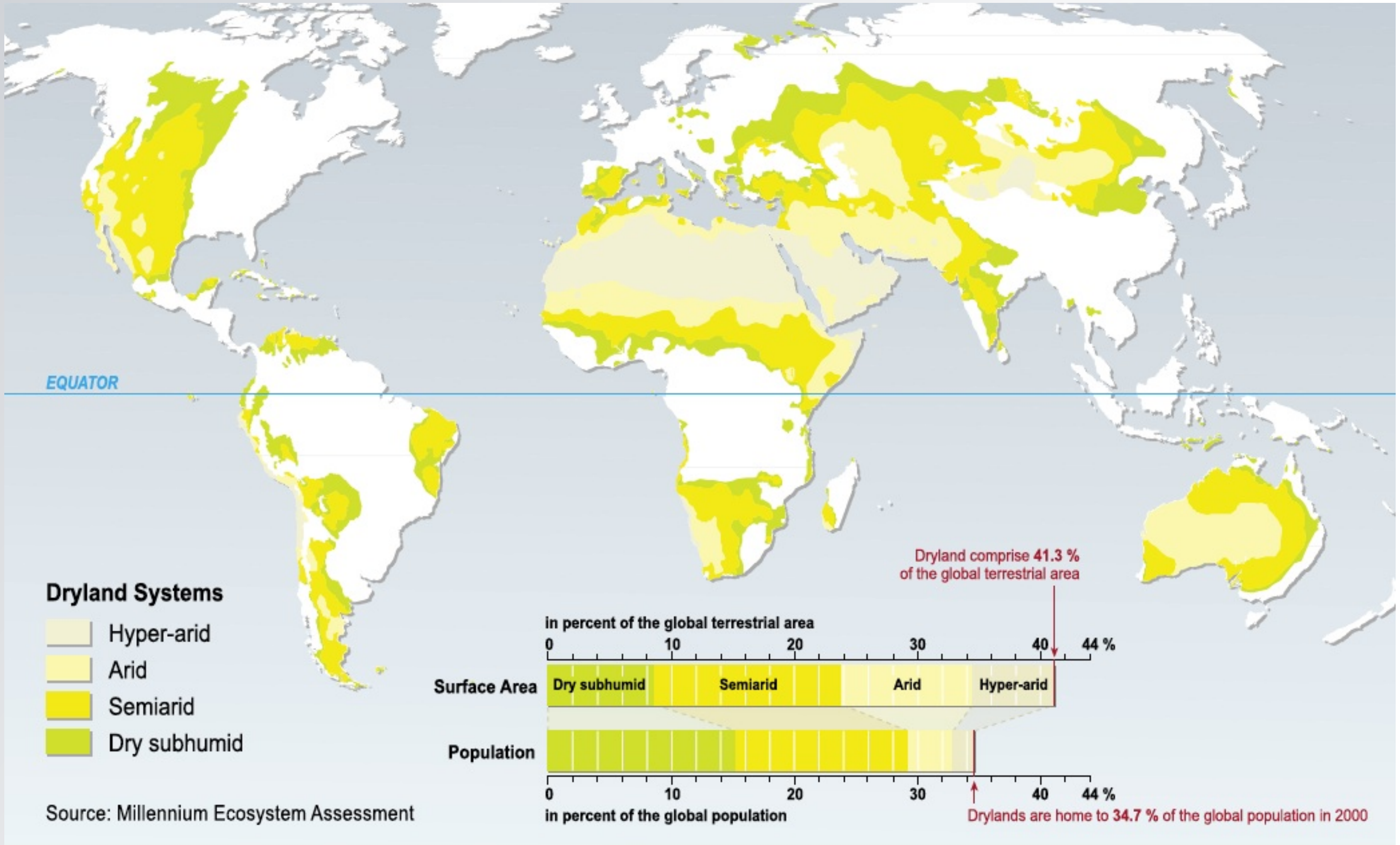
→ negative CO_2 footprint

Carbon Cycle

Black Carbon Sequestration:

- Produce charcoal and bury it somewhere → reduce CO_2 in the atmosphere
- Produce terra preta from charcoal and use it in agriculture → improve soil
- Do it in the drylands to re-cultivate the land → stop desertification

