

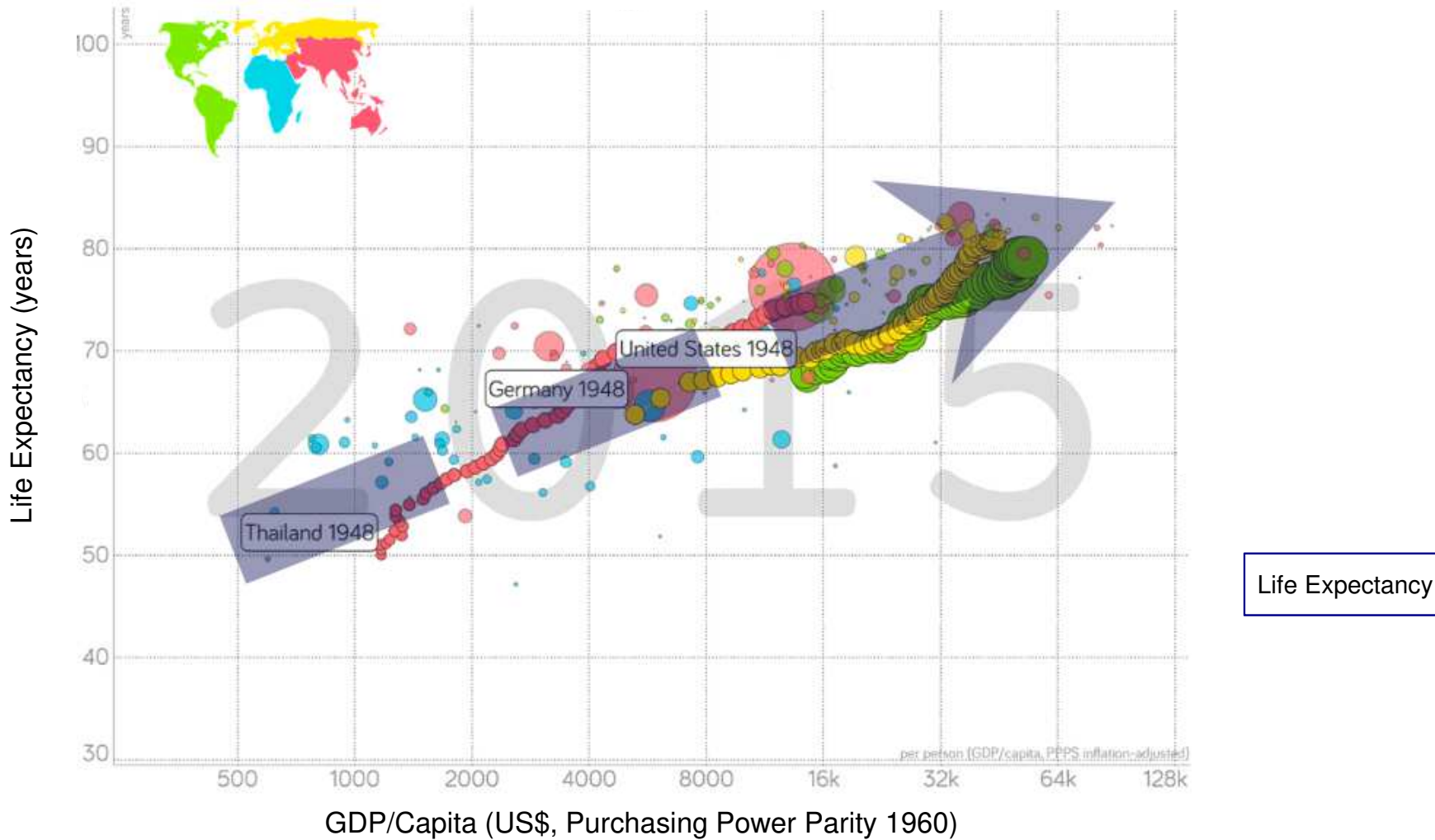
HM Lectures for Future

Energie...
...Zusammenhänge...
Bedarf, Verfügbarkeit, Nutzung

Ein Energie-Systemblick

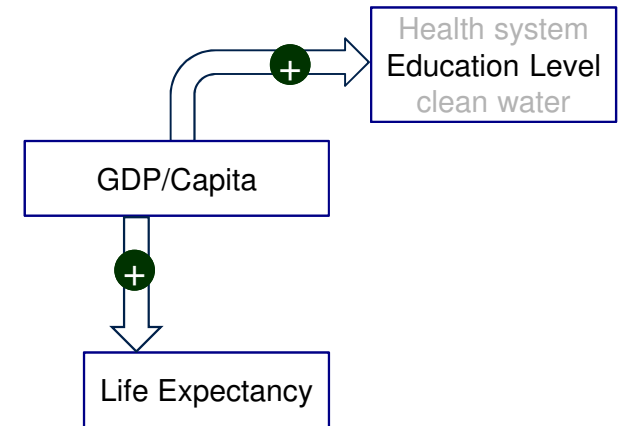
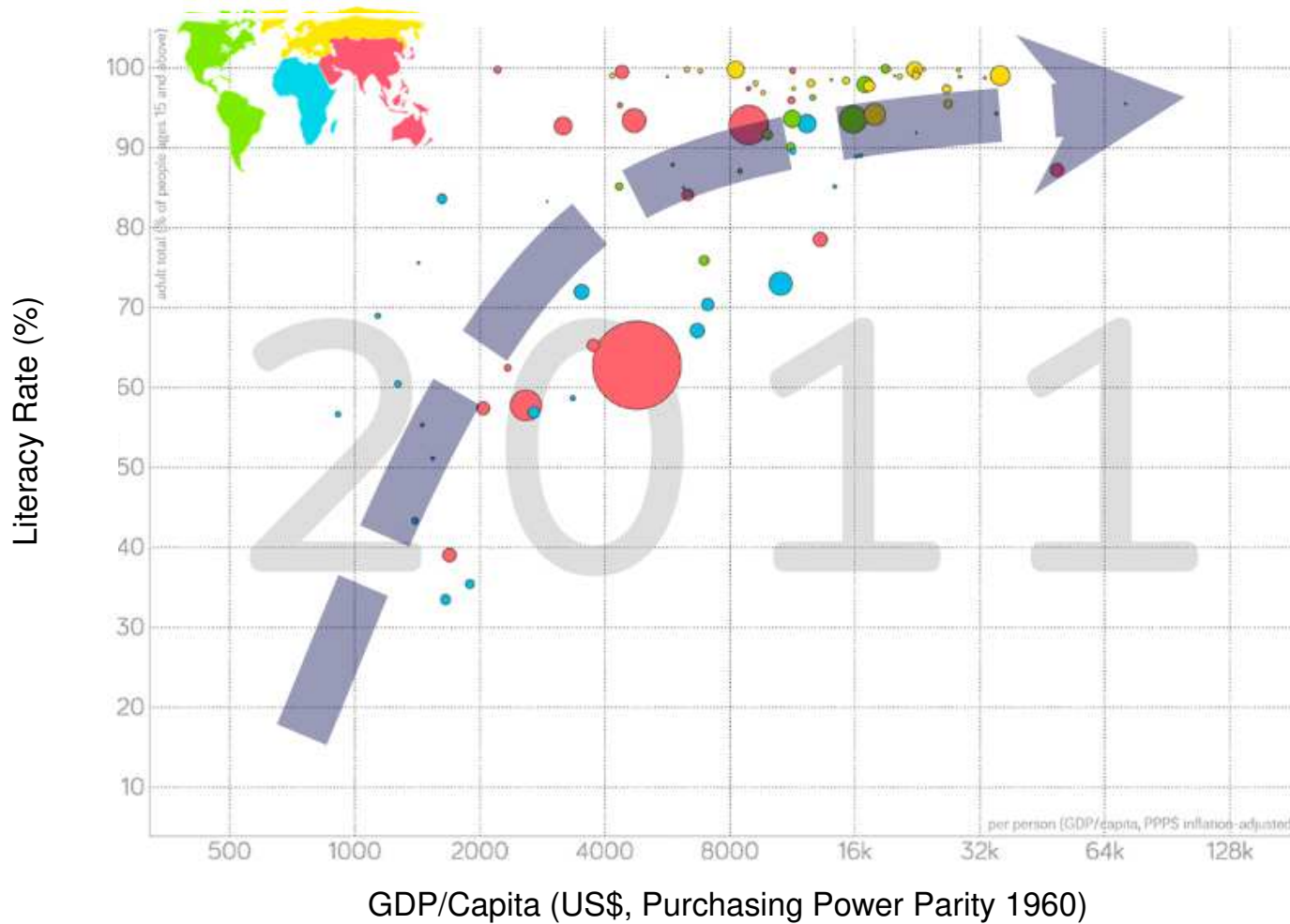


Who wants to Live a Long Life?



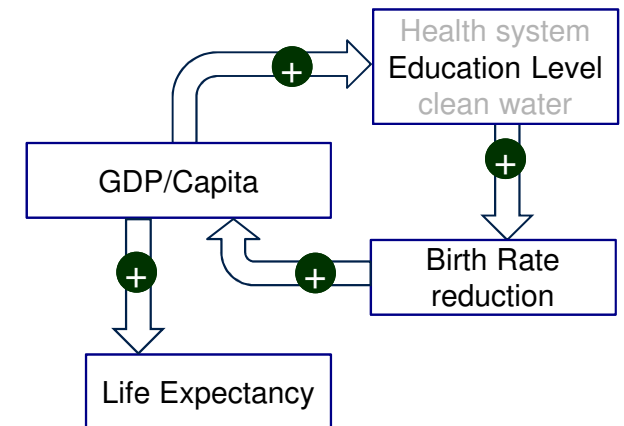
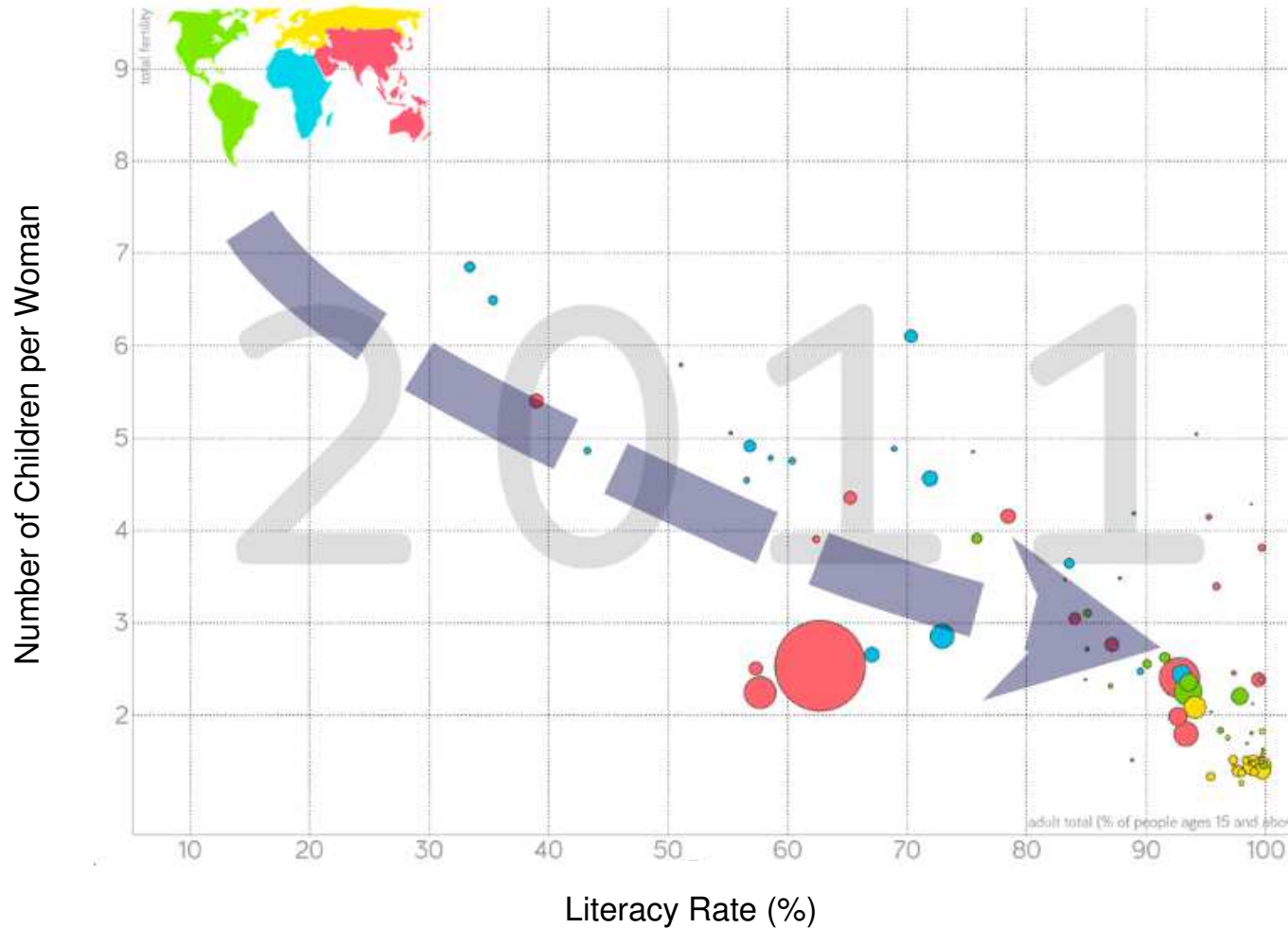
Sources: <https://www.gapminder.org/tools/> (2018-01-23), O. Rosling, A. Rosling Rönnlund: "Factfulness: Ten Reasons We're Wrong About the World..." 2018

