SDG Conference 2018 UiB, 8-9 February
Knowledge for our common future
Sustainable energy for all - SDG7 - leave no one behind

Renewable Energy Resources

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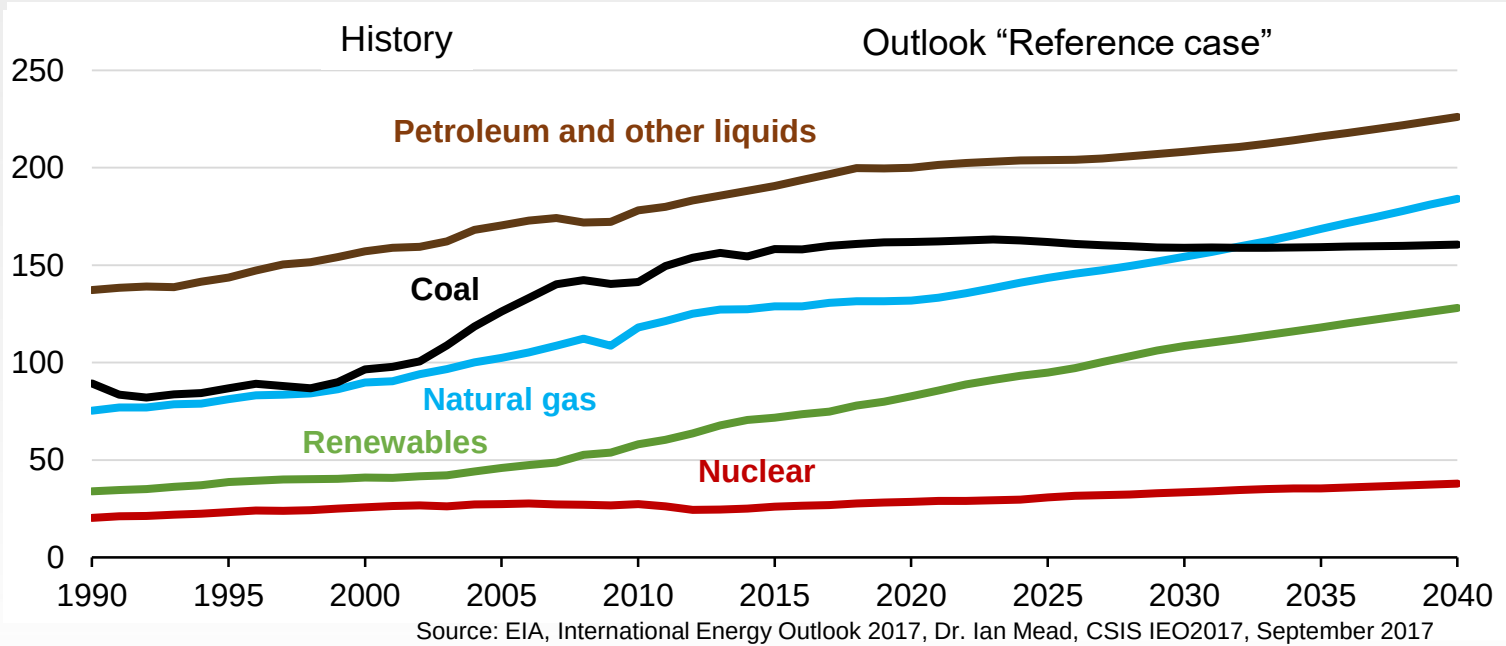
Outline

- The need for energy
- Primary energy versus energy services
- Key new renewables: Wind and solar
- Resources available
- Storage

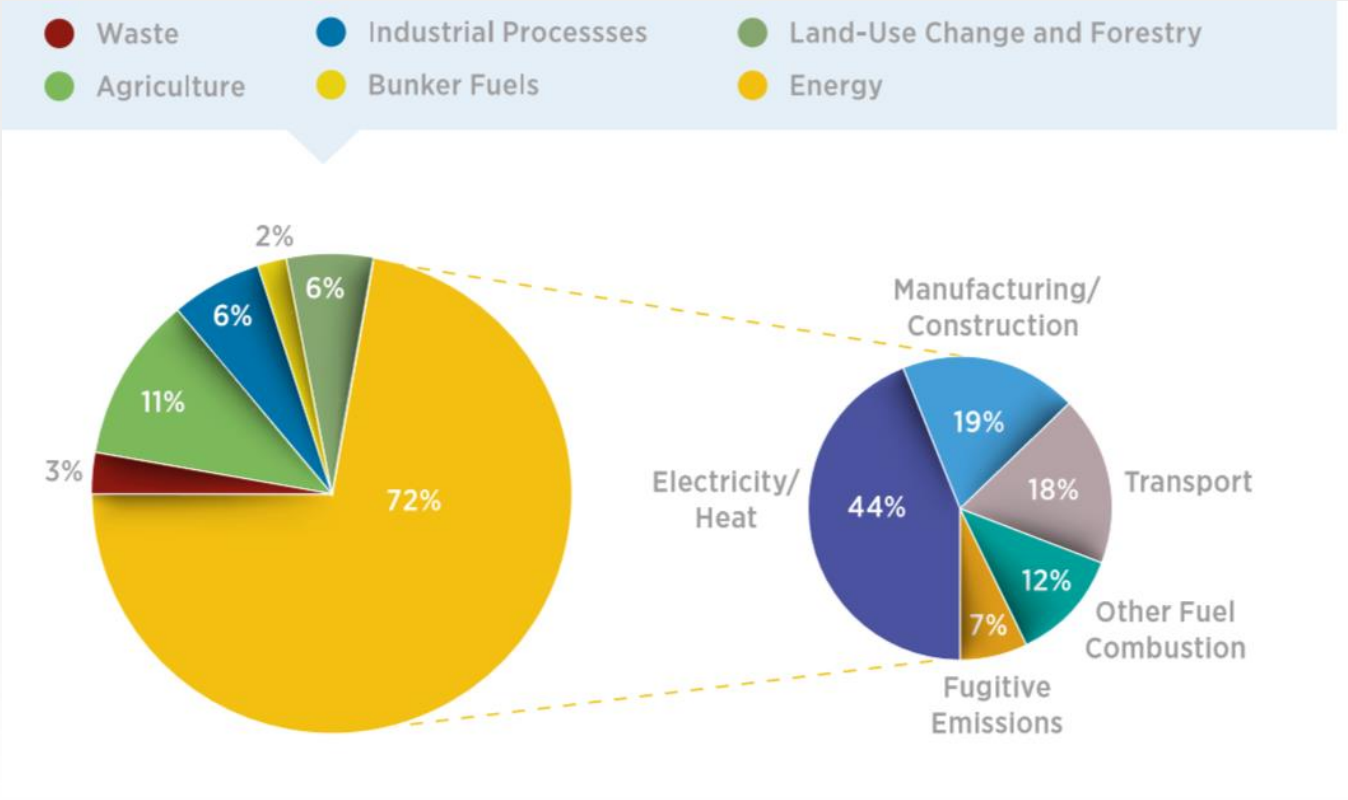
The world needs more energy! True?



Source: EIA, International Energy Outlook 2017, Dr. Ian Mead, CSIS IEO2017, September 2017

About 78 % of present primary energy comes from fossil fuels.

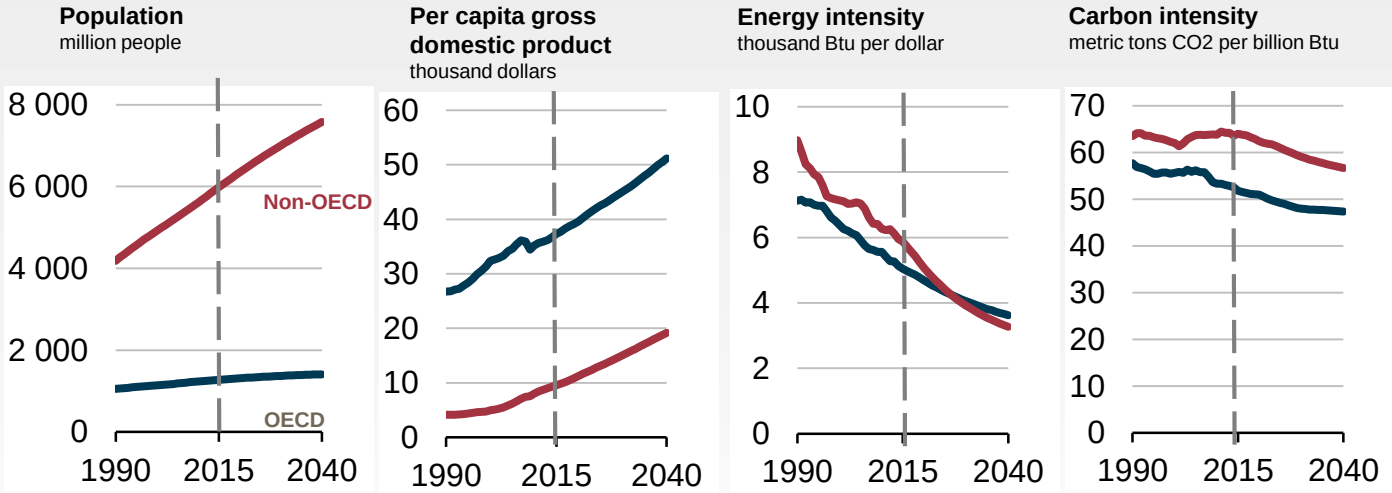
The concern: Greenhouse gas emissions



Global Greenhouse gas emissions by sector (2012).
Source: World Resource Institute, 2015