Drylands cover 40% of the earth's land surface



Charcoal & terra preta

Water Cycle

Natural water supply:

- Rain/wells/rivers

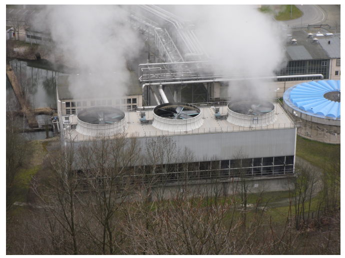
"Nature"

Products from Water

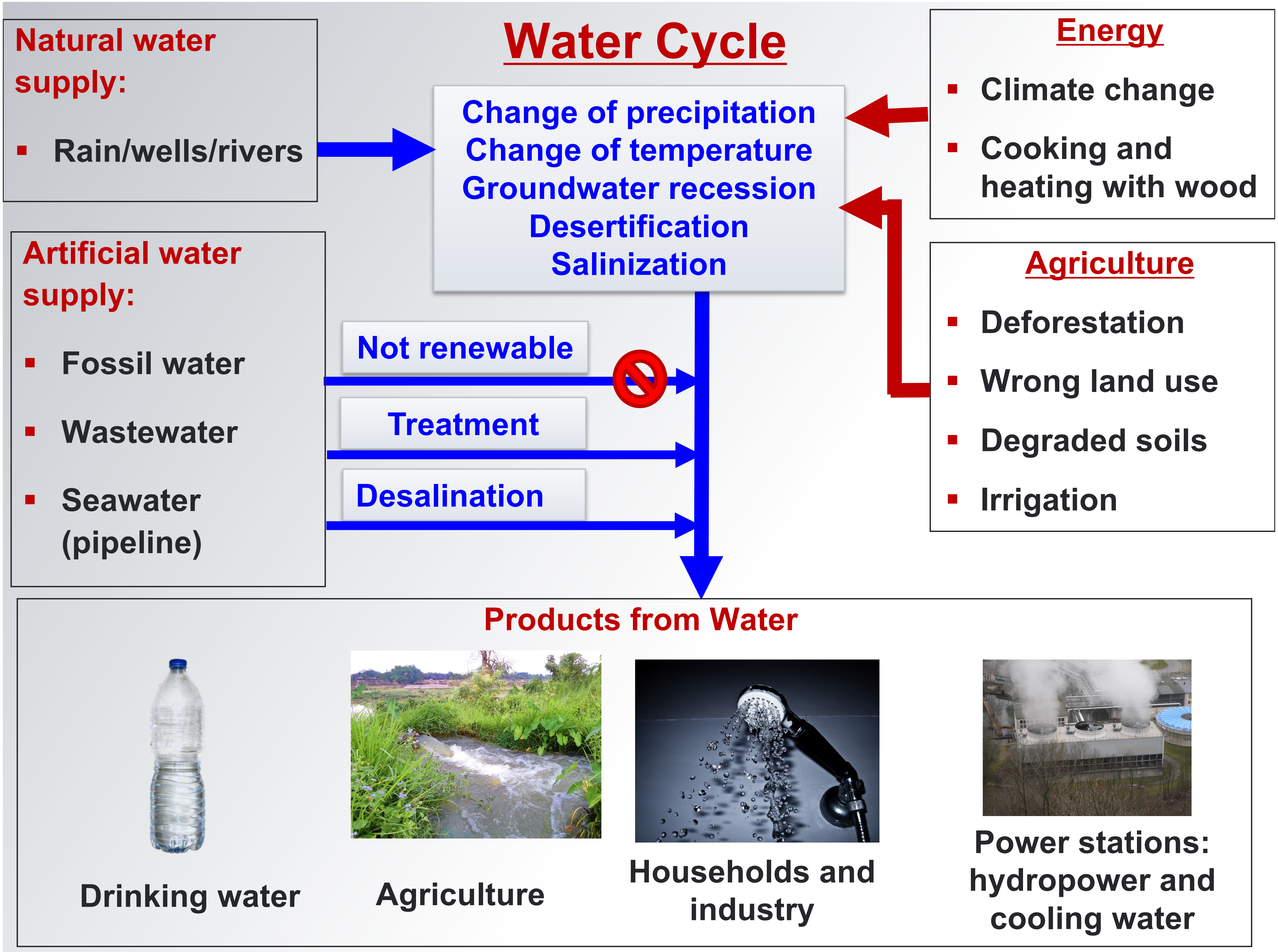
Drinking water

Agriculture

Households and industry

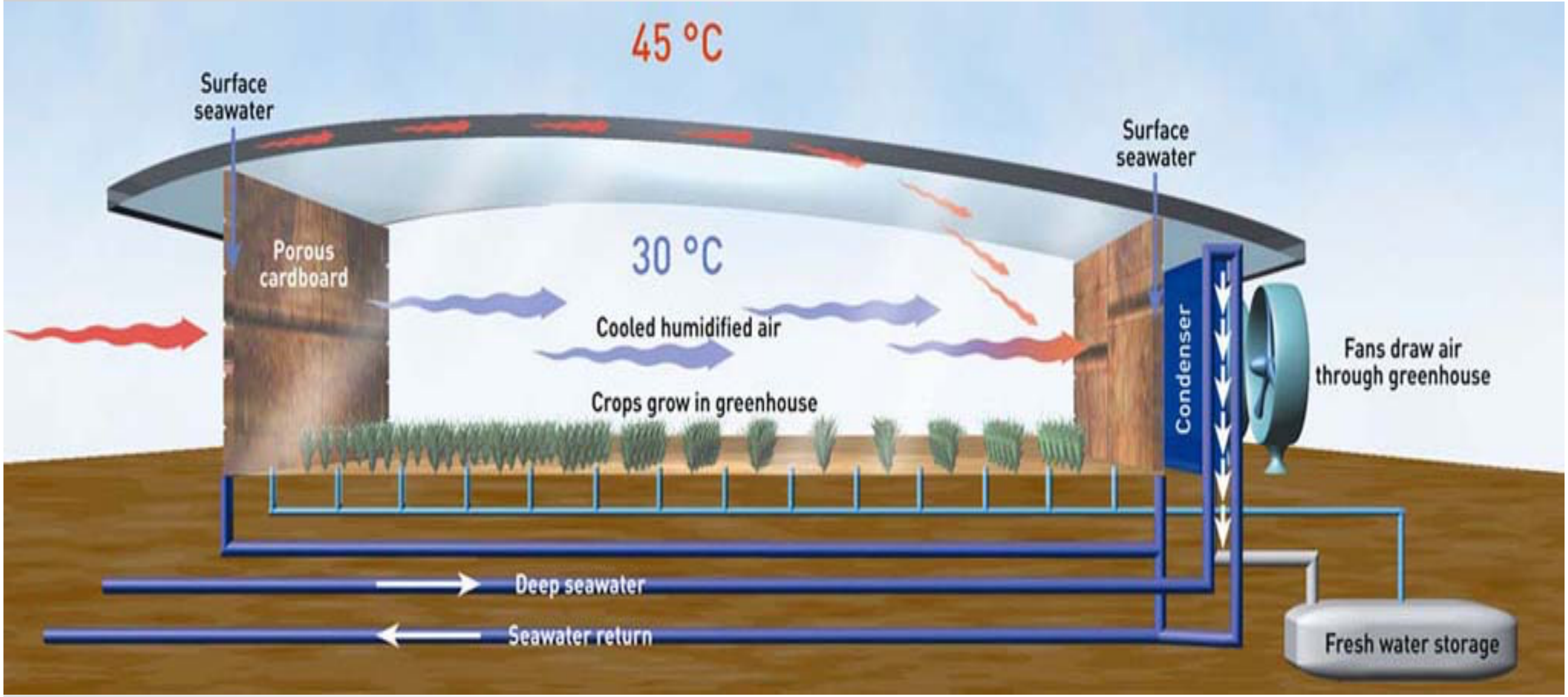


Power stations: hydropower and cooling water


Water Cycle
Natural water supply:
Rain/wells/rivers
Change of precipitation
Change of temperature
Groundwater recession
Desertification
Salinization
Energy
Climate change
Cooking and heating with wood
Agriculture
Deforestation
Wrong land use
Degraded soils
Irrigation
Artificial water supply:
Fossil water
Wastewater
Seawater (pipeline)
Not renewable
Treatment
Desalination
Products from Water
Drinking water
Agriculture
Households and industry
Power stations: hydropower and cooling water