What GDP is Good For...



Sources: <https://www.gapminder.org/tools/> (2018-01-23), <https://comboni.de/kontinentartikel/bildung-ist-der-schluessel-zum-frieden> (2020-10-26)

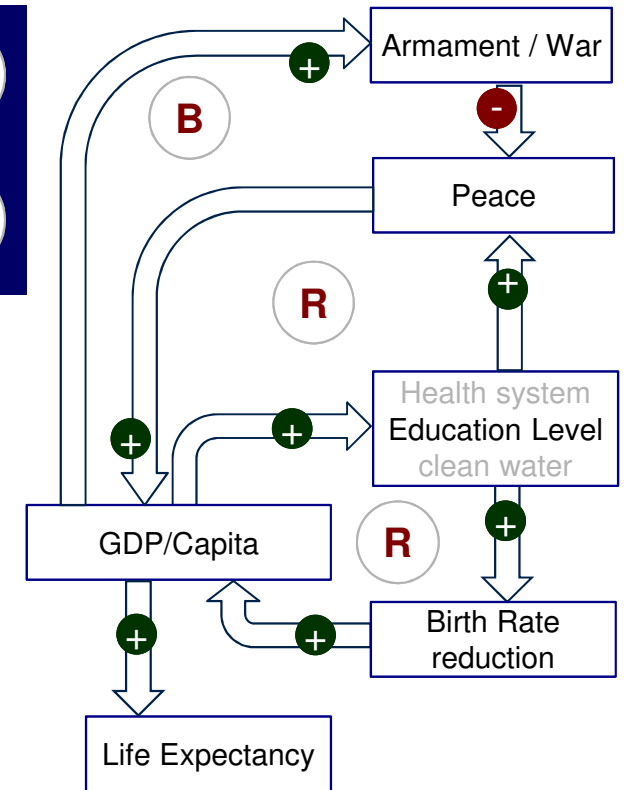
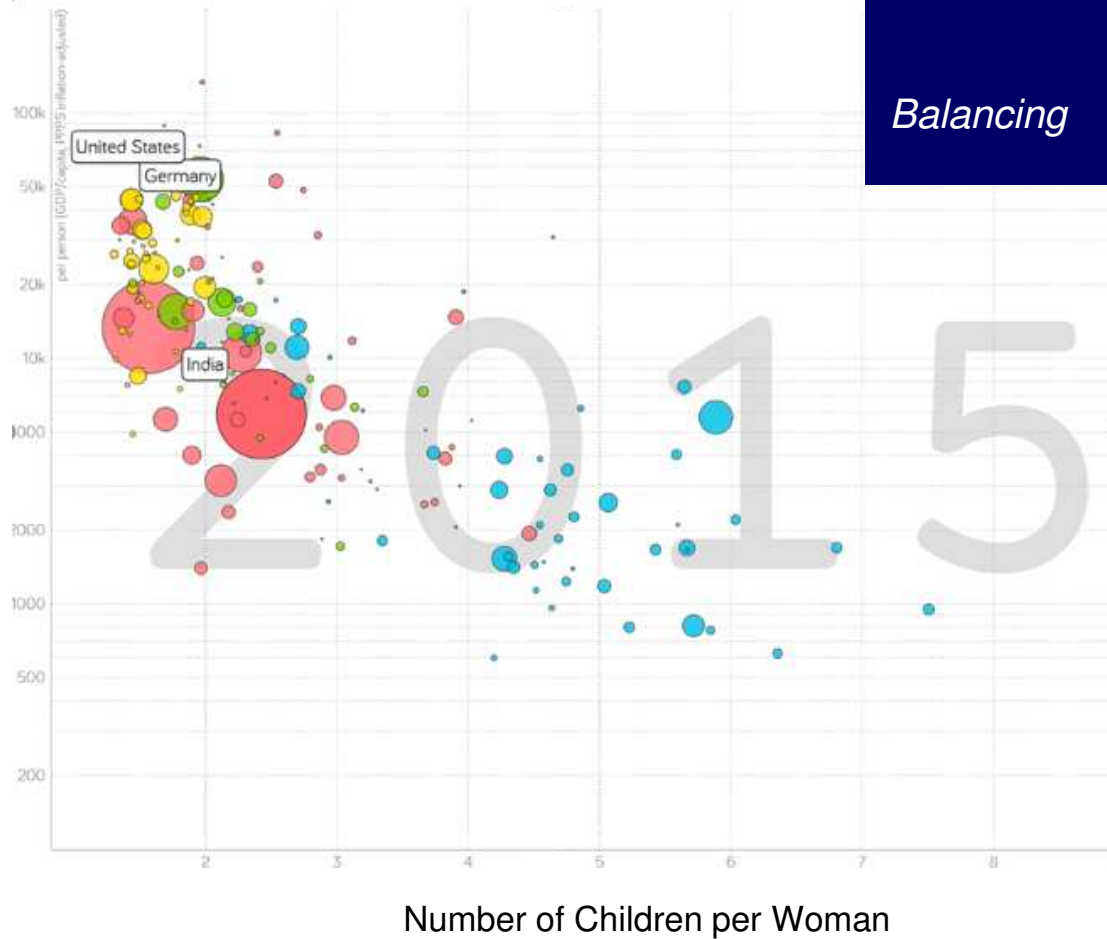
Impact of GDP and Education Level on...



Sources: <https://www.gapminder.org/tools/> (2018-01-23), O. Rosling, A. Rosling Rönnlund: "Factfulness: Ten Reasons We're Wrong About the World..." 2018

GDP and Education Level Base of a Re-Inforcement Cycle

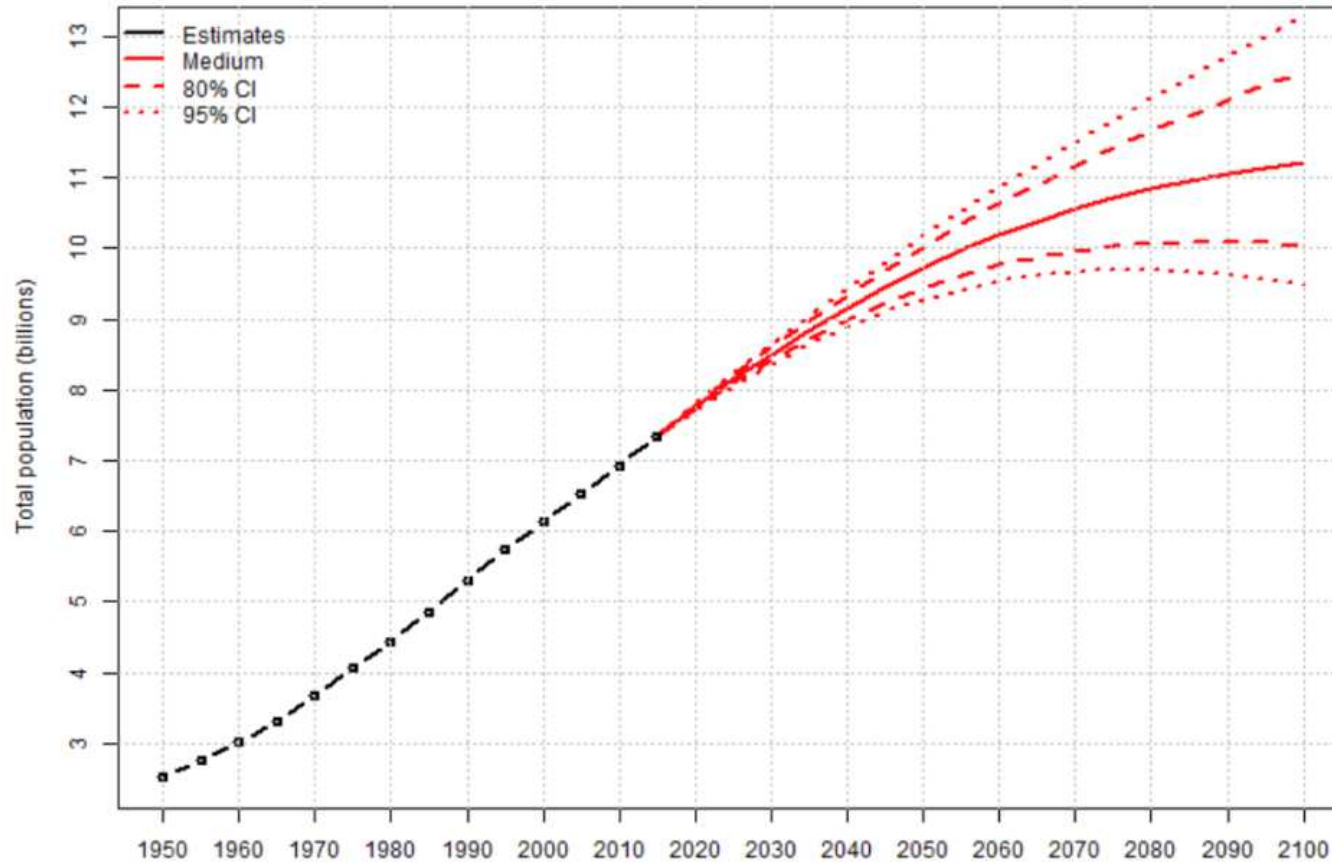
GDP/Capita (US\$, Purchasing Power Parity 1960)



Im Sudan (75% Analphabeten, 4,5 Kinder pro Frau) ist es für Mädchen drei Mal wahrscheinlicher, schwanger zu werden und an den Komplikationen der Geburt zu sterben, als die Schule zu beenden (UNICEF. 2018).

