Environmental sustainability of basic research: What to do and what to avoid?

- Climate Crisis
- Energy transition
- HECAP+ paper

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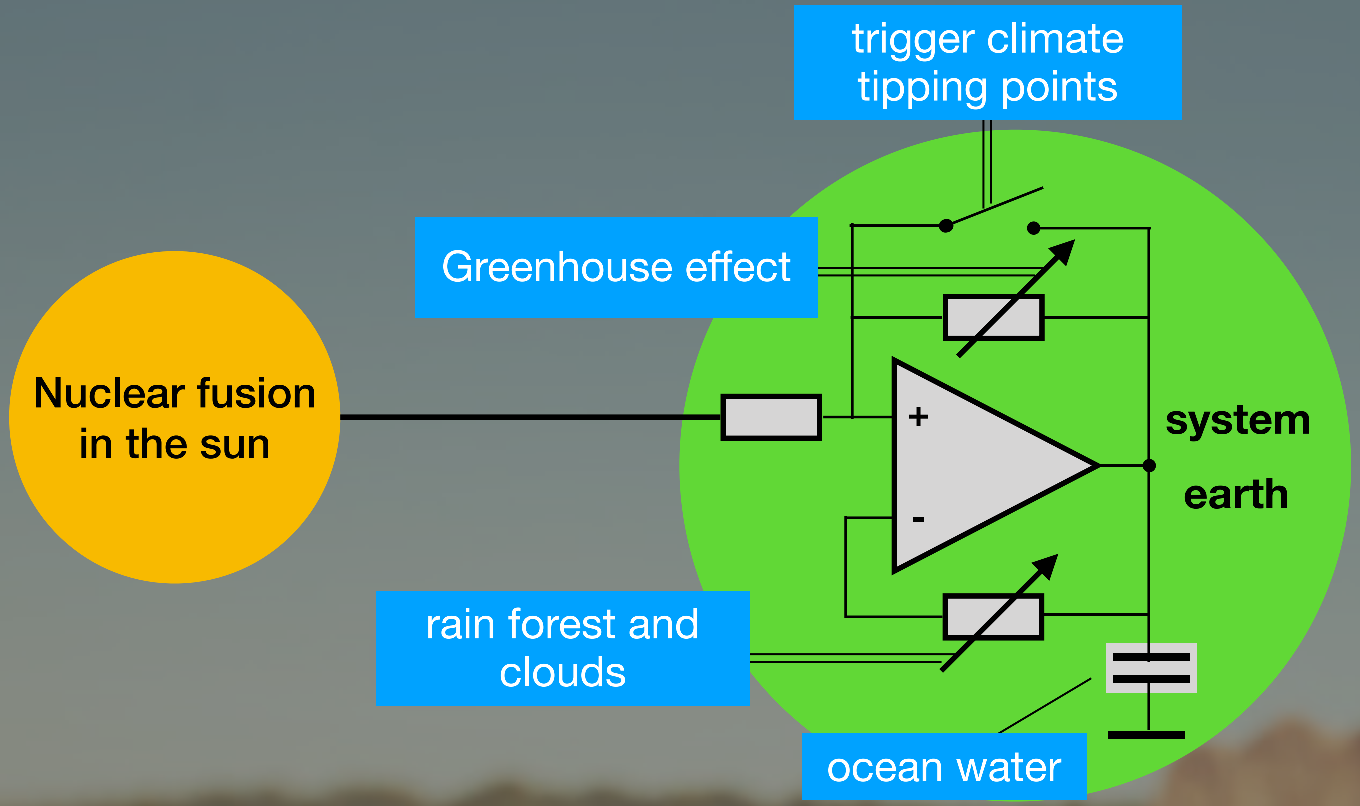
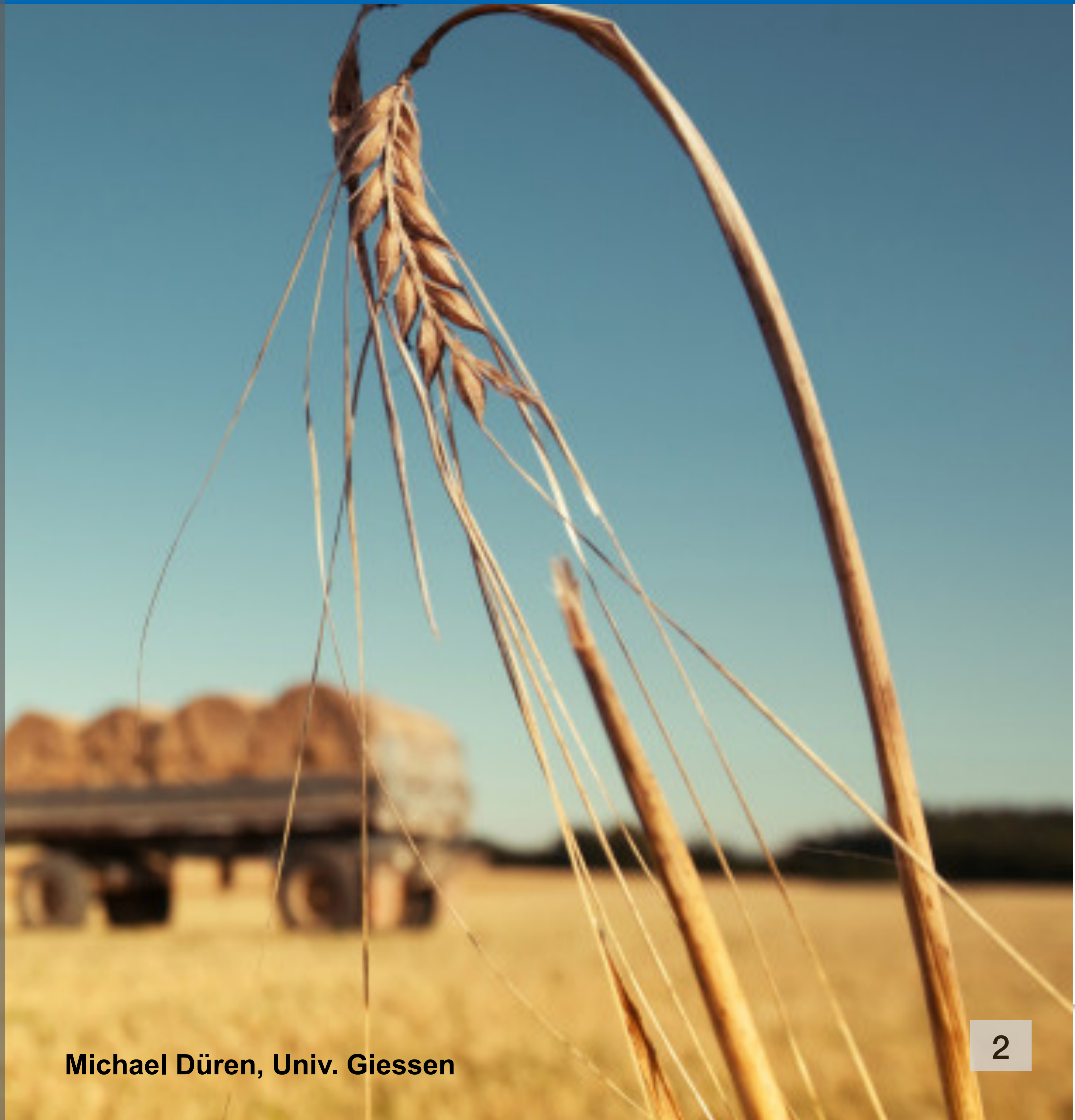
ZEU

eurizon European network for developing new horizons for RIs

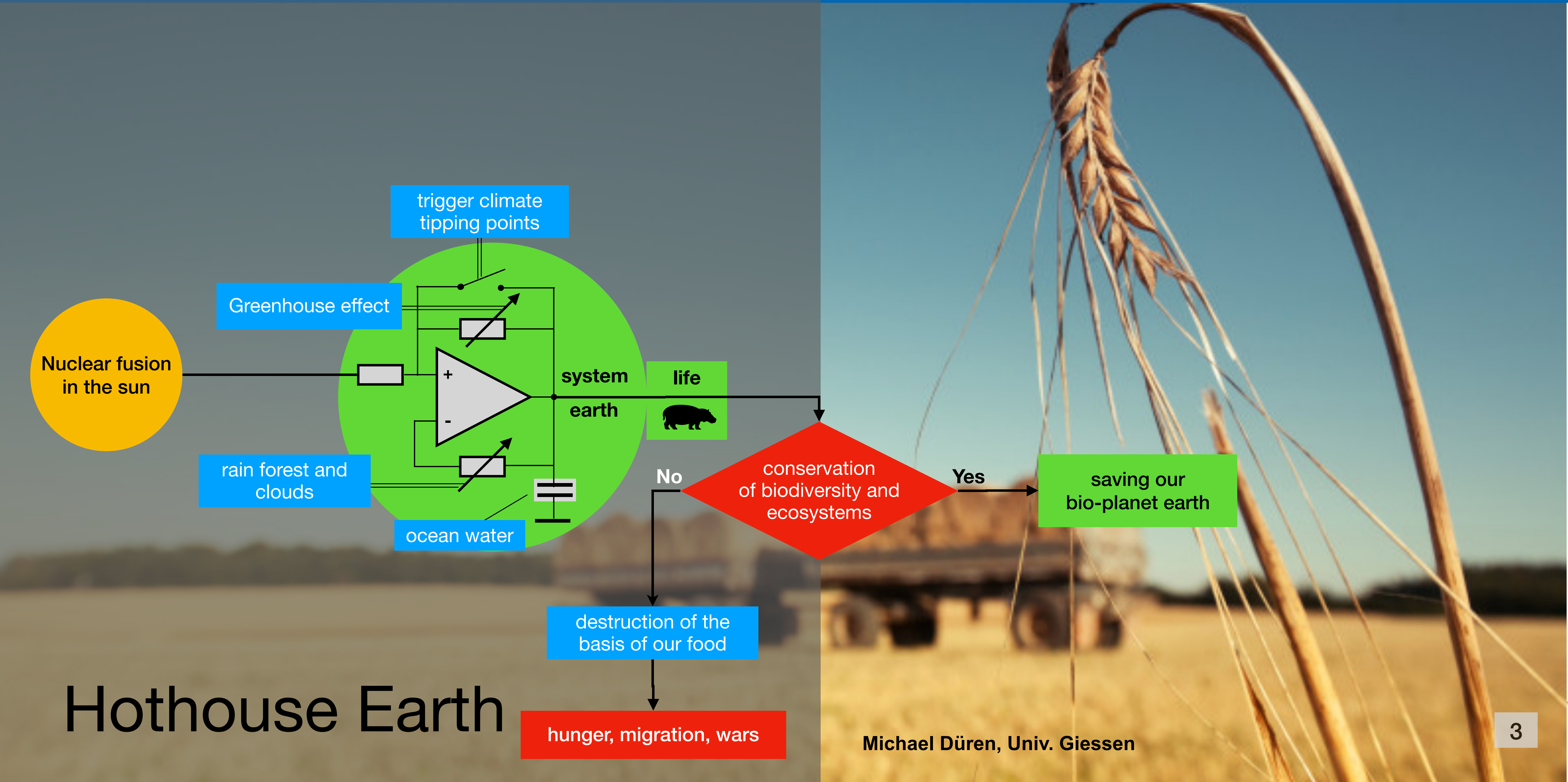
Wuppertal, 26.07.2023



Hothouse Earth



Climate Change for Physicists



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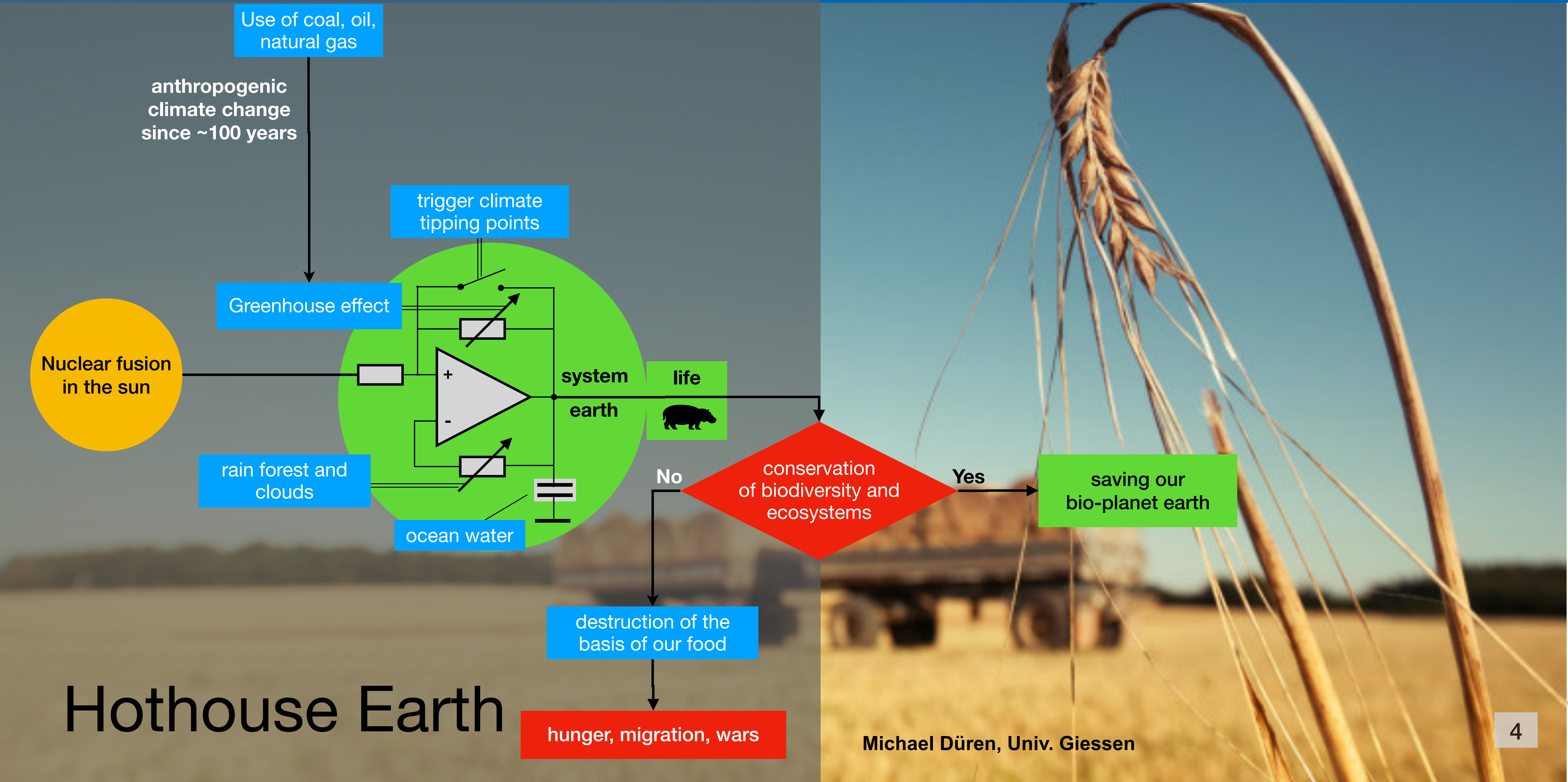

Hothouse Earth

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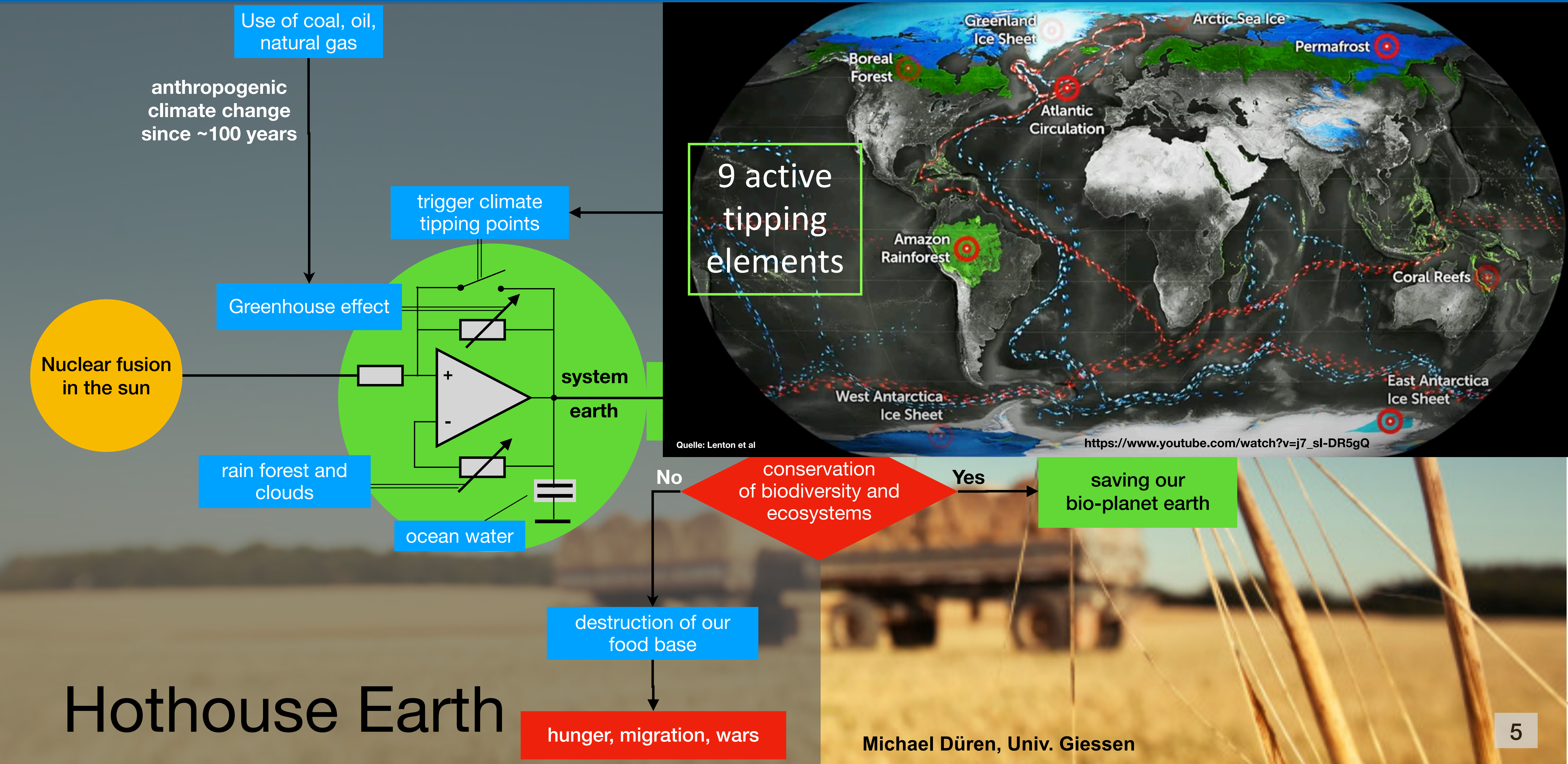
CO_2 emissions trigger tipping points (irreversible)



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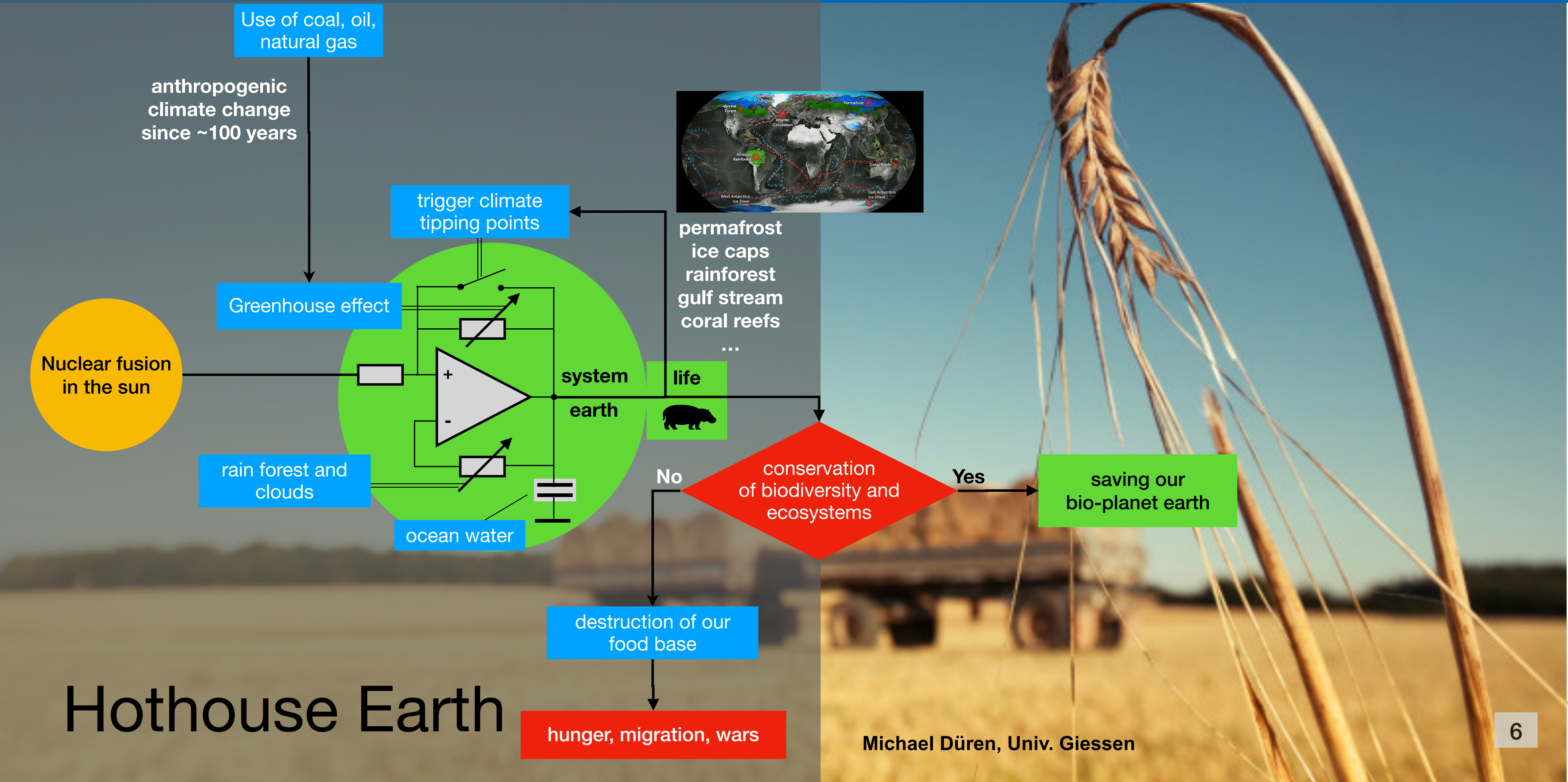

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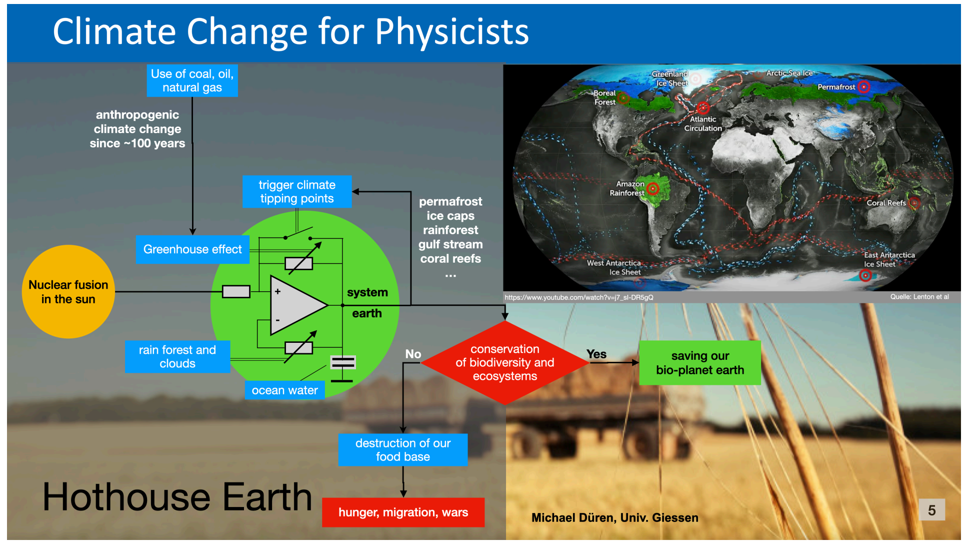


Deutsche Physikalische Gesellschaft DPG

PHYSIKonkret No. 66

Non-fossil energy: A Global Challenge for Climate Protection

- Today, around 80 percent of mankind's primary energy needs are met by fossil fuels[1].
- Climate protection requires a halt to net CO_2 emissions by 2050[2].
- Climate change doesn't wait: The pace of change to a non-fossil energy world must be accelerated with all possible speed.

As early as 1987, the German Physical Society, together with the German Meteorological Society DMG, published the call "Warning of impending global climate change due to human activity "[3].

Rapid changes in the climate with an average increase in the earth's temperature of more than 1.5°C will have risks for life, world food and biodiversity that are difficult to assess[4,5]. To avoid this, science therefore calls for a rapid reduction of net CO_2 emissions down to zero. The situation is aggravated by so-called climate tipping points[6], at which warming due to additional effects, such as the melting of the Arctic ice, continues and is difficult to predict whether it is accelerated.

Recent calculations show that some of them could already be exceeded at an average warming of less than 2°C or are already exceeded today.

Nevertheless, the share of fossil fuels in meeting the world's total energy demand has remained almost constant to date at around 80%[1]. Modern solar and wind power plants – just like nuclear energy – each contribute only about 4%[1].

The use of fossil fuels must be ended worldwide by 2050 at the latest[2] to limit global warming to 1.5°C with a certain degree of confidence. To achieve this, around 140 million gigawatt hours (GWh) per year must be replaced by non-fossil energy forms; this corresponds theoretically to the energy output of 16,000 conventional power plants.

The challenge is huge, and it is global. Germany contributes about 2 % and Europe about 14 % to the total CO_2 emission. Nevertheless, the efforts to reduce emissions in Europe are important and pioneering, especially regarding the responsibility and role model function of the industrialized countries. These have a duty to develop the path to transform society while maintaining the competitiveness of business and industry in the global marketplace and, in addition, to help financially weak countries so that they too can achieve net zero emissions by mid-century.

"Climate change threatens humanity - with science and technology, courage and determination, we can stop him."

Joachim Ullrich, President of the German Physical Society

However, solar and wind energy are volatile. Storage and transport of the energy generated from these sources require a massive expansion of electrochemical and chemical storage systems (batteries, hydrogen, methane, ammonia, etc.) as well as heat and pump storage systems. For the latter, there are innovative concepts that use old mines and opencast mines.[7]

Saving energy is particularly important and must be pursued consistently. This includes efficient thermal insulation of buildings, heating with heat pumps[8], lighting with LEDs and much more, right up to a fundamental redesign of mobility and its forms of propulsion.

Climate change will not wait: The figures make it clear that the pace of the energy turnaround must be accelerated with all our might. This requires, in particular, a political framework such as emissions trading and realistic CO_2 pricing, as well as the removal of obstacles to the development of a climate-friendly energy and transport system.

Global primary energy consumption per second

Wind, solar, biofuels, etc.; Hydro; Nuclear; Coal, oil and gas; Traditional biomass; Naive extrapolation; Energy saving?; The energy gap; CO_2-free production; 20 000 GW; 10 000 GW; 1970 1980 1990 2000 2010 2021 2030 2040 2050 Year

Drastic reduction of fossil fuels
The drastic reduction in greenhouse gas emissions deemed necessary by the Intergovernmental Panel on Climate Change to achieve the goals of the Paris Agreement is here schematically applied to fossil energy production[10].

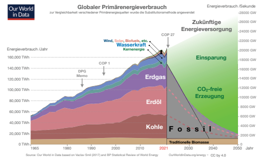
a) Net global greenhouse gas (GHG) emissions; Implemented policies; Nationally Determined Contributions (NDCs) range in 2030; Limit warming to 2°C; Limit warming to 1.5°C

CO_2 emissions must be drastically reduced to prevent with some certainty an irreversible climate catastrophe (blue curve)[9].

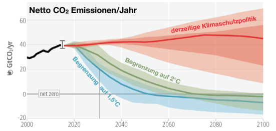
English Version

"Climate change threatens humanity - with science and technology, courage and determination, we can stop him."

