

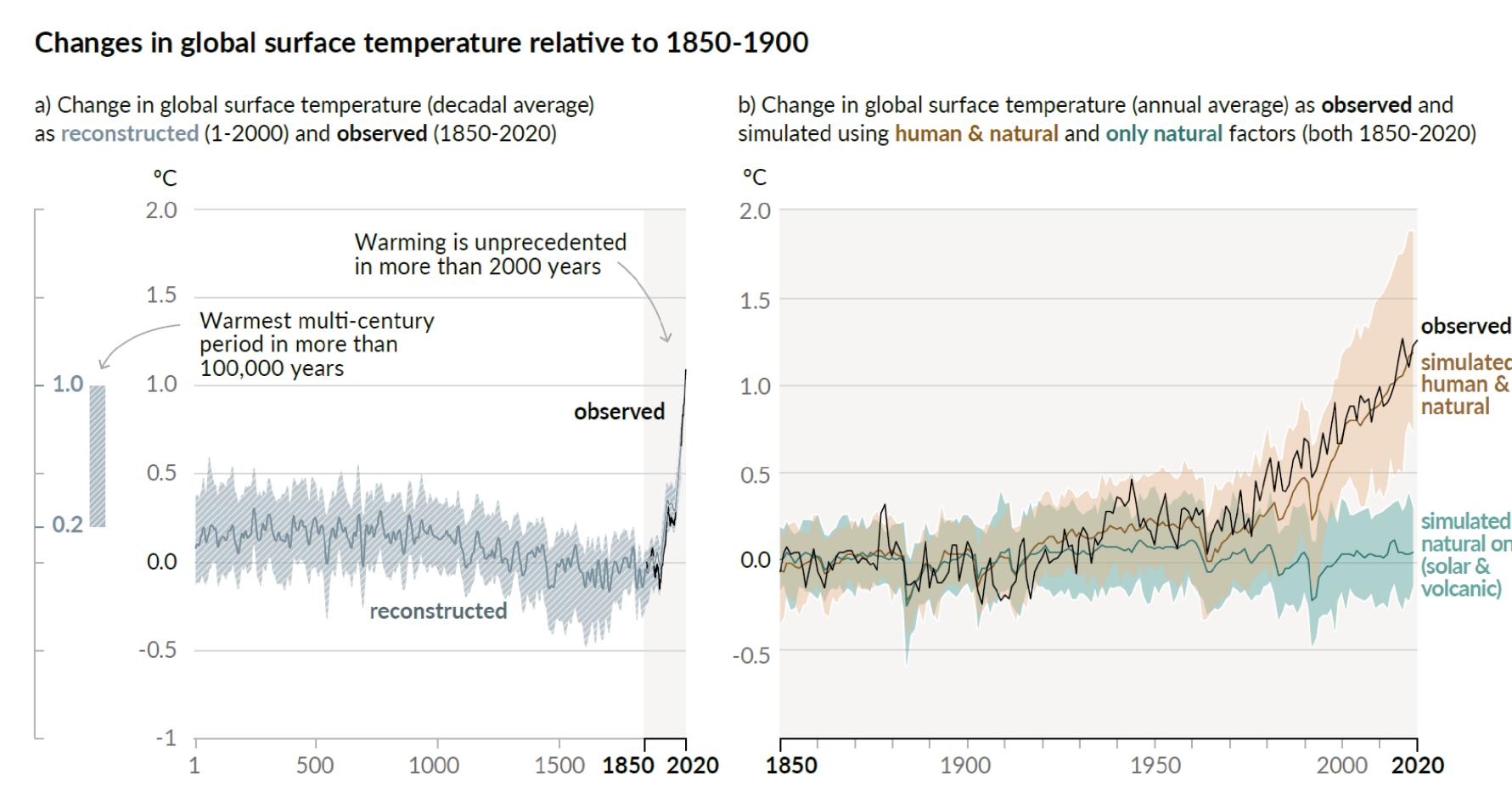
Wéi verbesseren ech d'CO₂ Bilanz vu mengem Haus?

How do I reduce the CO₂ footprint of my house?

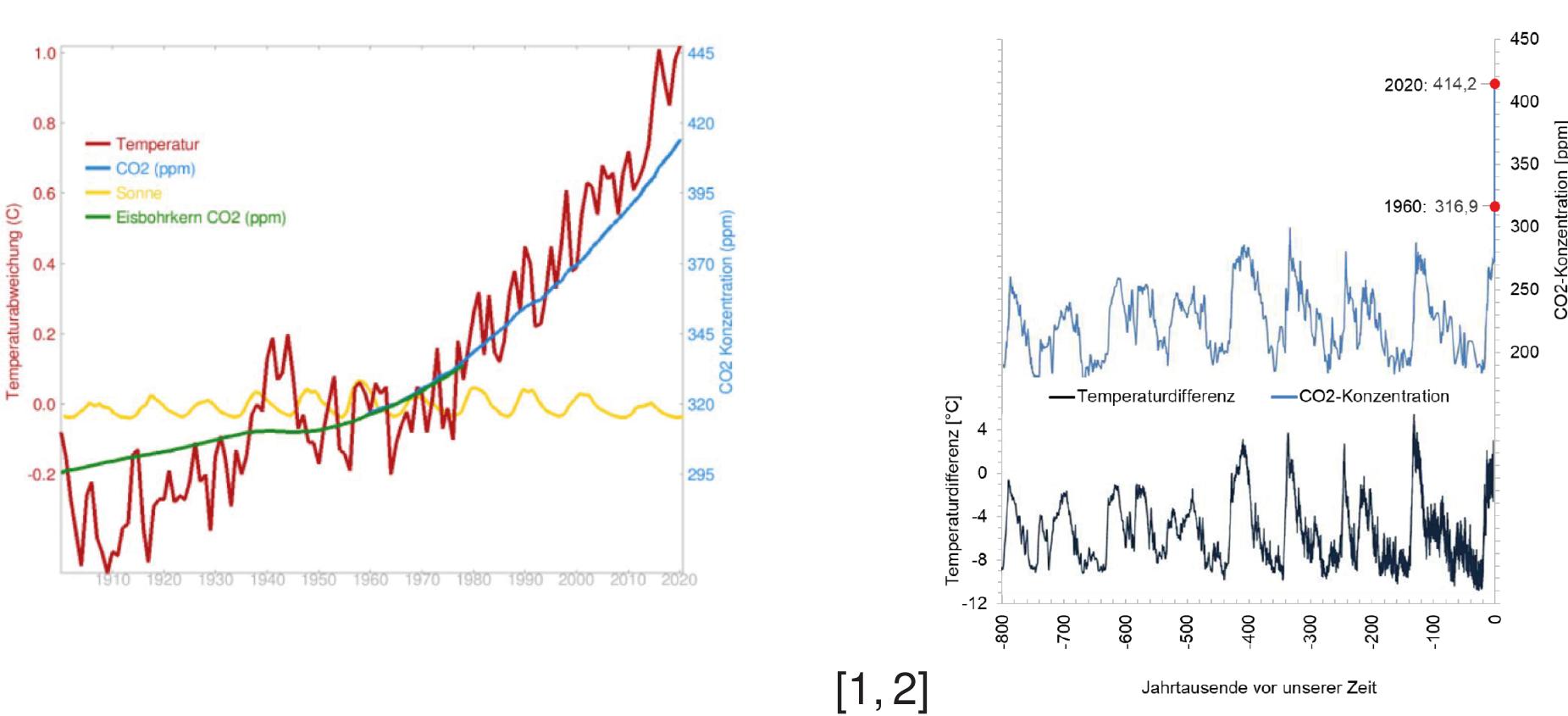
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Äerderwiermung Global warming