Drivers in CO_2 emissions

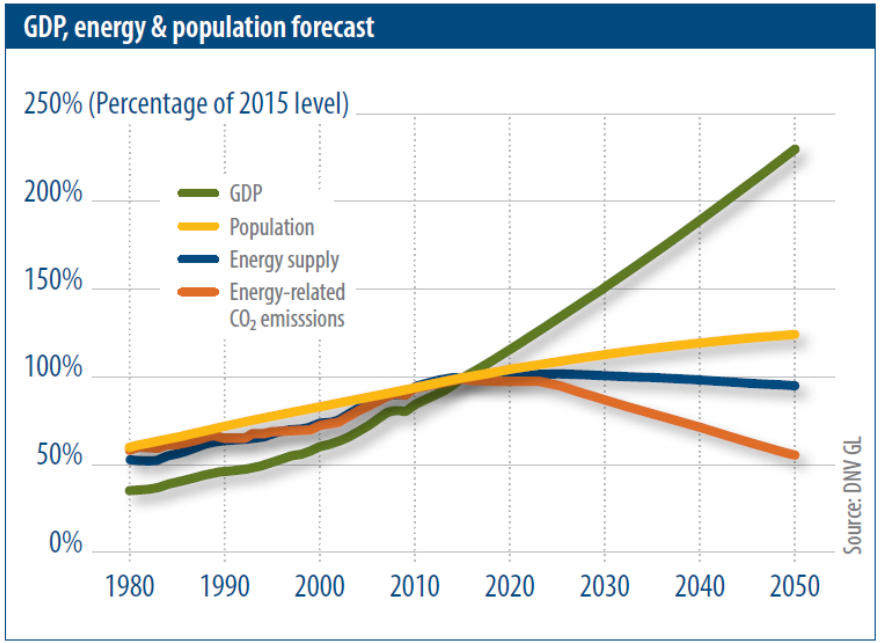
$$CO_{2em} = N_{people} * \frac{GDP}{N_{people}} * \frac{Energy}{GDP} * \frac{CO_2}{Energy}$$

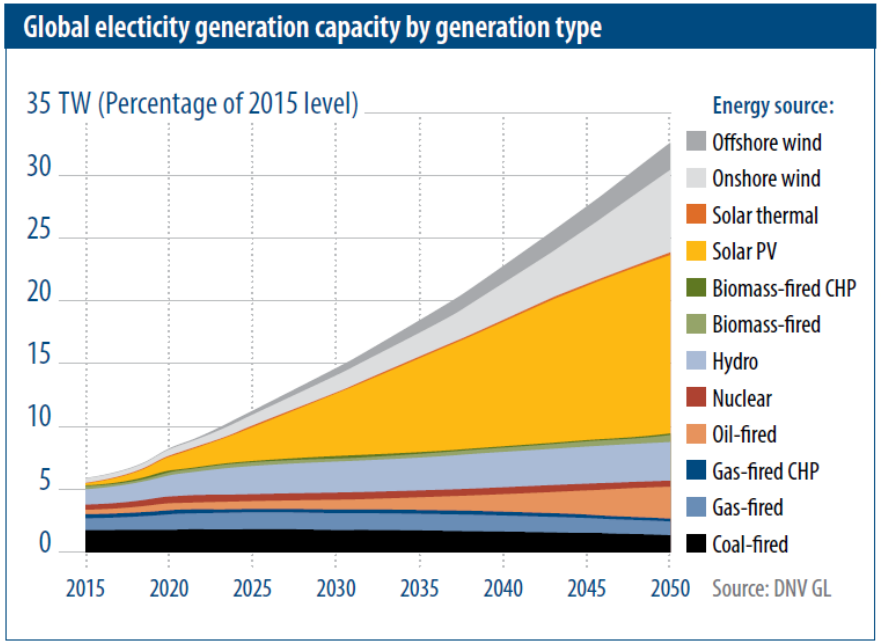


Source: EIA, International Energy Outlook 2017, Dr. Ian Mead, CSIS IEO2017, September 2017

More renewables and higher efficiency

Forecast by DNV-GL (2017)



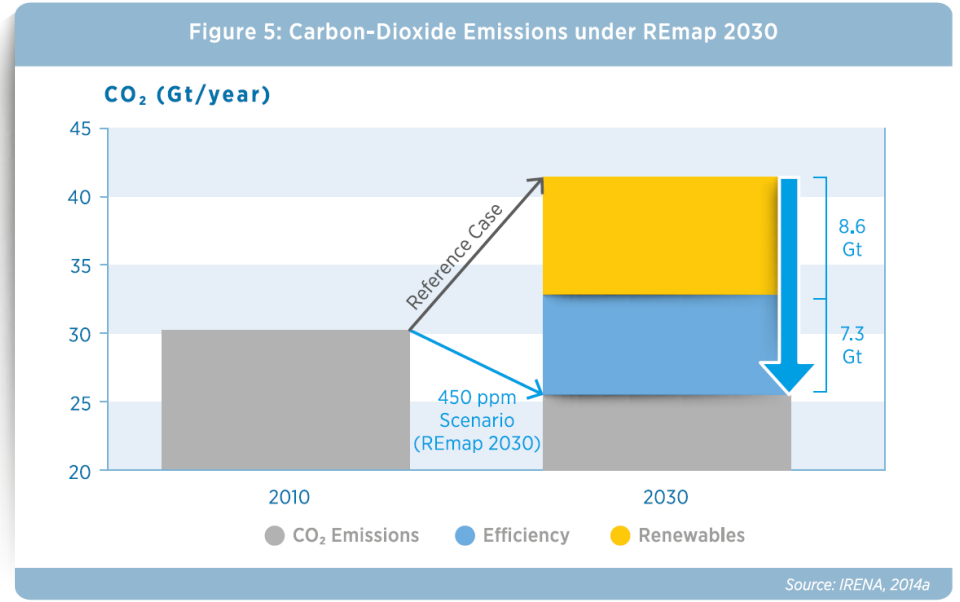


Graphics: pv magazine/Harald Schütt

Affordable and clean energy…

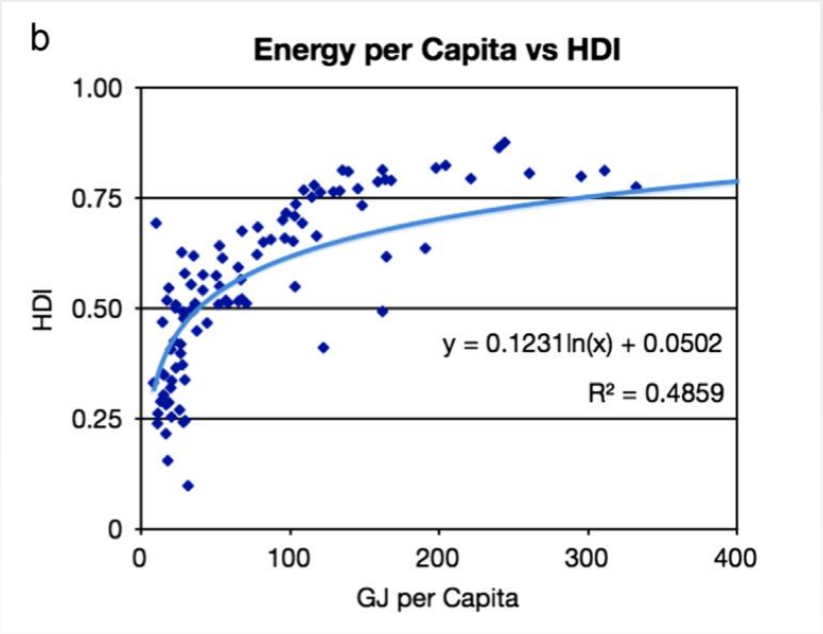
Important to several SDGs

- Improve availability
- Increase efficiency
- More renewables
- Improve standard of living without increased use of energy