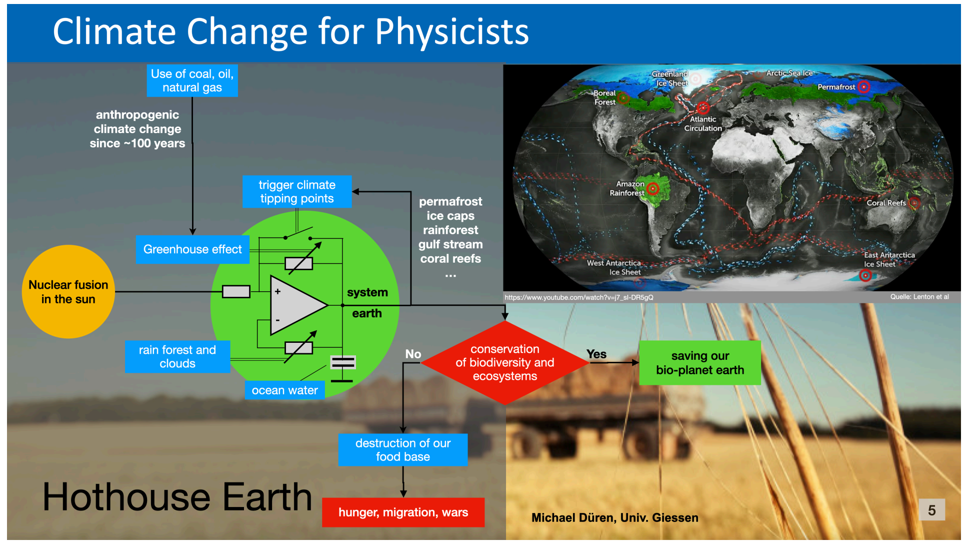
Joachim Ullrich, President of the German Physical Society

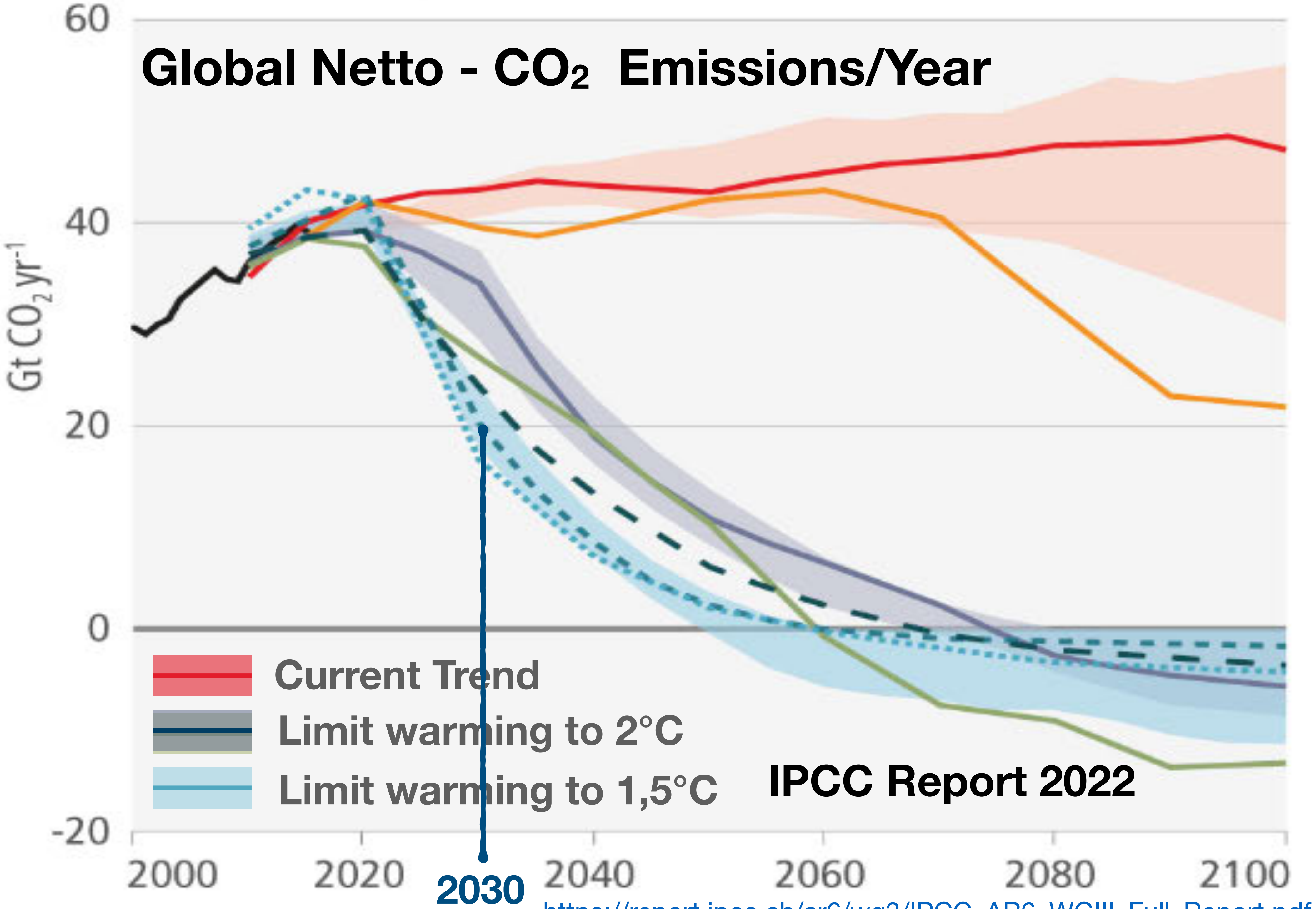


„Courage and determination?"



CO_2 emissions trigger tipping points (irreversible)





https://report.ipcc.ch/ar6/wg3/IPCC_AR6_WGIII_Full_Report.pdf

Required reduction: 50% in ~7 years

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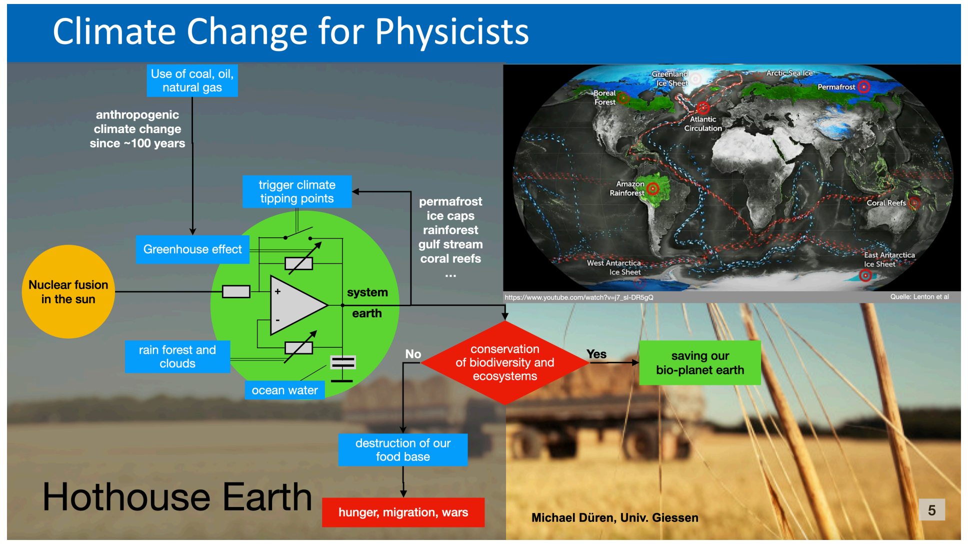

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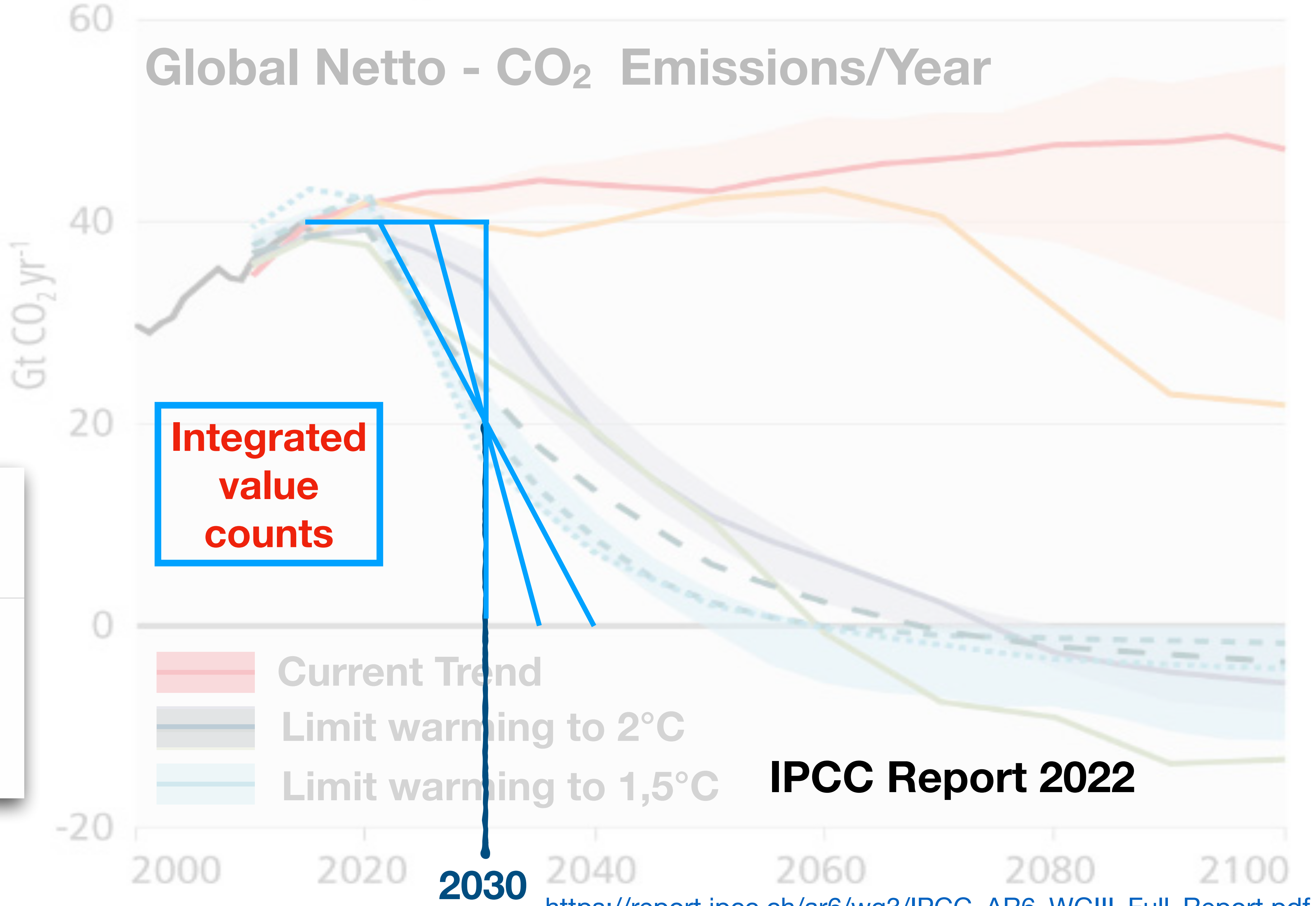
The New York Times 20.03.23 14:07

An: Michael Düren >

Breaking News: Earth to hit critical warming threshold by early 2030s, climate panel says



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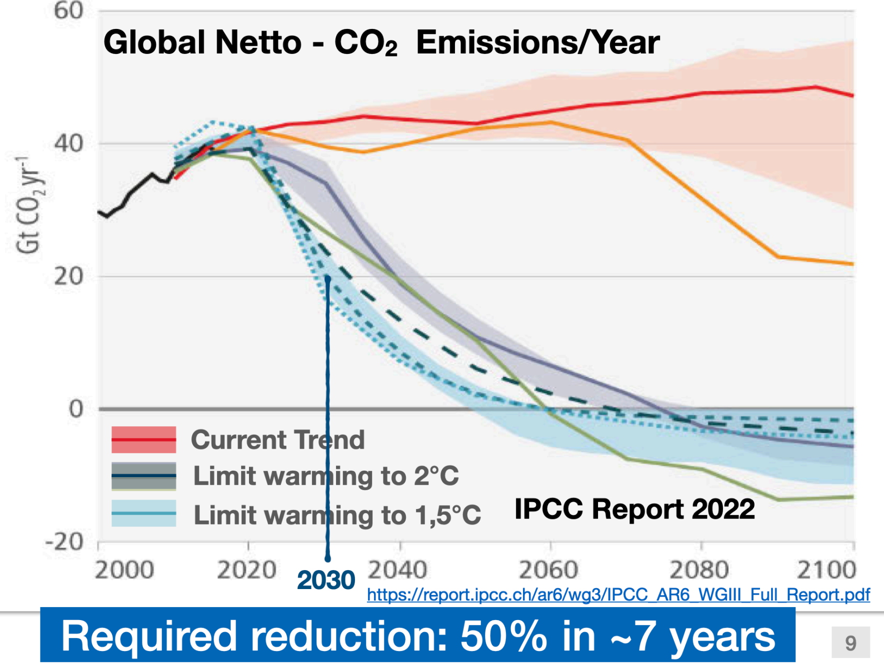

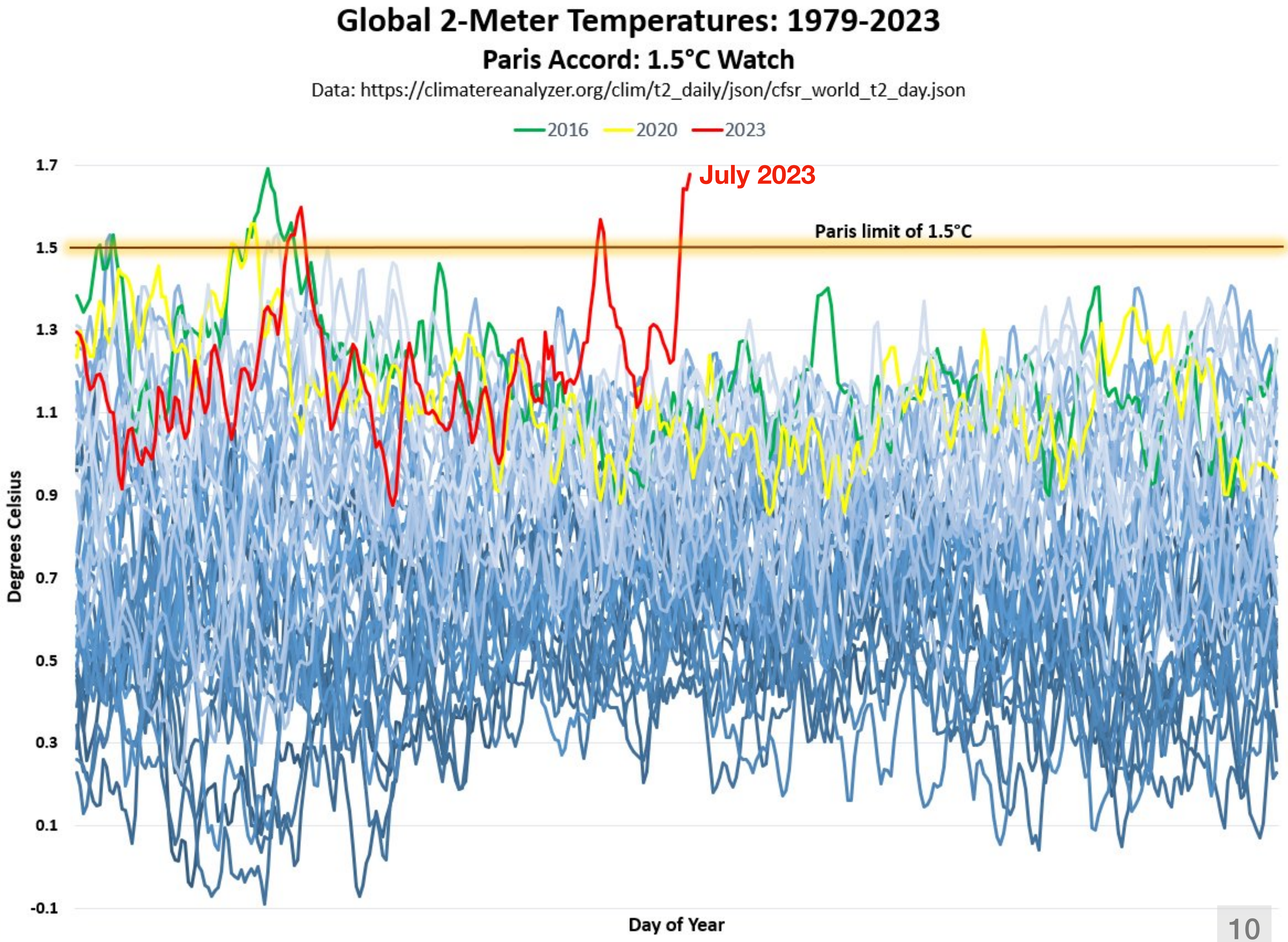

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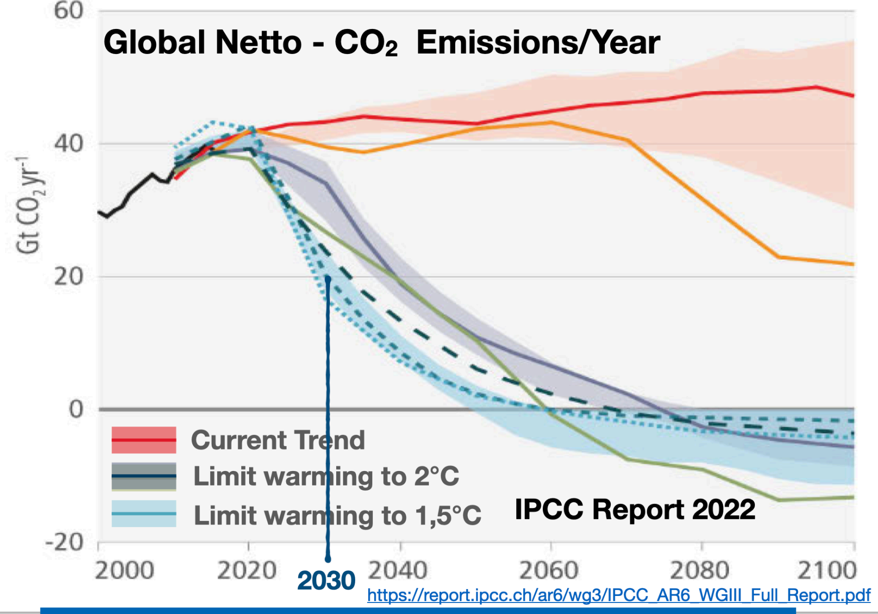

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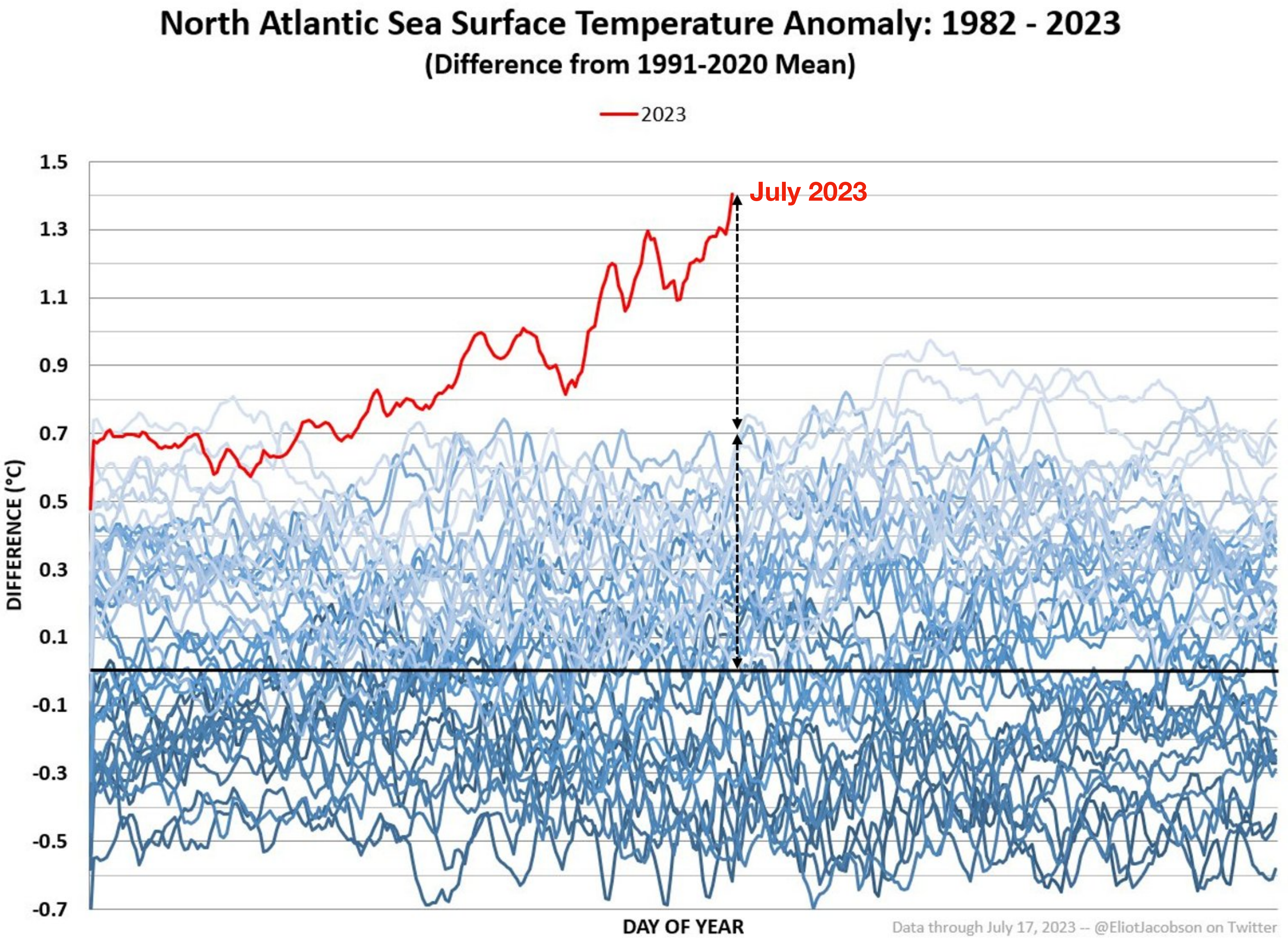

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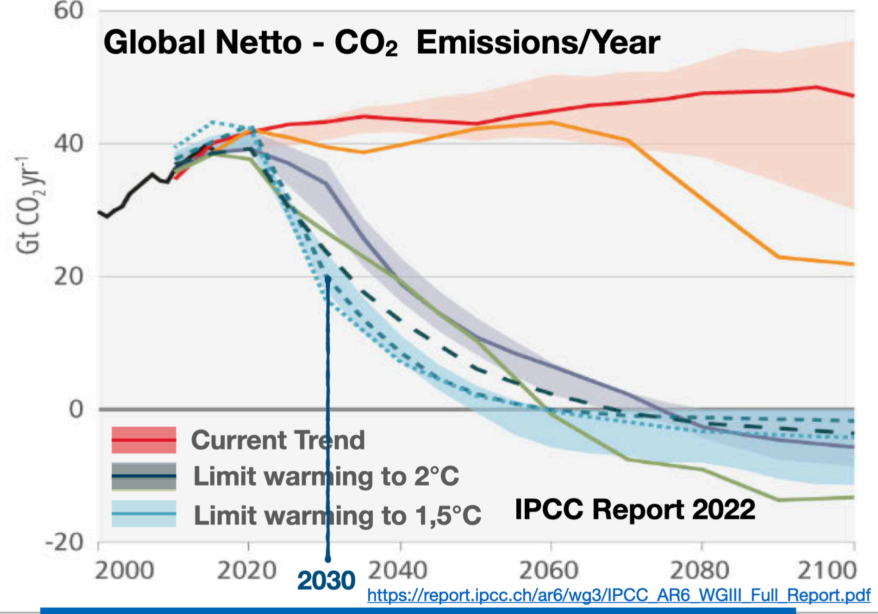

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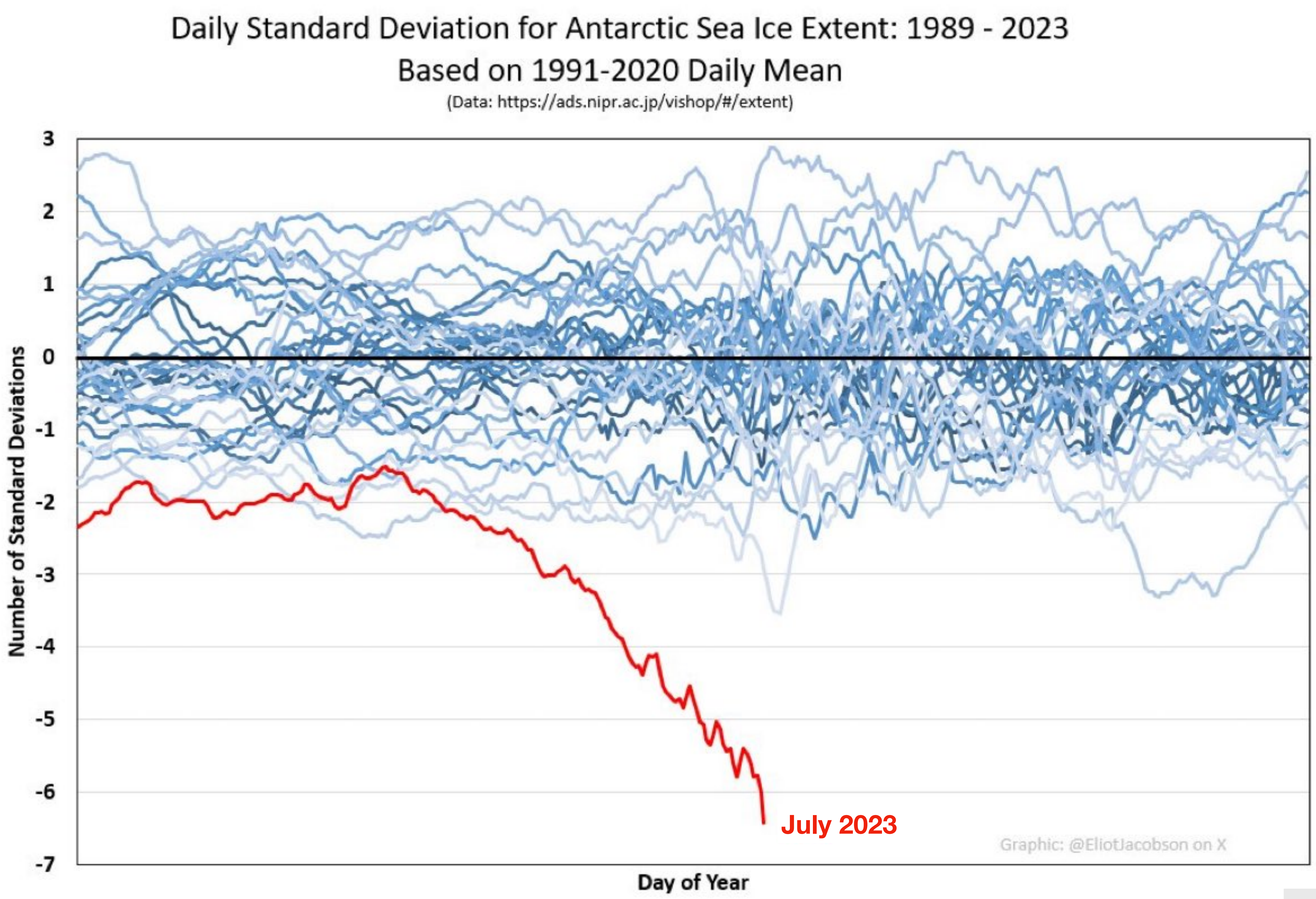