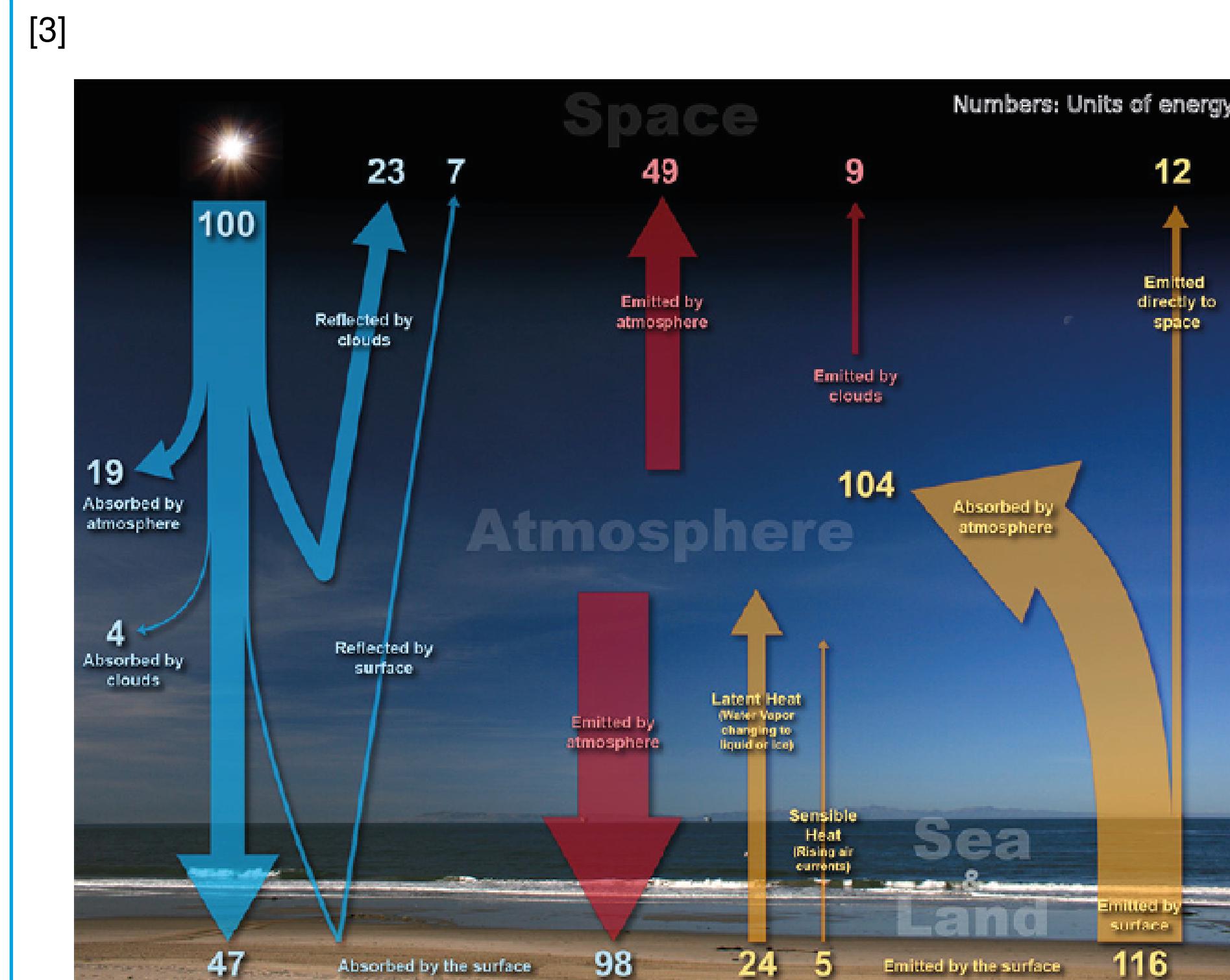


- Gemëttelt Temperatur op eiser Äerd geet erop [1]
- The mean surface temperature of the earth is rising [1]