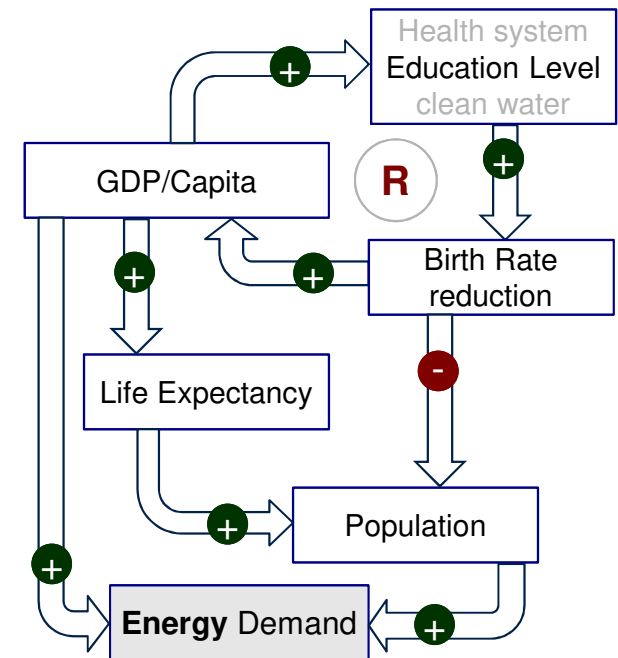
Sources: <https://www.gapminder.org/tools/> (2018-01-23), O. Rosling, A. Rosling Rönnlund: "Factfulness: Ten Reasons We're Wrong About the World..." 2018

Worldwide Population Forecast



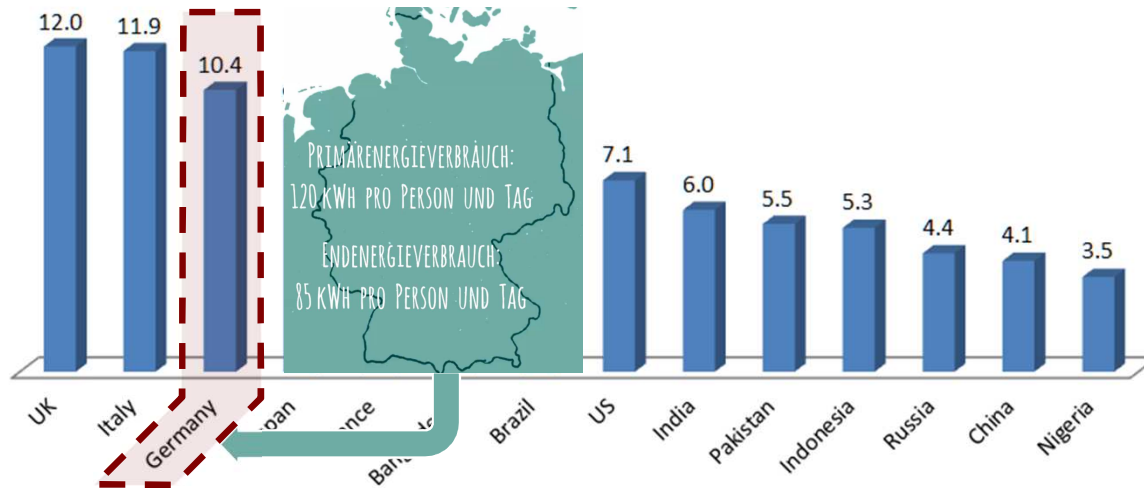
Source: United Nations, Department of Economic and Social Affairs, Population Division (2015). *World Population Prospects: The 2015 Revision*. New York: United Nations.

With how many people do we have to calculate?

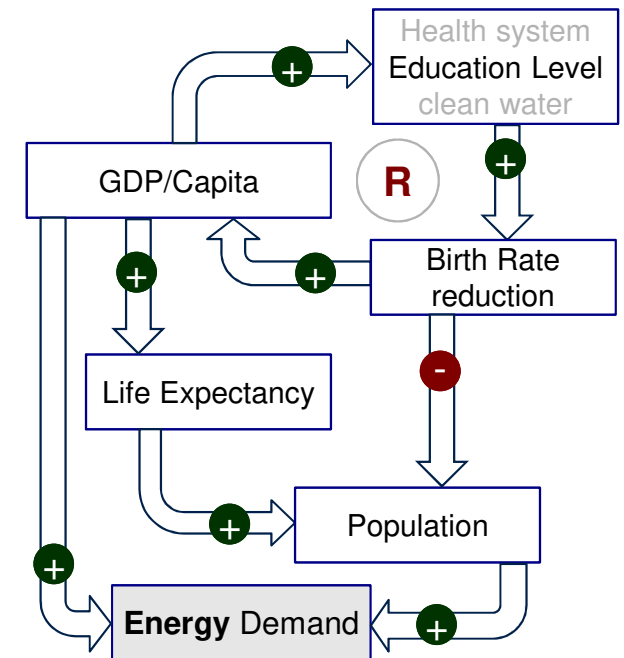


Finally an Answer on... How Much Energy do we need?

GDP per kg Oil Equivalent
(US\$ Purchasing Power Parity 1960 per kg per capita)



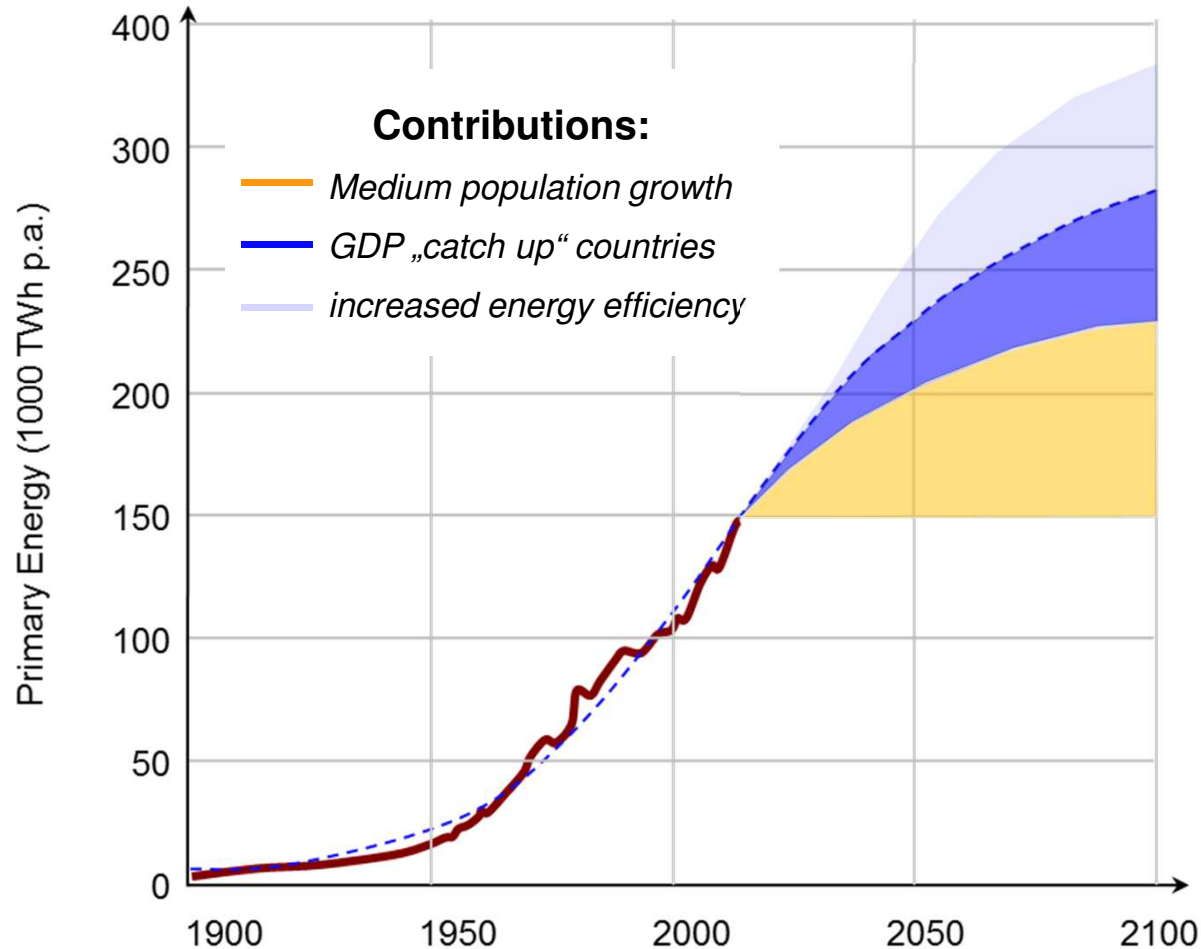
How much energy
is needed to get rich?
Indicator: *Primary Energy
Supply [toe/Cap/a]*



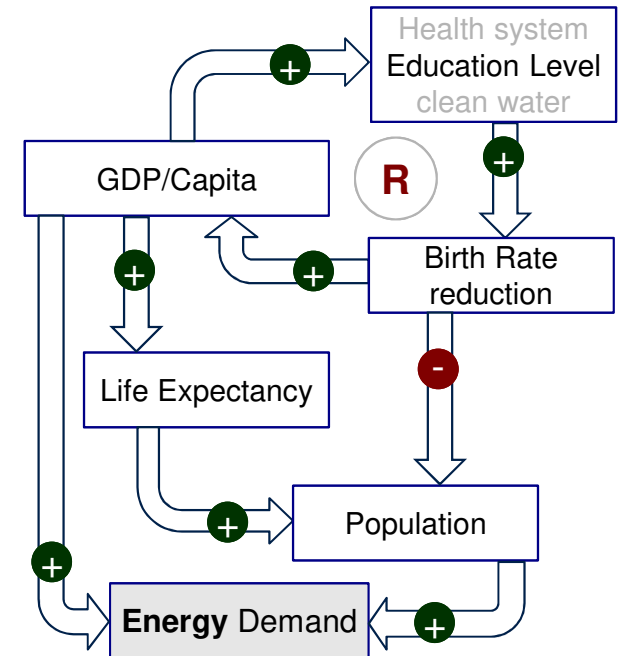
Sources: By 未知との遭遇 - Own work, CC BY-SA 3.0, <https://commons.wikimedia.org/w/index.php?curid=31191111> (2020-10-13)

Brian Walsh et al. "Pathways for balancing CO₂ emissions and sinks", NATURE COMMUNICATIONS | 8:14856 | DOI: 10.1038/ncomms14856, 2017

Finally an Answer on... How Much Energy do we need?