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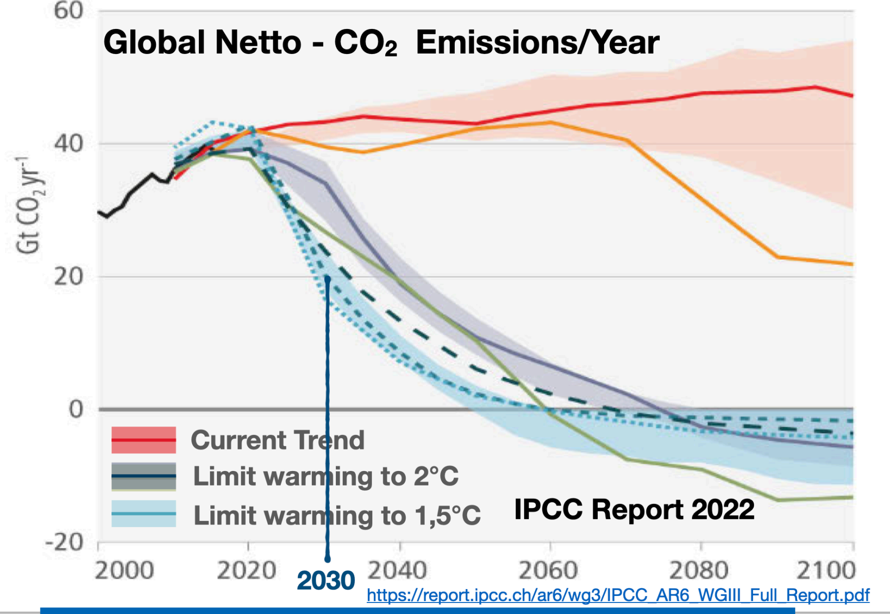
Energy transition for physicists



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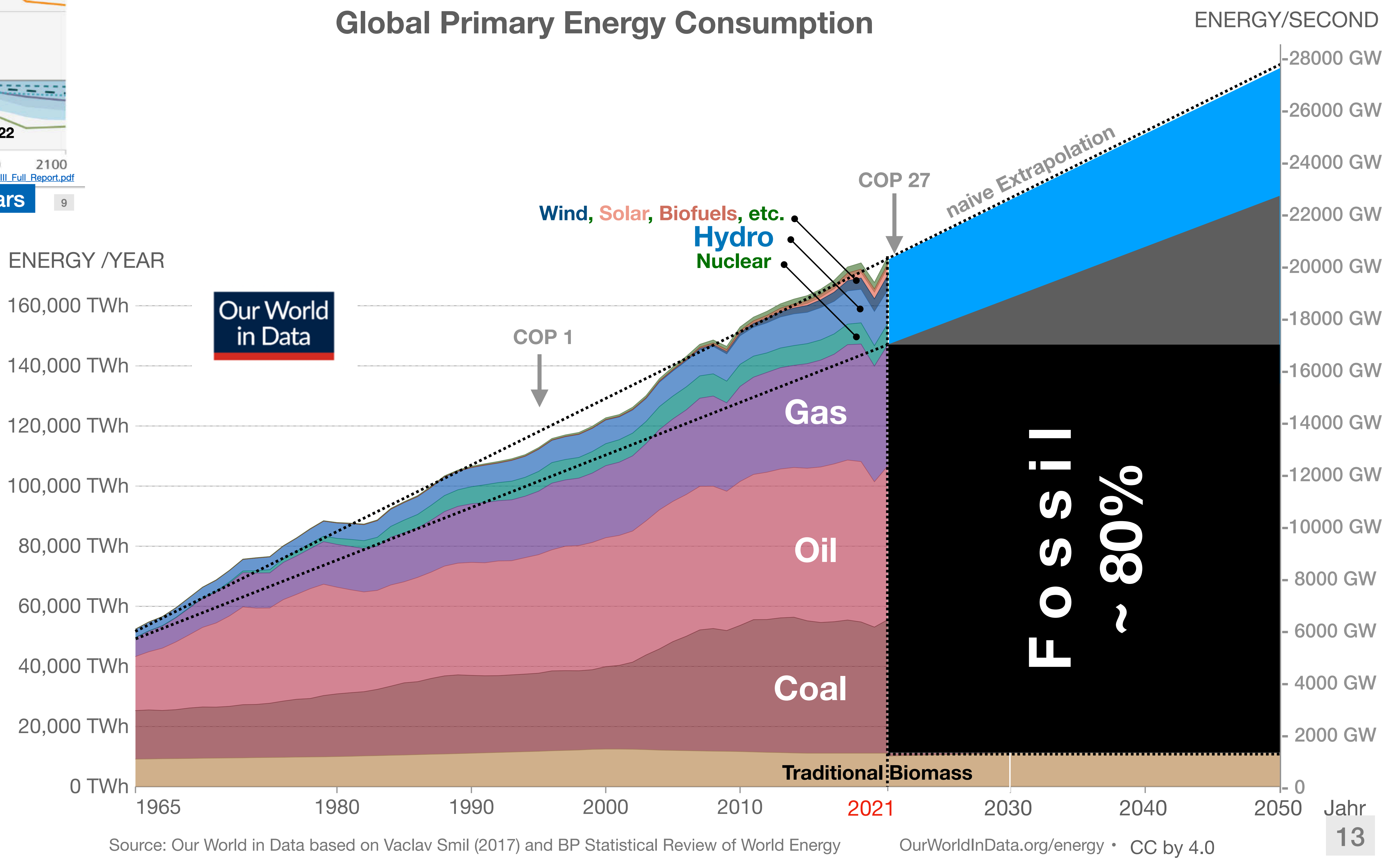

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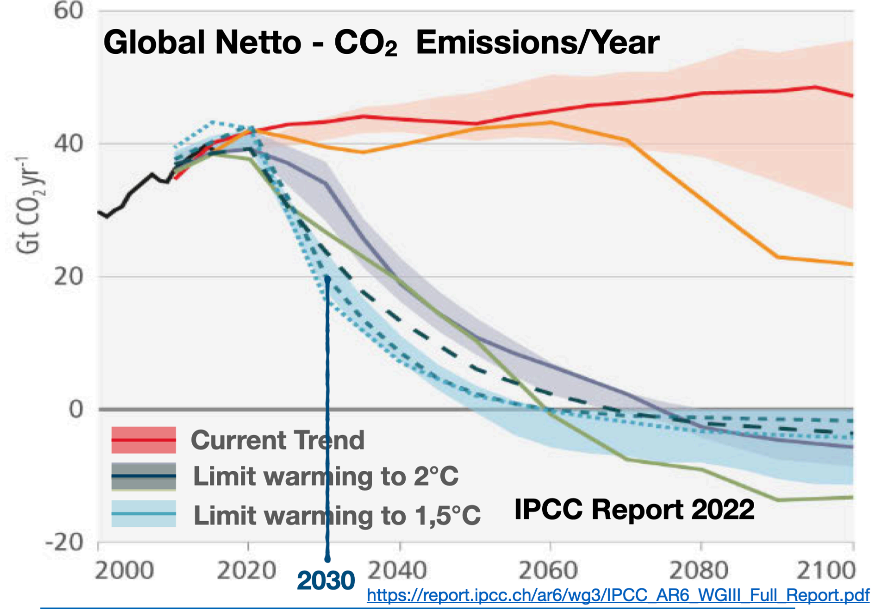

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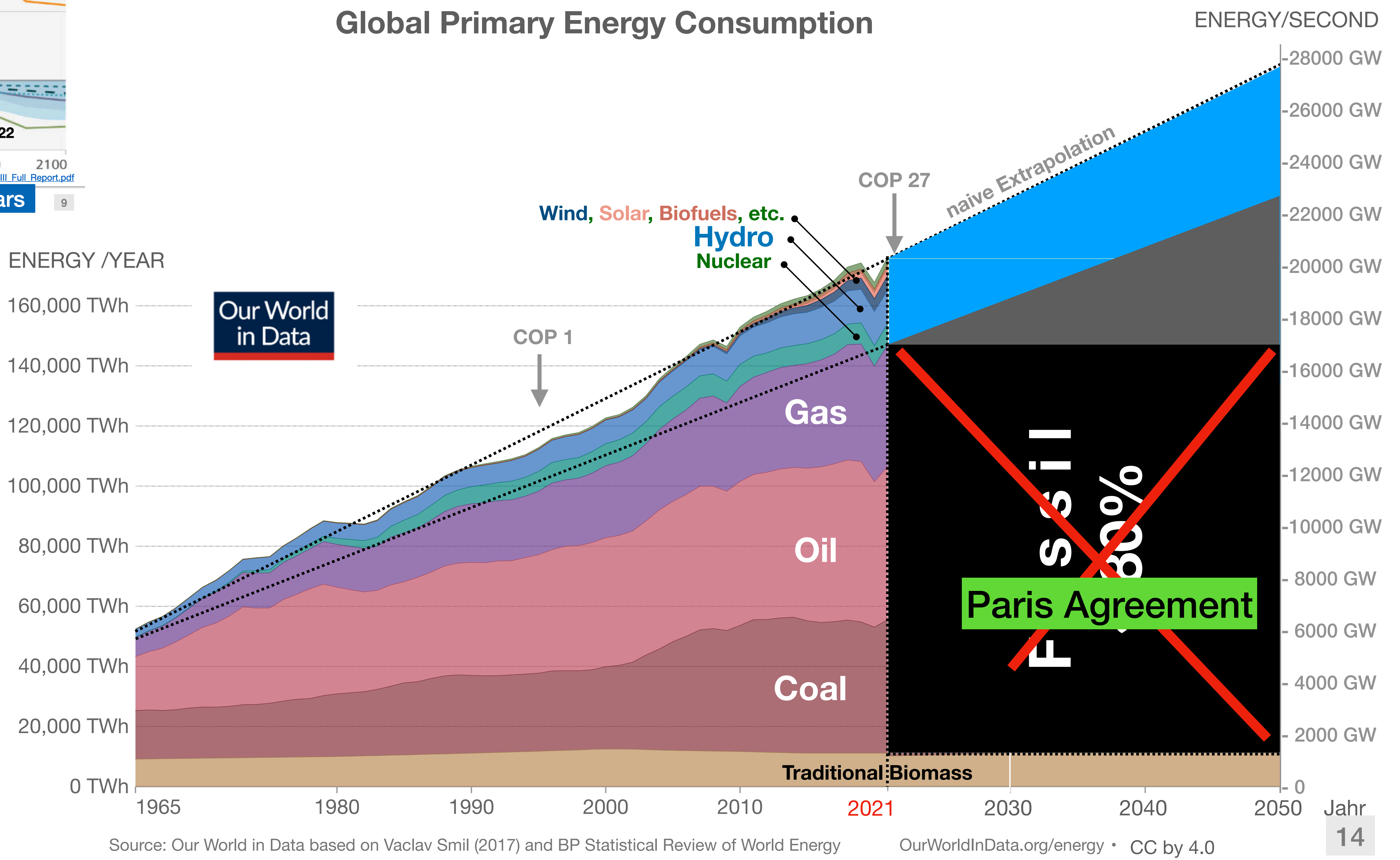

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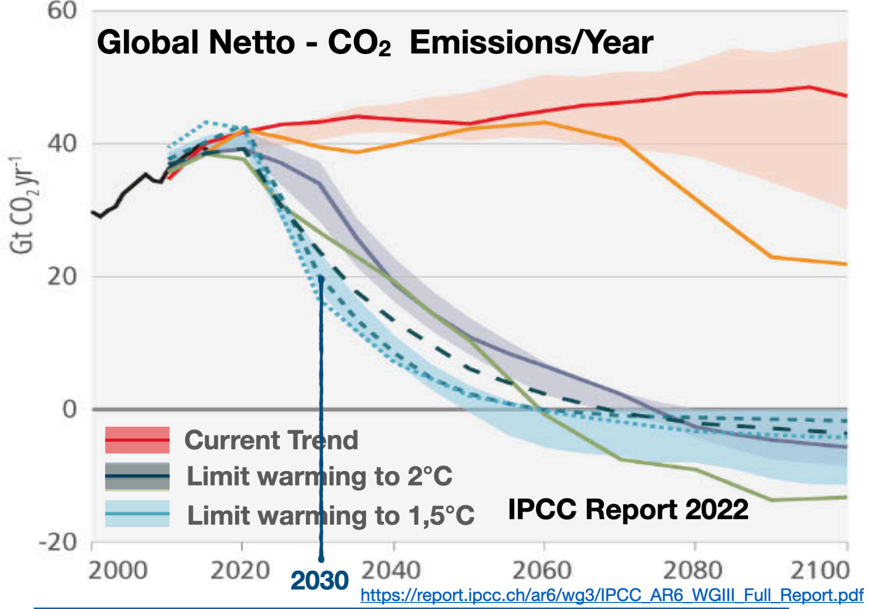
The global energy gap



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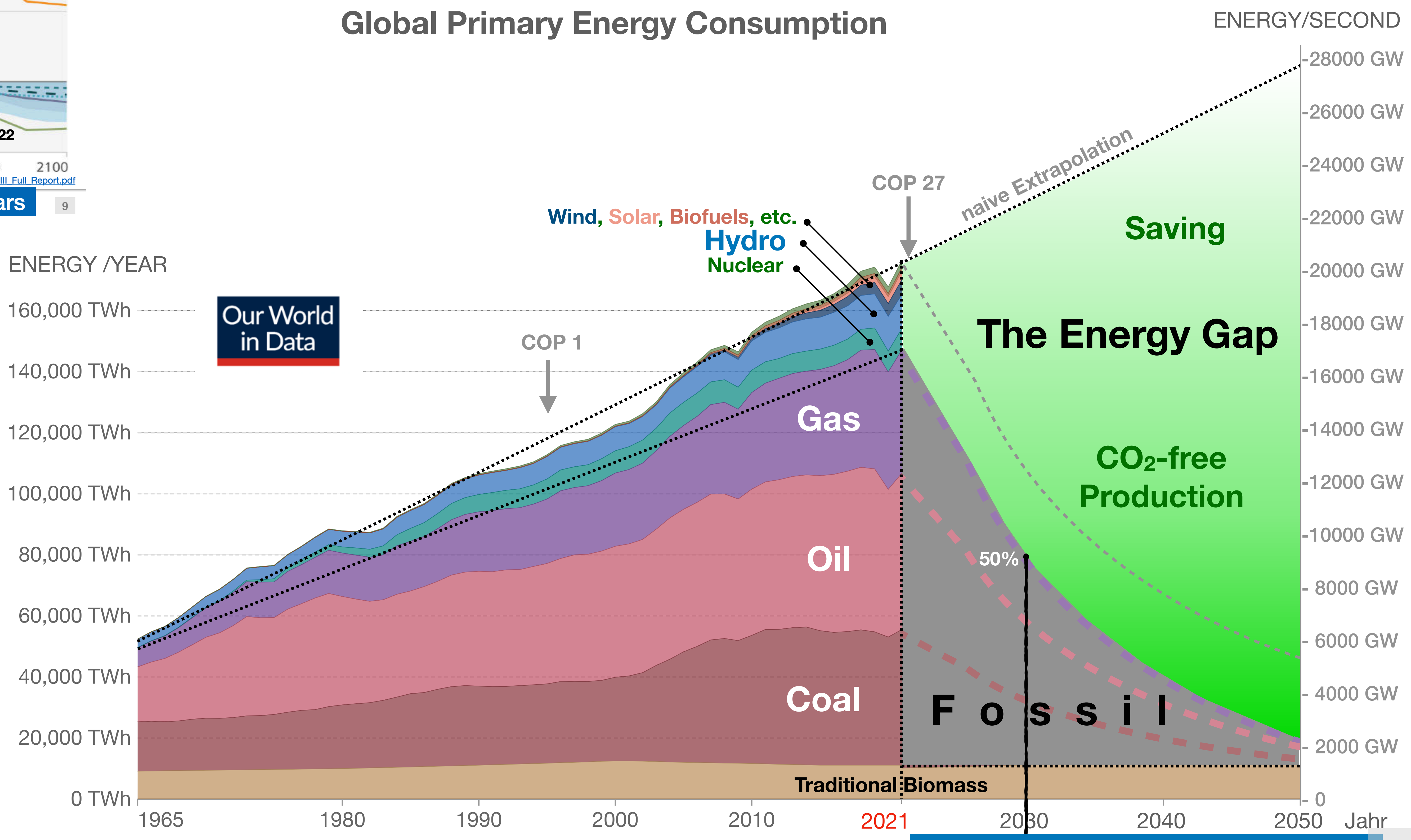

Source: Our World in Data based on Vaclav Smil (2017) and BP Statistical Review of World Energy

50% until 2030 (7 Jahre)

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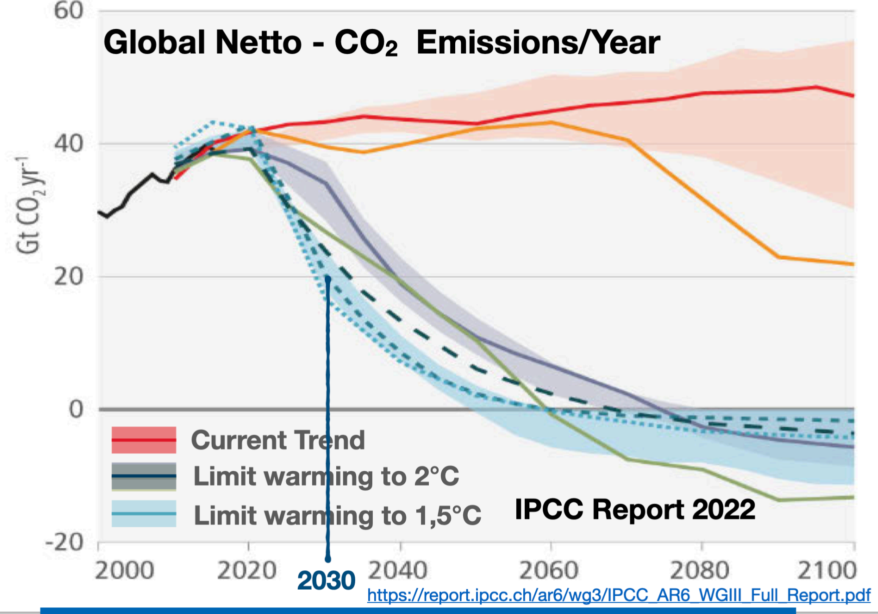

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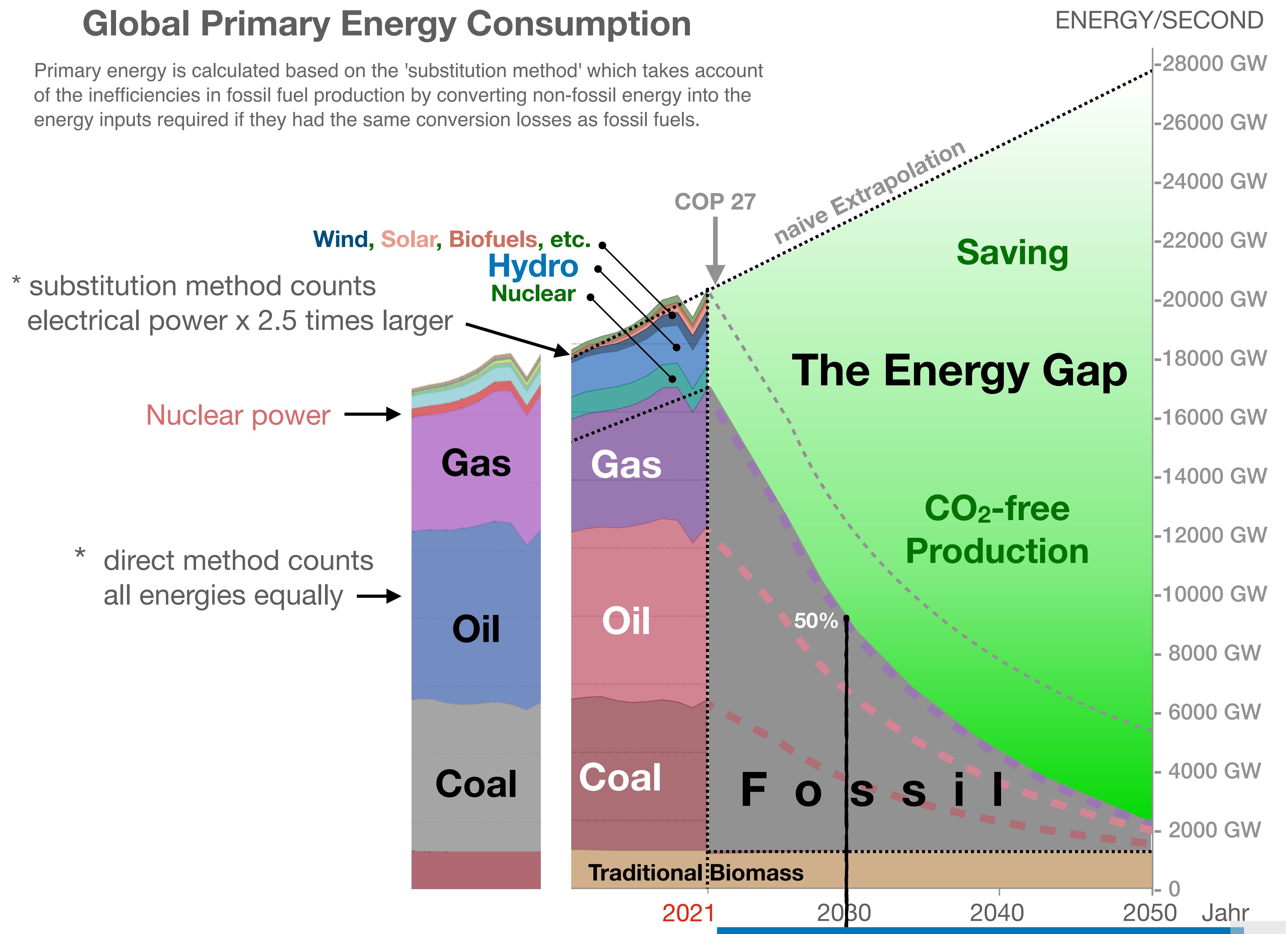

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50% until 2030 (7 Jahre)

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The global energy gap

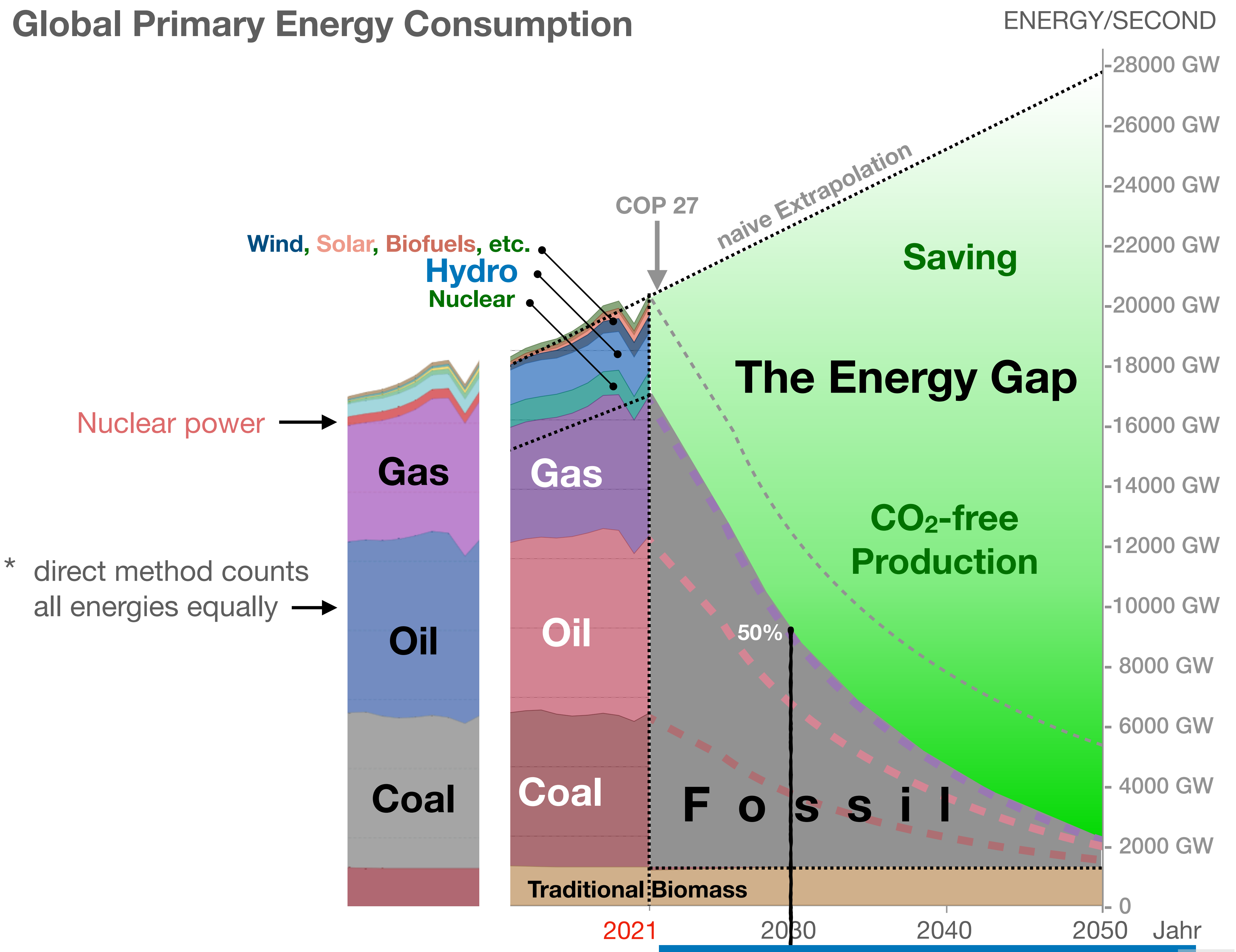
Options:

1. Expand CO_2-free energies (excluding hydro)

   factor ~12 in 7 years required;

   >11000 new power plants with 1 GW

   = 27 per week



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50% until 2030 (7 Jahre)

The global energy gap

Options:

1. Expand CO_2-free energies (excluding hydro)

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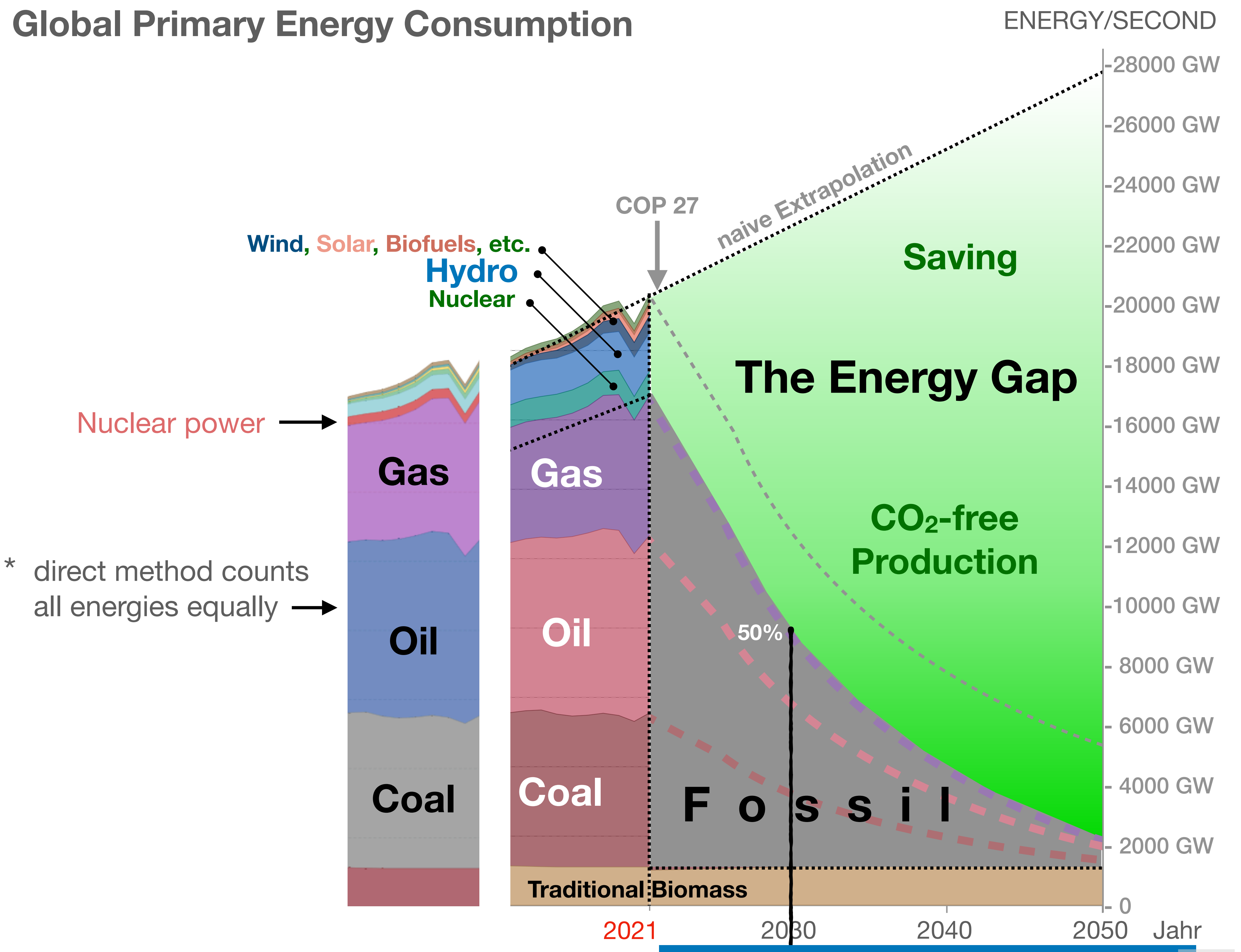
   = 27 per week