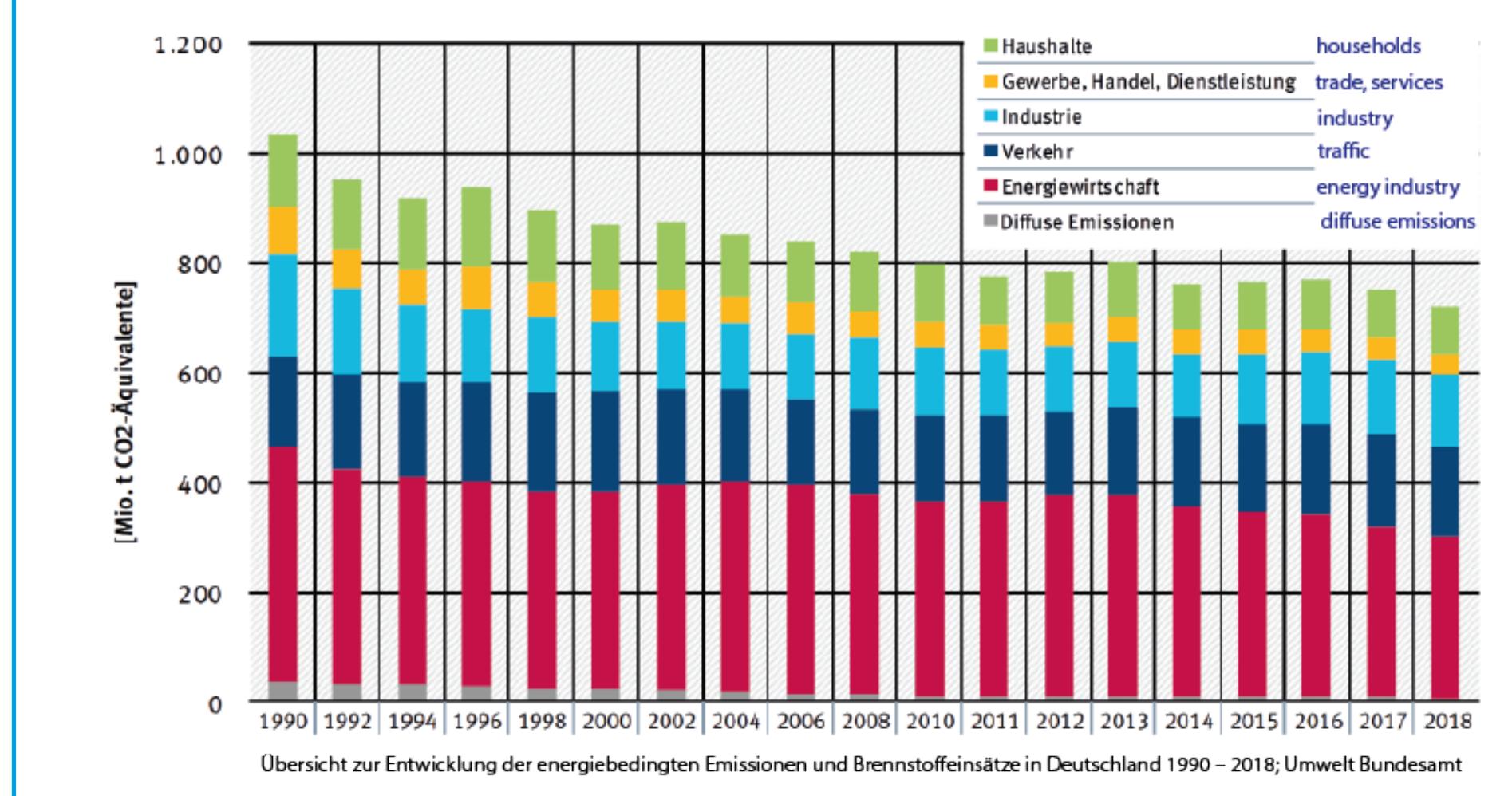
- Direkt Korrelation tëschent CO₂ an gemëttelter Äerdtemperatur
- Direct correlation between CO₂ in the atmosphere and the surface temperature

Den Zähreneffekt The green house effect



- Absorbéierung von Sonnenstrahlung an der Atmosphär féiert zu enger Erhéitung vun der Äerdtemperatur.
- Absorption of sunlight in the atmosphere leads to an increase in temperature.
- Molekülen an der Atmosphär déi Infraroutstrahlung absorbéieren (CO₂) sinn dofir responsabel
- Green house molecules in the atmosphere (such as CO₂) increase IR radiation towards the Earth surface which increases the temperature.

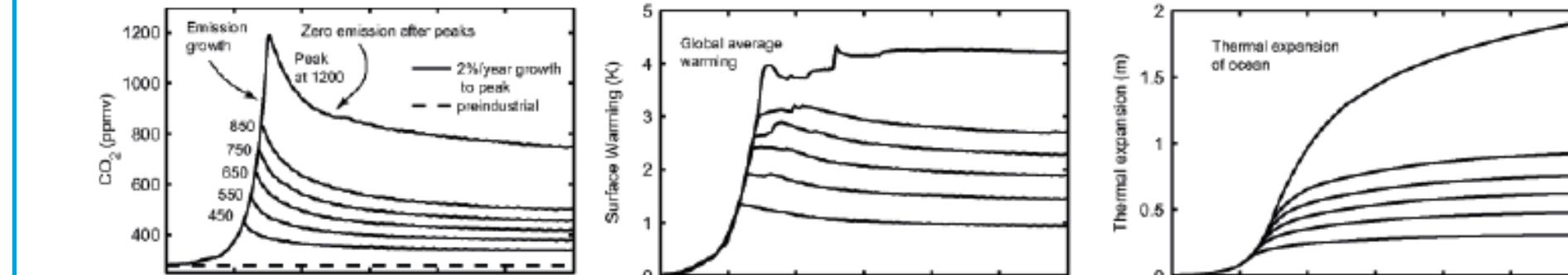
CO₂ Emissioune; CO₂ emissions



- Energie bedéngt Emissioune entstinn bei der Stroum- an Wäermtproduktioun, an der Industrie, an den Haiser durch Héitzen, am Verkéier duerch Verbrennen vum Benzin/Diesel an och am Handel.

Energy related emissions of greenhouse gases arise from the production of electricity and heat, due to industrial processes, in houses due to heating, due to traffic related emissions and in the commerce.