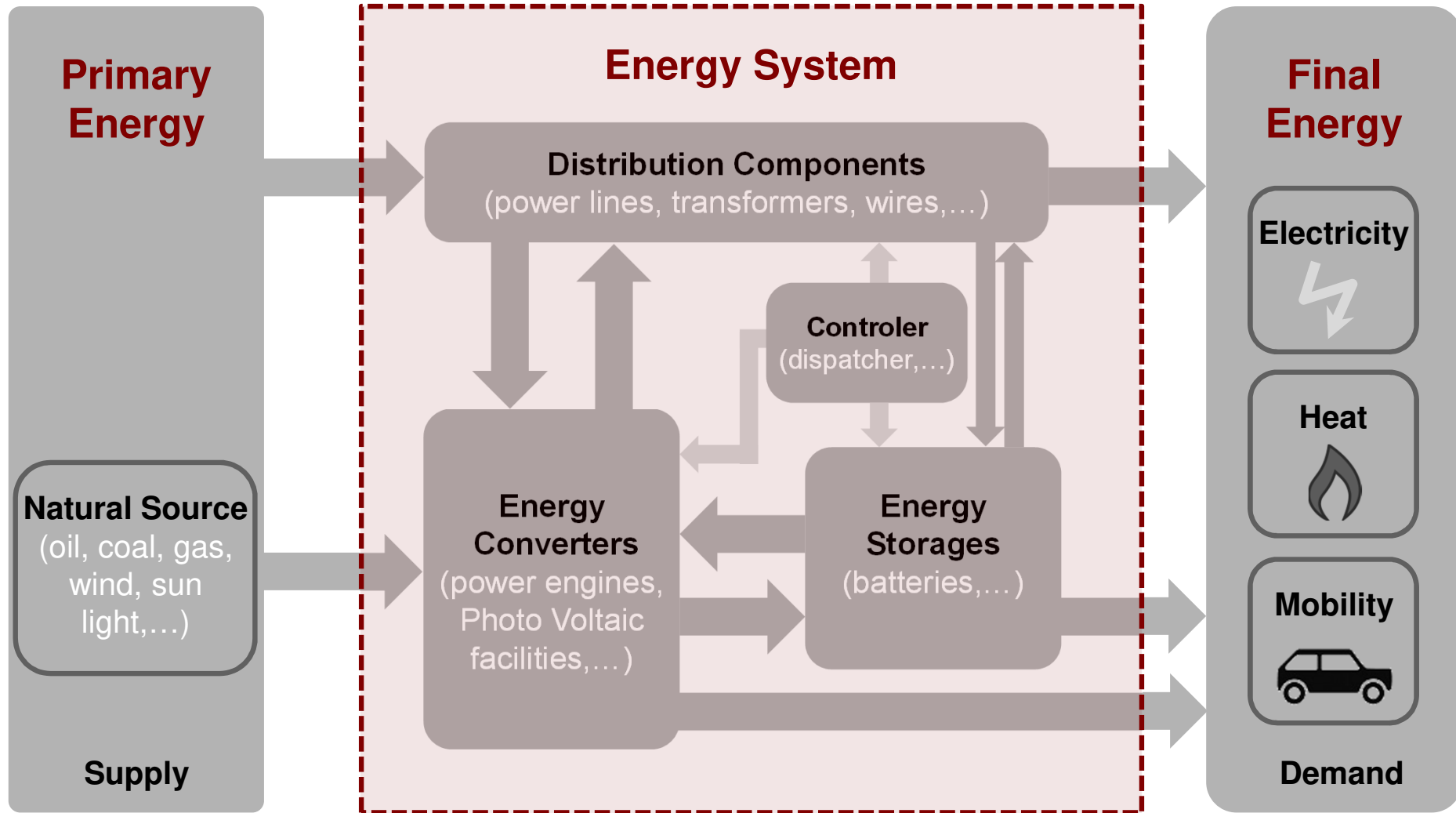


How much energy is needed to get rich?
Indicator: *Primary Energy Supply [toe/Cap/a]*

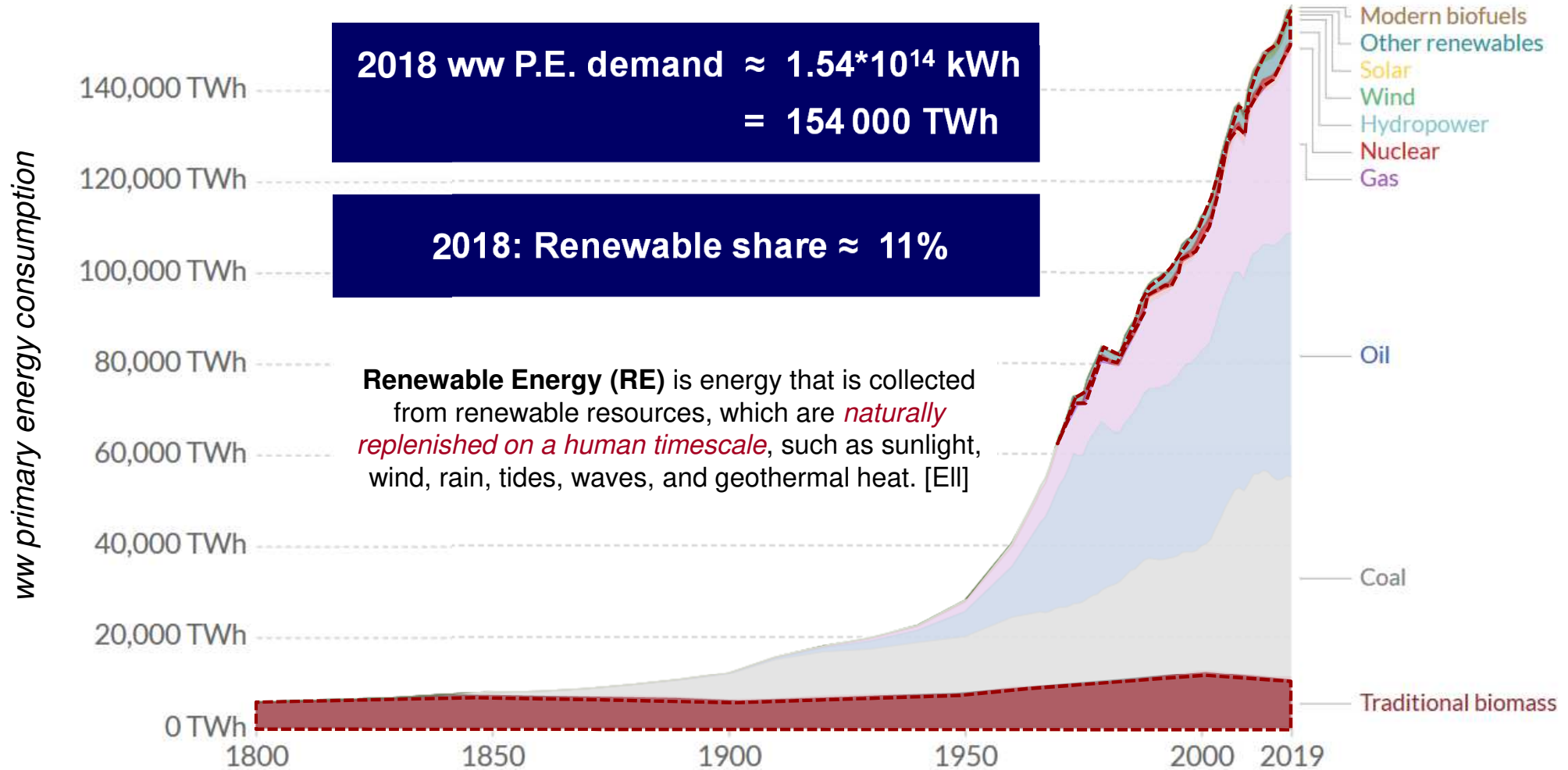


Sources: By 未知との遭遇 - Own work, CC BY-SA 3.0, <https://commons.wikimedia.org/w/index.php?curid=31191111> (2020-10-13)

Brian Walsh et al. "Pathways for balancing CO₂ emissions and sinks", NATURE COMMUNICATIONS | 8:14856 | DOI: 10.1038/ncomms14856, 2017

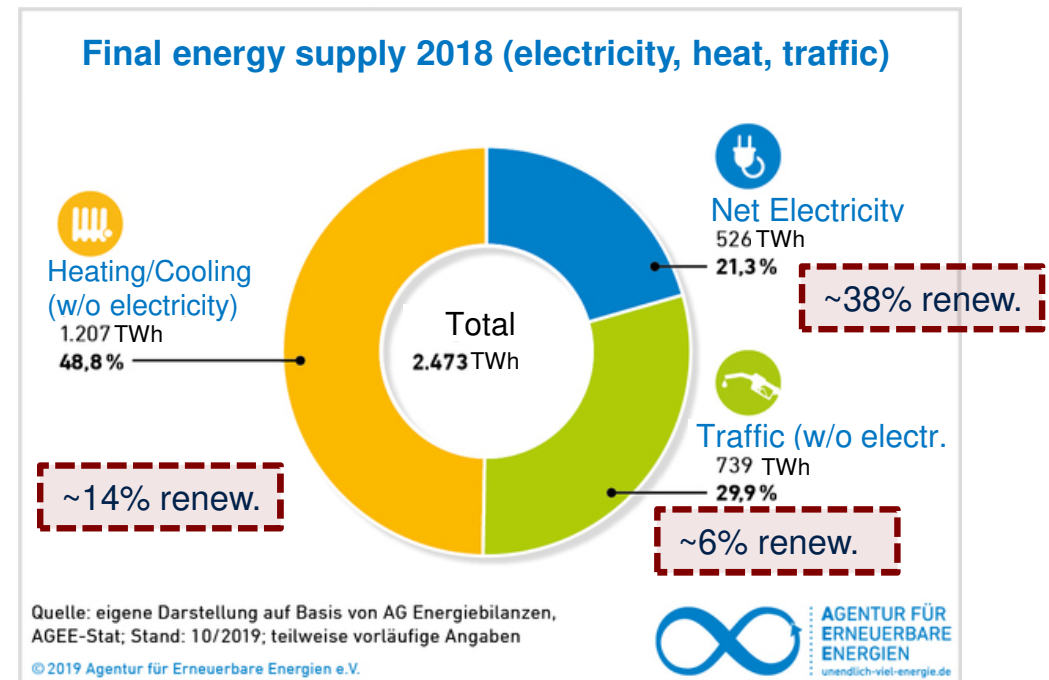
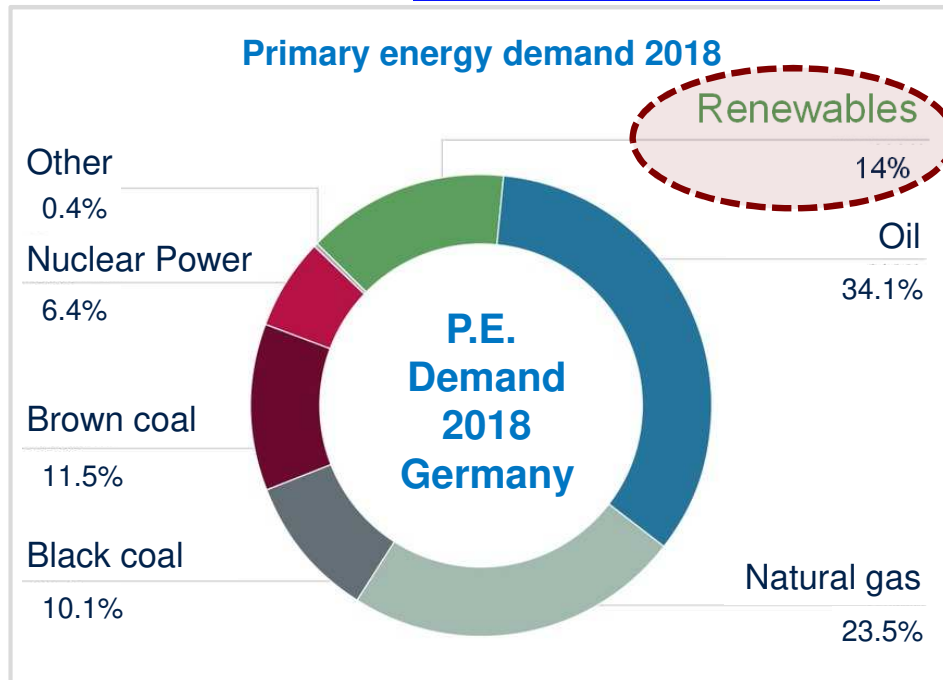
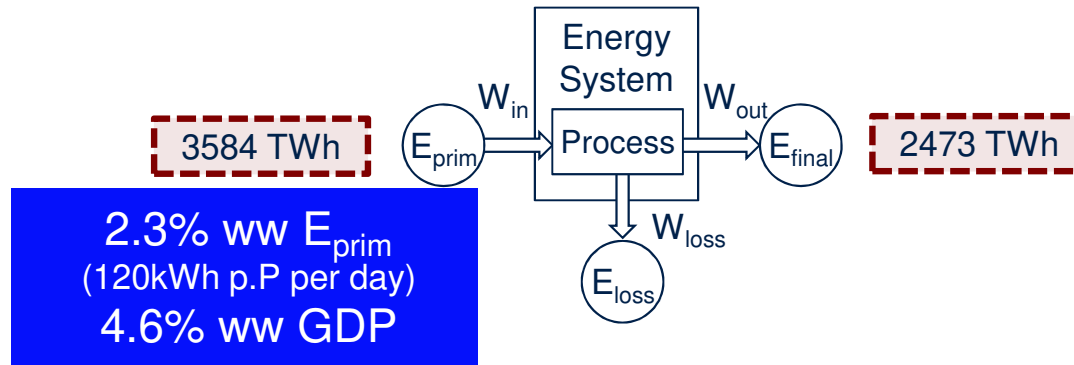