2. Increase energy efficiency

   factor ~2 in 7 years



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50% until 2030 (7 Jahre)

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The global energy gap

Options:

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   >11000 new power plants with 1 GW

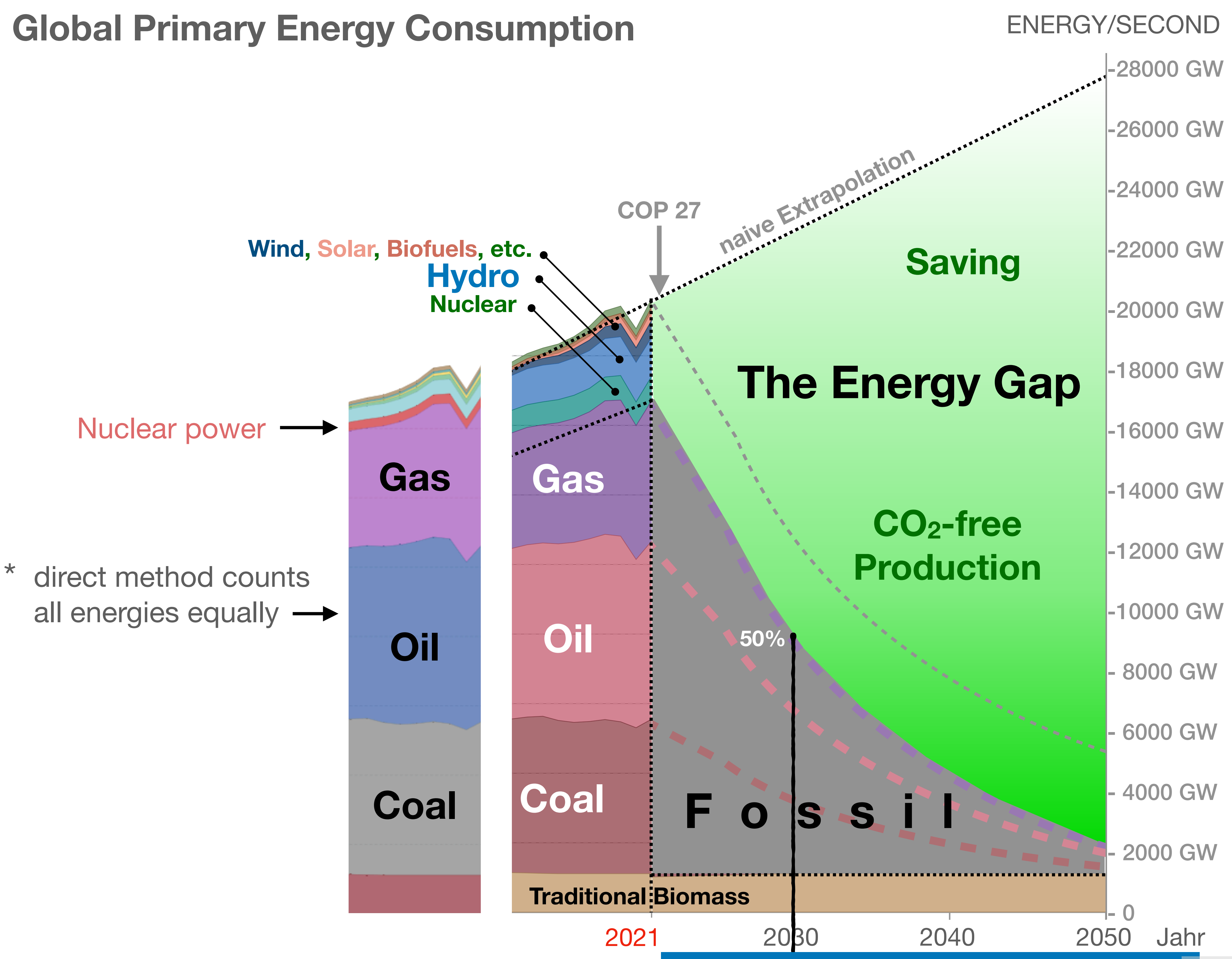
   = 27 per week

2. Increase energy efficiency

   factor ~2 in 7 years

3. Save energy

   factor ~2 in 7 years



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50% until 2030 (7 Jahre)

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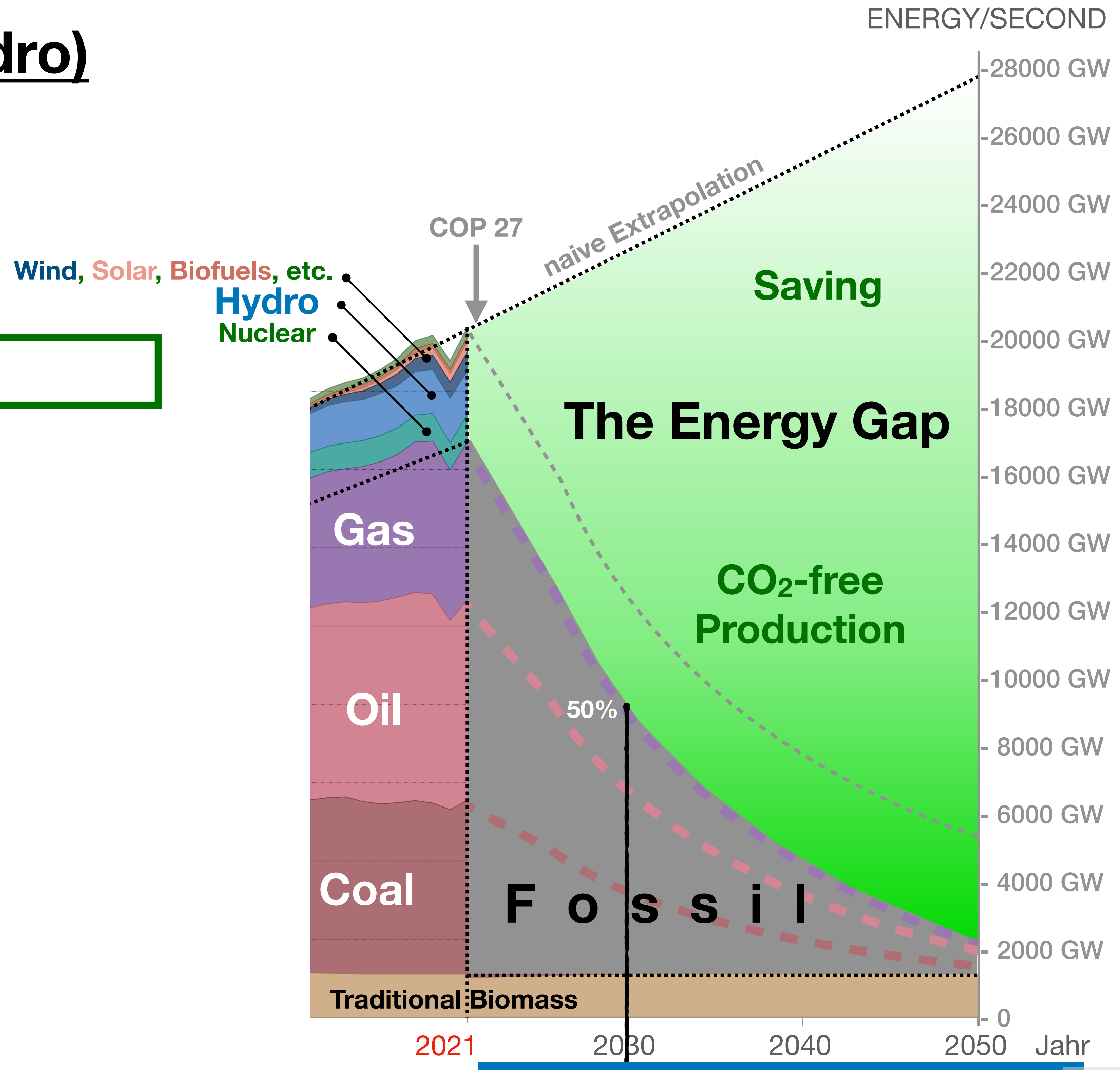
Option 1: green energy

Expand CO_2-free energies (excluding hydro)

(Factor ~12 in 7 years)

System change: fossil → renewable

1. Wind power and PV locally



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50% until 2030 (7 Jahre)

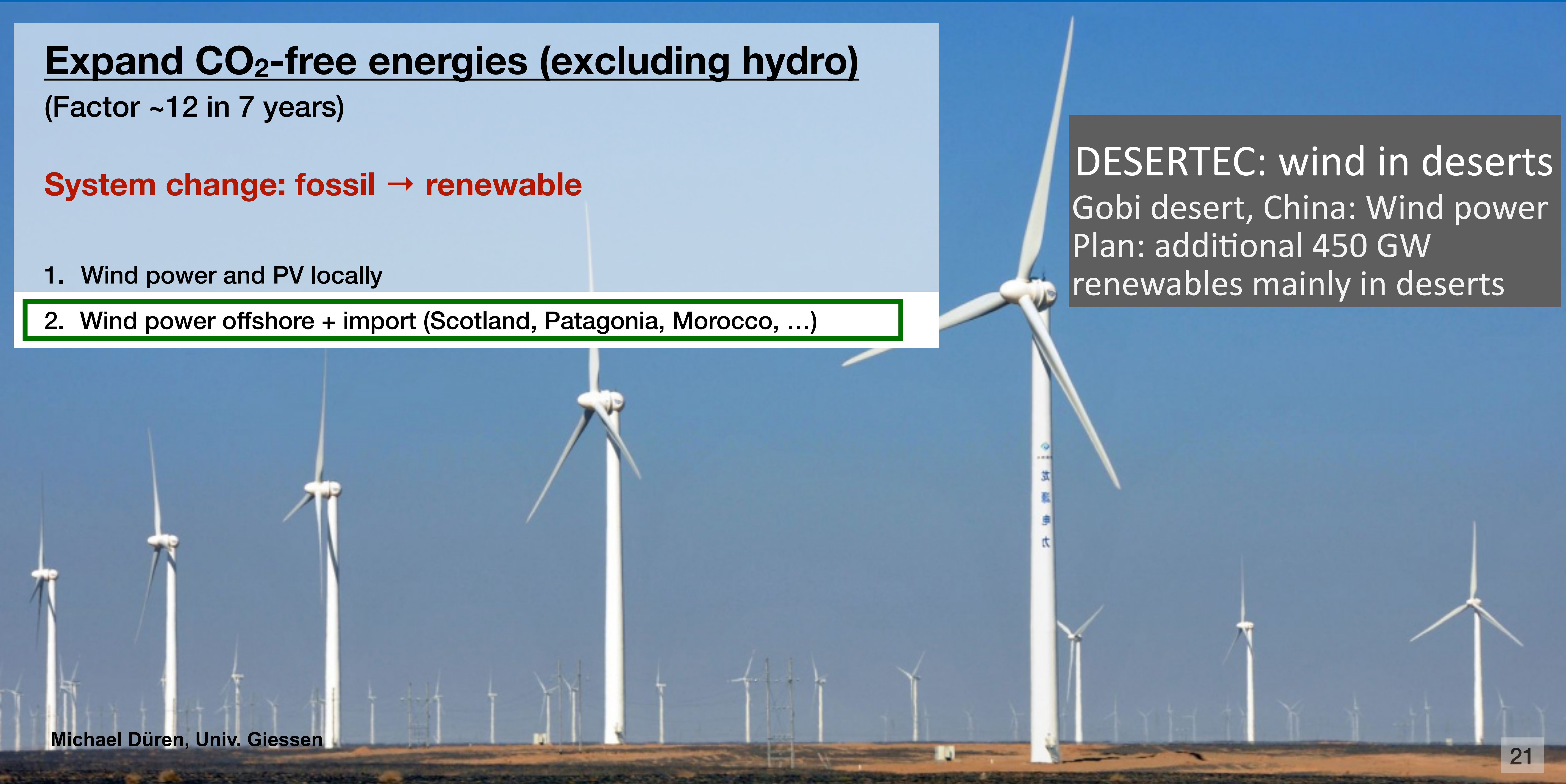
Option 1: green energy

Expand CO_2-free energies (excluding hydro)

(Factor ~12 in 7 years)

System change: fossil → renewable

1. Wind power and PV locally
2. Wind power offshore + import (Scotland, Patagonia, Morocco, …)



DESERTEC: wind in deserts

Gobi desert, China: Wind power Plan: additional 450 GW renewables mainly in deserts

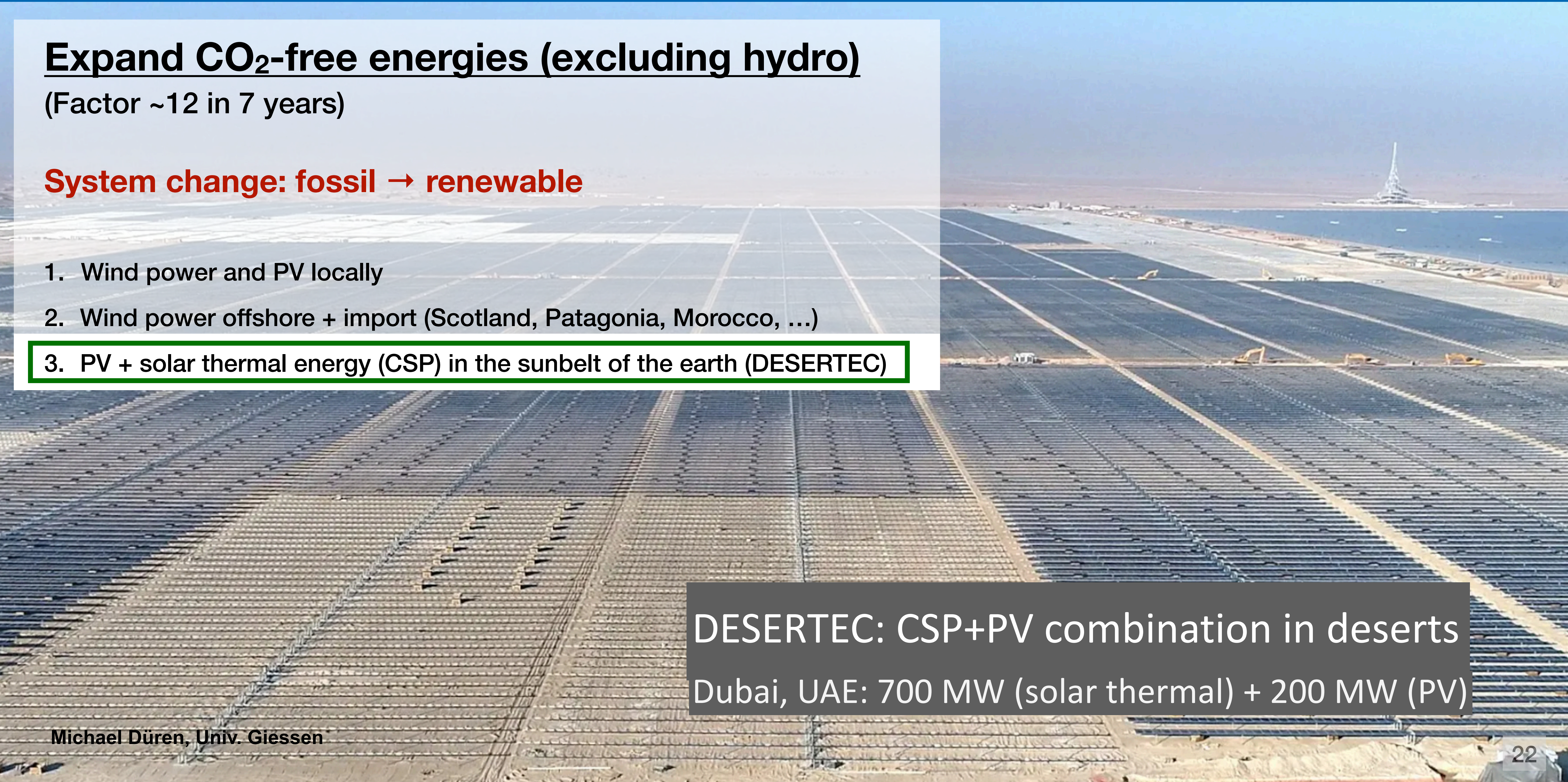
Option 1: green energy

Expand CO_2-free energies (excluding hydro)

(Factor ~12 in 7 years)

System change: fossil → renewable

1. Wind power and PV locally
2. Wind power offshore + import (Scotland, Patagonia, Morocco, ...)
3. PV + solar thermal energy (CSP) in the sunbelt of the earth (DESERTEC)



DESERTEC: CSP+PV combination in deserts

Dubai, UAE: 700 MW (solar thermal) + 200 MW (PV)

Option 1: green energy

Expand CO_2-free energies (excluding hydro)

(Factor ~12 in 7 years)

System change: fossil → renewable

1. Wind power and PV locally
2. Wind power offshore + import (Scotland, Patagonia, Morocco, …)
3. PV + solar thermal energy (CSP) in the sunbelt of the earth (DESERTEC)
4. Storage:
   - Trams with batteries and overhead line

„Tram on autobahn“

Option 1: green energy

Expand CO_2-free energies (excluding hydro)

(Factor ~12 in 7 years)

System change: fossil → renewable

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4. Storage:
   - Trams with batteries and overhead line
   - CSP with heat storage in desert regions

„Tram on autobahn“

DESERTEC: power tower in deserts

Atacama desert/Chile 210 MW, 16 h heat storage power day and night

Option 1: green energy

Expand CO_2-free energies

(Factor ~12 in 7 years)

System change: fossil → renewa

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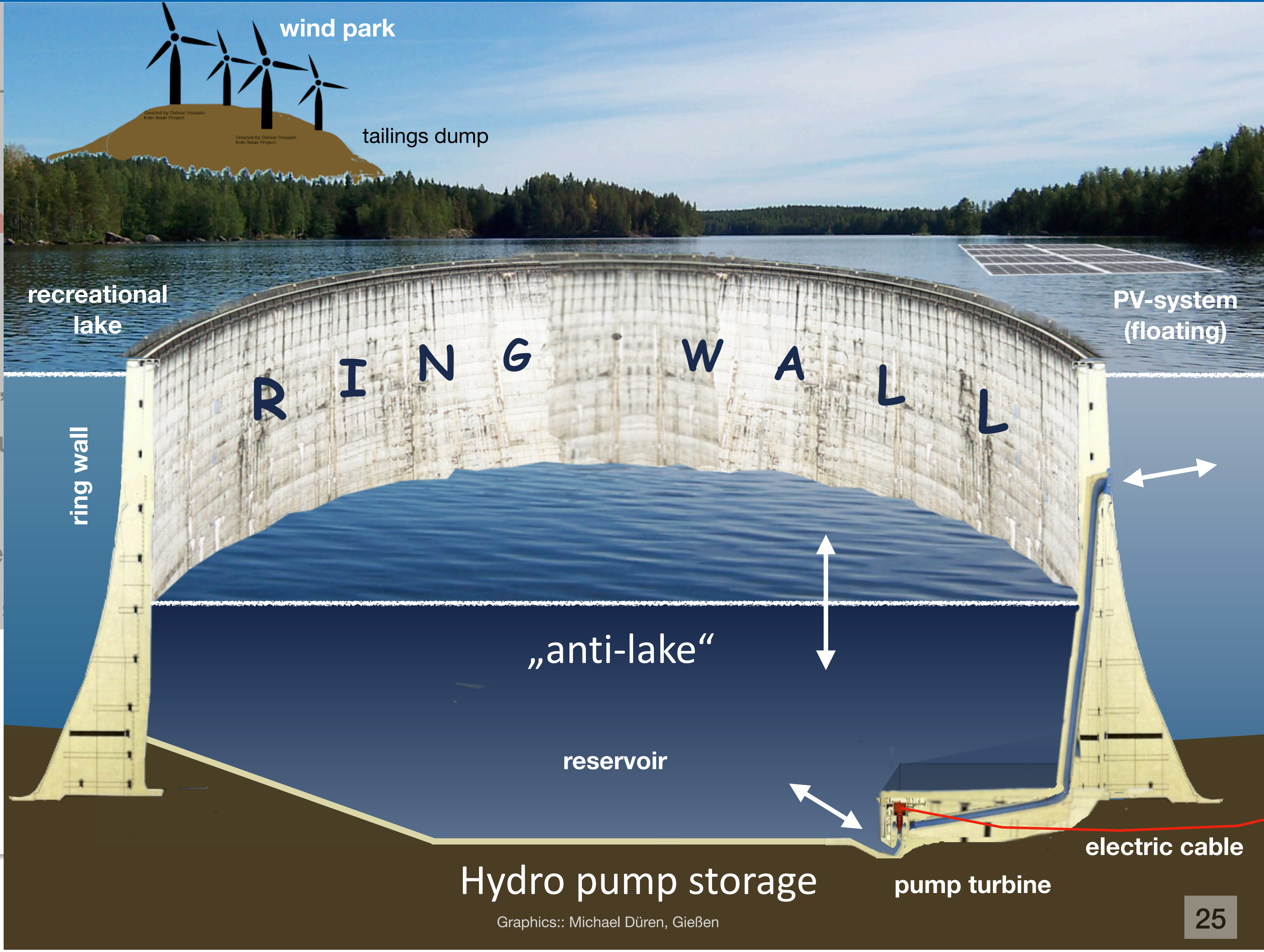
2. Wind power offshore + import (Scotland,
3. PV + solar thermal energy (CSP) in the su
4. Storage:
   - Trams with batteries and overhead line
   - CSP with heat storage in desert region
   - Ring water storage power plants in abandoned open pit mines, lakes, ocean



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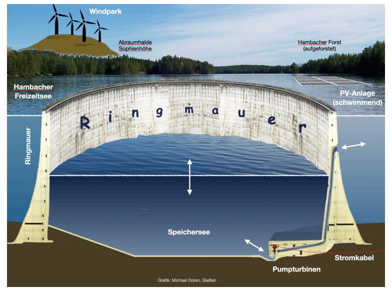
2. Wind power offshore + import (Scotland, Patagonia, Morocco, …)
3. PV + solar thermal energy (CSP) in the sunbelt of the earth (DESERTEC)
4. Storage:
   - Trams with batteries and overhead line
   - CSP with heat storage in desert regions
   - Ring water storage power plants in lakes and in the sea
   - Chemical energy carriers (e.g. H_2) as long-term storage

„Tram on autobahn“



„anti-lake“

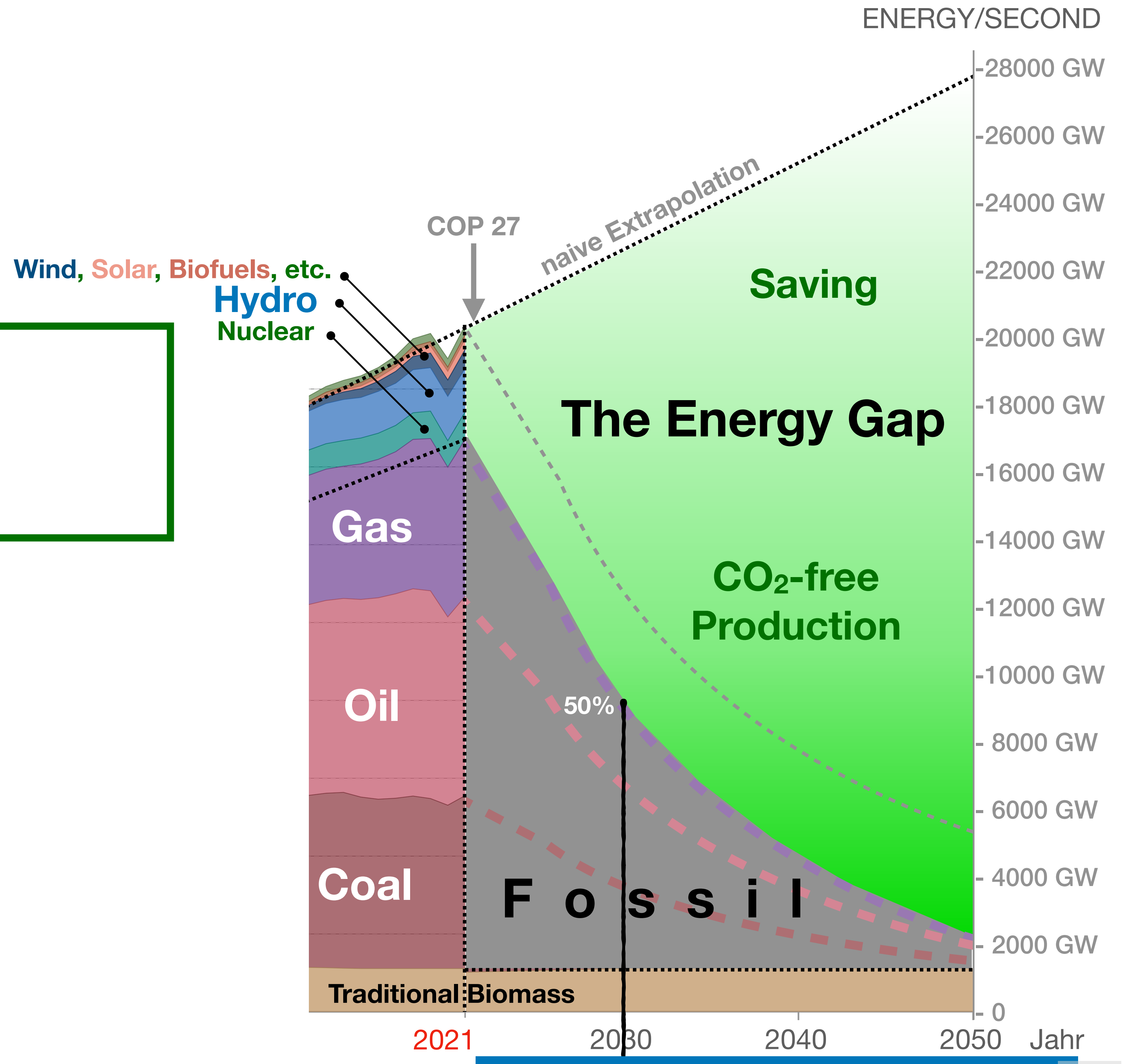
Option 2: efficiency

Increase energy efficiency

(Factor ~2 in 7 years)

System change of technology

1. LEDs for lighting (factor 10 vs. light bulb)
2. Electrification of engines (factor 3-5 vs. combustion engine)
3. Heat pumps for heating (factor 3-5 vs. gas heating)



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Data based on Vaclav Smil (2017) and BP Statistical Review of World Energy

50% until 2030 (7 Jahre)