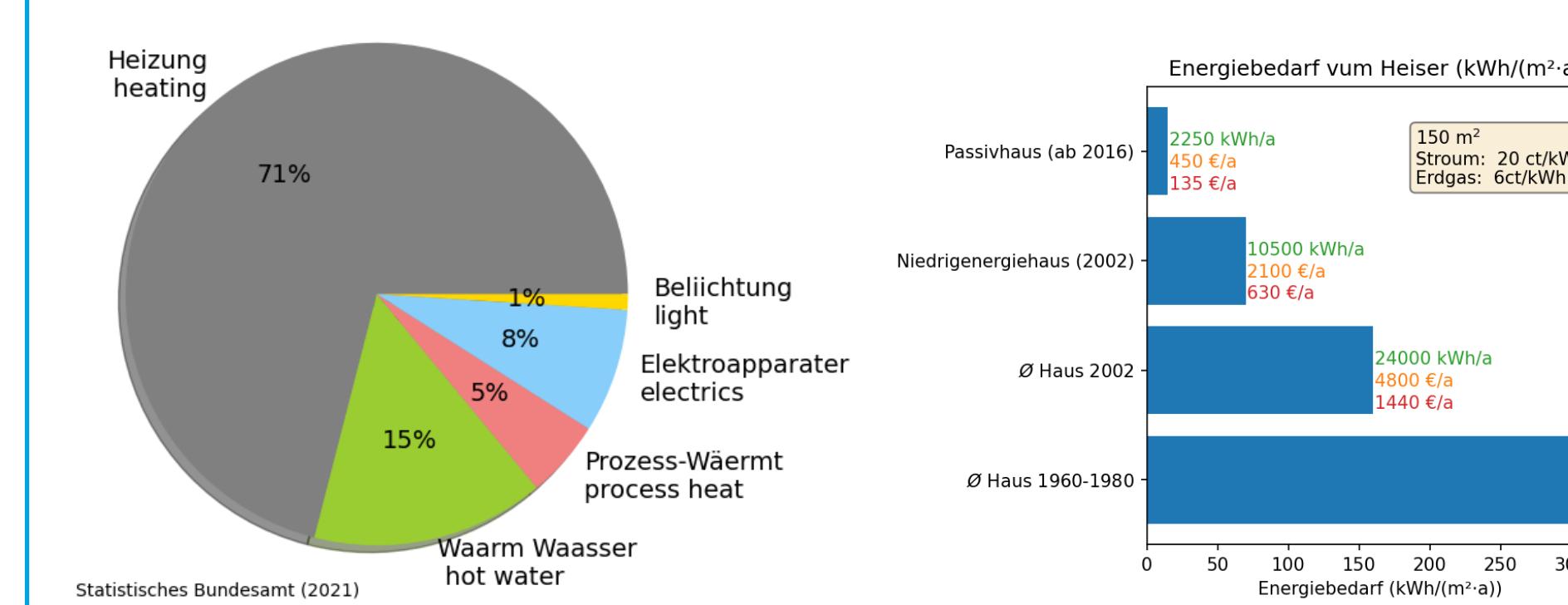
Laangzäitfolgen vum CO₂, Long-term consequences



- Theoretesch Modelle déi viraussoen wéi sech CO₂ Konzentratoun an der Atmosphär iwwert déi nächstens 1000 Joer wäert verhalen. Et gëtt just d'Maximal-Konzentratoun un CO₂ verännert an dann geet een doven aus dass keng weider CO₂ Emissioune wäerte méi dobäi kommen. De maximalen CO₂ Wäert bestëmmt d'Erhëtzten vun der Äerd an och de Mieresspigel (just thermesch Ausdehnung abezunn).
- Den CO₂ de mer haut produzéieren huet nach ganz laang (Joerhonnerten) een Impakt op d'Temperatur an och de Mieresspigel!!!

Predictions of the evolution of the CO₂ as a function of time, for different maximum concentrations. After the peaks, no further CO₂ emissions are assumed. The peak CO₂ concentration dictates the temperature of the planet and the sea level. The CO₂, which is produced today will stay in the atmosphere for several hundred years impacting the temperature and the sea level!!!