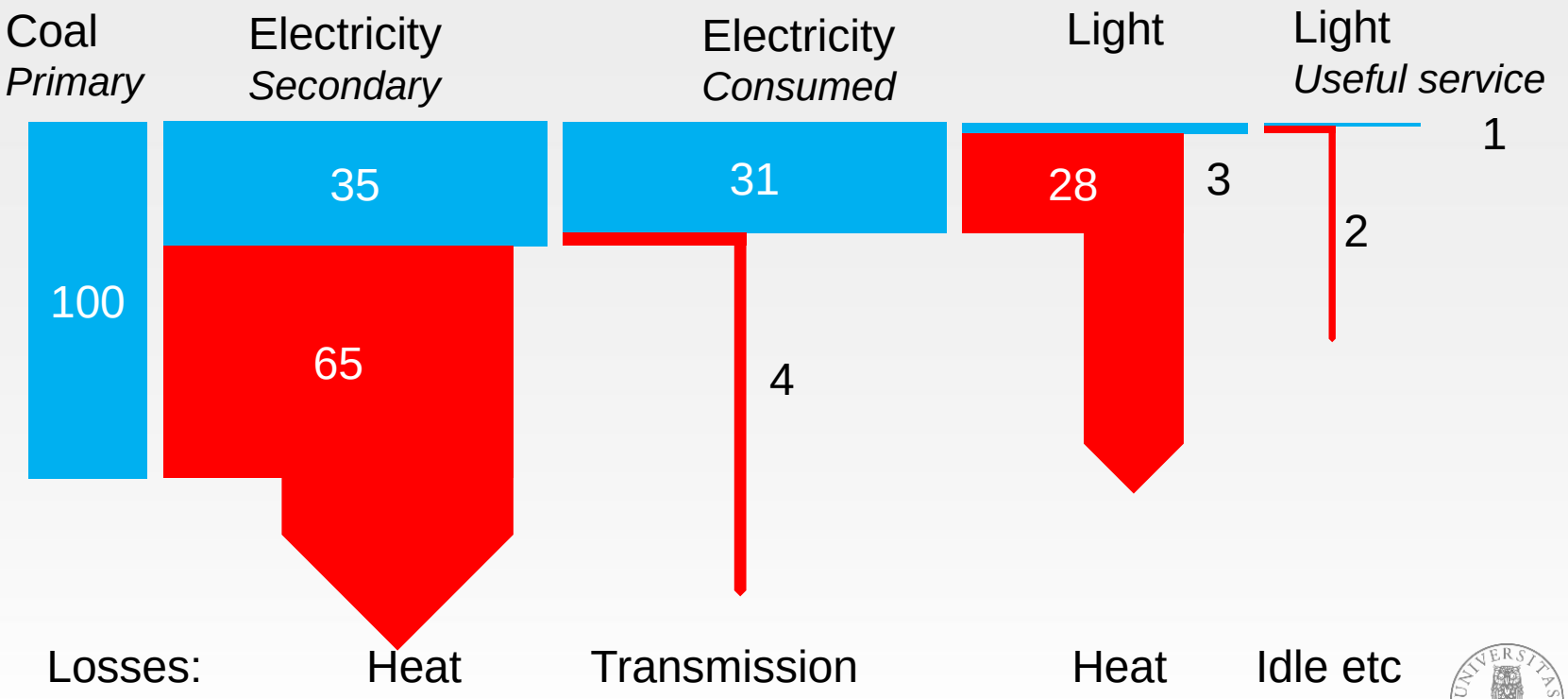
More energy to improve standard of living? True?

- UN Human development index (HDI) combines
  - Life expectancy at birth
  - Education level
  - Economy
    - GDP per capita in purchasing power parity (PPP)

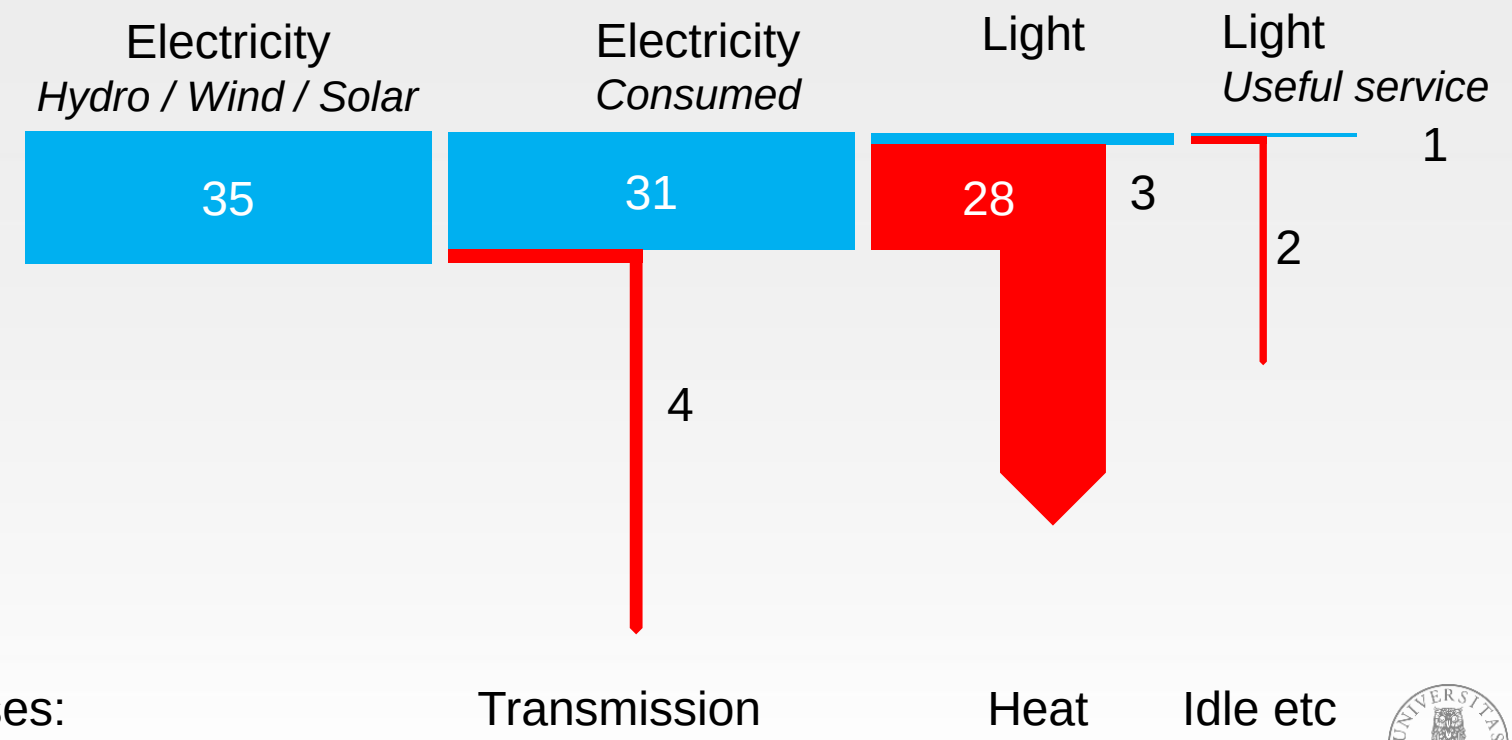


Jessica G.Lambert et al. Energy, EROI and quality of life. Energy Policy 64(2014)153–167