Option 2: efficiency

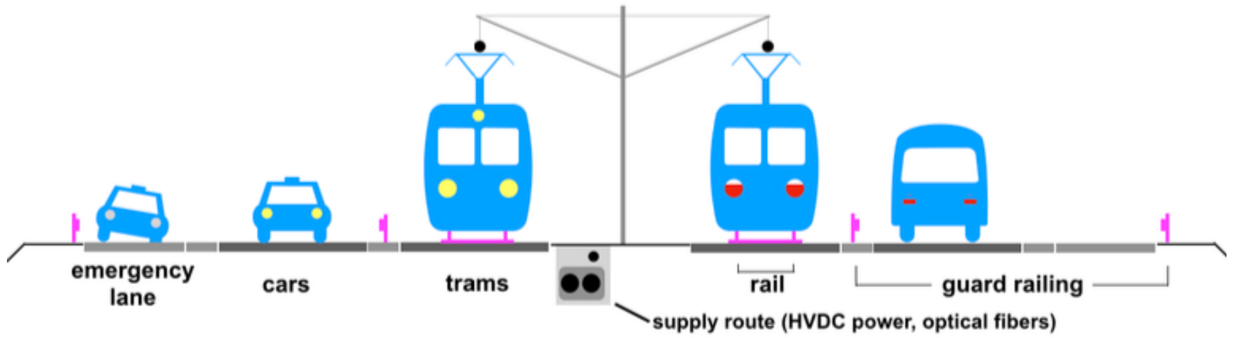
Increase energy efficiency

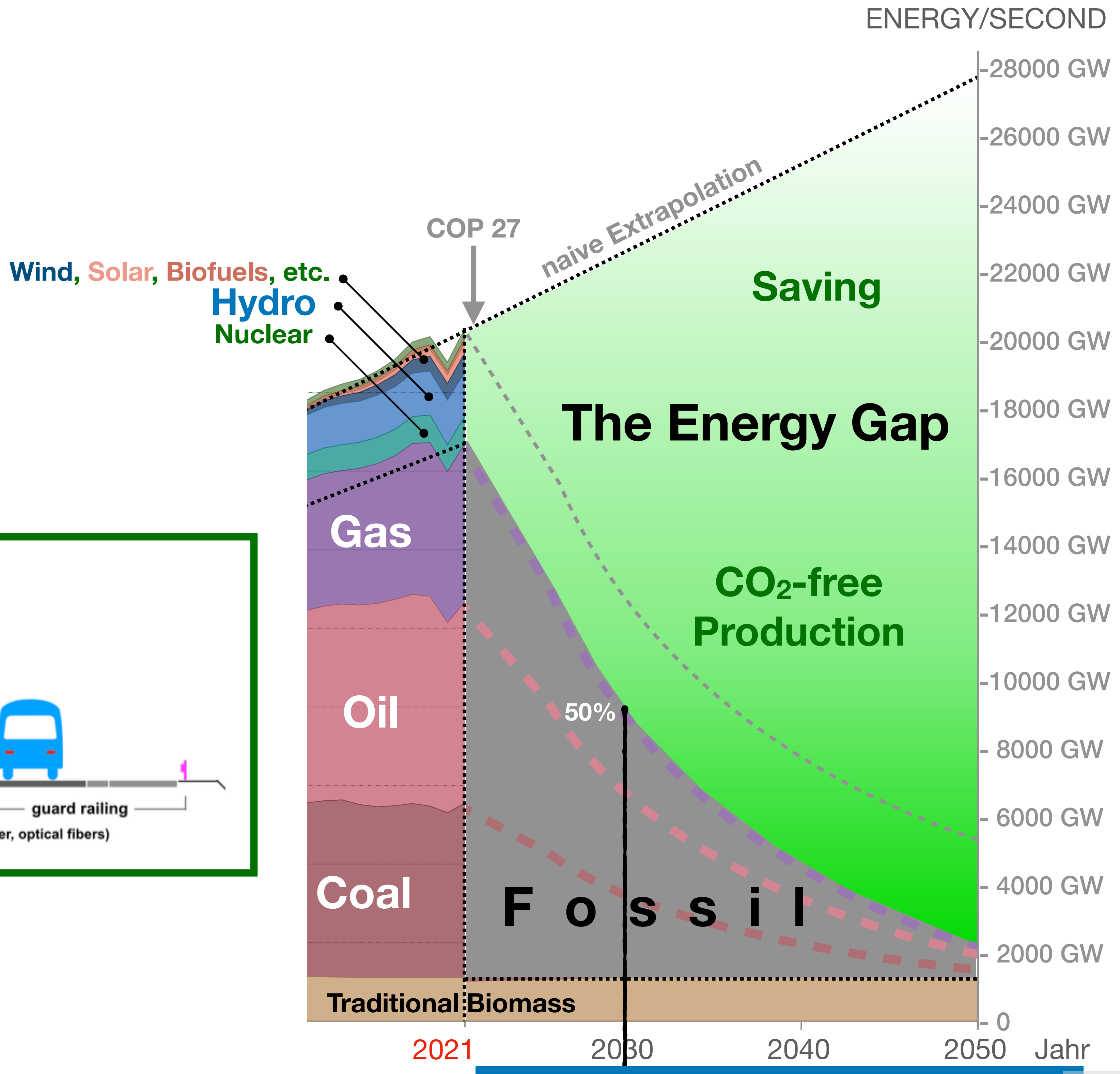
(Factor ~2 in 7 years)

System change of technology

1. LEDs for lighting (factor 10 vs. light bulb)
2. Electrification of engines (factor 3-5 vs. combustion engine)
3. Heat pumps for heating (factor 3-5 vs. gas heating)
4. Rail traffic on motorways (factor 10 vs. cars/trucks)

   (Speed trams on autobahn)





50% until 2030 (7 Jahre)

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Technology change is key to sustainability

Back to the future

„Overhead line“ on the ground (France)

Von Lunon92 - Selbst fotografiert, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=14970987

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Technology change is key to sustainability

Battery charging at tram stop (Australia)

Autonomous driving along dashed lines
(no rails on this road, China)

Speed-Tram on the Auto-Bahn

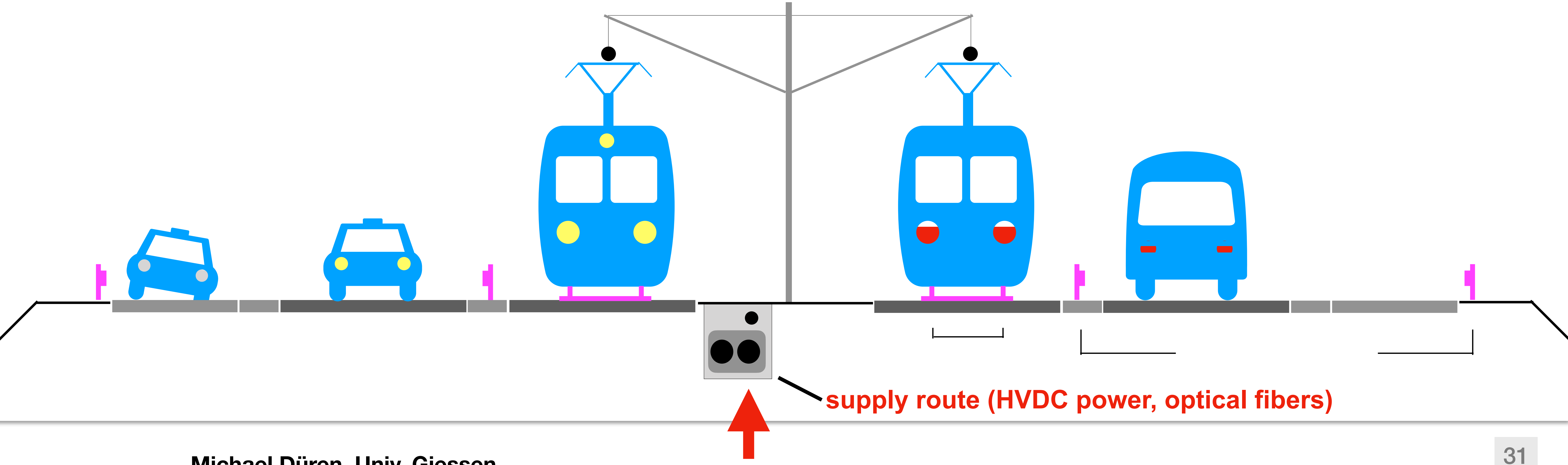
Energy for transport reduced by factor 10

Put rails on roads and highways

- **without additional land use & expropriations**
- **speed up approvals and construction**

Enabling the energy transition

- **supply route for HVDC at various HV levels across the country (no new overhead HV lines needed)**
- **batteries of Speed-Trams are connected to the grid (double use; stabilisation of the national grid)**



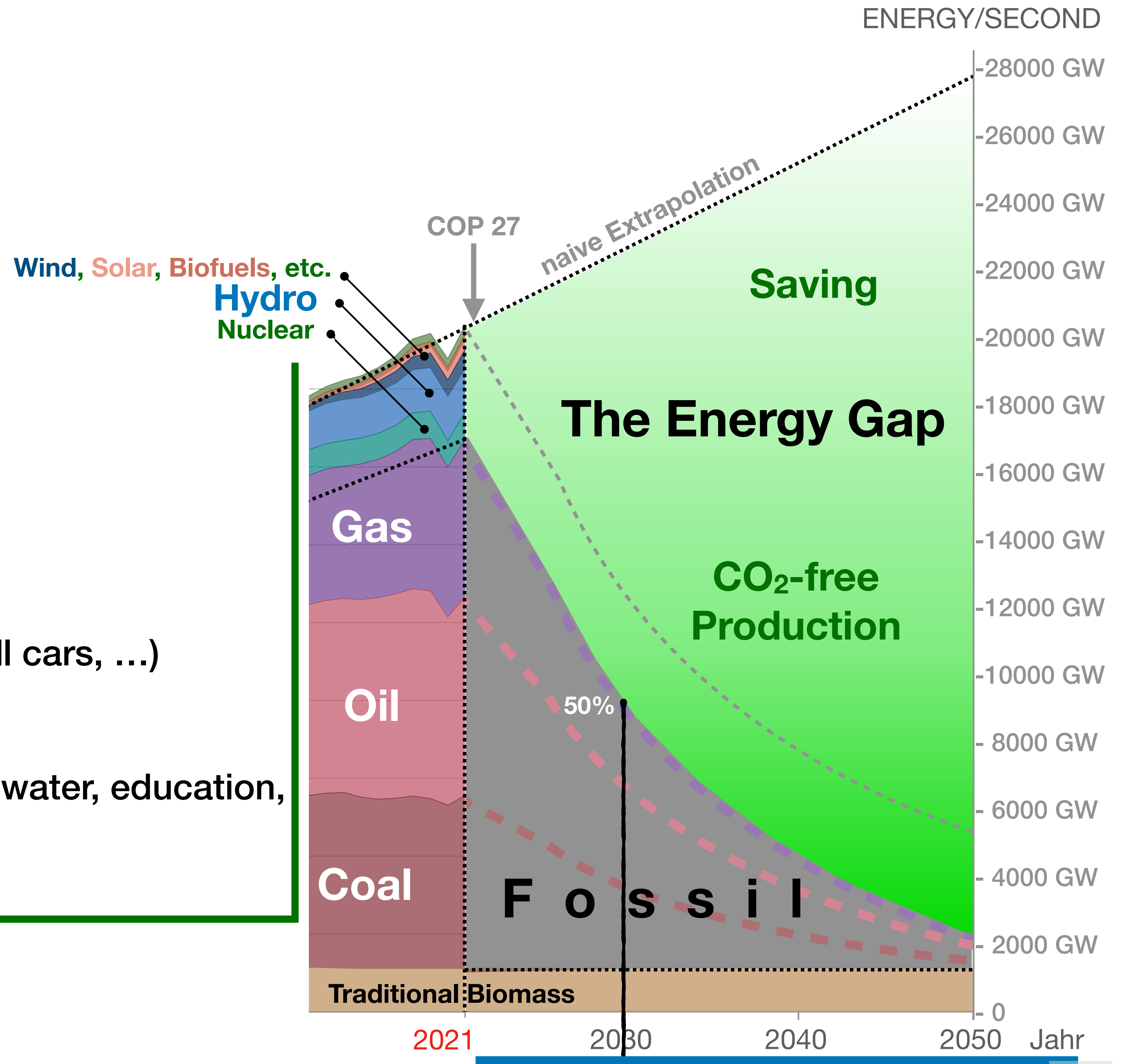
Option 3: saving - What to do and what to avoid?

Save energy

(Factor ~2 in 7 years)

System change of behaviour

1. Less travel: online conferences, holidays nearby
2. Less commuting: home office, local co-working spaces
3. Eat little fish and meat; no beef
4. Fewer consumer items, more repair options
5. Less globalisation (local food, local factories)
6. Use public transport and light vehicles (bicycles, scooters, small cars, …)
7. No flights (if possible)
8. Energy priority for essential things (agriculture, fertilisers, clean water, education, internet: social contacts, remote work, remote construction …)



Our World in Data based on Vaclav Smil (2017) and BP Statistical Review of World Energy

50% until 2030 (7 Jahre)

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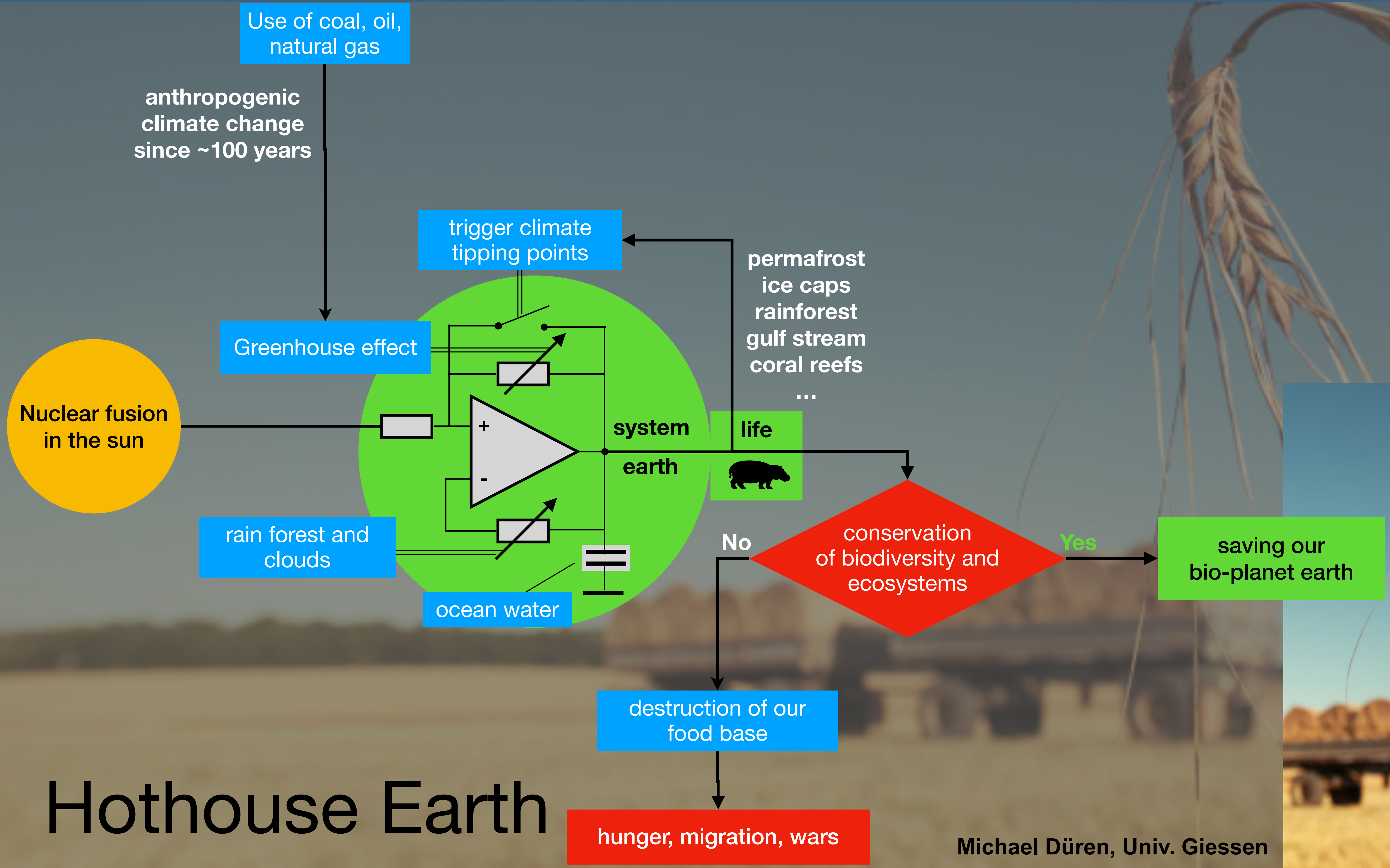
Survival of civilisation?

2023-2030



Hothouse Earth

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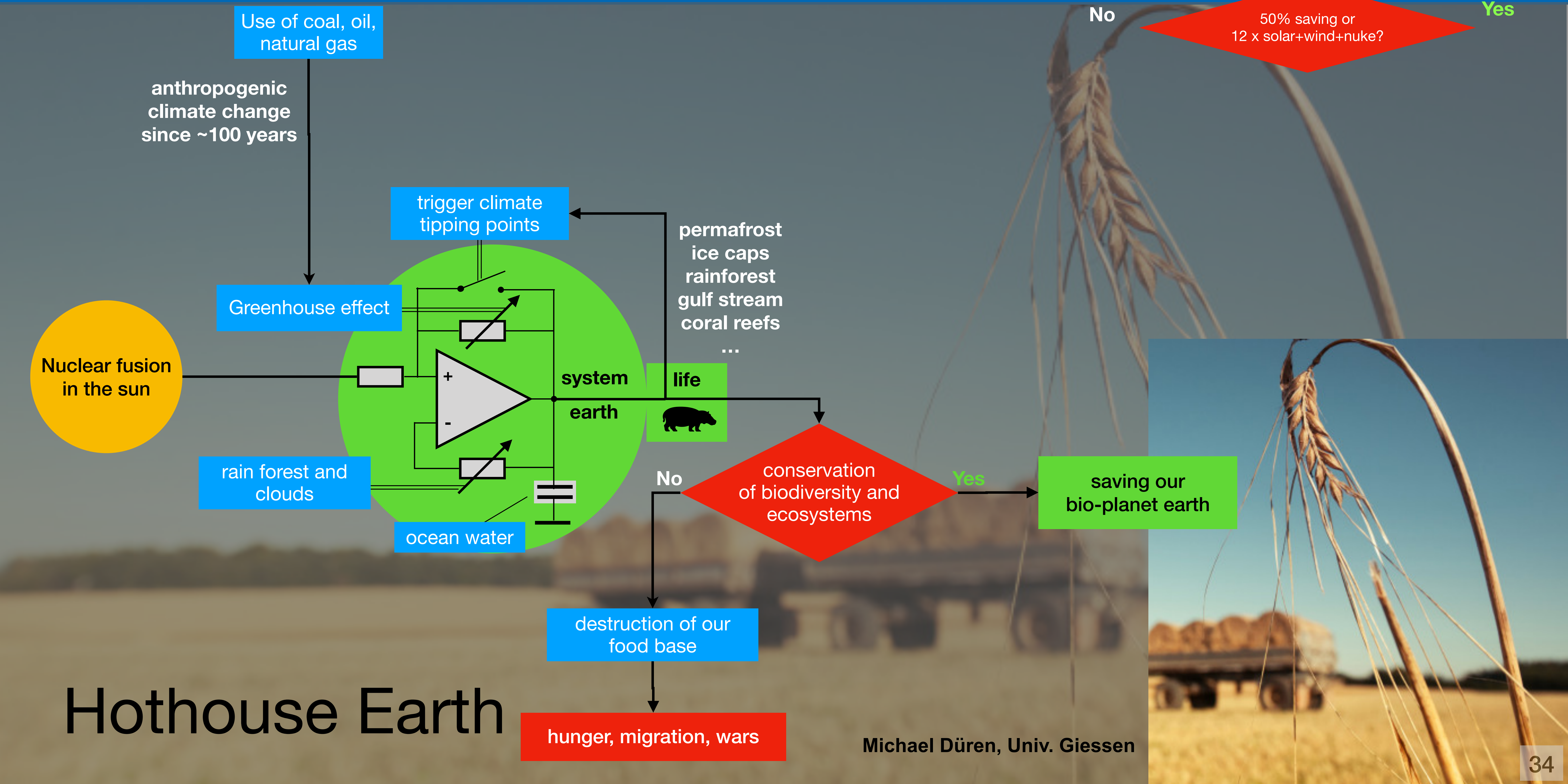
Survival of civilisation?



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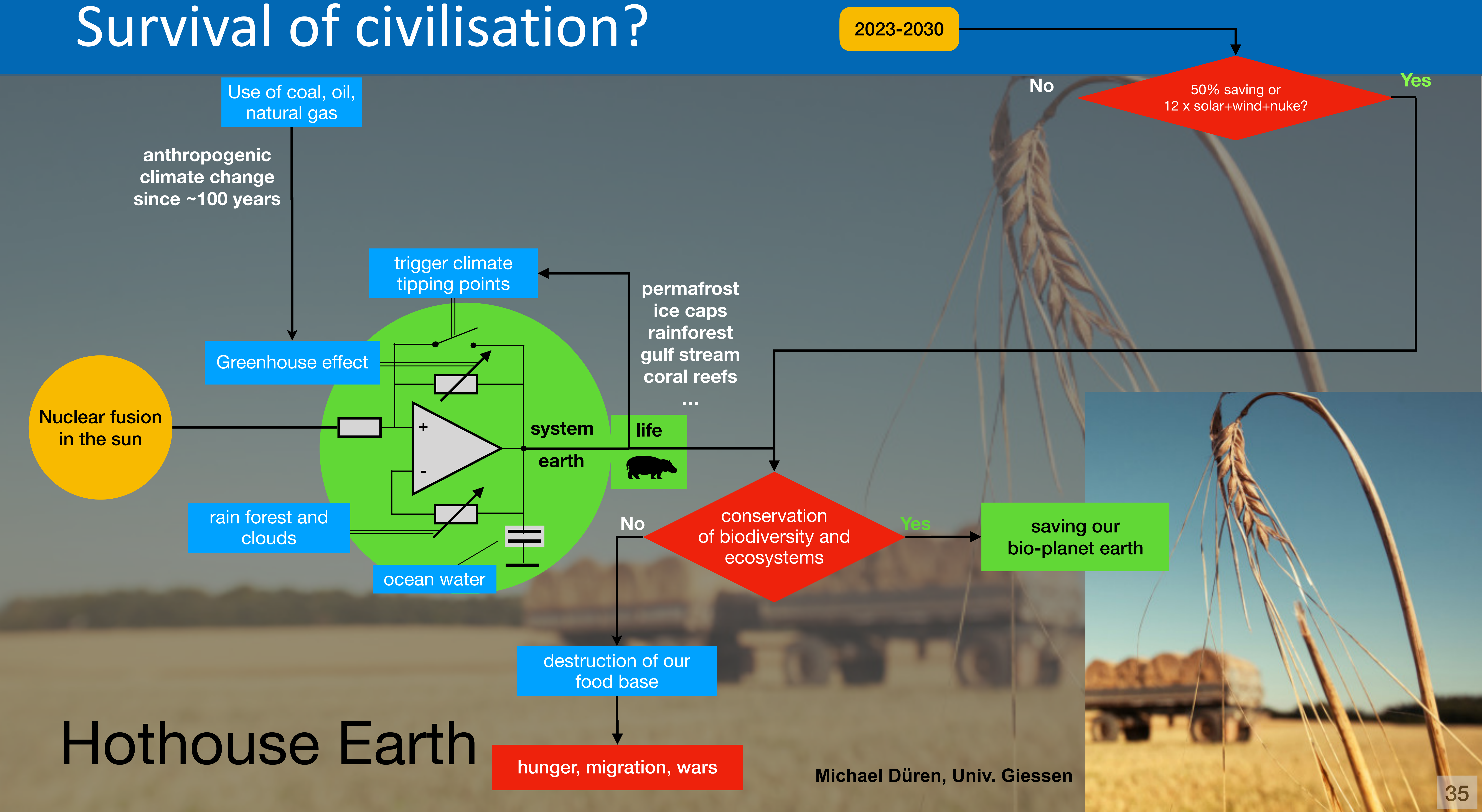
Michael Düren, Univ. Giessen

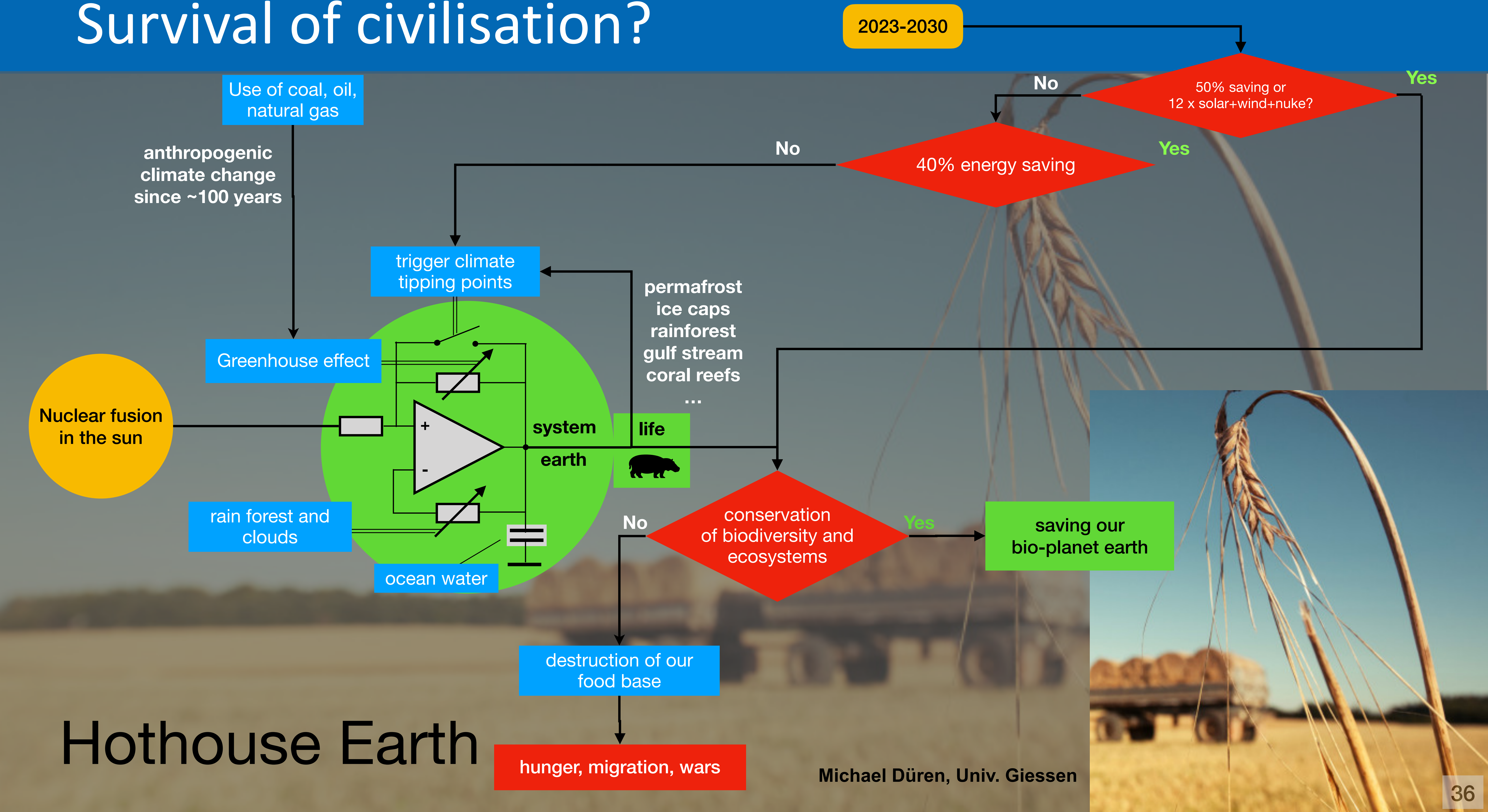
Survival of civilisation?



Hothouse Earth

Michael Düren, Univ. Giessen

Survival of civilisation?



Hothouse Earth

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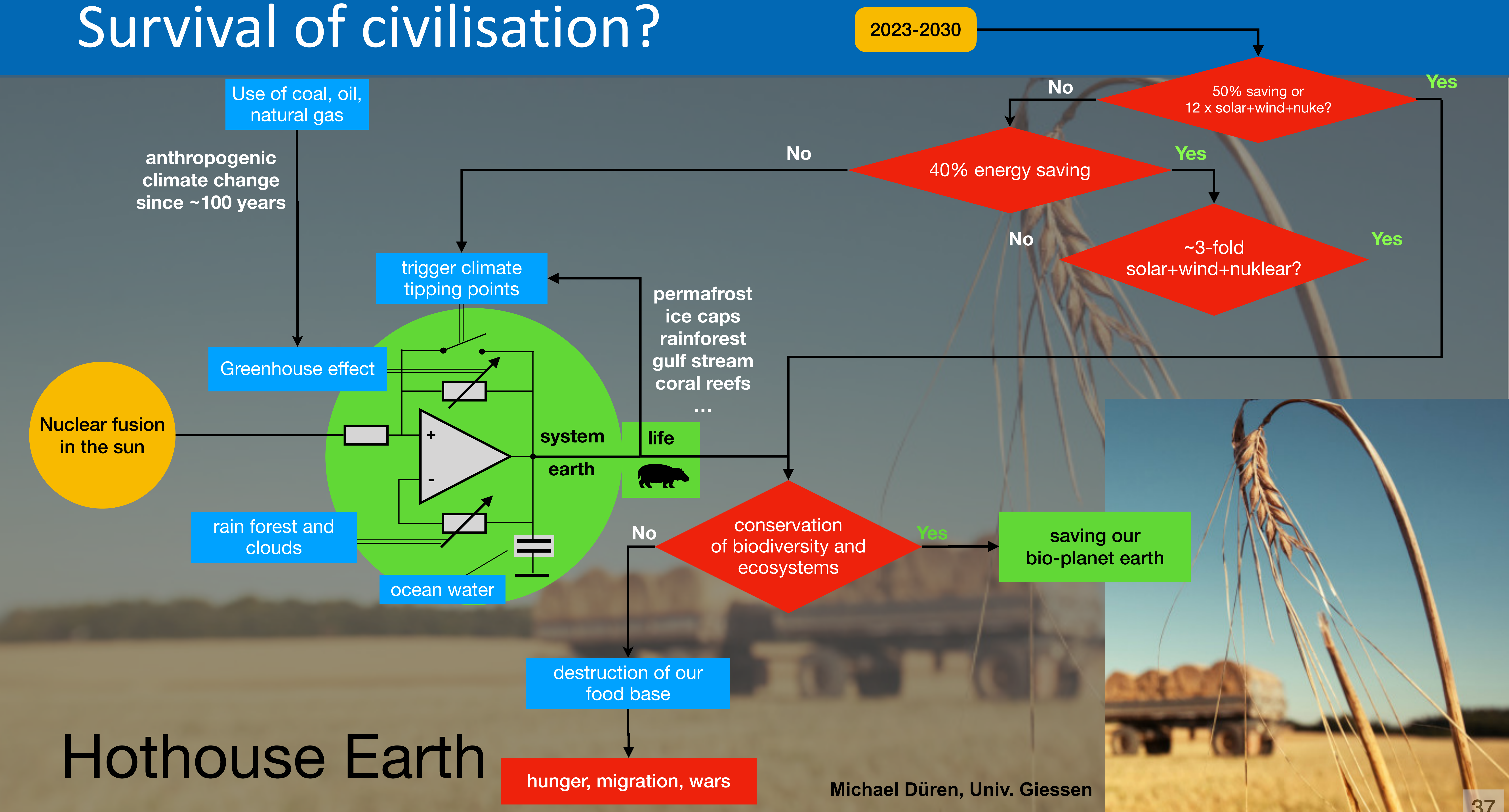
Survival of civilisation?