Energieverbrauch vun Haiser Energy consumption of houses

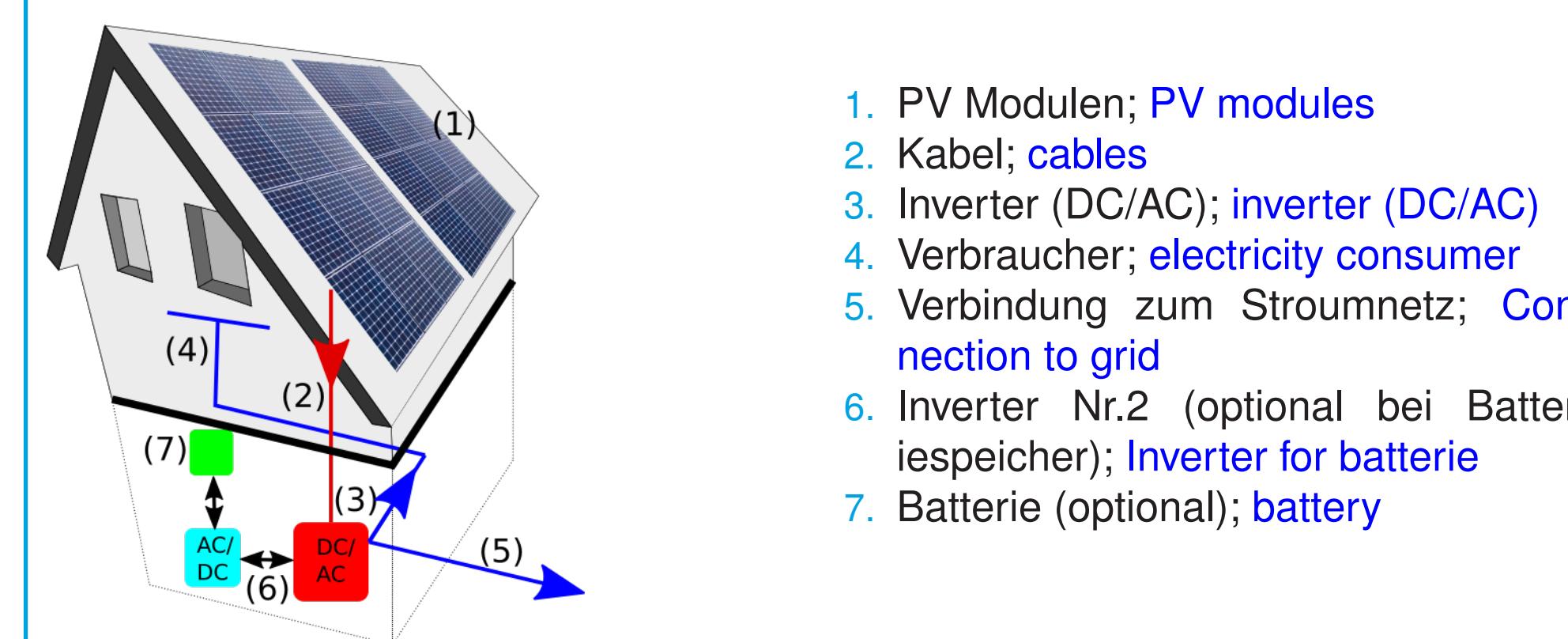


- Thermesch Isolatioun ass extrem wichtig a bestëmmt zum groussen Deel den CO₂ Impakt vum Gebai
- Heating dominates the energy consumption of a house and needs to be reduced via thermal insulation and modernisation
- Passivhäuser verbrauchen just en Brochdeel vun der Energie déi en aalt Haus verbraucht.
- Passive houses have a strongly reduced energy consumption compared to old houses
- Stroum als Energieträger ass deier. Et mécht just Sëen Gebaier mat Stroum ze hëtzen wann se gutt isoléiert sinn.
- Electricity is expensive and should only be used as primary source of energy in properly isolated (passive) houses

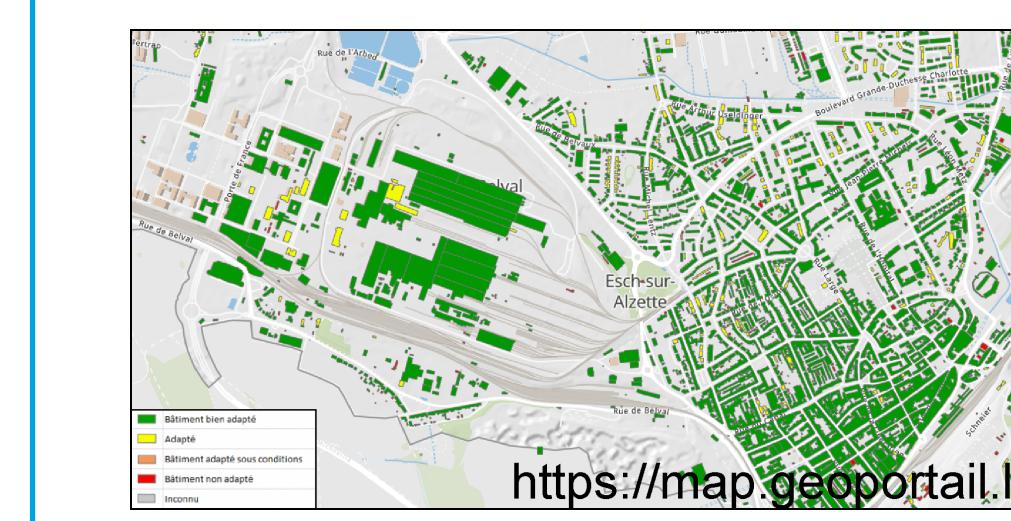
Photovoltaik um Hausdaach Rooftop PV system

- Wat sinn d'Bestanddeeler vun enger privater PV-Anlag?

What are the components of a rooftop PV system?



- Solarpotenzial vu mengem Daach; The PV potential of my roof



- Wéiwill kascht eng PV-Anlag op mengem Daach?

What are the costs of a rooftop PV system?

Beispill 1:
5kW Anlaag Flaachdaach, Treier

Example 1:
5kW System Flat roof

Beispill 2:
10kW; O-W; Daach schief, Berchem

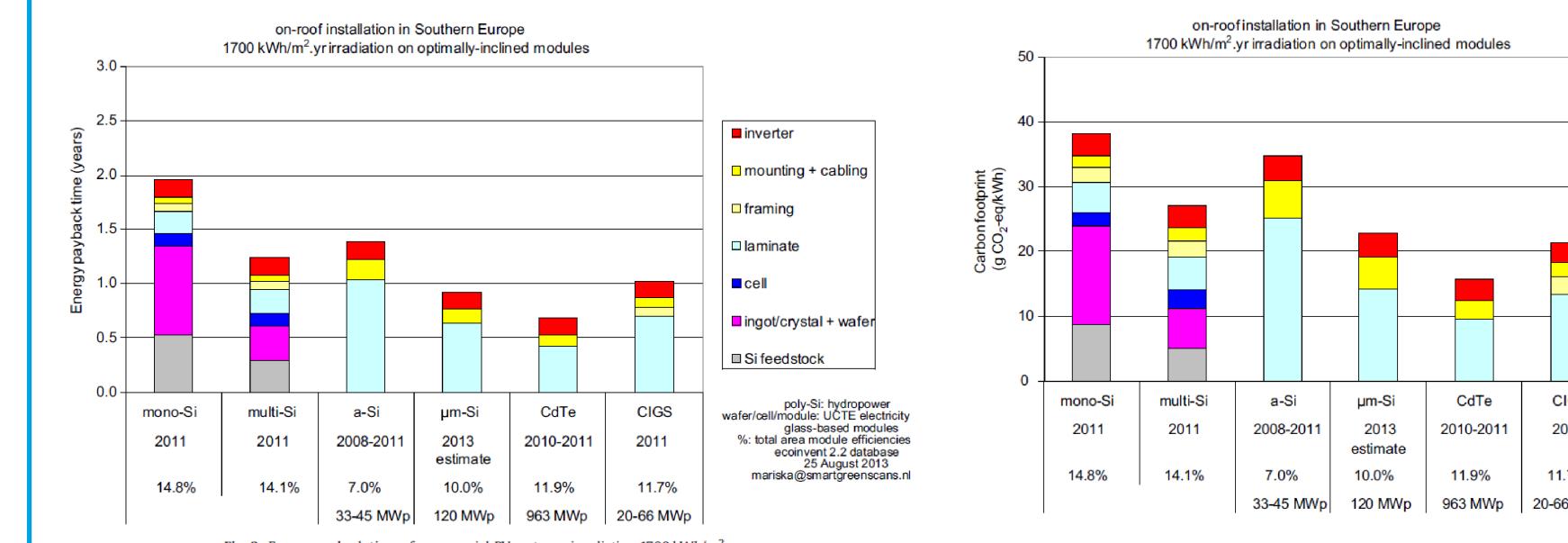
Example 2:
10kW System East-West; inclined

Baudeel:	Prais	Baudeel:	Prais
PV Modulen	≈ 3k€	PV Modulen	≈ 8k€
Inverter	≈ 1k€	Inverter	≈ 3k€
Fixierung Flaachdaag	≈ 1k€	Daach Ost+West	≈ 7k€
Installation + Kabel	≈ 2k€	Installation + Kabel	≈ 4k€
Batteriespeicher	≈ 6k€		

- Staatlech Ënnerstëtzung zu Lëtzebuerg: 500€/kWp
- Financial assistance in Luxembourg: 500€/kWp [7]

- Wéiwill Energie an CO₂ gëtt bei der Hierstellung vun der Solarzell produzéiert? How much energy and CO₂ is produced during the fabrication of a solar cell?