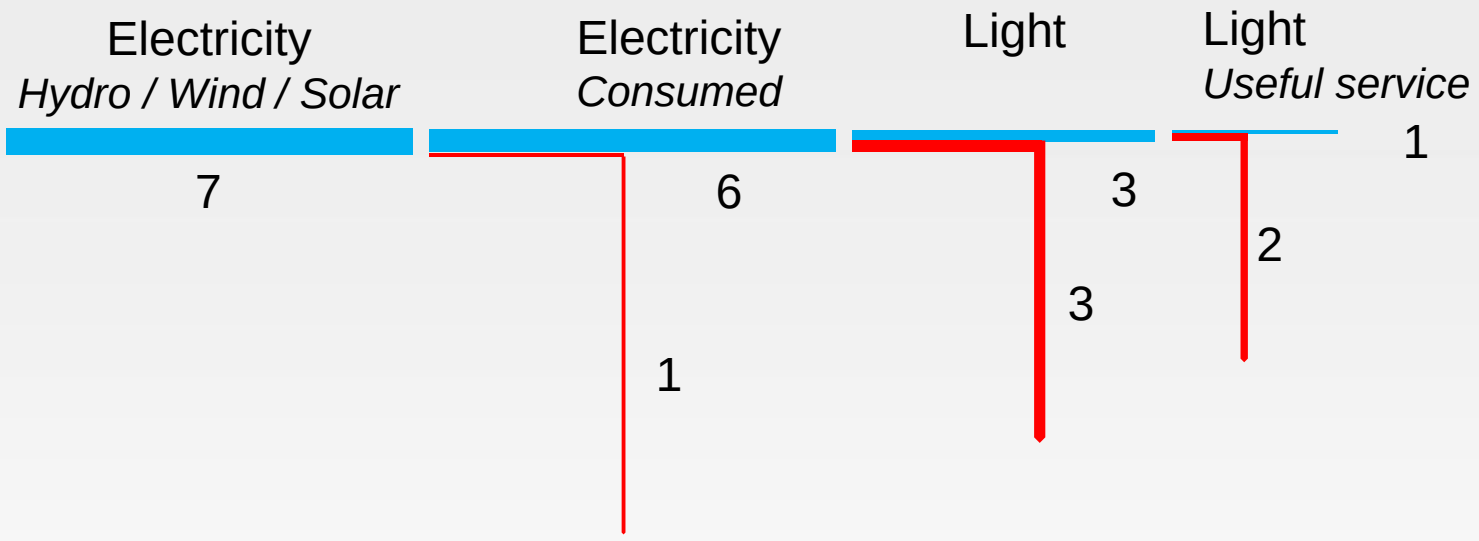
From coal to light - incandescent light bulb



From renewables to light - incandescent light bulb



From renewables to light - LED light bulb



Energy services versus primary energy

Same service!

Coal →
Incandescent light

100

Renewables →
Incandescent light

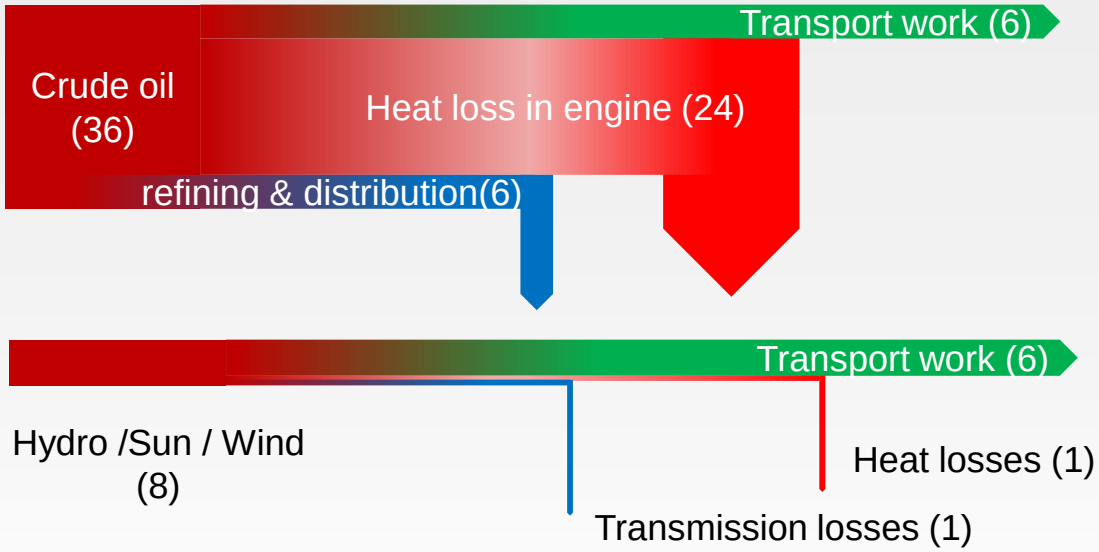
35

Renewables →
LED light

7

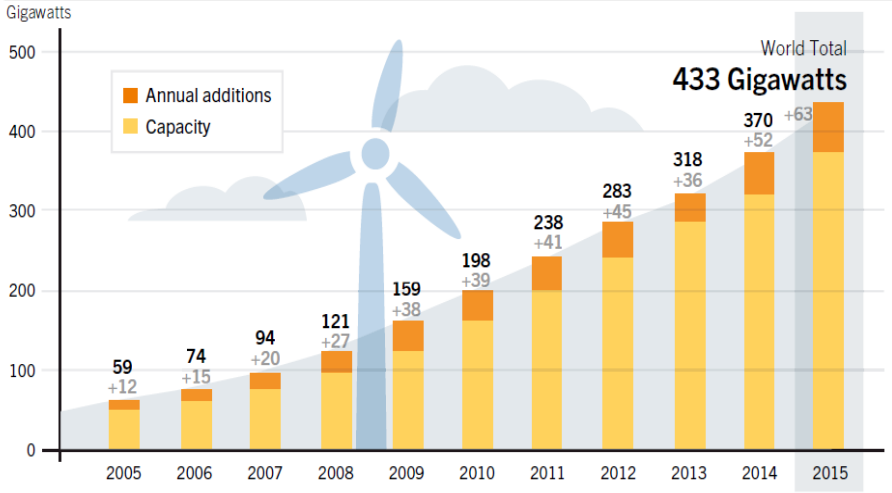
Example: Private cars in Norway

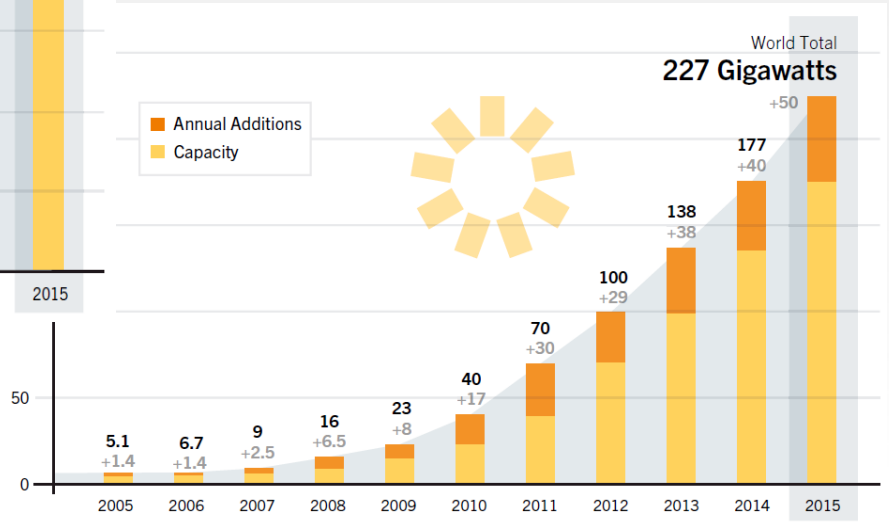
- Transport work (service): ~6TWh/year



Renewables and electrification

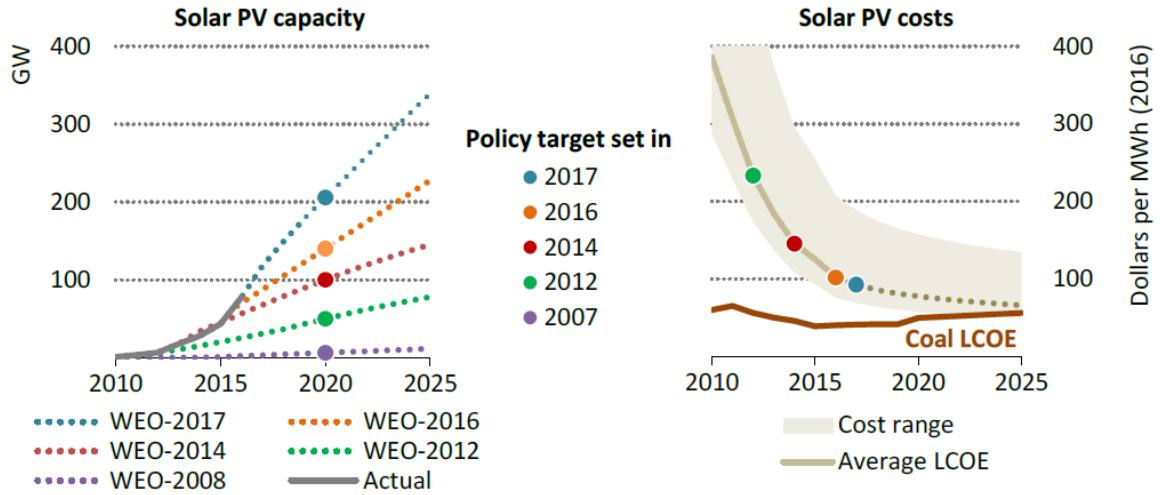
Wind and Solar in front





A silent revolution?