Hothouse Earth

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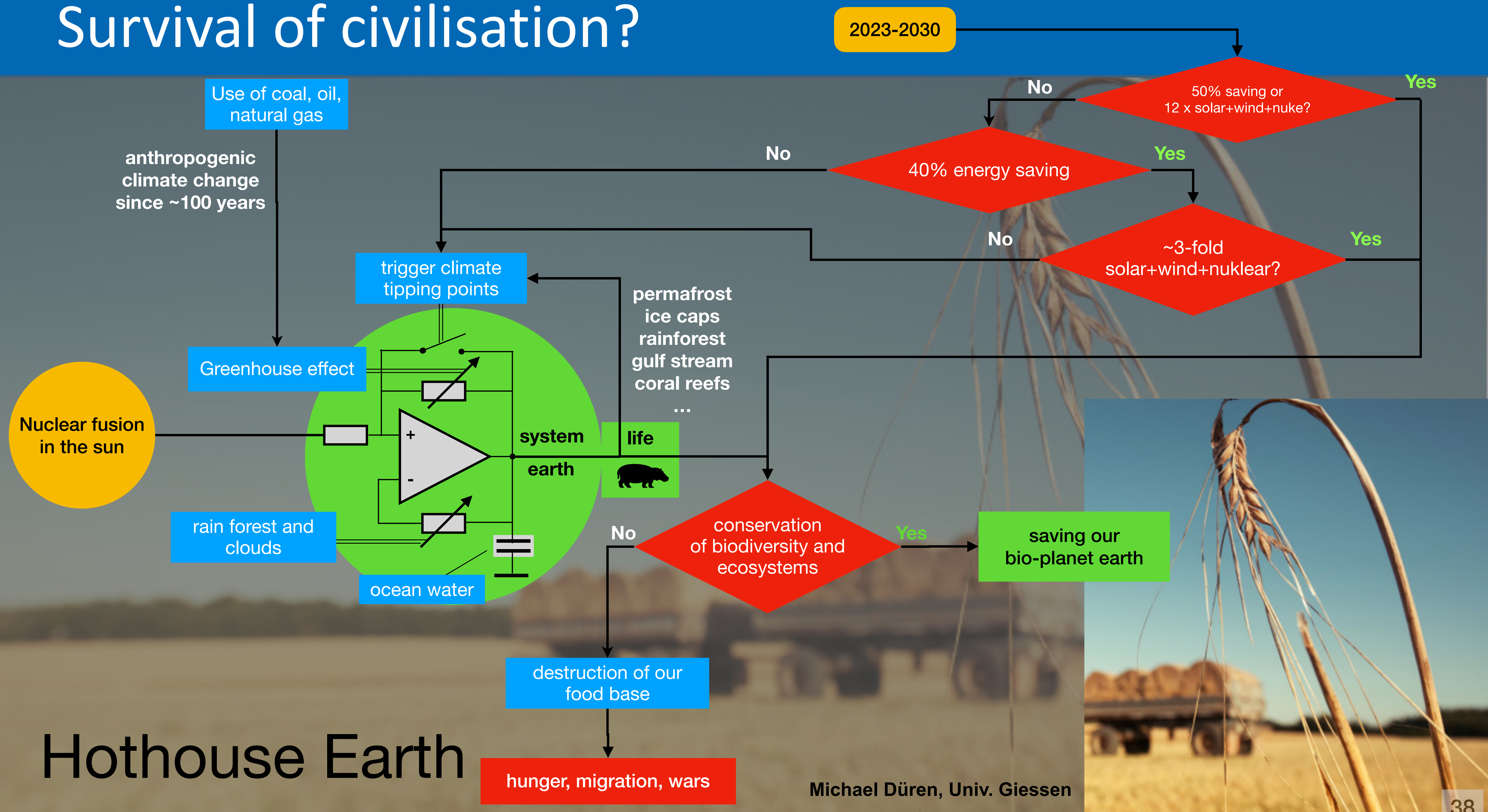
Survival of civilisation?



Hothouse Earth

Michael Düren, Univ. Giessen

Conclusion: Sorry, we’re f*cked

A few degrees make the difference

HECAP+ paper: Environmental sustainability in basic research

(High Energy Physics, Cosmology, Astroparticle Physics, and Hadron and Nuclear Physics)


arXiv:2306.02837v1 [physics.soc-ph] 5 Jun 2023

Environmental sustainability in basic research

A perspective from HECAP+

Abstract

The climate crisis and the degradation of the world's ecosystems require humanity to take immediate action. The international scientific community has a responsibility to limit the negative environmental impacts of basic research. The **HECAP+ communities** (**High Energy Physics, Cosmology, Astroparticle Physics, and Hadron and Nuclear Physics**) make use of common and similar experimental infrastructure, such as accelerators and observatories, and rely similarly on the processing of big data. Our communities therefore face similar challenges to improving the sustainability of our research. This document aims to reflect on the environmental impacts of our work practices and research infrastructure, to highlight best practice, to make recommendations for positive changes, and to identify the opportunities and challenges that such changes present for wider aspects of social responsibility.

Version 1.0, 5 June 2023

Please read this document in electronic format where possible and refrain from printing it unless absolutely necessary. Thank you.

155 pages

June 2023

Chapters

- **Introduction**
- **Energy**
- **Mobility**
- **Food**
- **Computing**
- **Research Infrastructure and Technology**
- **Resources and Waste**

https://sustainable-hecap.github.io

HECAP+ paper: Environmental sustainability in basic research

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Recommendations — Impelling Positive Change

Individual actions: „You and me“

-

Further group actions: „Collaborations and projects“

-

Further institutional actions: „Universities, CERN, …“

-

HECAP+ paper: Environmental sustainability in basic research

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Recommendations — Impelling Positive Change

Individual actions:

- Consider the environmental impact of work practices.
- Be proactive in seeking best practice.
- Make and model positive change in research activities.
- Drive positive group and institutional actions.

HECAP+ paper: Environmental sustainability in basic research

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Recommendations — Impelling Positive Change

Further group actions:

- Include critical assessment of the environmental impact of all activities during planning stages.
- Monitor, assess, report on and set targets in relation to the environmental impacts of research activities.
- Drive institutional actions, and encourage, support and incentivise individual actions, e.g., through training.

HECAP+ paper: Environmental sustainability in basic research

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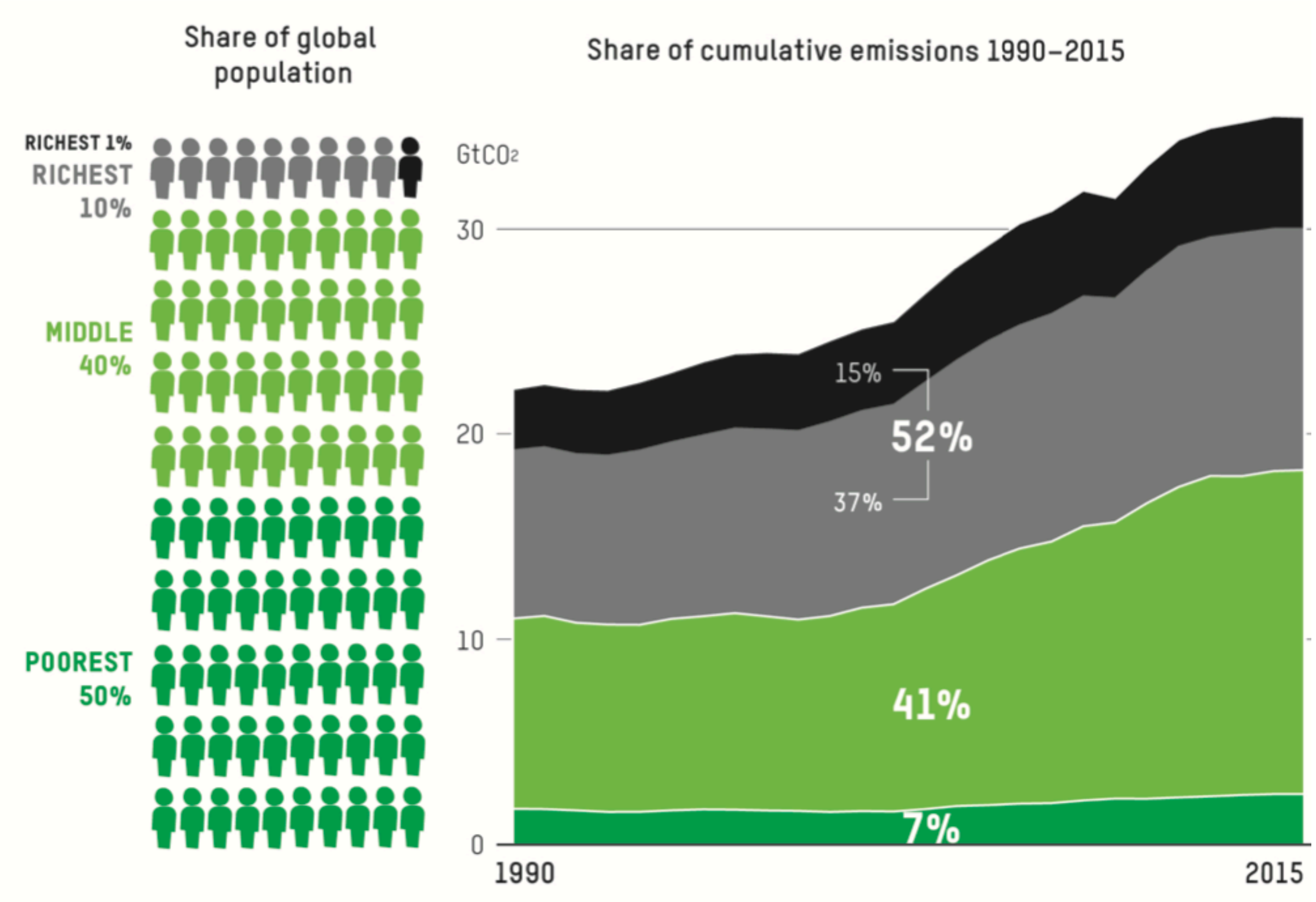
Recommendations — Impelling Positive Change

Further institutional actions:

- Require funding applications to outline plans for monitoring, reporting and minimising adverse environmental impacts, and for ensuring that research is undertaken in line with principles of social justice.
- Allow flexibility in policies and procedures e.g., budget allocation, that enable environmentally sustainable choices to be made.
- Ensure that degree programmes include a focus on global citizenship, encompassing environmental sustainability and associated social justice implications.
- Acknowledge focus on environmental sustainability and social justice in the accreditation of degrees by governments and professional bodies.
- Encourage, support and incentivise individual and group actions, e.g., by considering them in professional development and appraisal processes.

HECAP+ paper: Environmental sustainability in basic research



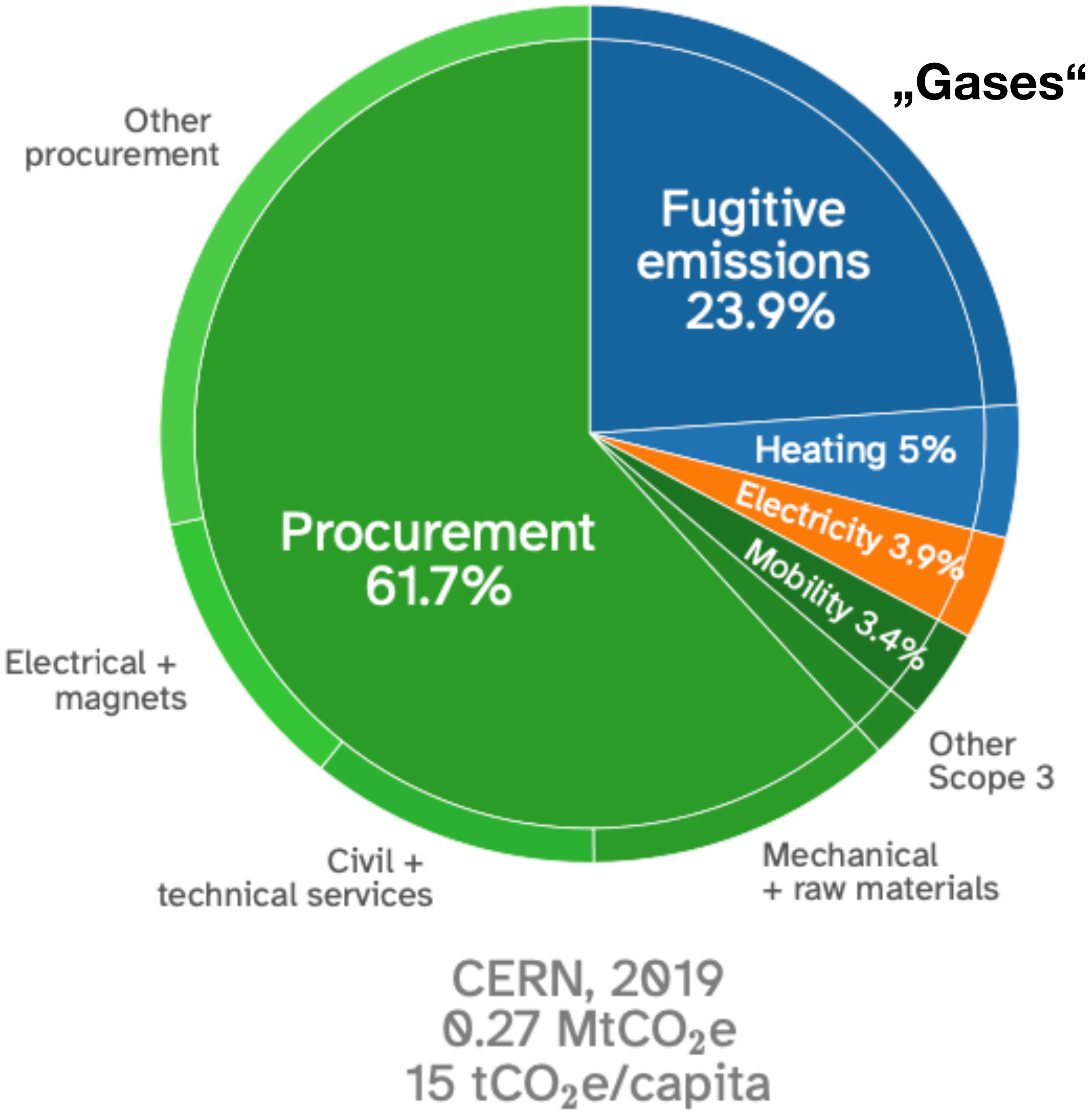
„Our“ emissions

10% richest people (>2800€/month)

cause

52% of emissions

HECAP+ paper: Environmental sustainability in basic research



„CERN“ emissions

CO_2-equivalence

during LHC shut-down (2019)

Carbon footprint:

Scope 1 = direct emission (e.g. fossil heating)

Scope 2 = indirect emission (electricity)

Scope 3 = purchase materials, services, …

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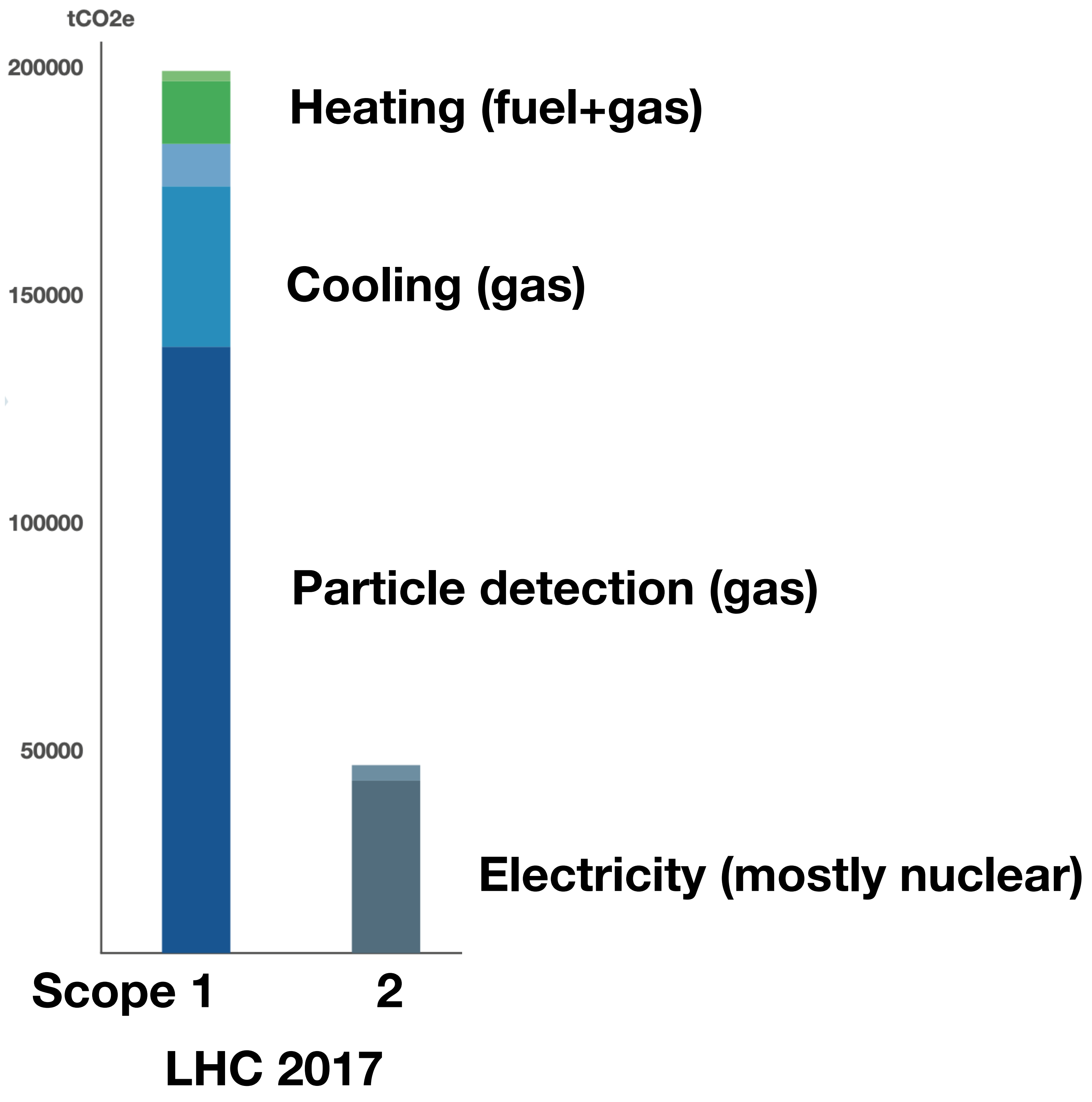

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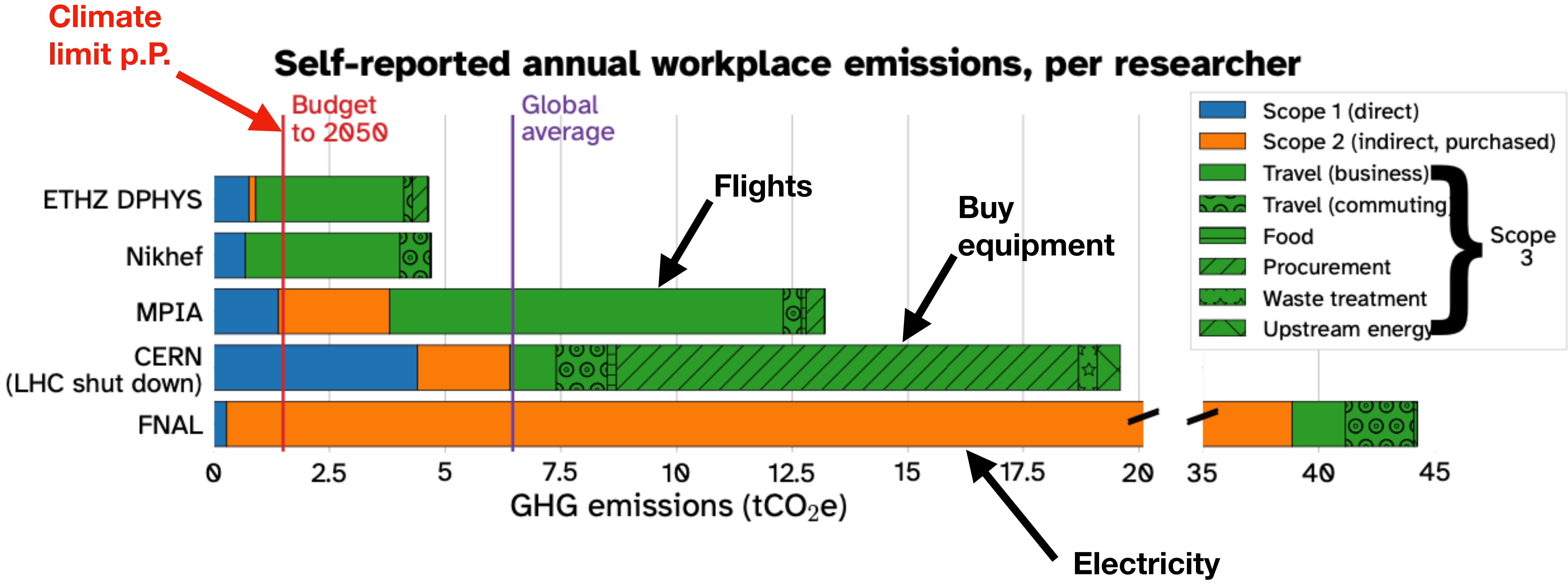
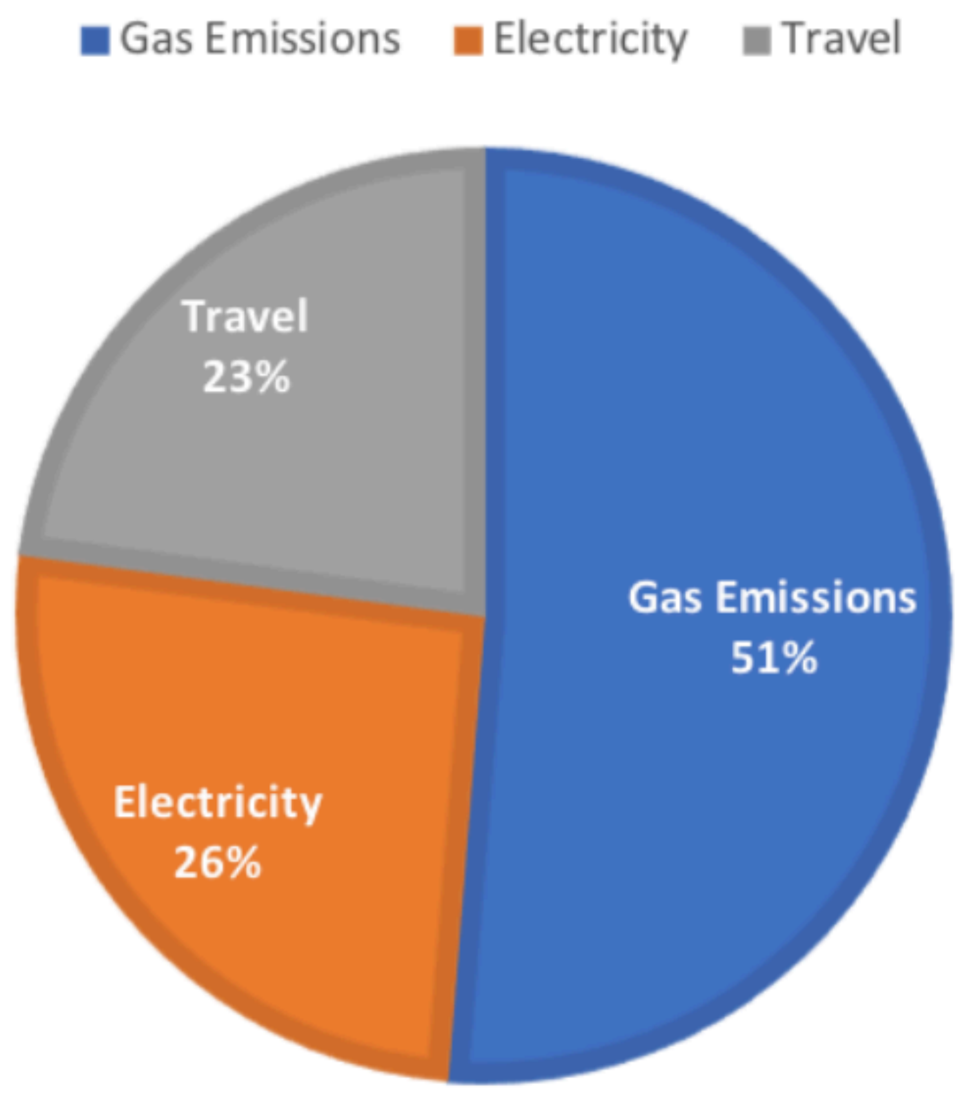
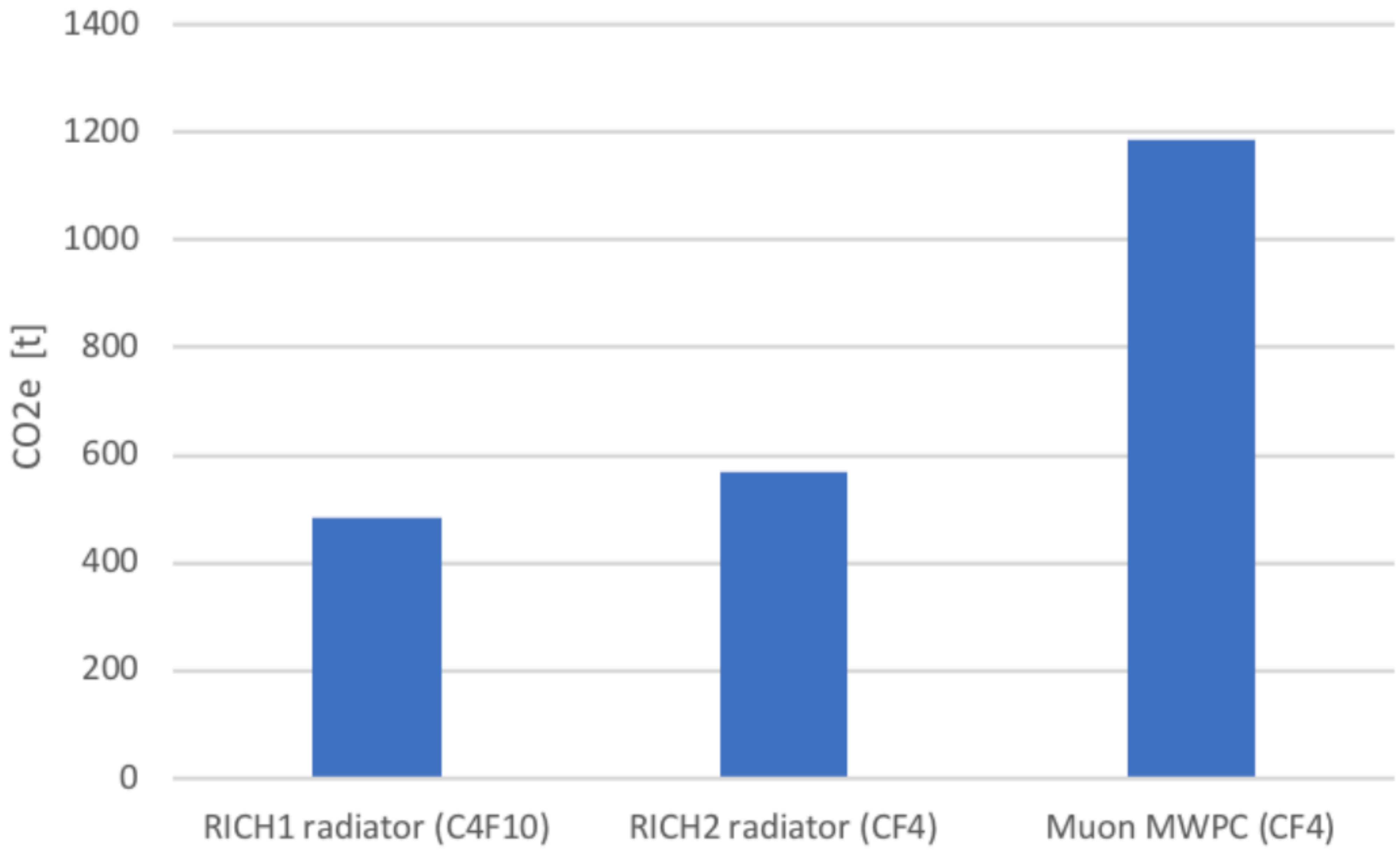