[5]



- Zäit déi d'Solaranlag Energie muss produzéieren bis se sech energetesch rentéiert: „Energy payback time“.

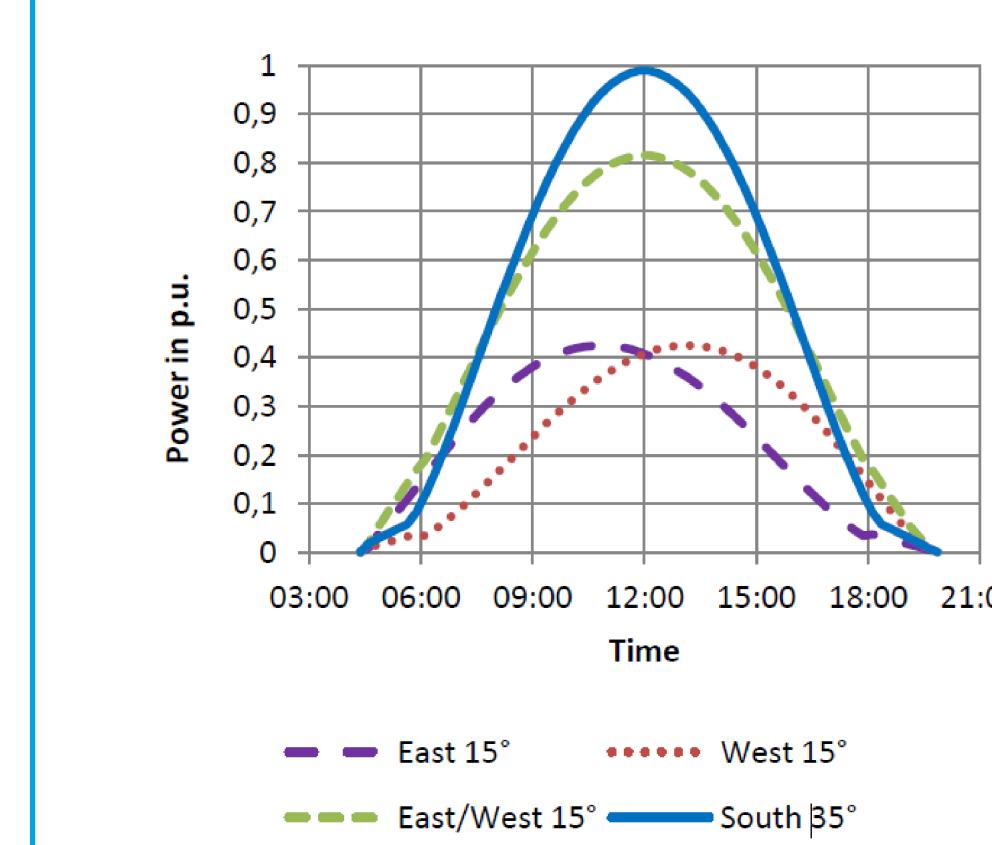
time the PV system must produce energy until it is energetically profitable: „Energy payback time“

- A Süd-Europa ass dat ongeféier 1-2 Joer; Bei eis zu Lëtzebuerg 2-3 Joer; In the South of Europe (≈ 1-2 years; In Luxembourg: 2-3 years)
- Solarzellen hunn Garantie vun 20-25 Joer;
- Solar cells are sold with a warranty of 20-25 years
- Solarzellen sinn a punkto Energie an och vum CO₂ Budget hier absolut rentabel; och zu Lëtzebuerg.
- Solar cells are highly profitable in terms of energy production and CO₂ budget; also in Luxembourg

- Brauch ech een Daach dat no Süden ausgerichtet ass? Nee

Do I need a roof that faces South? No

[6]



- Wéiwill kréien ech pro kWh déi agespeist gin?

How much do I earn when I produce solar power that is fed into the grid?

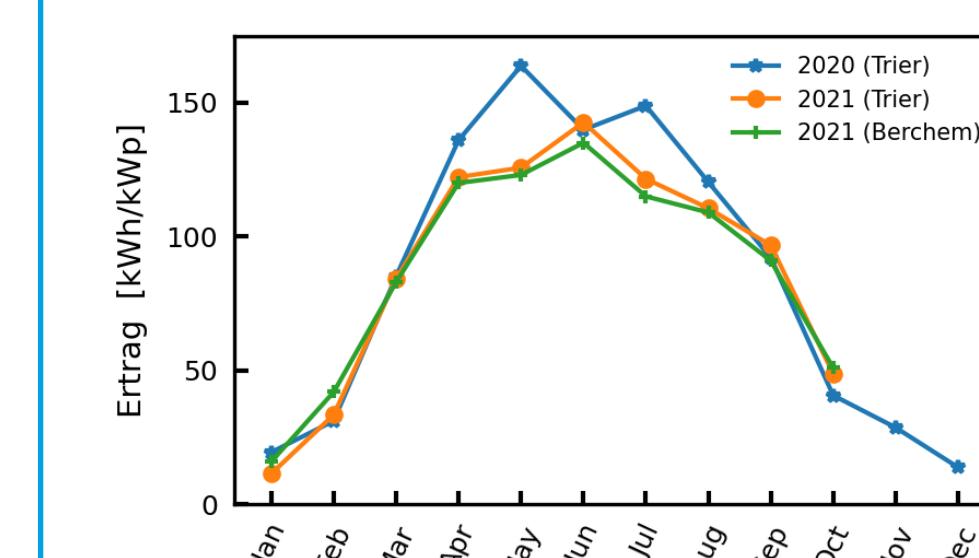
[7]: <https://www.myenergy.lu>

Für Privatanlagen zwischen 0 kWp und 10 kWp*	Erste Einspeisung € / kWh	Für Privatanlagen zwischen 10 kWp und 30 kWp*	Erste Einspeisung € / kWh
2021	0,1552	2021	0,1458
2022	0,1506	2022	0,1415
2023	0,1461	2023	0,1372