Ww Primary Energy Demand

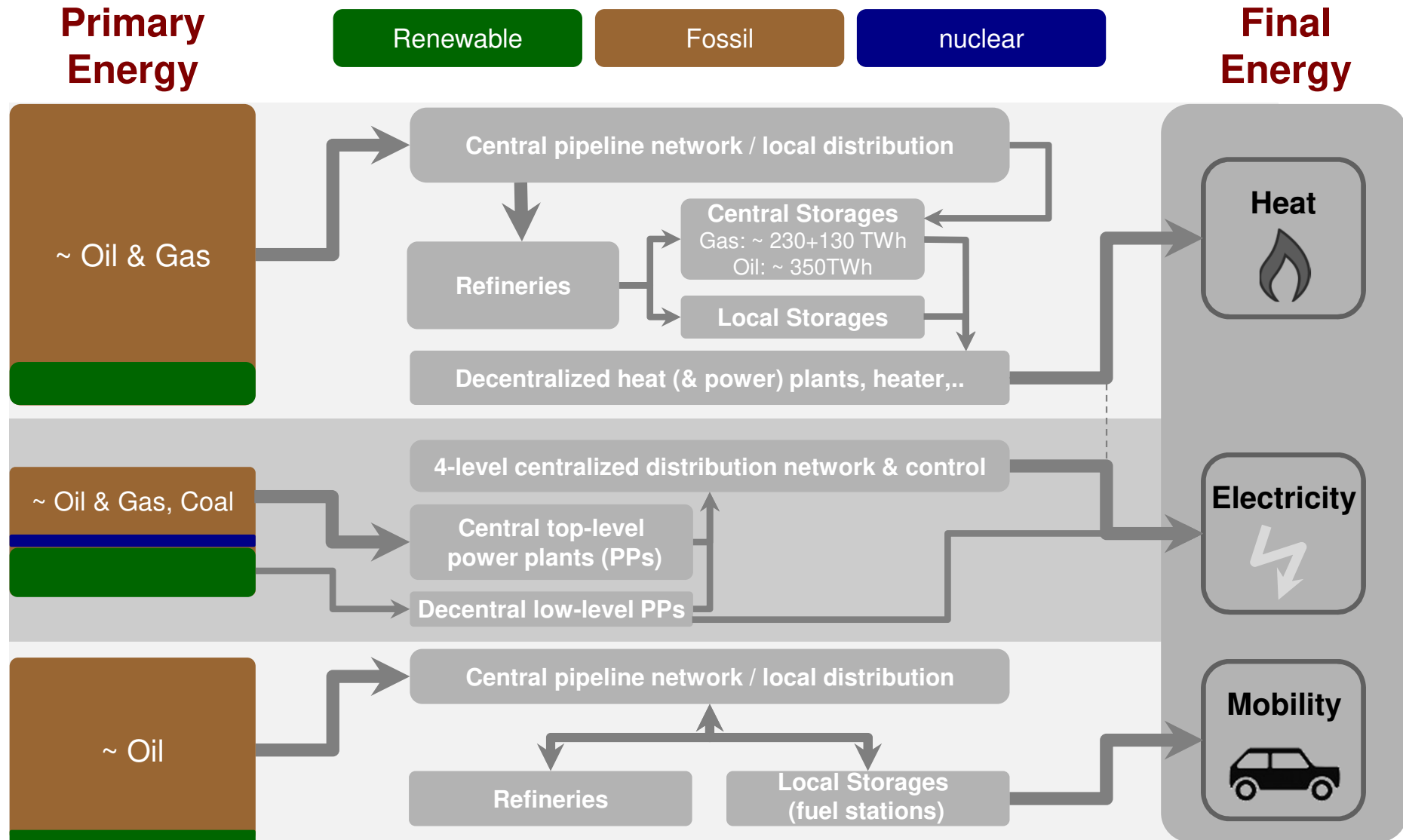


Sources: 1) Hannah Ritchie and Max Roser, University of Oxford "our world in data - Energy": <https://ourworldindata.org/energy> 2018 (2020-10-30)

2) [EII] Ellabban, Omar; Abu-Rub, Haitham; Blaabjerg, Frede (2014). "Renewable energy resources...", *Renewable and Sustainable Energy Reviews*. **39**: 748–764 [749].

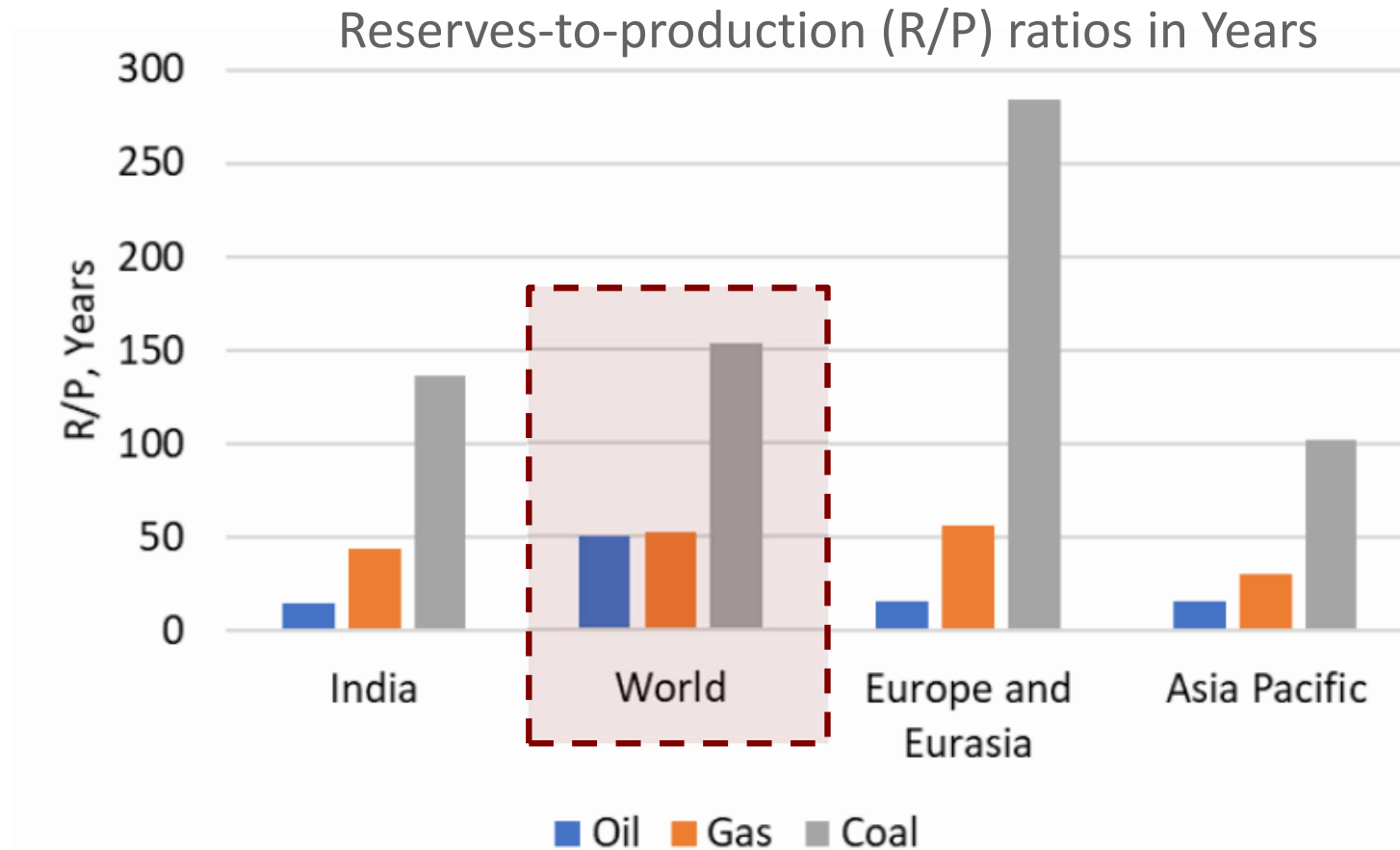


Sources: <https://www.bmwi.de/Redaktion/DE/Infografiken/Energie/energie-primarverbrauch.html> (2019-11-28)
<https://www.unendlich-viel-energie.de/mediathek/grafiken/endenergieverbrauch-nach-strom-waerme-und-verkehr> (2019-11-28)