Physicist's emissions

HECAP+ paper: Environmental sustainability in basic research



LHCb: Run 3 emissions



leaking gases …

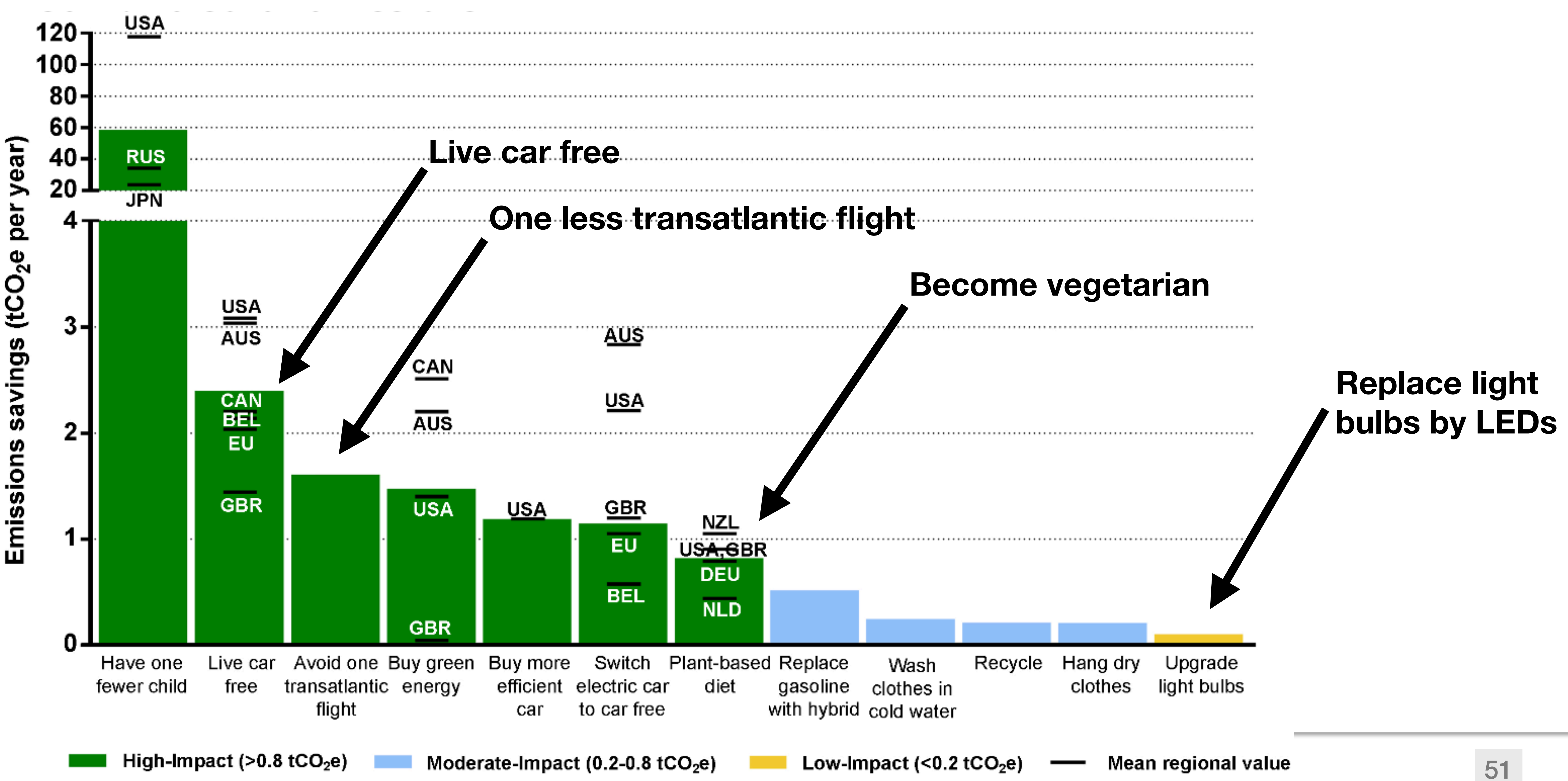
HECAP+ paper: Environmental sustainability in basic research

Name	Chemical Formula	Lifetime [years]	Global warming potential (GWP) [100-yr time horizon]
Carbon dioxide	CO_2	–	1
Dimethylether	CH_3OCH_3	0.015	1
Methane	CH_4	12	25
Sulphur hexafluoride	SF_6	3,200	22,800
	Hydrofluorocarbons (HFCs)		
HFC-23	CHF_3	270	14,800
HFC-134a	$C_2H_2F_4$	14	1,430
	Perfluorocarbons (PFCs)		
PFC-14	CF_4	50,000	7,390
PFC-116	C_2F_6	10,000	12,200
PFC-218	C_3F_8	2,600	8,830
PFC-3-1-10	C_4F_{10}	2,600	8,860
PFC-5-1-14	C_6F_{14}	3,200	9,300

Table 6.2: Environmental impact associated with GHGs, from Ref. [218], which also forms the source for the calculations in the CERN environmental report and the EU regulations described in Ref. [219].

Global warming potential of greenhouse gases

Personal Emissions (Plot deleted from HECAP+ paper)



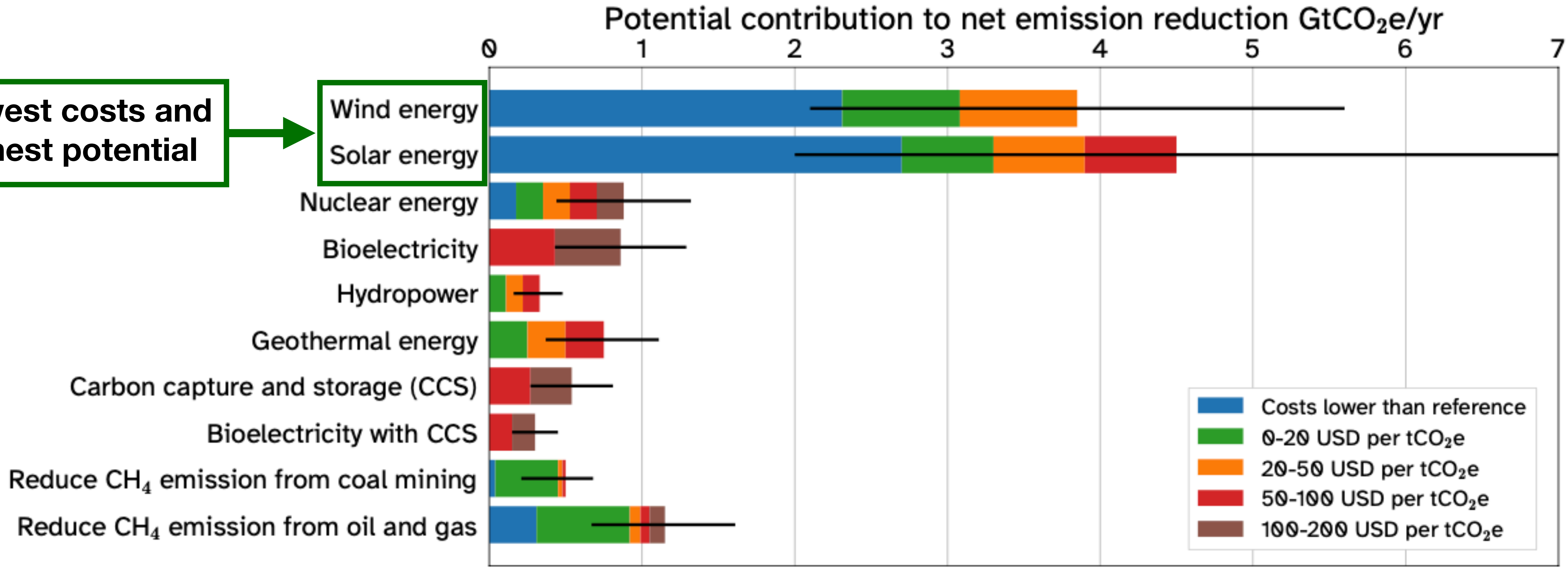
Michael Düren, Univ. Giessen

Figure from https://doi.org/10.1088/1748-9326/aa7541

HECAP+ paper: Environmental sustainability in basic research

Lowest costs and highest potential

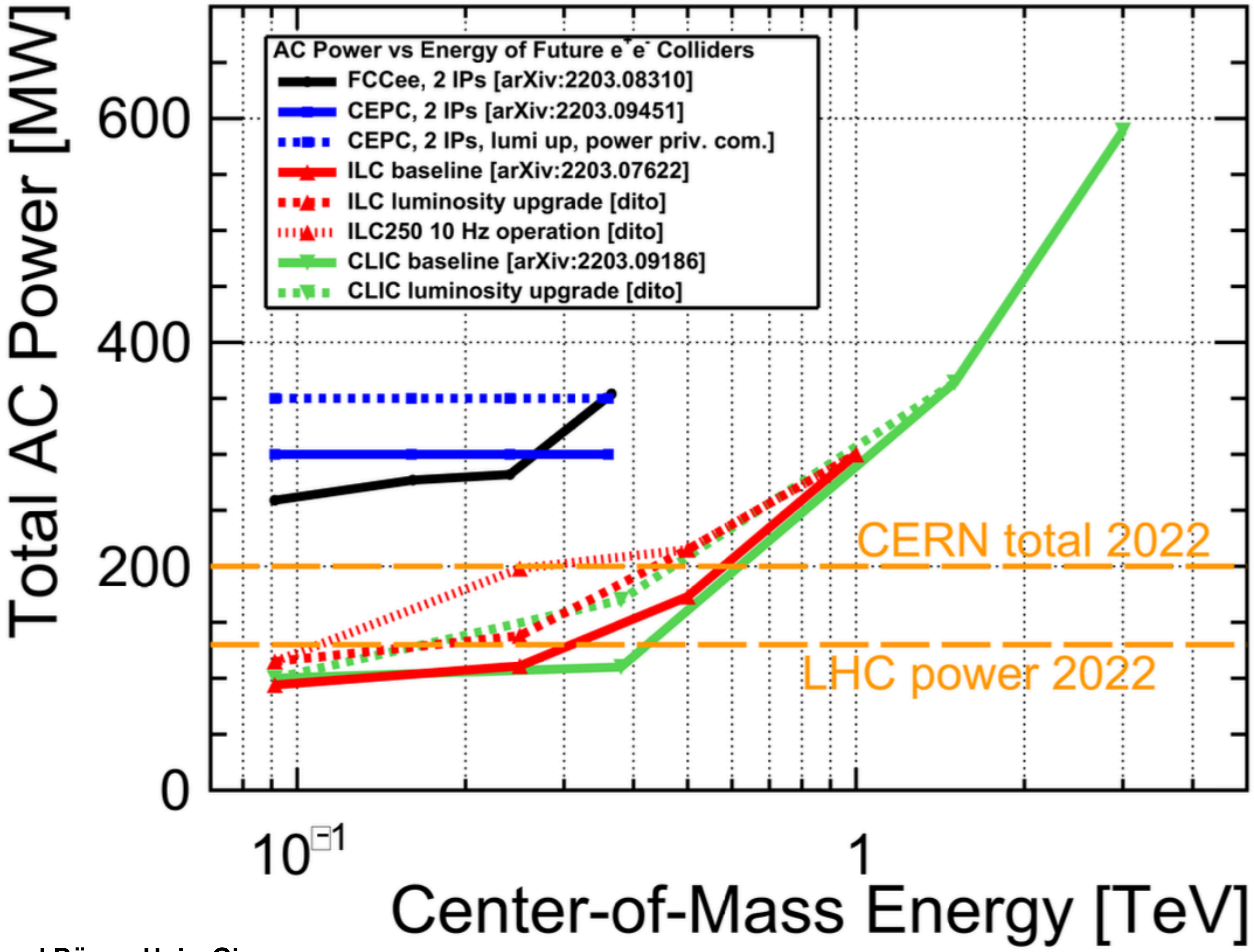
Mitigation potential of energy-related options to 2030



Costs calculated with respect to conventional power generation; mitigation potential assessed with respect to current policy reference scenarios. For all measures save emissions reductions, the cost categories are indicative, and estimates depend heavily on factors such as geographical location, resource availability and regional circumstances. Relative potentials and costs will vary across countries and in the longer term.

IPCC analysis

HECAP+ paper: Environmental sustainability in basic research



Power consumption of CERN, LHC and future colliders

CERN-Link

<u>Proposal:</u>
Power line exclusively for international research:

3.6 GW (day)
2.2 GW (night)

6-7 ct/kWh
Stable & low costs!

Ref: Thesis J. Hampp

Power from hydrogen has 2-3 x higher costs!

To be initiated by
CERN, HGF, Universities, … ?

HVDC Connector Tunesien - Italy (Sicilia)

entsoe European Network of Transmission System Operators for Electricity

EU Project history:

TYNDP 2012	TYNDP 2014	TYNDP 2016	TYNDP 2018	TYNDP 2020	TYNDP 2022

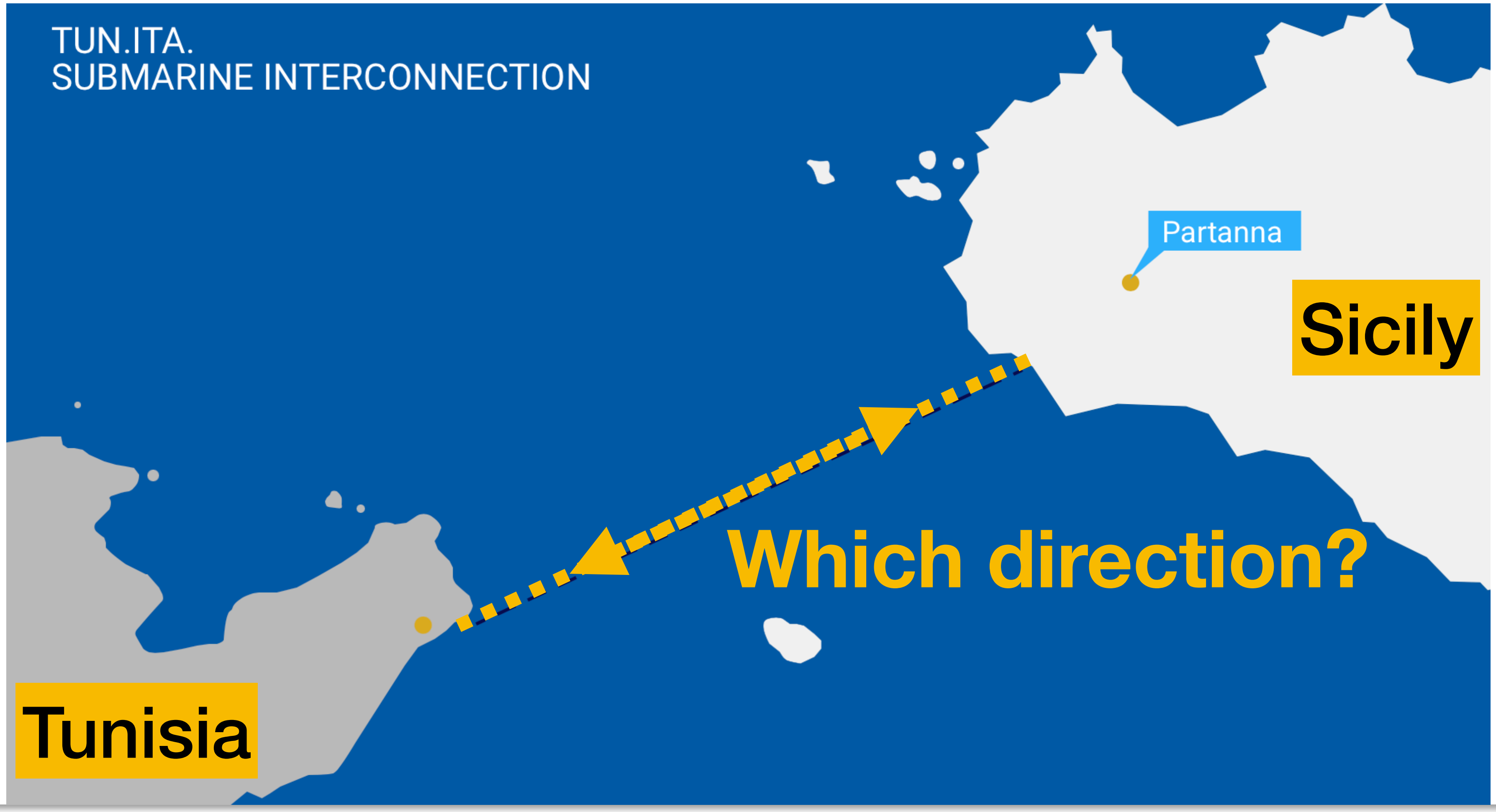
200 km 400 kV 600 MW

600 M€

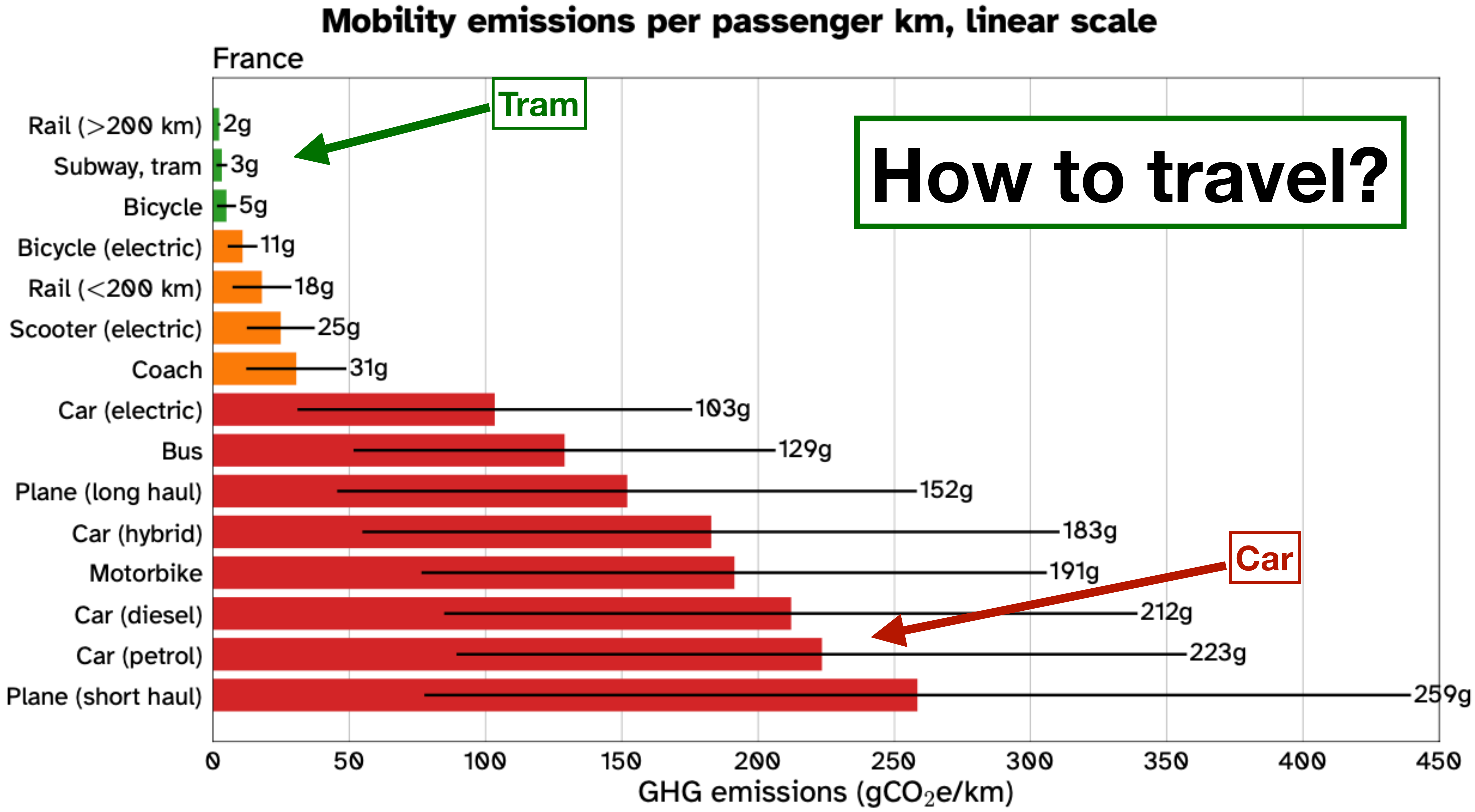
Funding EBRD, EU Grant, KfW

Application deadline: June 30, 2023

Commissioning 2028

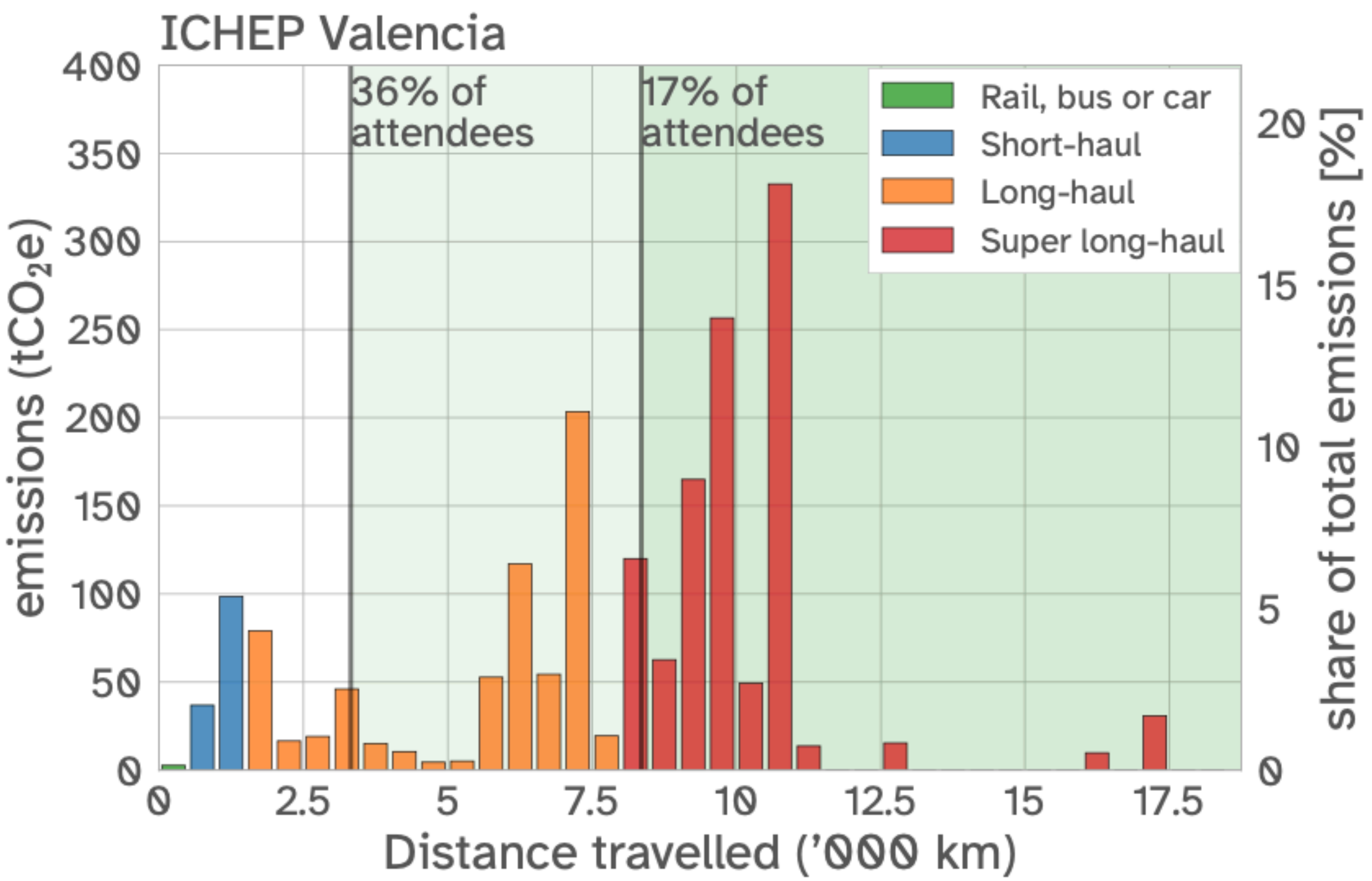


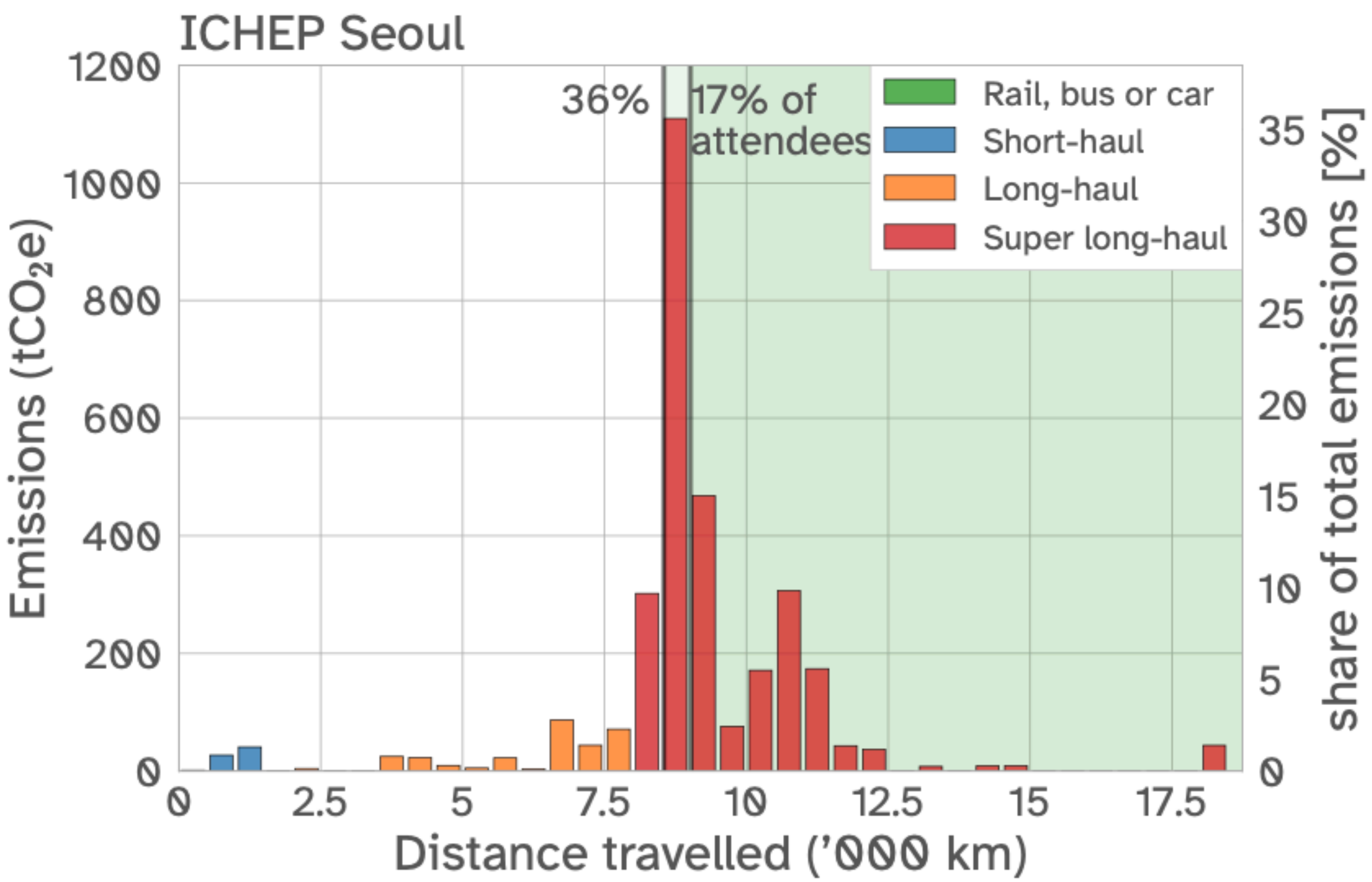
Option 3: What to do and what to avoid?