- ab dem Datum vun der éischter Aspeisung garantéiert fir 15 Joer
- Guaranteed tariff for 15 years starting from the point of the first feed-in

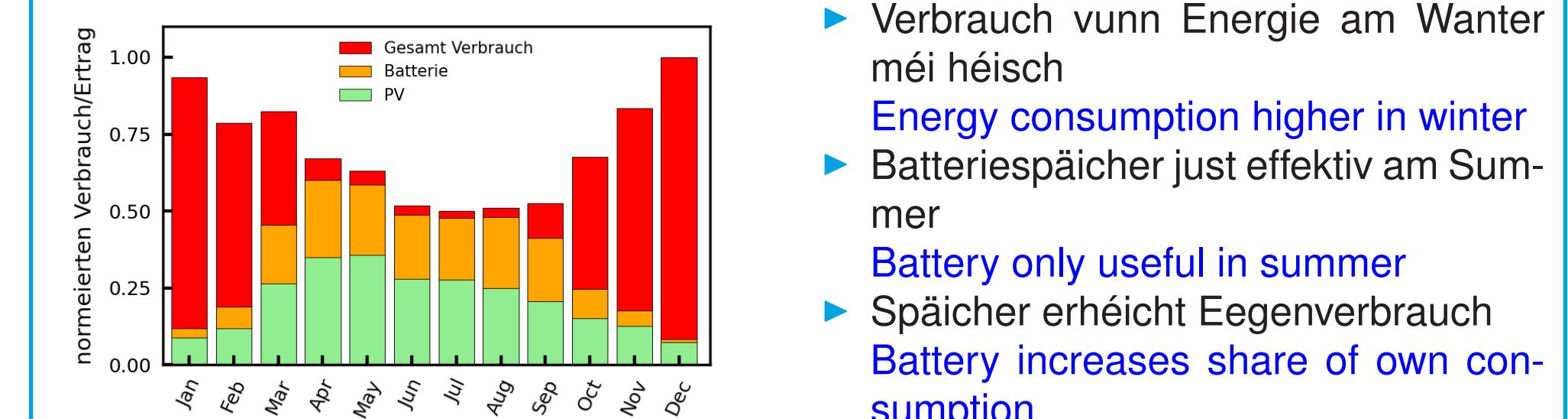
Eng PV Anlaag doheem, virwaat? PV at home, why?

- Beispill: Zwee Haiser: O/W-Ausrichtung; Flaachdaach a schifen Daach [9]
- Case study: Two houses; E/W-orientation: flat and inclined rooftop [9]

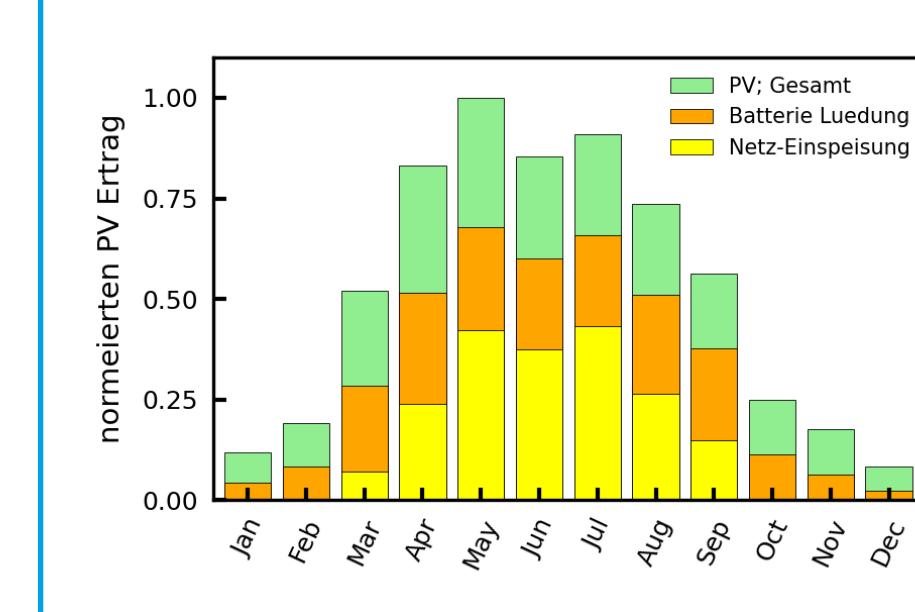


- Stark saisonal Énnerscheeder
- Strong seasonal changes in power production
- Ganz änlech Stroumproduktioun op den zwee Diecher
- Very similar energy production on the two roofs

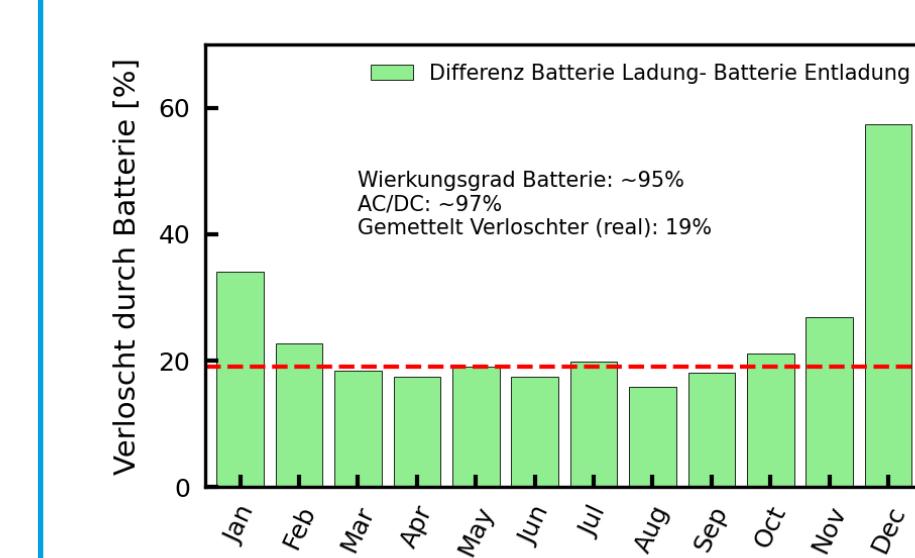
- Norméierten Energieertrag 2020 (Passivhaus matt Wäermtpompel)
- Normalized energy production in 2020 (passive house with heat pump)