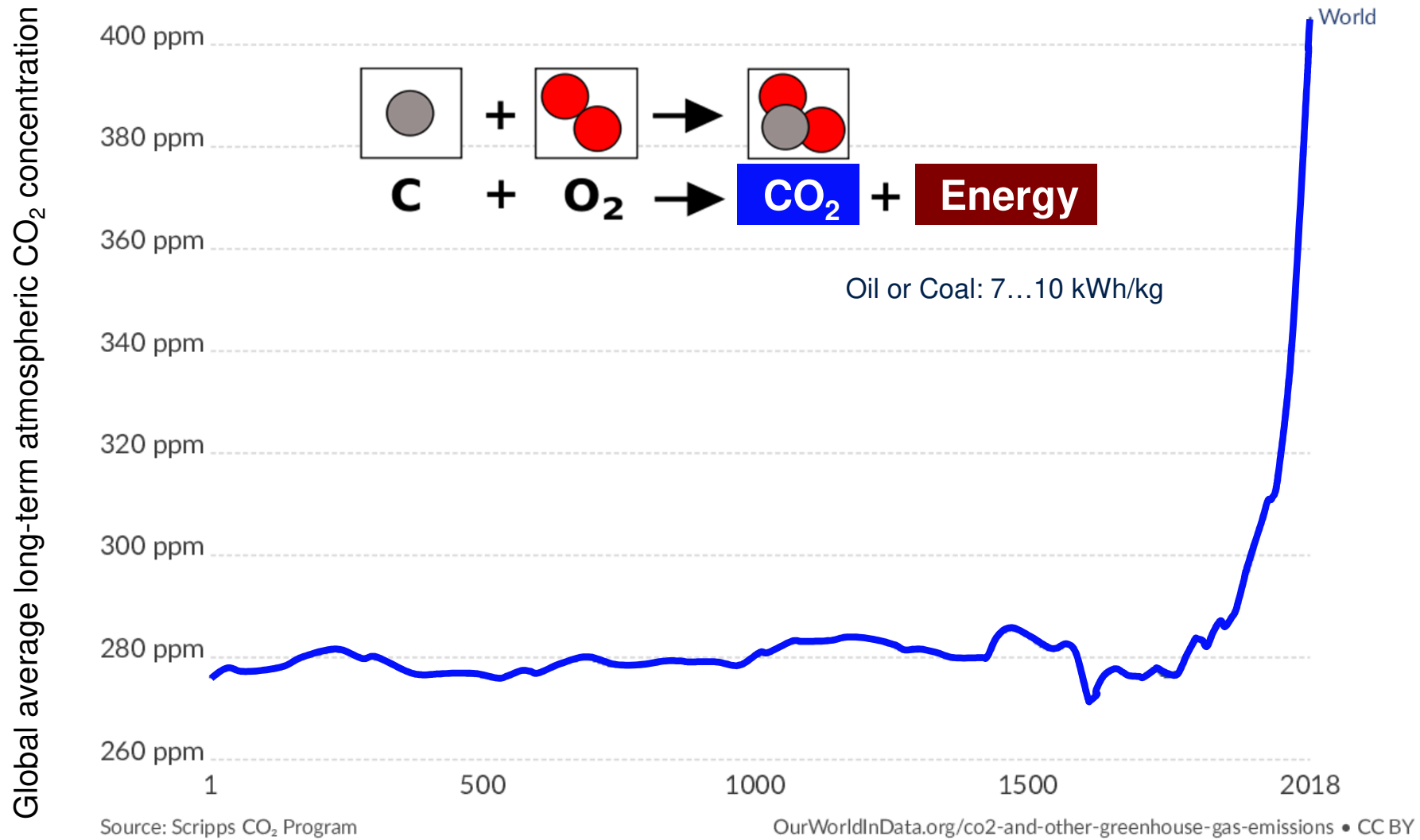


For how long are Fossil Resources Available?

Fossil Energy is a fuel (and related energy) formed by natural processes, such as anaerobic decomposition of buried dead organisms, containing energy originating in **ancient photosynthesis**. [Sak]



Source: Gupta, Arvind. (2018). HYDROGEN FROM BIOMASS BY OXY-STEAM GASIFICATION-A QUANTITATIVE ANALYSIS OF CASES. 10.5071/26thEUBCE2018-2CV.4.22.

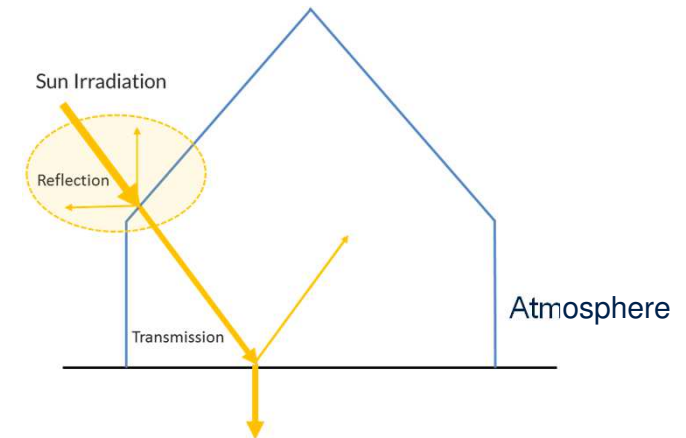
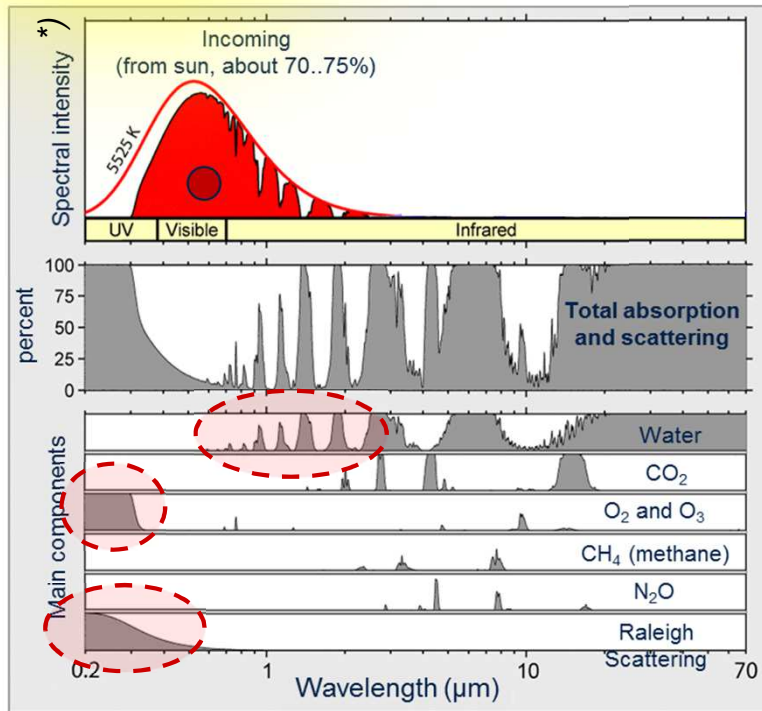
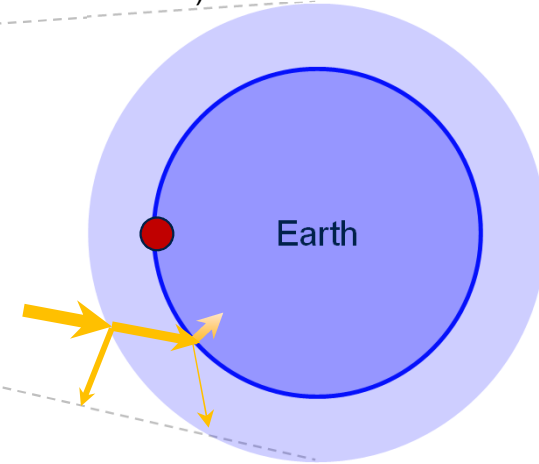
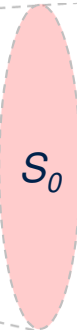
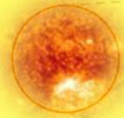


Sun - THE Renewable Resource

Greenhouse Effect

$T \approx 5525K$
($P_{max} : \lambda \approx 500nm$)

$1368 W/m^2$
(„solar constant“)



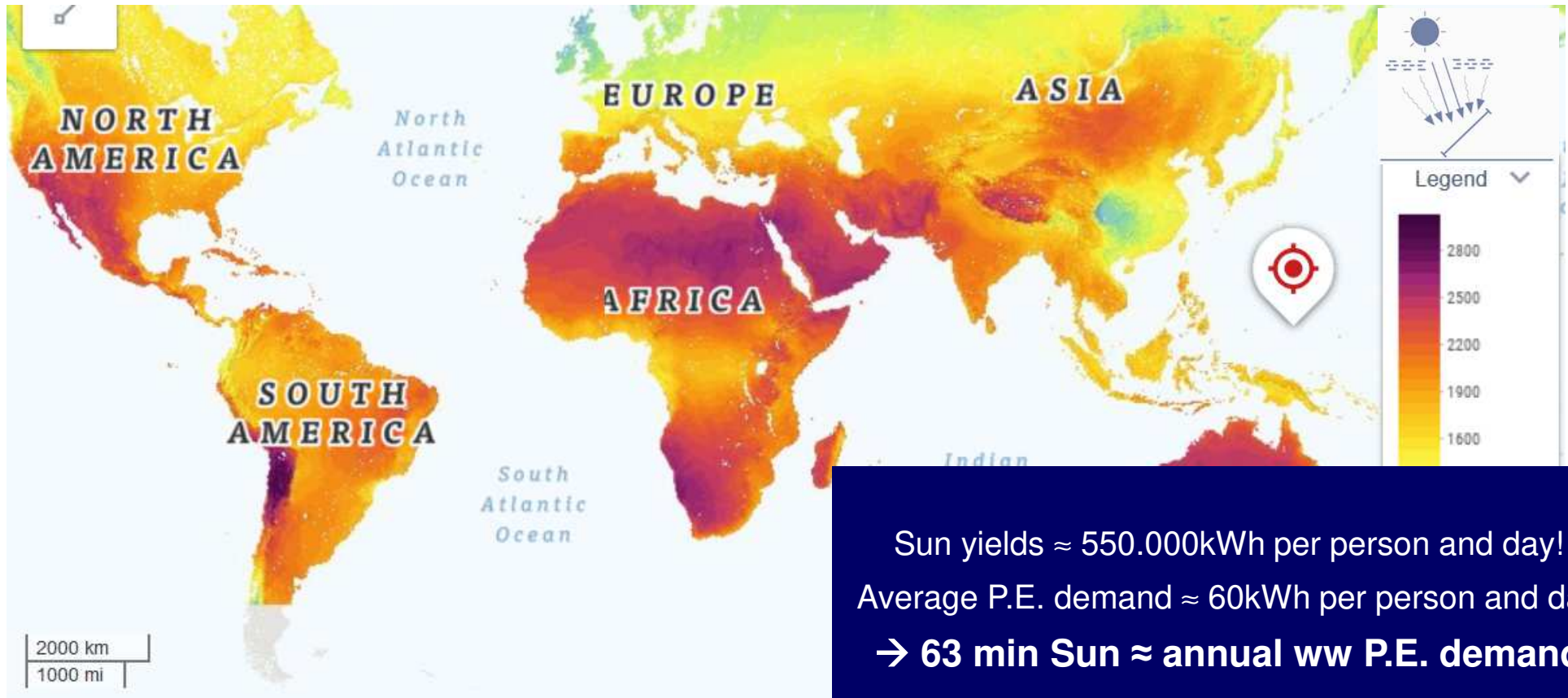
Sources: https://en.wikipedia.org/wiki/Greenhouse_effect (2018-02-27)
<https://commons.wikimedia.org/w/index.php?curid=75333400> (2020-10-27)

*) $\frac{\text{Energie}}{\text{Zeit Fläche Wellenlänge}}$

Sun - THE Renewable Resource

Greenhouse Effect

Global tilted irradiation at optimum angle $S_0 \approx 1368 \text{ W/m}^2$ („solar constant“)



Source: The World Bank - <https://globalsolaratlas.info>, CC BY 4.0, <https://commons.wikimedia.org/w/index.php?curid=73047799> (2019-06-05)