Figure 1.3 ▷ Evolution of China policy targets and projections for solar PV installed capacity, and solar PV levelised costs, in selected *WEOs*

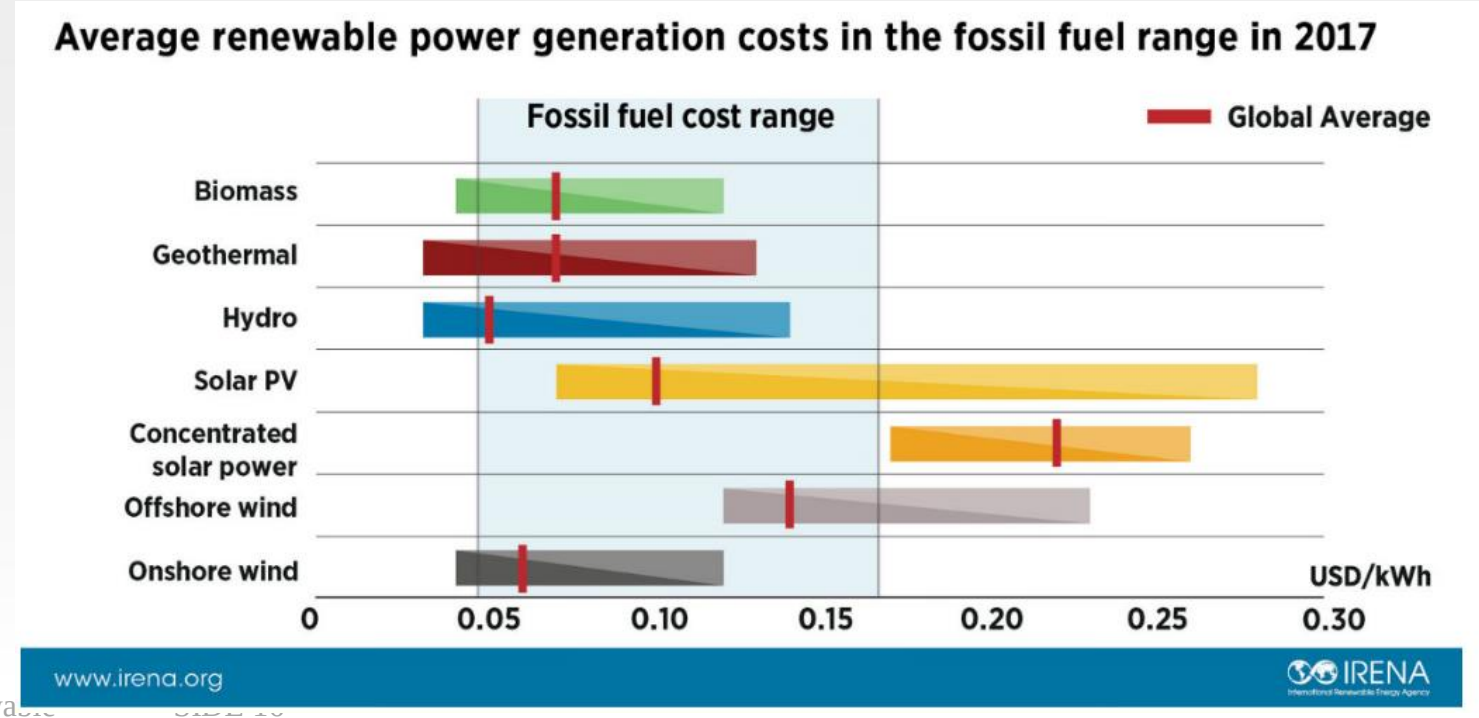


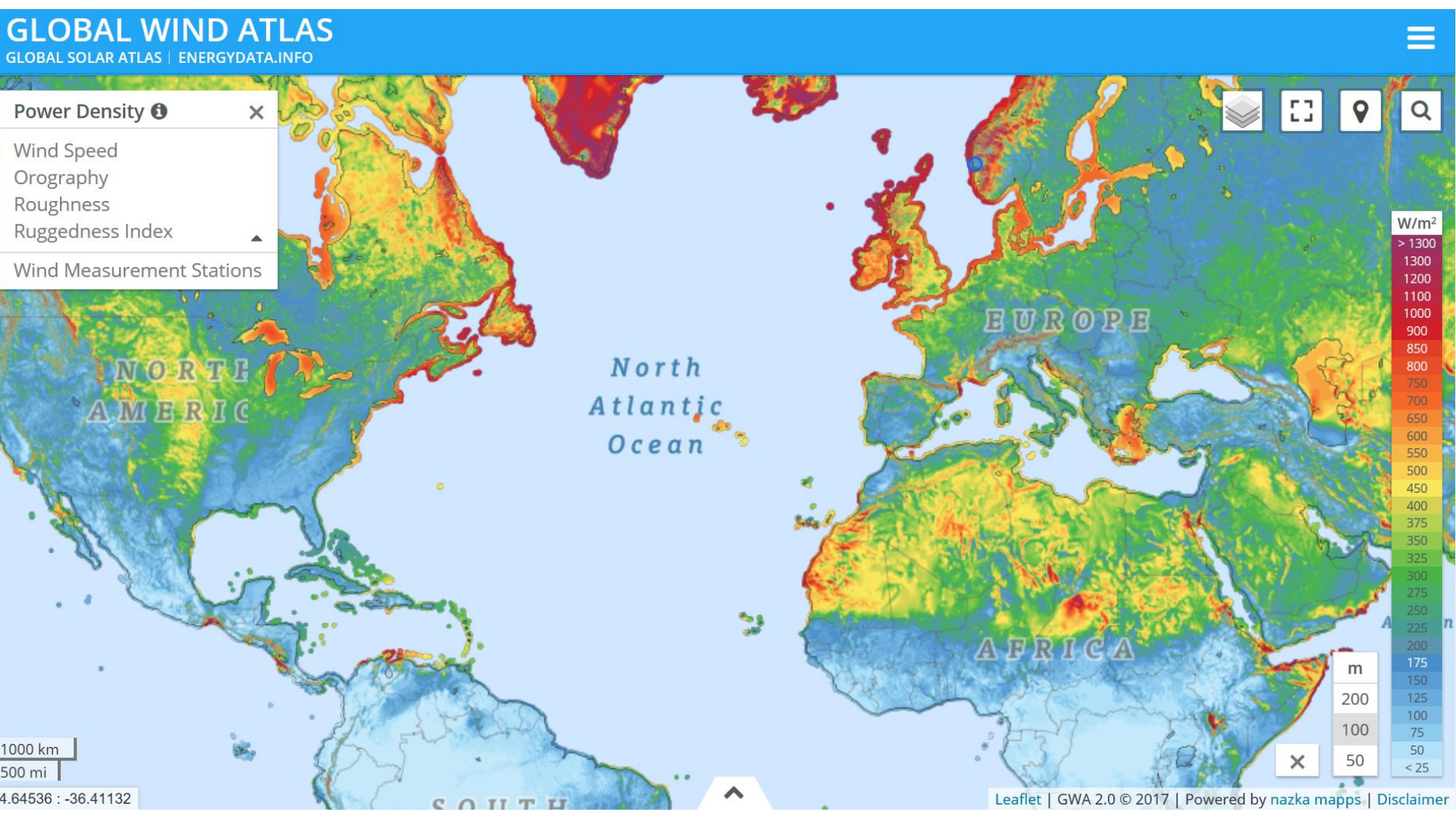
The projections for solar PV in China in successive WEOs show the virtuous circle of policy-driven deployment & lower costs, bringing the technology to competitiveness with coal

Note: PV = photovoltaic; LCOE = levelised cost of electricity.