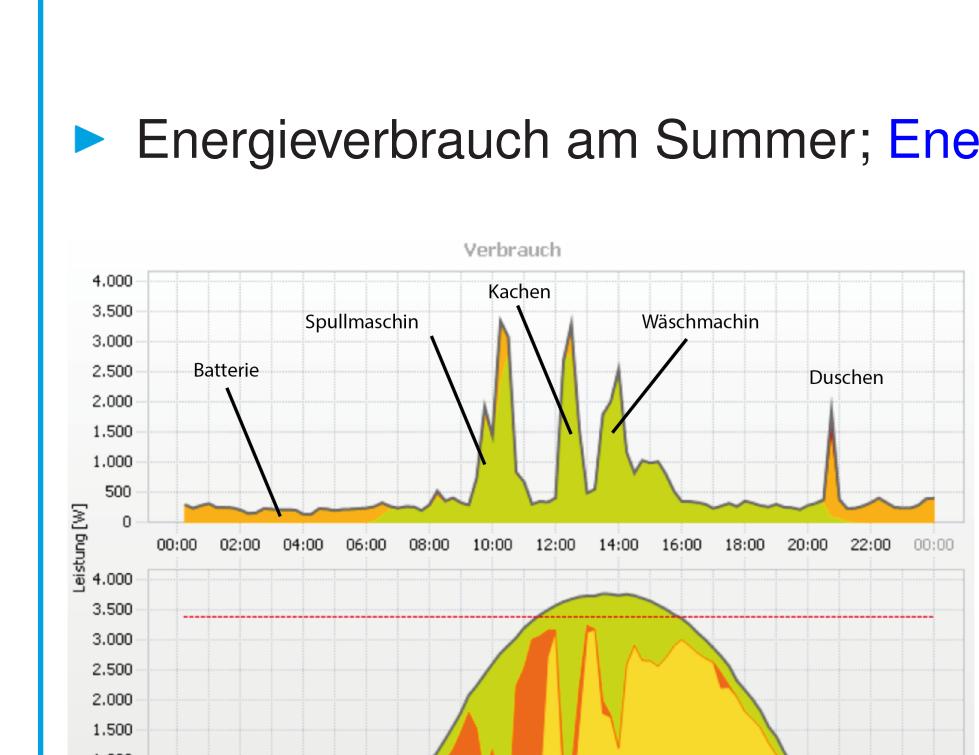
- Verbrauch vun Energie am Wanter méi héisch
- Energy consumption higher in winter
- Batteriespäicher just effektiv am Summer
- Battery only useful in summer
- Späicher erhéicht Eegenverbrauch
- Battery increases share of own consumption



- Am Summer gëtt méi produzéiert wéi verbraucht gëtt
- During the summer, the energy production is higher than the consumption
- Iwerschësseg Energie gëtt an d'Stroumnetz agespeist
- Excess energy will be fed into the grid
- Zousätzlechen finanziellen Gewénn
- Additional positive financial impact



- Batteriespäicher féiert och zu zousätzleche Verloschter
- Charging and discharging of battery also leads to losses
- Am Summer wann de Späicher och benotzt gëtt verlëiert een ongeféier 20% vun der Energie déi een soss géif an d'Netz aspeisen
- In summer the battery consumes approx. 20% of the energy that would otherwise be fed into the grid



- Am Summer ass een duerch de Batteriespäicher praktesch onofhängeg vum Stroumnetz (>90%), och an der Nuecht
- During the summer the battery covers almost the complete power consumption of the house (>90%, including the night)

- Ass eng PV Anlaag finanziel lukrativ?

Is the PV installation a good financial investment?

- Matt Späicher: Investitioun: 15k€ (5kW Anlag), Erspuernis pro Joer: 1000€, No 15 Joer ass d'Solaranlag ofbezelt
- Investment: 15k€ (5kW installation), Saving per year: 1000€, after 15 years the system is profitable
- Oun Späicher: Investitioun: 9k€ (5kW Anlag), Erspuernis pro Joer: 1000€, No 9 Joer ass d'Solaranlag ofbezelt.
- Without battery: Investment: 9k€ (5kW installation), Saving per year: 1000€, after 9 years the system is profitable

- Ass eng PV-Anlag CO₂ technesch lukrativ?

Is the PV system reducing the CO₂ footprint?

- garantiert Liewensdauer: 25 Joer ⇒ Energy payback time: ≈ 3 Joer guaranteed lifetime: 25 years ⇒ Energy payback time: ≈ 3 years
- CO₂ Erspuernis pro Joer (Stroummix: 160g/kWh [8]): 750kg/Joer ⇒ 16.5 Tonnen CO₂ in 25 Joer
- Matt Batterie: Reduktioun em 1 Tonn CO₂ Erspuerness duerch méi laang energy payback time: ⇒ 15 Tonnen insgesamt with battery: reduction of approximately 1 ton of CO₂ saving due to longer energy payback time ⇒ 15 tons in 25 years

Quellen-Verzeichniss; References

- IPCC report Climate Change 2021, Summary for Policymakers
- Fraunhofer ISE, Aktuelle Fakten zur Photovoltaik in Deutschland, Dr. Harry Wirth
- <https://www.weather.gov/jetstream/energy>; The Physics of Climate Change | Book by Lawrence M. Krauss
- Susan Solomon, Gian-Kasper Plattner, Reto Knutti, and Pierre Friedlingstein, Irreversible climate change due to carbon dioxide emissions, <https://doi.org/10.1073/pnas.0812721106>
- M.J. (Mariska) de Wild-Scholten, Energy payback time and carbon foot print of commercial photovoltaic systems, Solar Energy Materials & Solar Cells 119 (2013) 296–305
- Evaluating the Impact of PV Module Orientation on Grid Operation, E. Tröster, Jan-David Schmitt
- <https://www.myenergy.lu/de/clevsolar/private-anlagen/einspeisetarife-beihilfen>
- Stromkennzeichnung - Enovos
- House data: Courtesy Alex Redinger, Phillip Dale