Agriculture with seawater greenhouse

Agriculture in arid regions:



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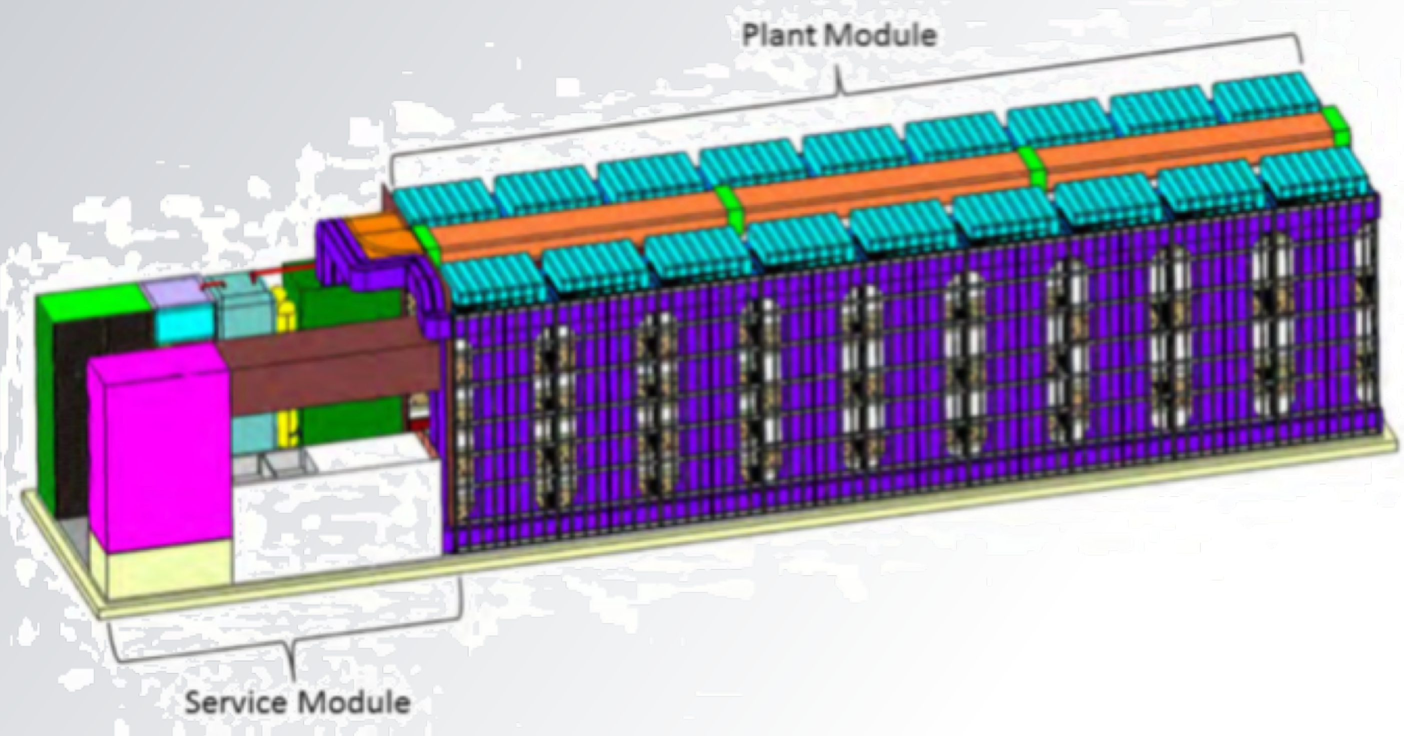
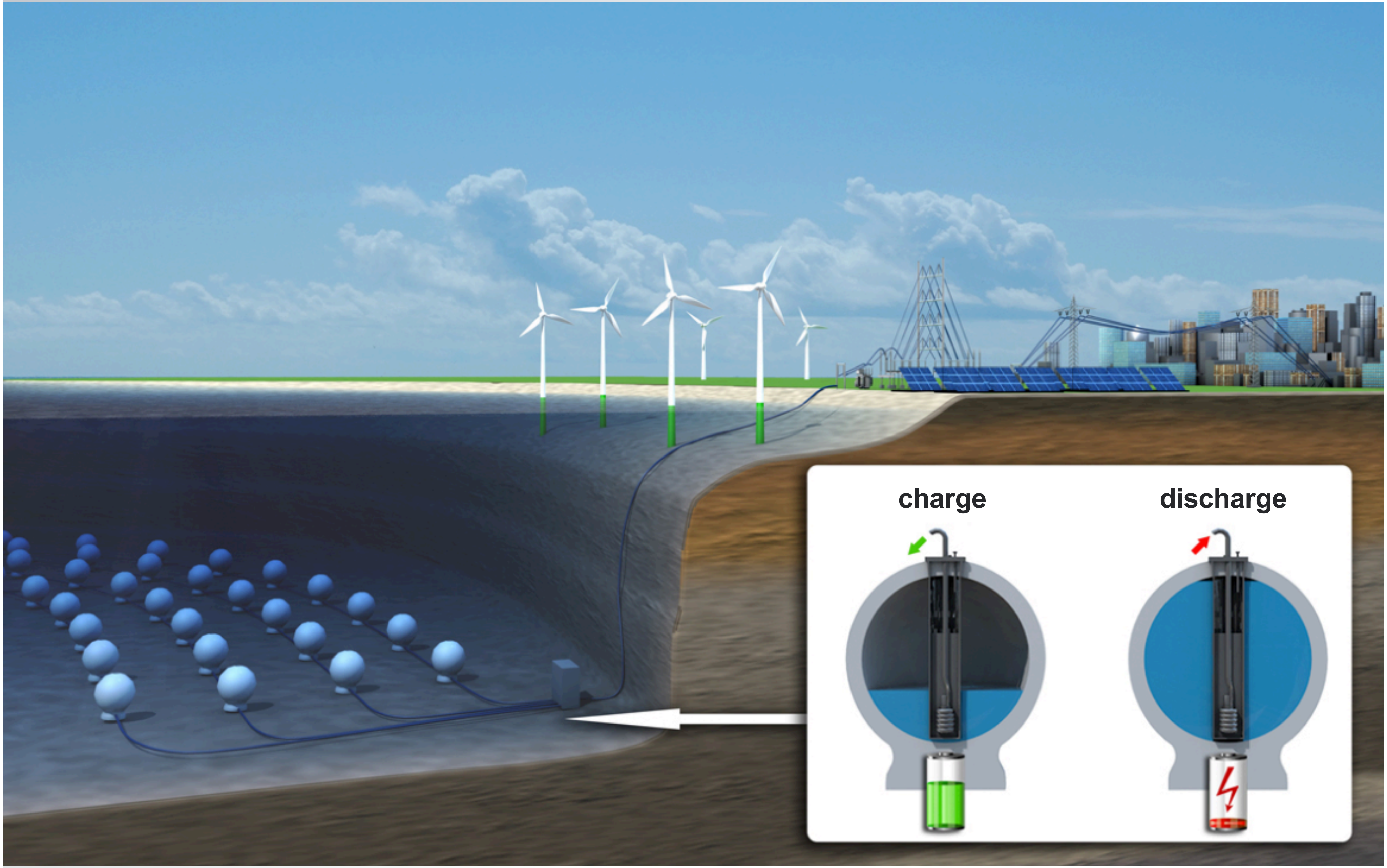
Agriculture with closed-loop greenhouses

- No water losses
- Artificial LED light
- No herbicides



Submarine Pump Storage Bowls in Deep Sea



Submarine Pump Storage Bowls

2016: „Meerei“ (Sea-Egg) - Model (3 m) @ Lake Constance (Germany)

FhG-IWES Project StEnSea (2016.1102):

„Energy Atoll“ in Shallow Sea

1. Artificial island to be used base for offshore wind power farms
   - HVDC converter station
   - Hotels, harbour, helicopter landing for maintenance crews
   - Touristic attraction
2. Inner barrier lake used as pumped-storage power station and as tidal power station
3. The island ring consists of the excavated material of the inner lagoon

Numerical example:

An atoll with a depth and radius of 200 m can store 1,7 GWh

M. Düren, March 2018

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“DESERTEC” Gas

An option to make long-term storage cheaper

- Produce renewable gas and fuels in the deserts
- Sell it to Europe using existing pipelines
- North Africa profits from foreign exchange & jobs

A common market is essential to reduce costs and volatility of renewables!

(Also valid for post-Brexit England)