Source: IEA World Energy Outlook 2017

Renewables are competing with fossil fuels in power generation wrt costs




GLOBAL WIND ATLAS
GLOBAL SOLAR ATLAS | ENERGYDATA.INFO
Power Density
Wind Speed
Orography
Roughness
Ruggedness Index
Wind Measurement Stations
EUROPE
North Atlantic Ocean
AFRICA
W/m²
> 1300
1300
1200
1100
1000
900
850
800
750
700
650
600
550
500
450
400
375
350
325
300
275
250
225
200
175
150
125
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< 25
m
200
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1000 km
500 mi
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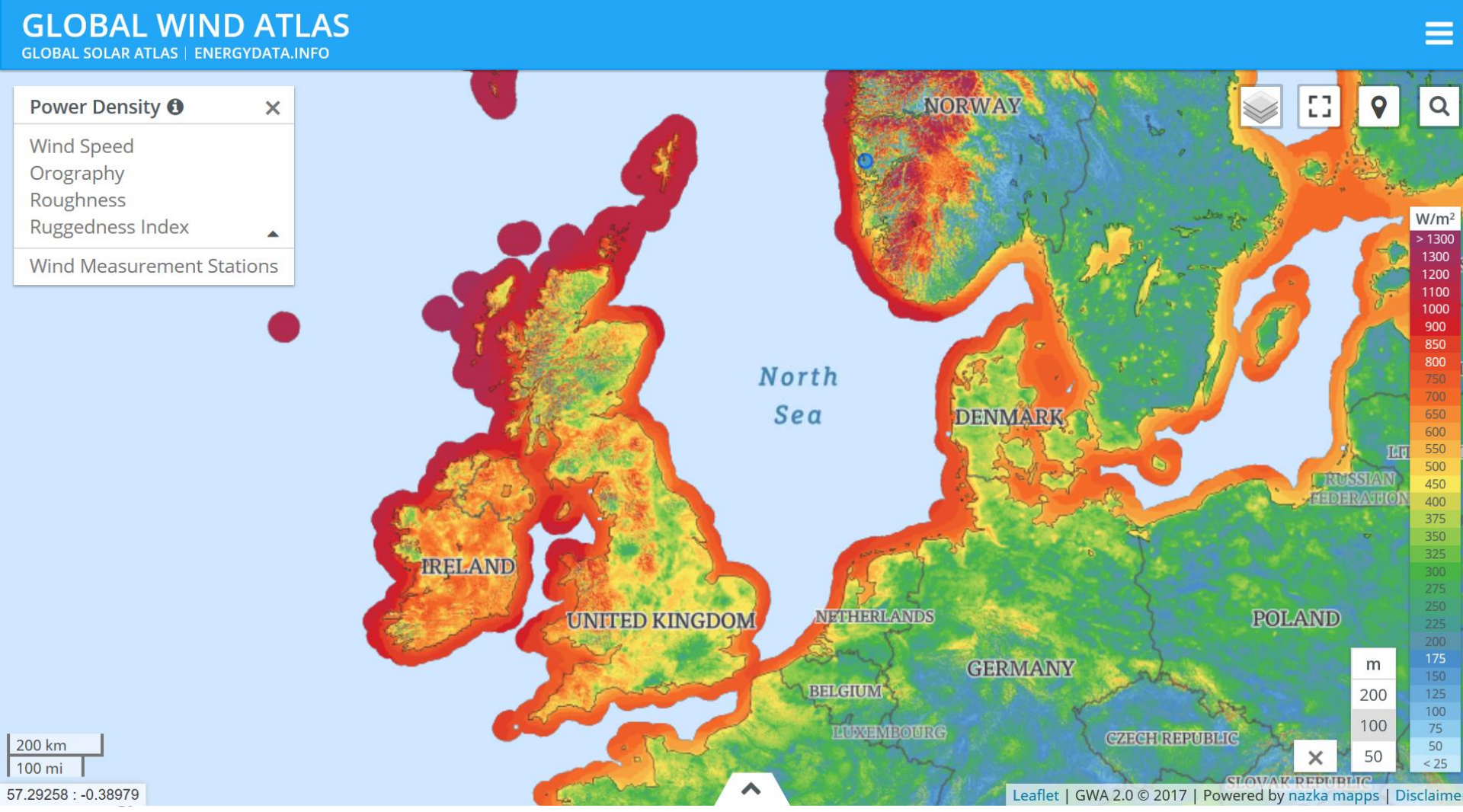
GLOBAL WIND ATLAS
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Power Density
Wind Speed
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NORWAY
North Sea
DENMARK
RUSSIAN FEDERATION
IRELAND
UNITED KINGDOM
NETHERLANDS
POLAND
GERMANY
BELGIUM
LUXEMBOURG
CZECH REPUBLIC
W/m²
> 1300
1300
1200
1100
1000
900
850
800
750
700
650
600
550
500
450
400
375
350
325
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100 mi
57.29258 : -0.38979
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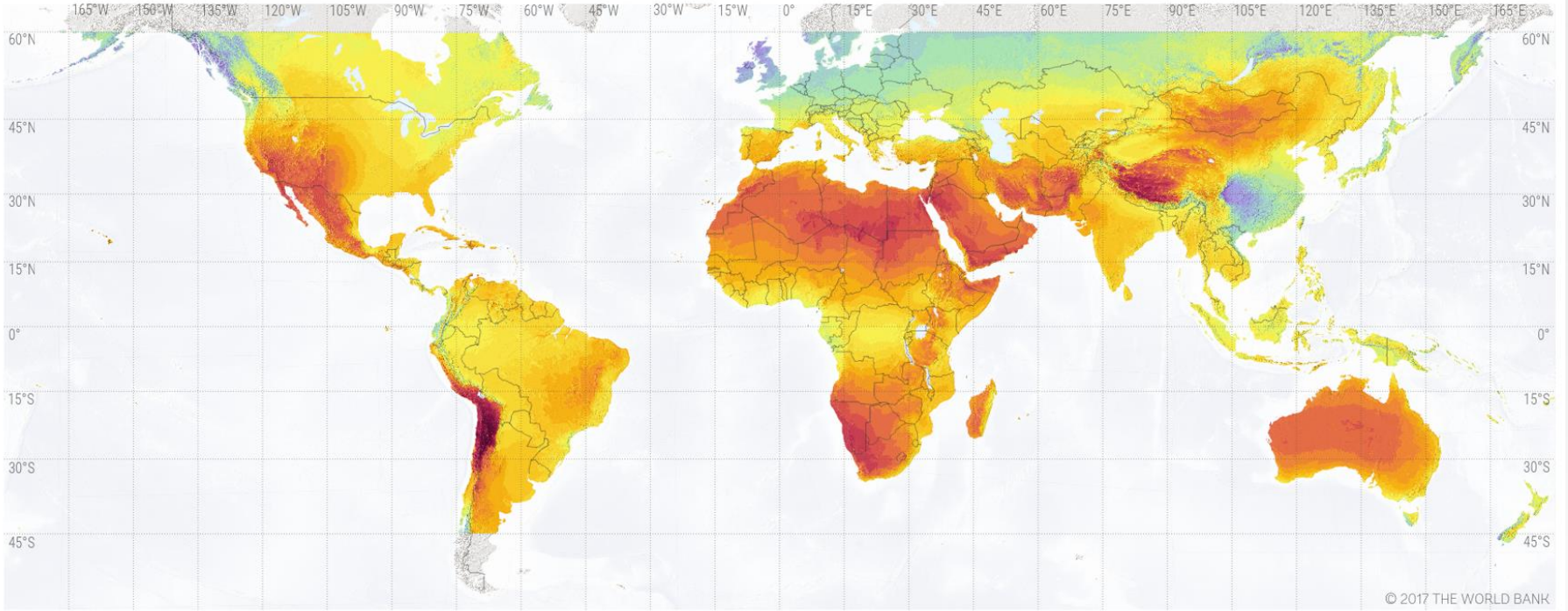
SOLAR RESOURCE MAP

PHOTOVOLTAIC POWER POTENTIAL

WORLD BANK GROUP
THE WORLD BANK IBRD • IDA | IFC International Finance Corporation