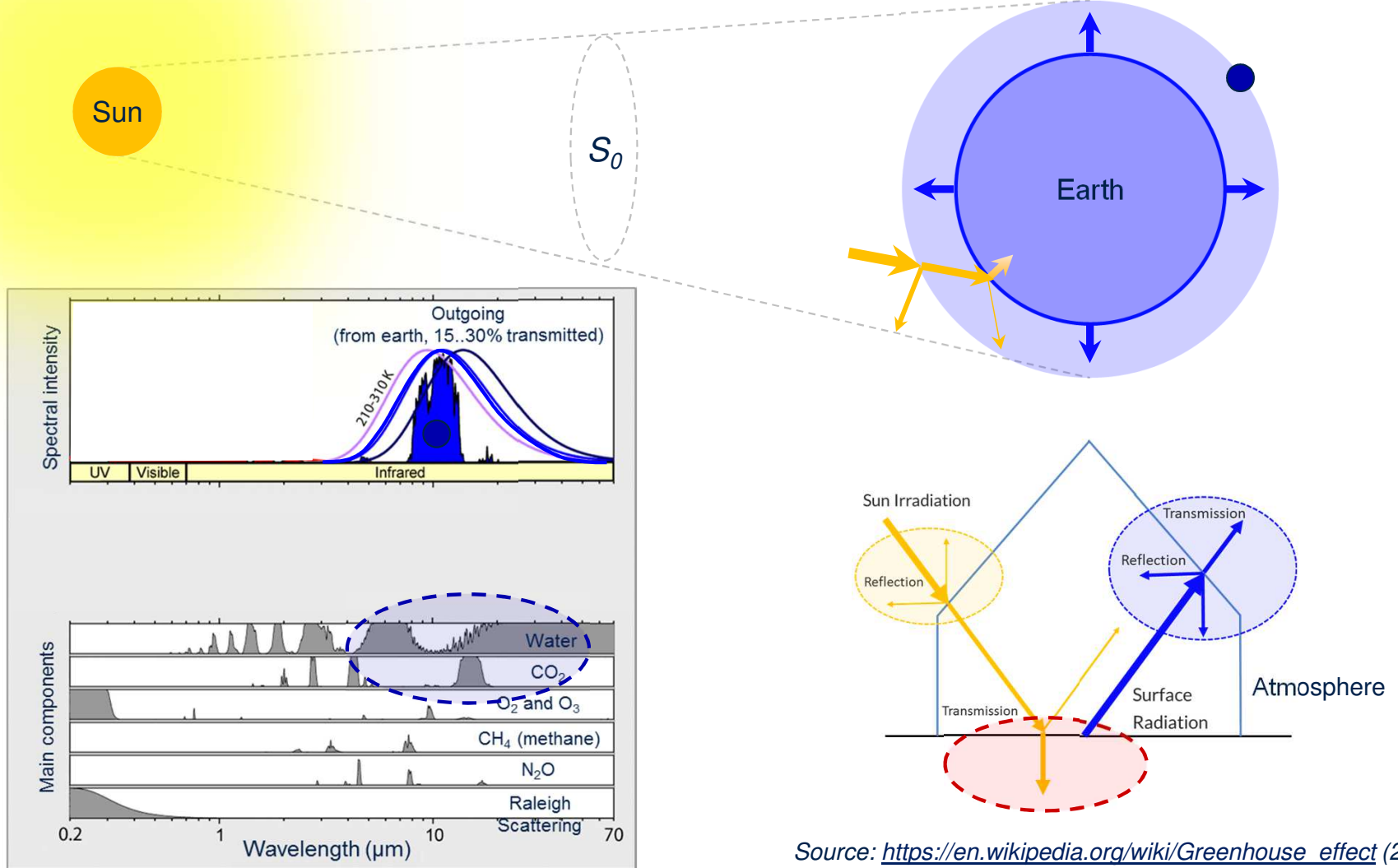
Sun - THE Renewable Resource

Greenhouse Effect

$T \approx 5525K$
($P_{max} : \lambda \approx 500nm$)

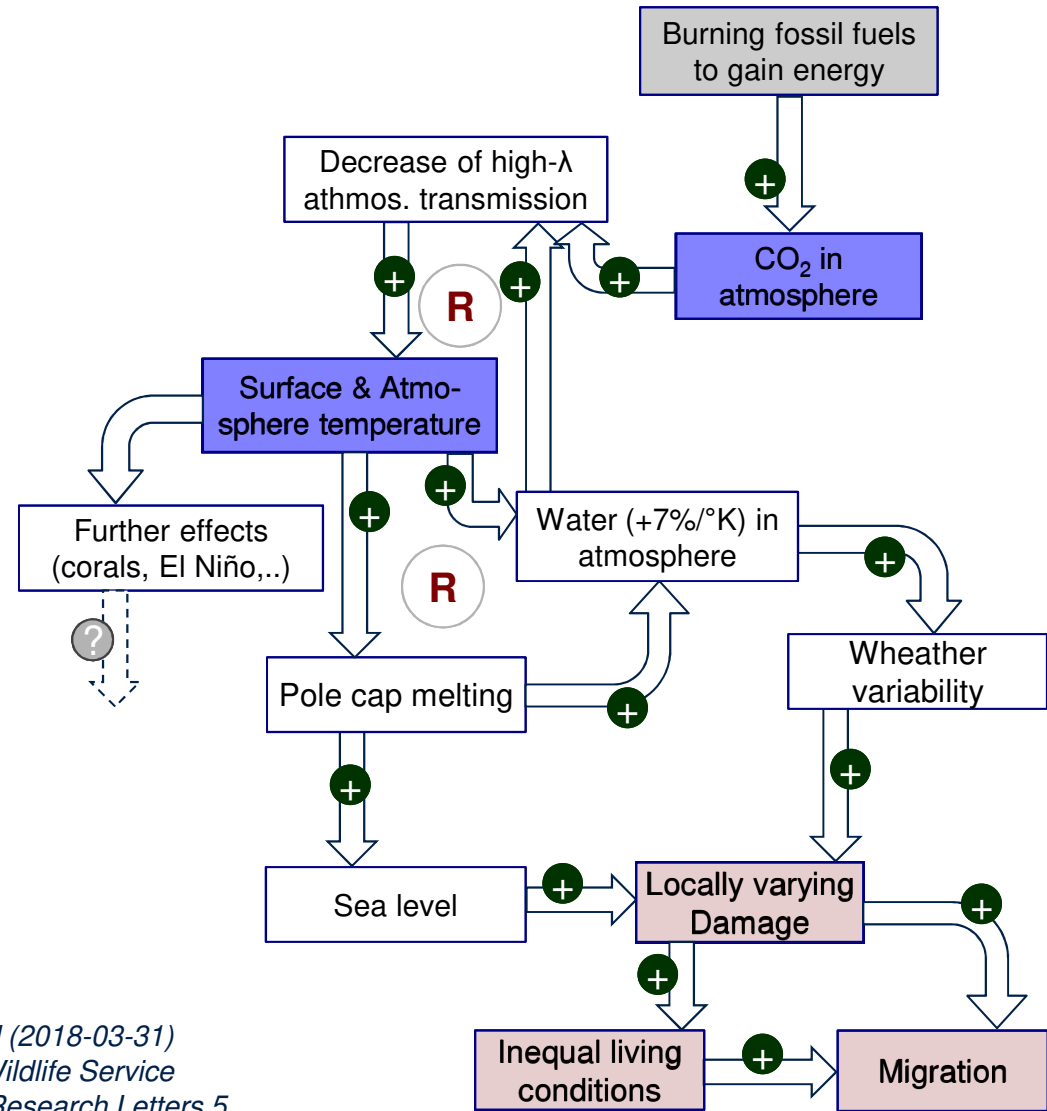
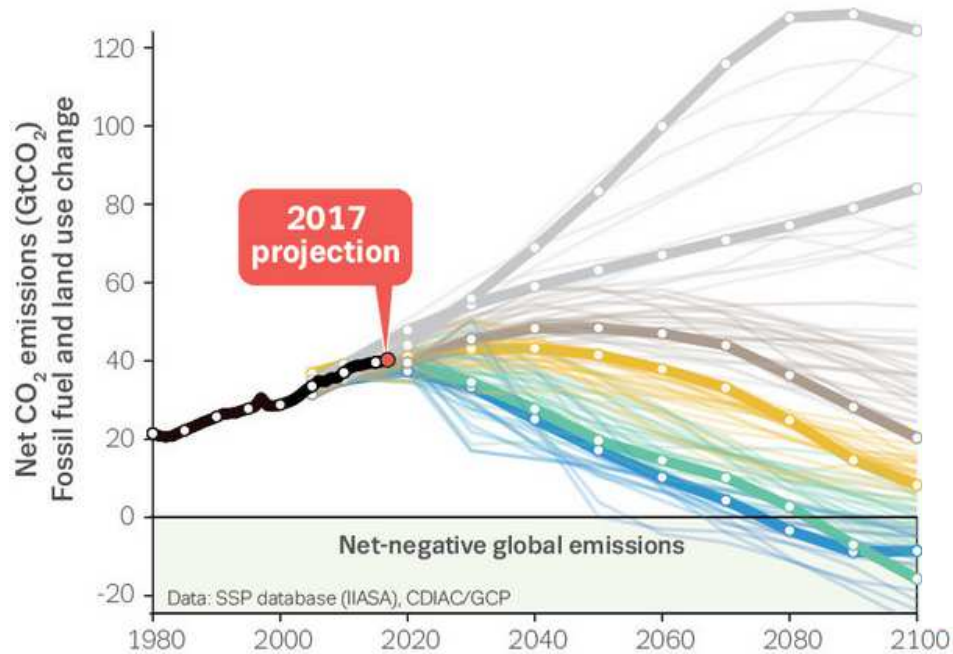
$1368 W/m^2$
(„solar constant“)

$T \approx 288K$
($P_{max} : \lambda \approx 500nm$)



Source: https://en.wikipedia.org/wiki/Greenhouse_effect (2018-02-27)

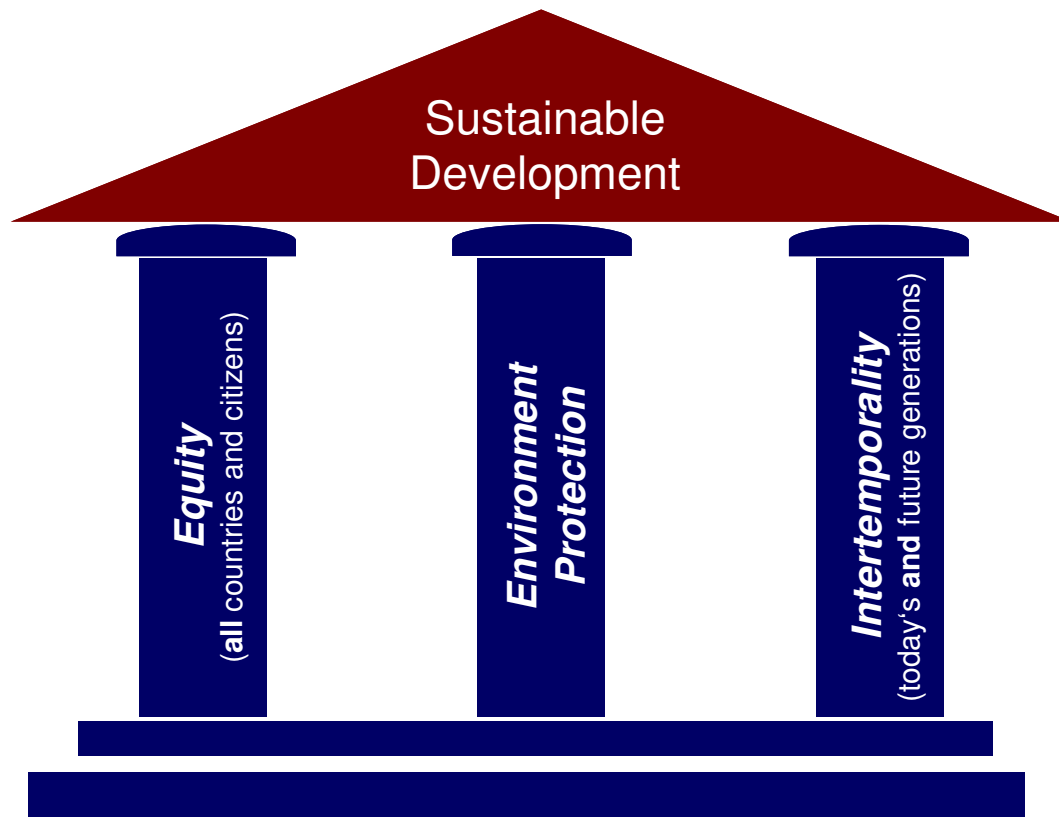
Cause-Effect Relations from Fossil Resource Burning ...to Global Warming and its Effects



Sources: <https://phys.org/news/2017-11-global-carbon-dioxide-emissions-stable.html> (2018-03-31)
<https://www.washingtonpost.com/> (2019-05-21) colourbox, U.S. Fish and Wildlife Service
 Bengtsson, L. (2010): The global atmospheric water cycle, *Environmental Research Letters* 5,
 doi:10.1088/1748-9326/5/2/025002

Sustainability – What does it Mean?