ESMAP
Energy Sector Management Assistance Program

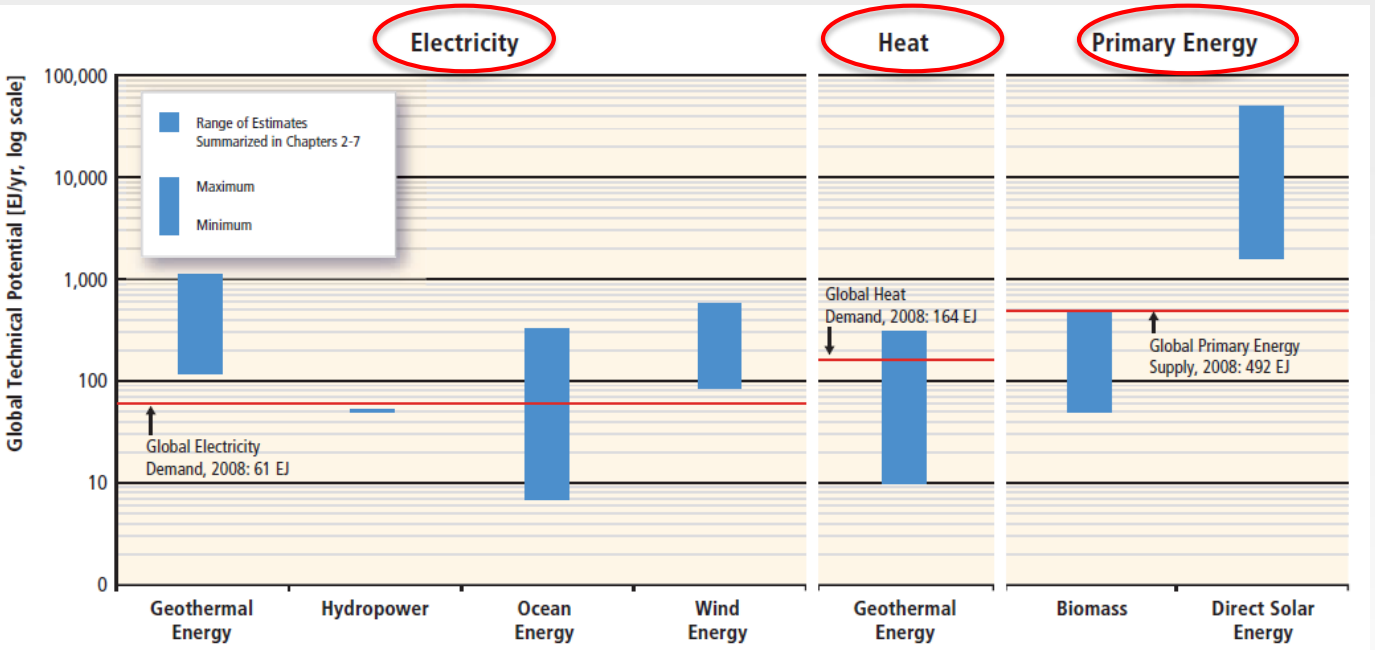
SOLARGIS



Long-term average of daily/yearly sum

Daily sum:	<	2.0	2.4	2.8	3.2	3.6	4.0	4.4	4.8	5.2	5.6	6.0	6.4 > kWh/kWp
Yearly sum:	<	730	876	1022	1168	1314	1461	1607	1753	1899	2045	2191	2337 >

The potential exceeds the demands.

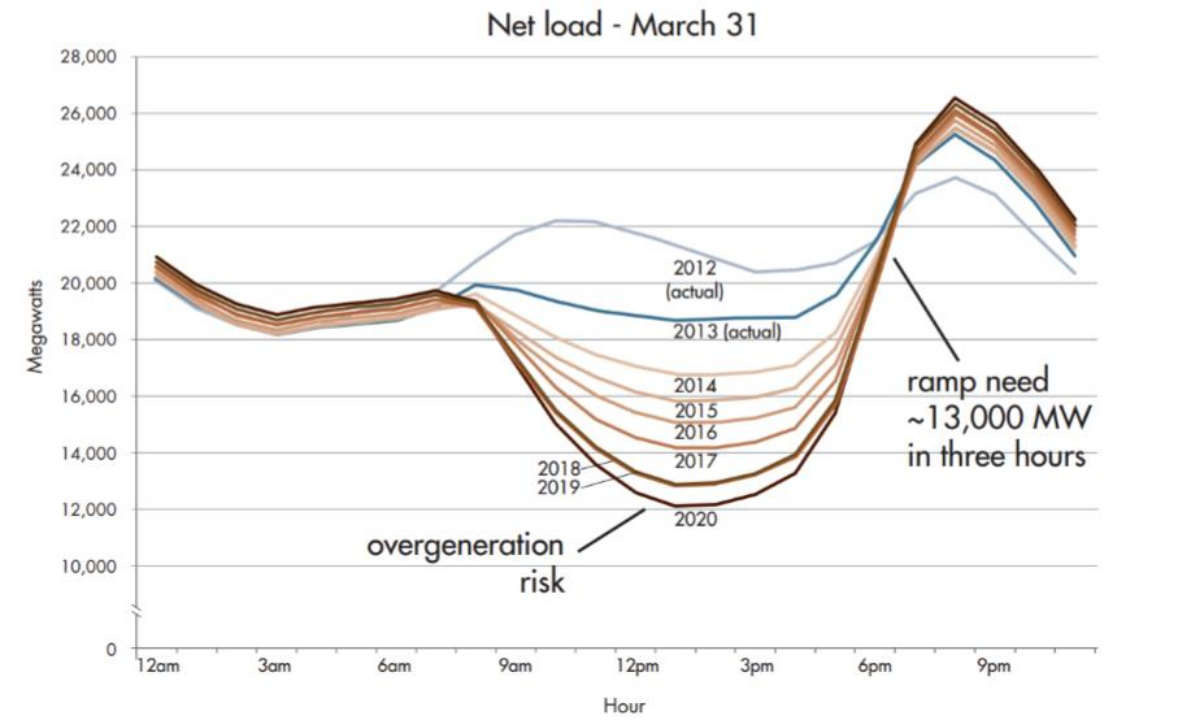


Range of Estimates of Global Technical Potentials

Max (in EJ/yr)	1109	52	331	580	312	500	49837
Min (in EJ/yr)	118	50	7	85	10	50	1575

Source: IPCC SRREN, 2011

Renewables: The intermittency challenge



Power needed except from solar

Source: Denholm et al. Overgeneration from Solar Energy in California: A Field Guide to the Duck Chart National Renewable Energy Laboratory, 2015

Storage technologies and applications

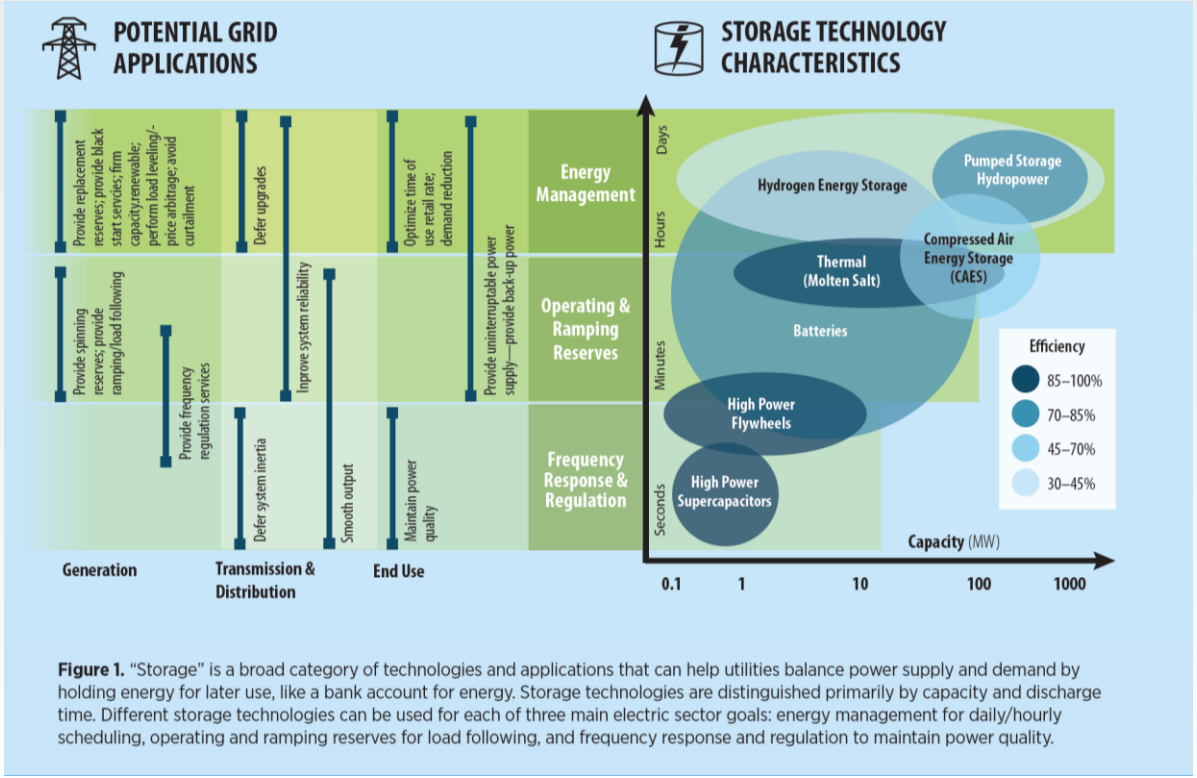
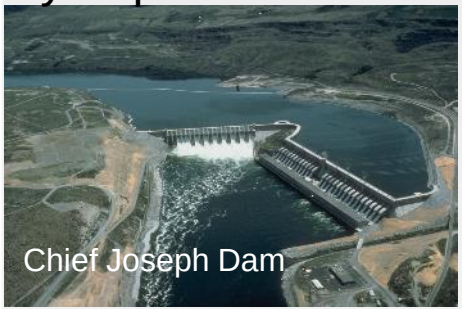


Figure 1. "Storage" is a broad category of technologies and applications that can help utilities balance power supply and demand by holding energy for later use, like a bank account for energy. Storage technologies are distinguished primarily by capacity and discharge time. Different storage technologies can be used for each of three main electric sector goals: energy management for daily/hourly scheduling, operating and ramping reserves for load following, and frequency response and regulation to maintain power quality.

Source: NREL, 2016: Energy Storage. Possibilities for Expanding Electric Grid Flexibility

Some additional renewable energy resources

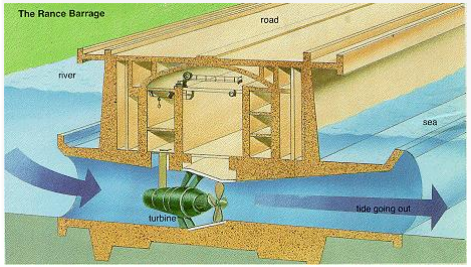
Hydropower



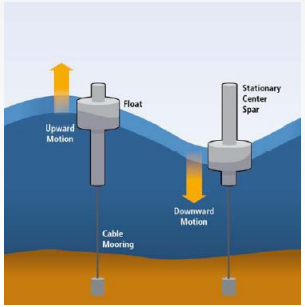
Biofuel

Geothermal

Tidal

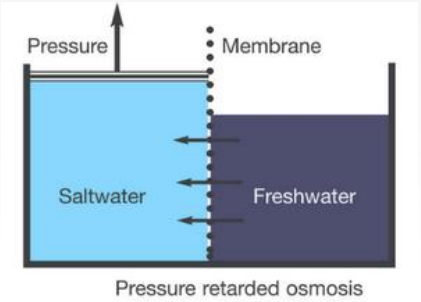


Waves



Ocean thermal gradient

Salinity gradients



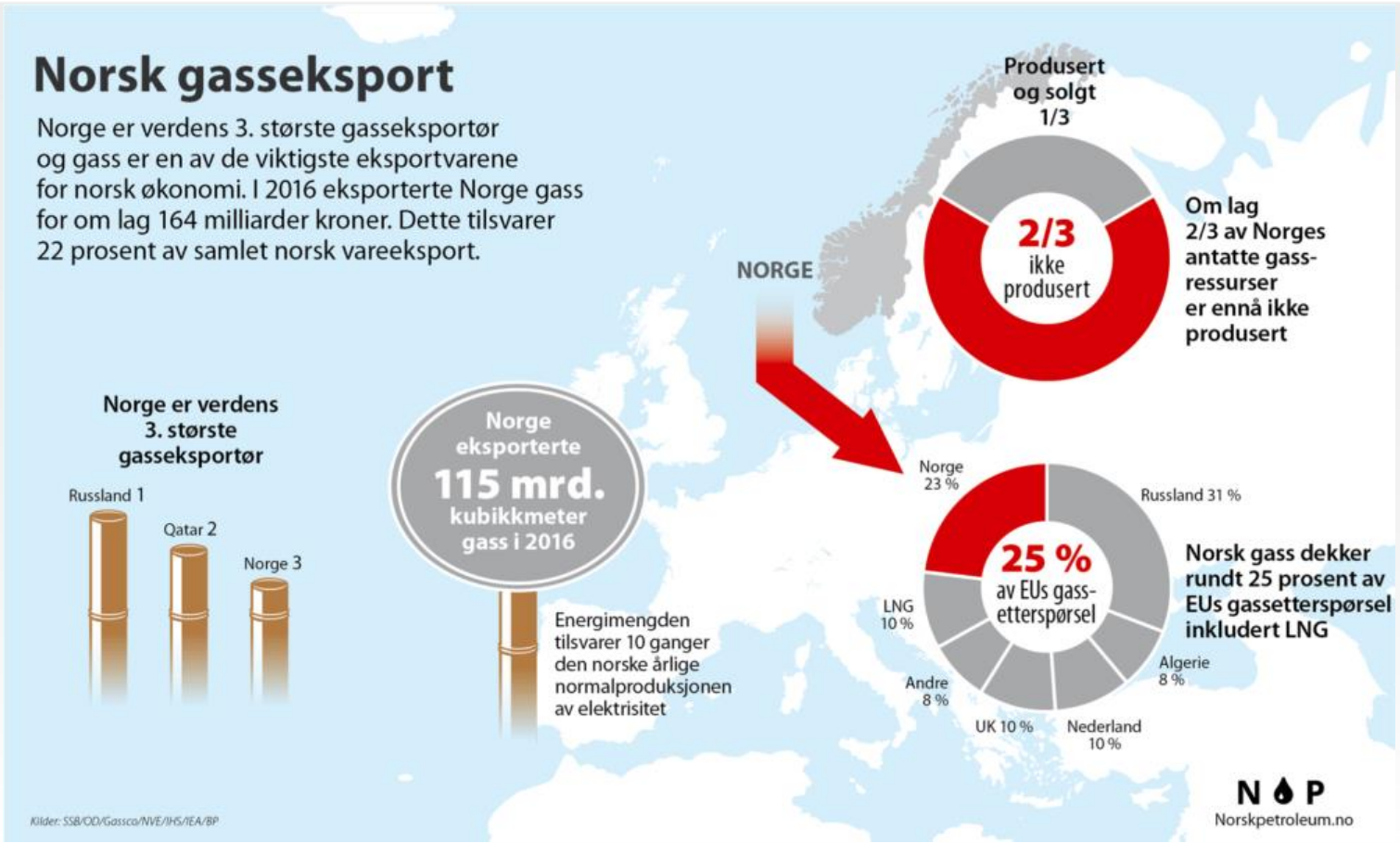
Conclusions

- The world needs more energy services – not primary energy
- Renewables, electrification and improved efficiency may reduce the total primary energy need, despite increased population and higher standard of living.
- Wind and solar are vast resources and complementary.
- Wind and solar can compete with fossil based power generation.
- Geothermal, tidal etc are site specific resources.
- Waves, salinity and ocean thermal gradient are not mature technologies.
- Energy storage is a key to increased penetration of renewables.

Eco-Lighthouse®

Statements by Karl Eirik Schøtt-Pedersen, “Norsk Olje og gass”, 29.01.18

1. Norway’s export of gas to EU corresponds to 10 times the Norwegian el-energy production
2. We need 150 000 wind turbines to replace the energy in this gas


Norsk gasseksport
Norge er verdens 3. største gasseksportør og gass er en av de viktigste eksportvarene for norsk økonomi. I 2016 eksporterte Norge gass for om lag 164 milliarder kroner. Dette tilsvarer 22 prosent av samlet norsk vareeksport.
Produsert og solgt 1/3
2/3 ikke produsert
Om lag 2/3 av Norges antatte gass-ressurser er ennå ikke produsert
NORGE
Norge er verdens 3. største gasseksportør
Russland 1
Qatar 2
Norge 3
Norge eksporterte 115 mrd. kubikkmeter gass i 2016
Energimengden tilsvarer 10 ganger den norske årlige normalproduksjonen av elektrisitet
Norge 23 %
Russland 31 %
25 % av EUs gass-etterspørsel
LNG 10 %
Algerie 8 %
Andre 8 %
UK 10 %
Nederland 10 %
Norsk gass dekker rundt 25 prosent av EUs gassetterspørsel inkludert LNG
Kilder: SSB/OD/Gassco/NVE/IHS/IEA/BP
NOD
Norskpetroleum.no

Statement 1.

- Gas export 2016: $115*10^9$ Sm^3/year (Norsk Petroleum)
- Gross energy content: 39.3 MJ/ Sm^3 or 10.9 kWh/Sm^3

- $115*10^9$ Sm^3 corresponds to 1254 TWh
- Norwegian el. Energy pr year about 140 TWh

I.e. Statement 1 approx. correct – but misleading?

Use of gas versus electricity

- Gas for generating el. power (efficiency maximum 50 - 60%)
  - I.e. 1kWh electrical energy per 2kWh gas energy.
- Gas for house heating (efficiency approx. 80%?)

- Renewables* for el. power (efficiency 100%)
- Renewables* for house heating (efficiency approx. 300%?)
  - I.e. 3kWh heat per 1kWh electricity

*) Hydro, wind, solar PV

«Primary energy factor» 2.5

- I.e. need 502TWh el. energy to replace 1254TWh gas.
- Wind energy: Capacity factor 0.4 – Need 143 GW installed power.
- Next generation wind turbines: 10MW , i.e. need 14 300 units.
- I.e. statement 2 is very misleading!
- 143 GW unrealistic?
- Present rate in EU: 15 GW/year
- Present rate in China: 25 – 30 GW/year

Conclusions

- Statements are not necessarily wrong, but misleading
- Even if energy is conserved it has various quality (2. law of thermodynamics)
- Renewables deliver high quality energy

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