Sustainable Development := Development that meets the needs of the present without compromising the ability of future generations to meet their own needs. [UN] *)



Bolivien ist nach Ecuador das zweite Land, das die „Erde“ als **Rechtsperson** ansieht und ihr als solche Rechte zugesteht.

Article 9 Constitution of Bolivia



The following are essential purposes and functions of the State, in addition to those established in the Constitution and the law:

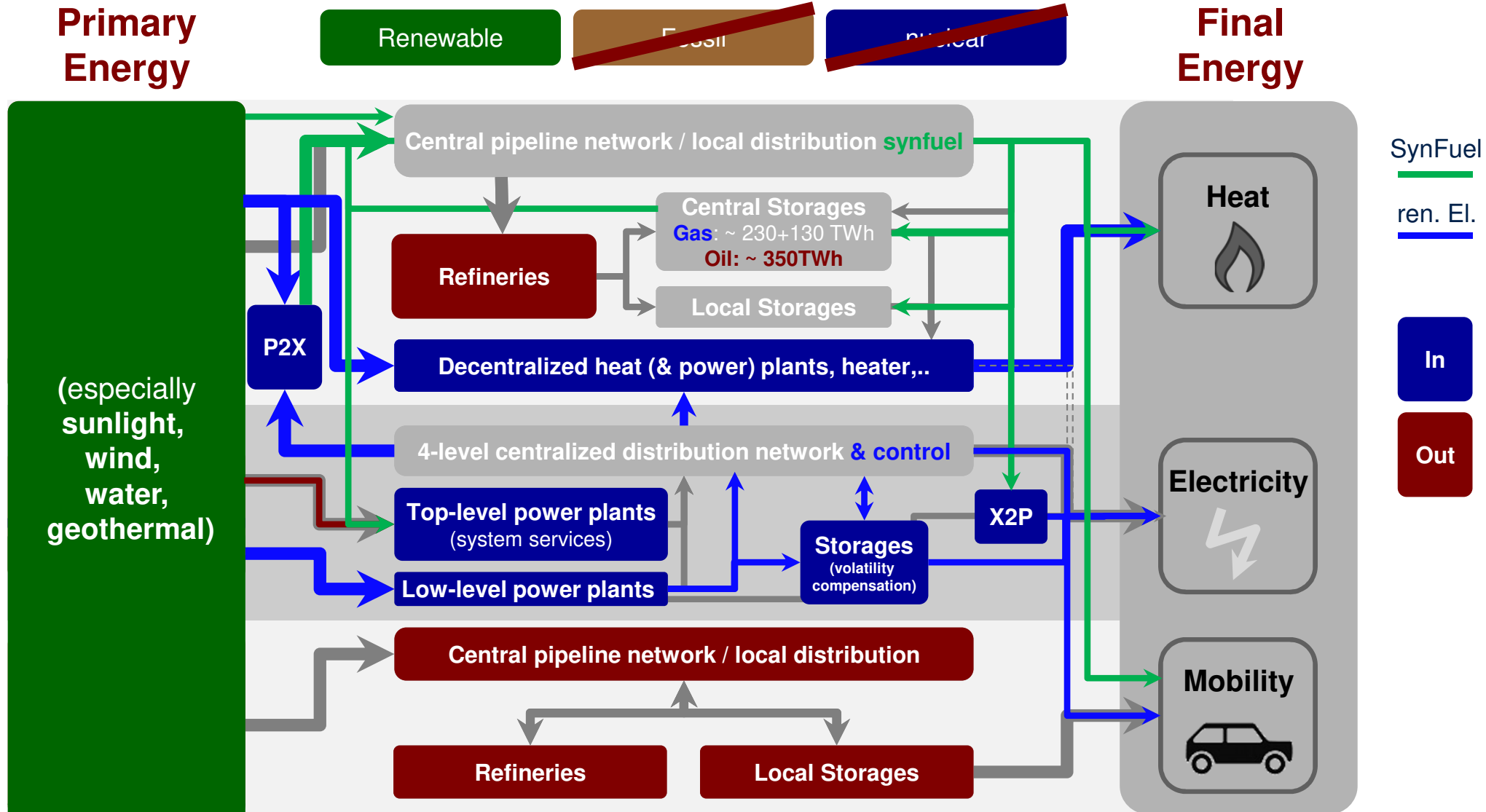
6. To promote and guarantee the responsible and planned use of natural resources, and to stimulate their industrialization through the development and strengthening of the productive base in its different dimensions and levels, as well as to preserve the environment for the welfare of present and future generations.

1.3 billion

The number of people who have no access to electricity

[UN]: <http://www.un-documents.net/ocf-02.htm> (2018-02-27)

“World Commission on Environment and Development” (WCED, 1987) → “Brundtland Report”



Biomass shares neglected

Primary
Energy

Renewable

Fossil

Nuclear

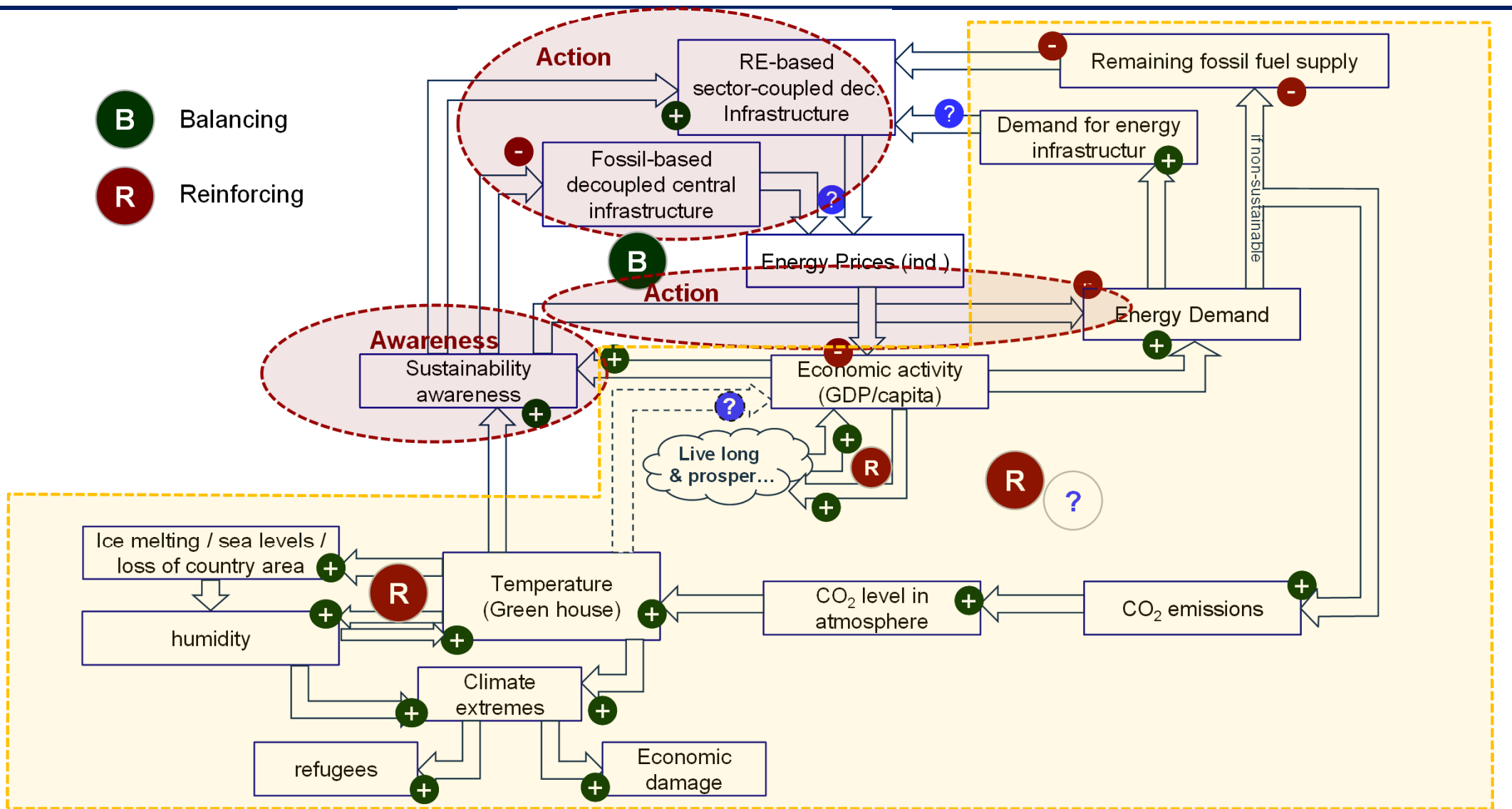
Final
Energy

Ein massiver Um-/Neubau der Energiesysteme steht uns ww bevor...

- E_{prim} steht nachhaltig, günstig und ausreichend zur Verfügung... aber nicht an allen Orten & Zeiten
 1. Wir müssen Energie E **und** Leistung $P = dE/dt$ betrachten!
- ~ 85% des Wegs zu nachhaltiger Versorgung sind (v.a. im Wärmesektor) noch zu gehen...
 2. Bedarf senken **und** lokal verfügbare E_{prim} Quellen erschließen („E-Zukunft ist lokal“)
 3. Fokus bzgl. Ausbau und Förderung auf Wärme legen (e.g. Geothermie, grundlastfähig!)
- Etliche nachhaltige E_{prim} Quellen (Sonne, Wind) stellen a) Strom b) volatil zur Verfügung
 4. Verbrauchssektoren sollten v.a. Strom nutzen (Wärmepumpe, eCar,..)
 5. auf Bedarf an Spitzen**leistung** dE_{fin}/dt (nicht nur Energie!) fokussieren (→ Speicher)
- Volatilität steigert Bedarf an Systemdienstleistungen massiv – Energie soll bezahlbar bleiben
 6. Energiekosten v.a. an benötigter Spitzen**leistung** lokaler Netze orientieren
 7. Energiekosten durch min. Spitzen**leistungs**bedarf lokaler Netze begrenzen (→ Speicher)

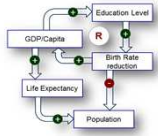
Biomass shares neglected

The Big Picture

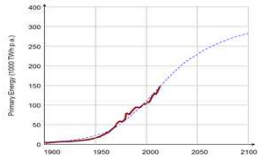


Base concept: Vanek et al. „Energy Systems Engineering“ p.56

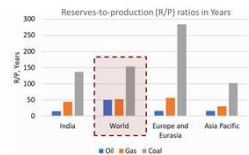
Energy as Part of a Socio-Economic Technical System Summary



Whatever we want or do.. it happens within a **systems context**. If we want to live long and prosper we need GDP and, in consequence, energy.



Under the assumption of sustainability, population and GDP will grow. Consequently, **energy demand will rise** at least until end of our century.



Fossil resources may still last for more than fifty years. But.. related CO₂ emission causes environmental & social devastation – it's **non sustainable**



Renewable Energy **and** Technology base are *offered* – for sustainable supply we need a) **efficiency increase** b) **sustainable energy systems**



Understanding the system context reflects an adequate first step – now we need action, i.e. **more students for more sustainable energy systems**