Source: Labos1.5 database. Estimates include production emissions, and may vary slightly based on occupancy of public transport, and between countries.

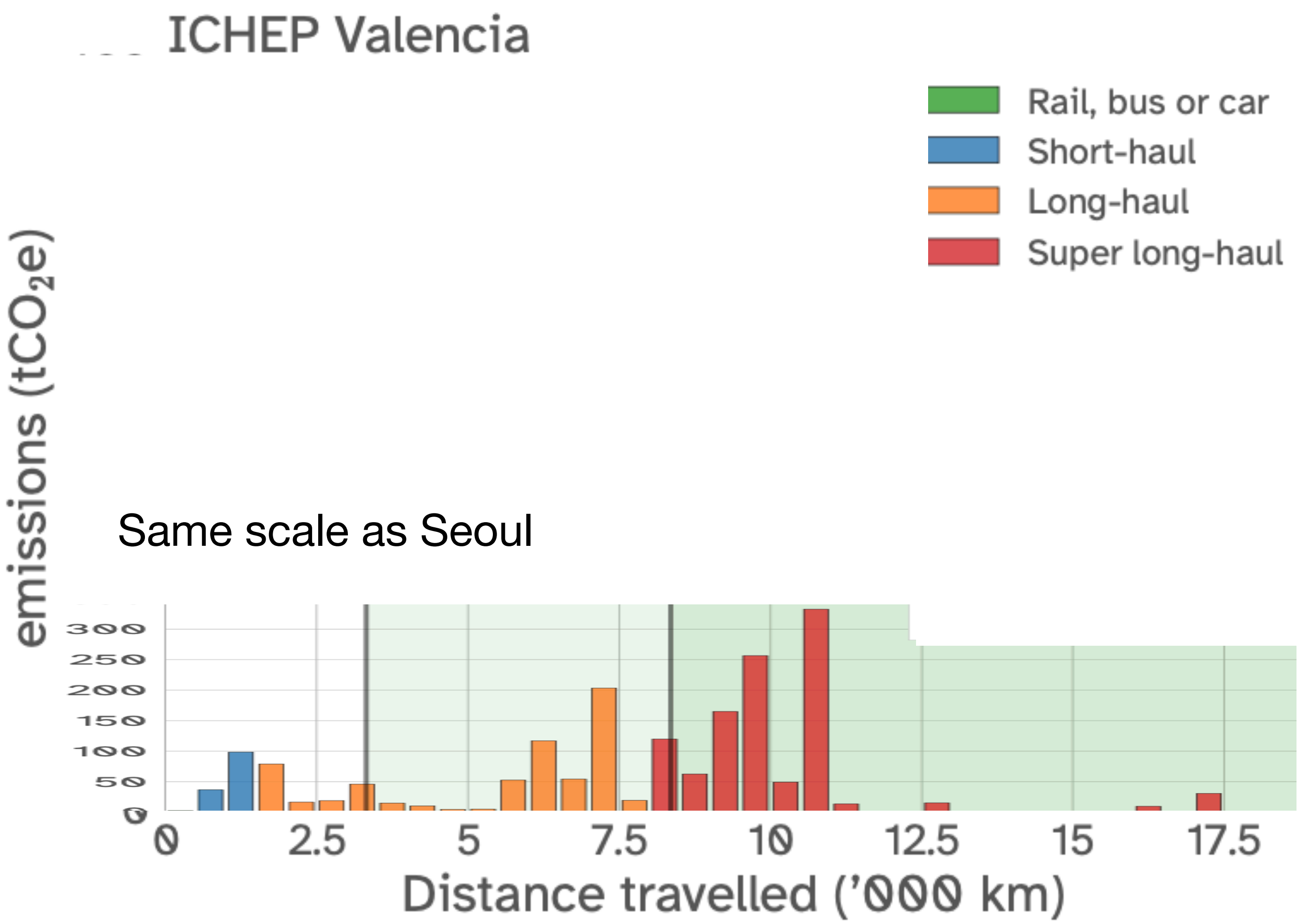
HECAP+ paper: Environmental sustainability in basic research

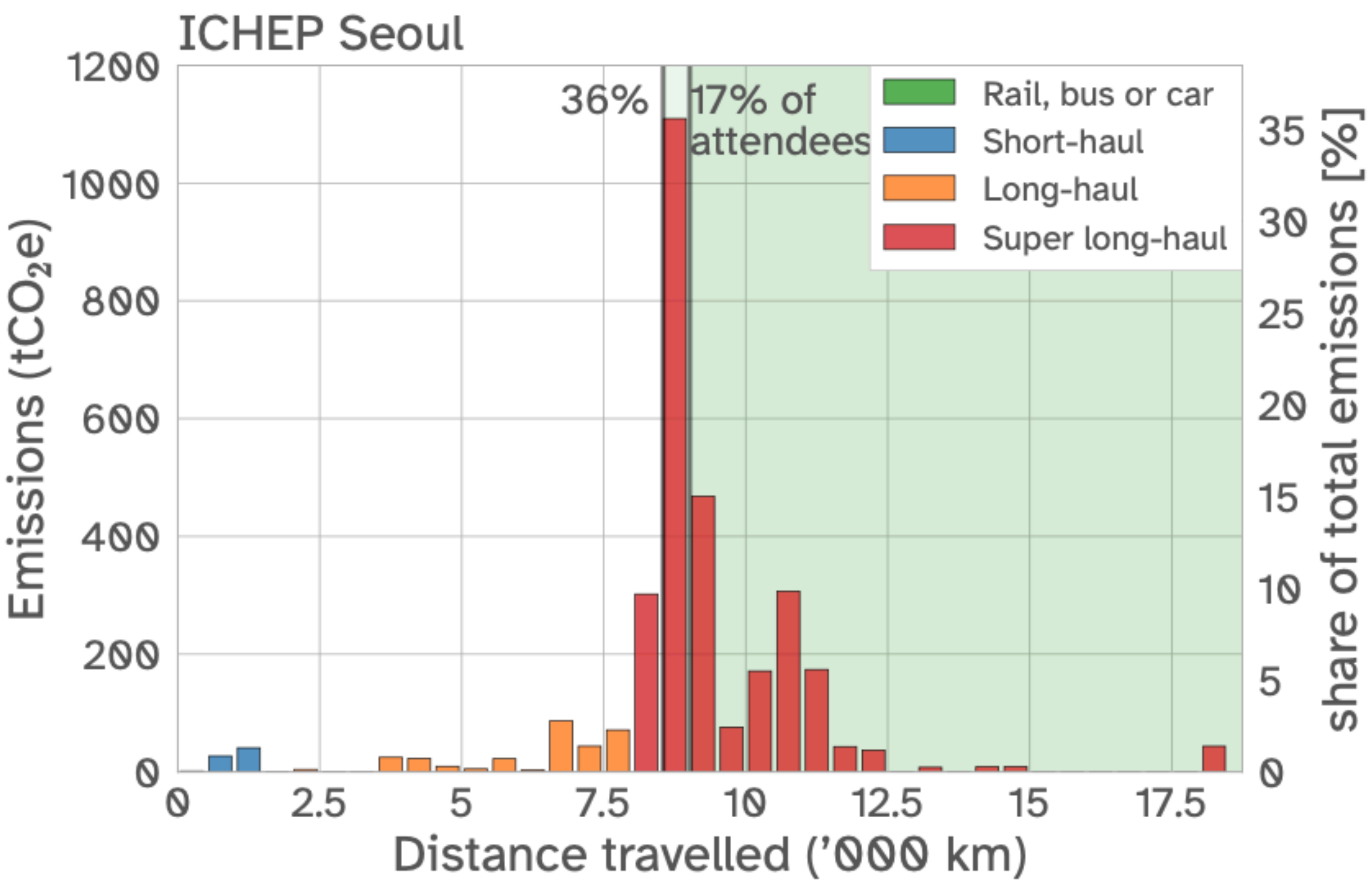




Where to make conferences?

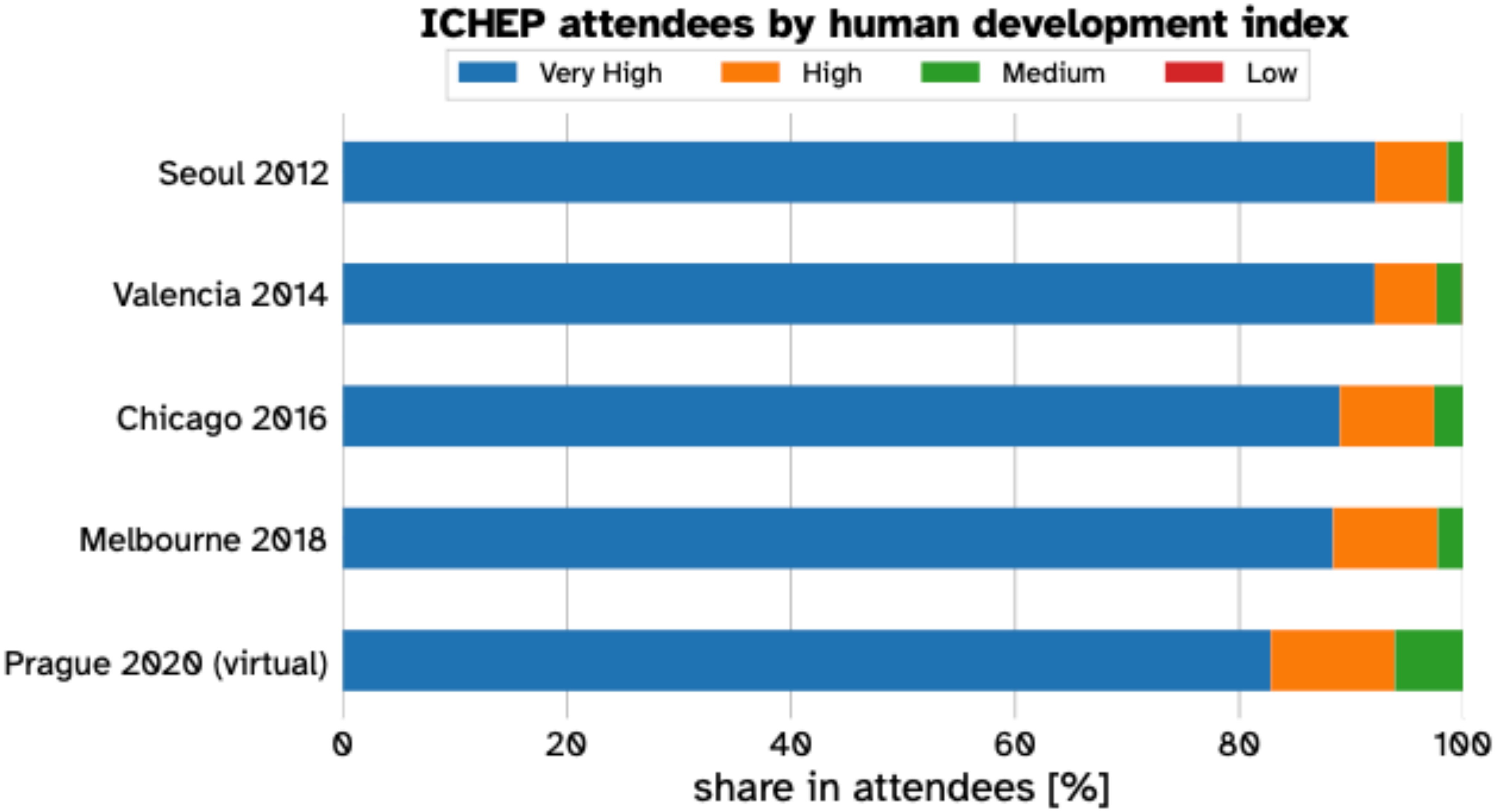
HECAP+ paper: Environmental sustainability in basic research





Where to make conferences?

HECAP+ paper: Environmental sustainability in basic research



Conferences for rich institutions

HECAP+ paper: Environmental sustainability in basic research

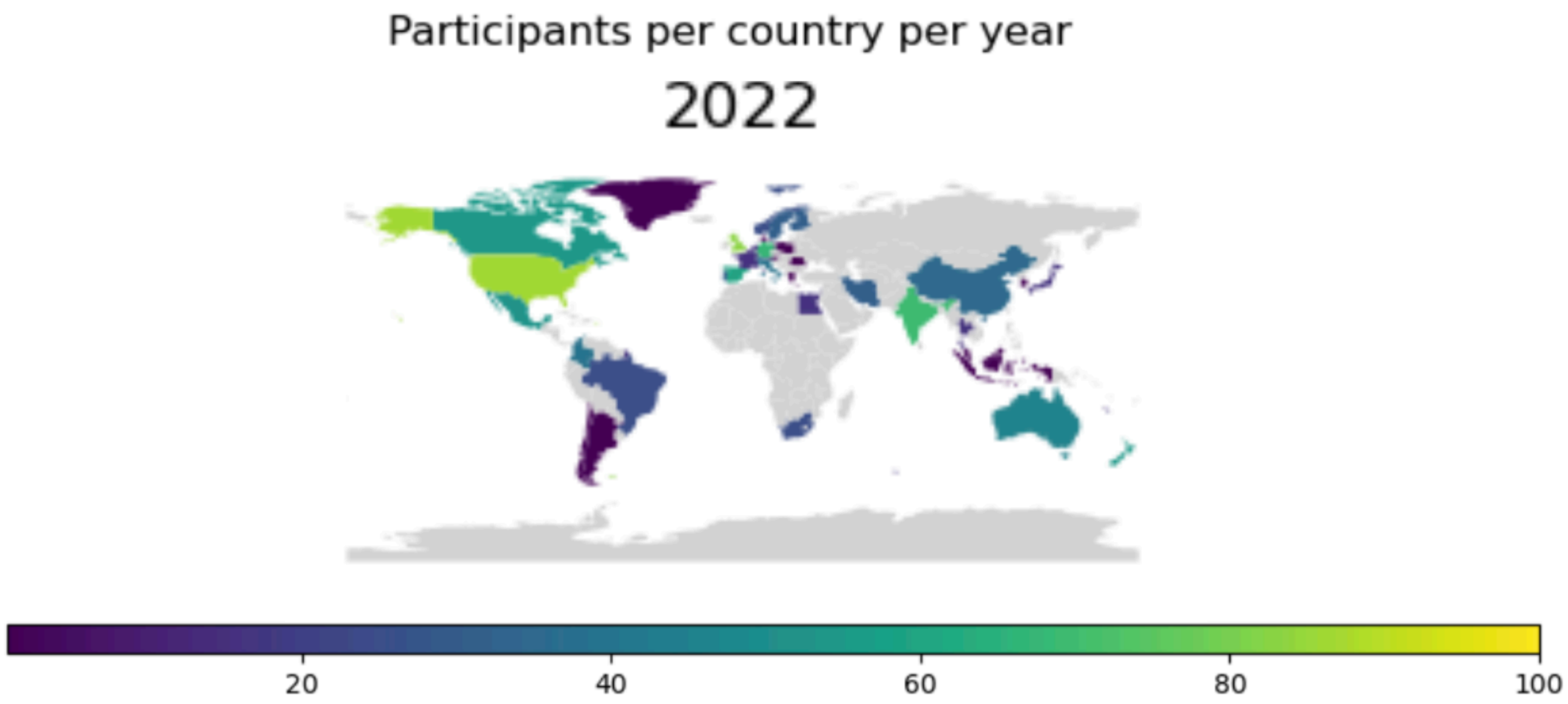
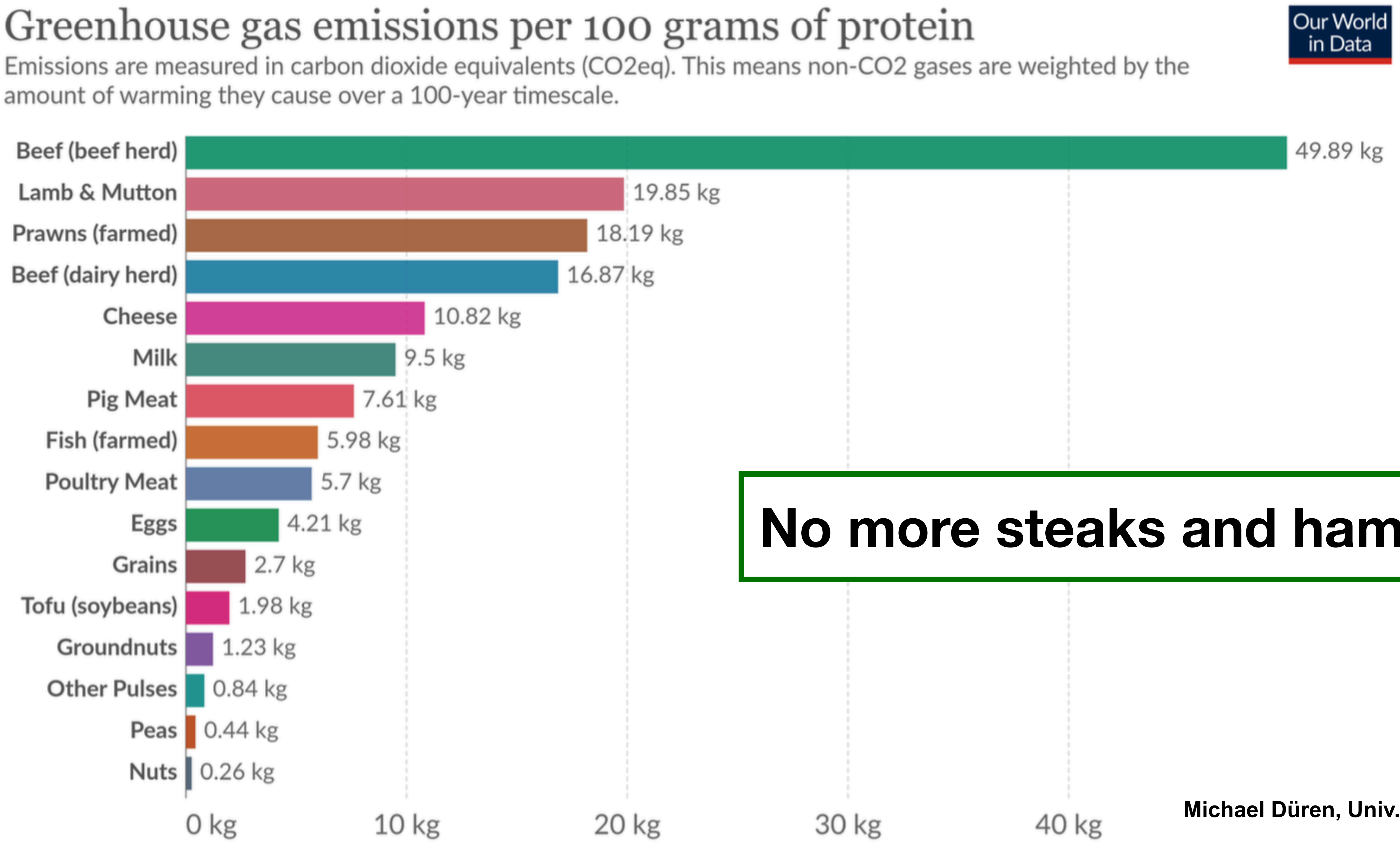


Figure 5.4: Geographical distribution of Cosmology from Home participants for each of the installments by year.

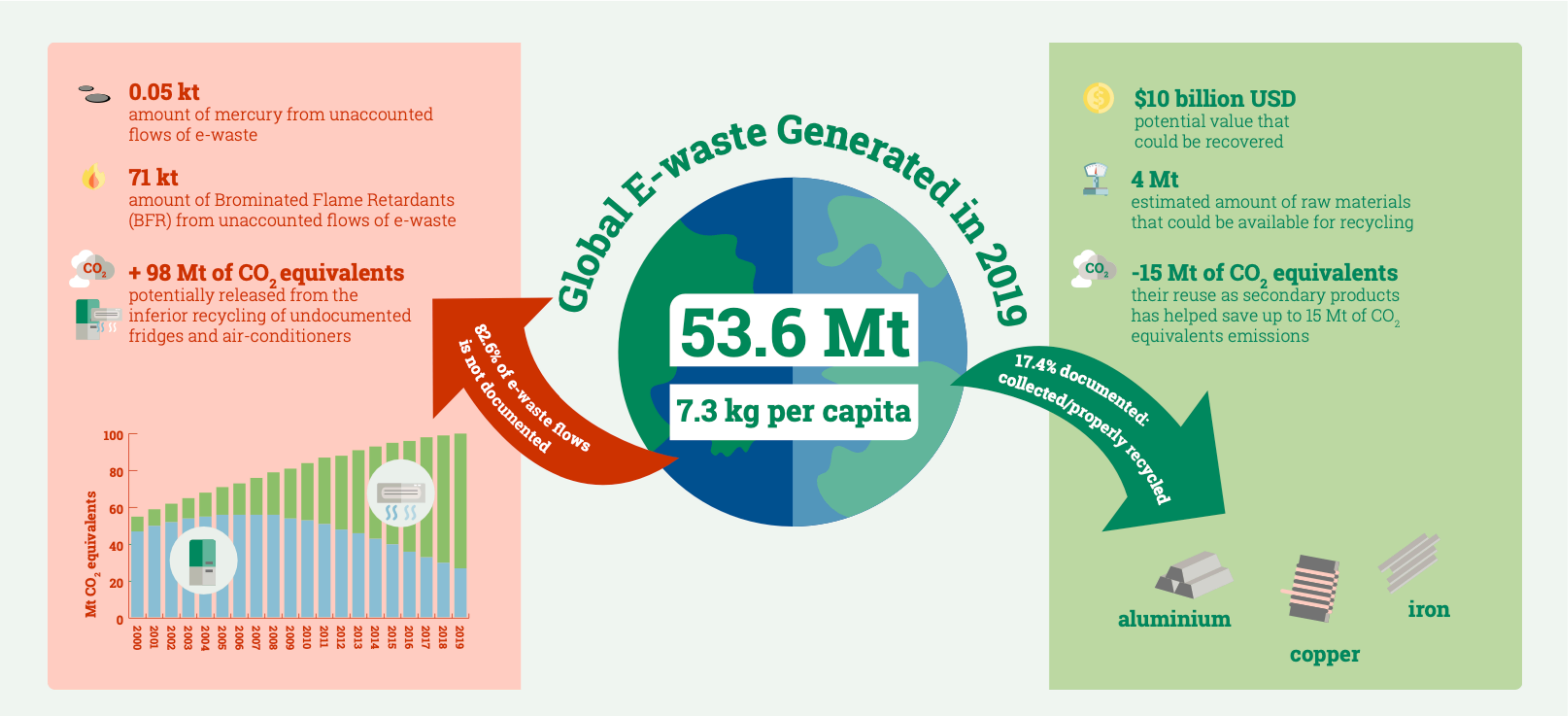
„Cosmology from Home“:
an online conference that includes all researchers

HECAP+ paper: Environmental sustainability in basic research



No more steaks and hamburgers?

HECAP+ paper: Environmental sustainability in basic research



Importance of
Re-use
Re-pair
Re-cycle

Manufacturers:
Build devices from standardised modules that can be repaired easily

Research institutions:
Have a pool of devices that can be used by many groups

The global energy gap

Options for computing:

1. Expand CO_2-free energies

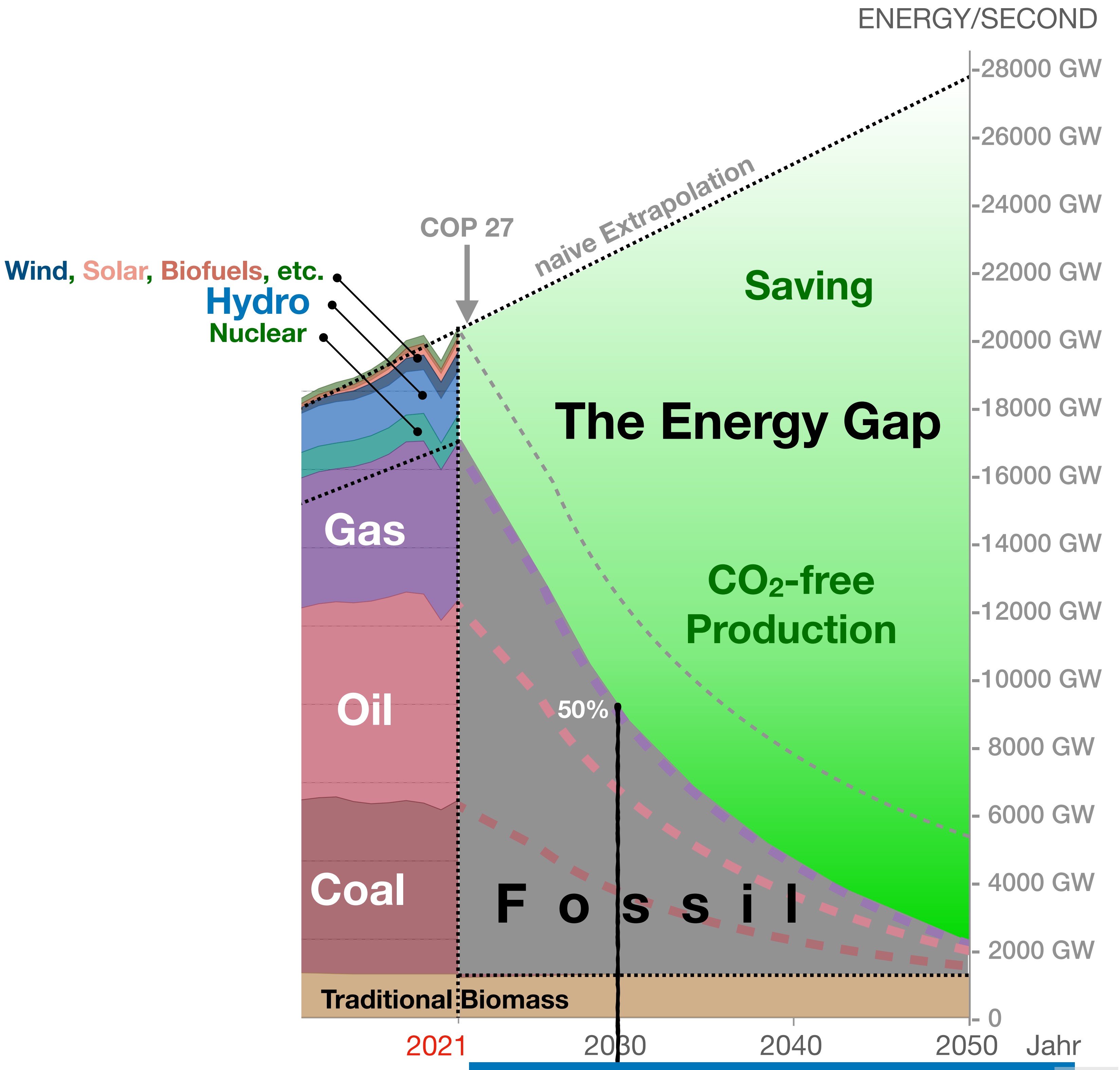
   Renewable power for computing: processors and cooling;
   Consider district heating and site selection;
   Job scheduling according to energy availability; …

2. Increase energy efficiency

   Optimised processors (clocks, GPUs),
   architecture, cooling system,
   software, quantum computing?, …

3. Save energy

   Prioritise research questions ☹️;
   Optimise debugging, statistics and precision;
   Modular and reusable software;
   Modular and repairable hardware, reduce purchases;
   …



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Data based on Vaclav Smil (2017) and BP Statistical Review of World Energy

50% until 2030 (7 Jahre)

HECAP+ paper: Environmental sustainability in basic research

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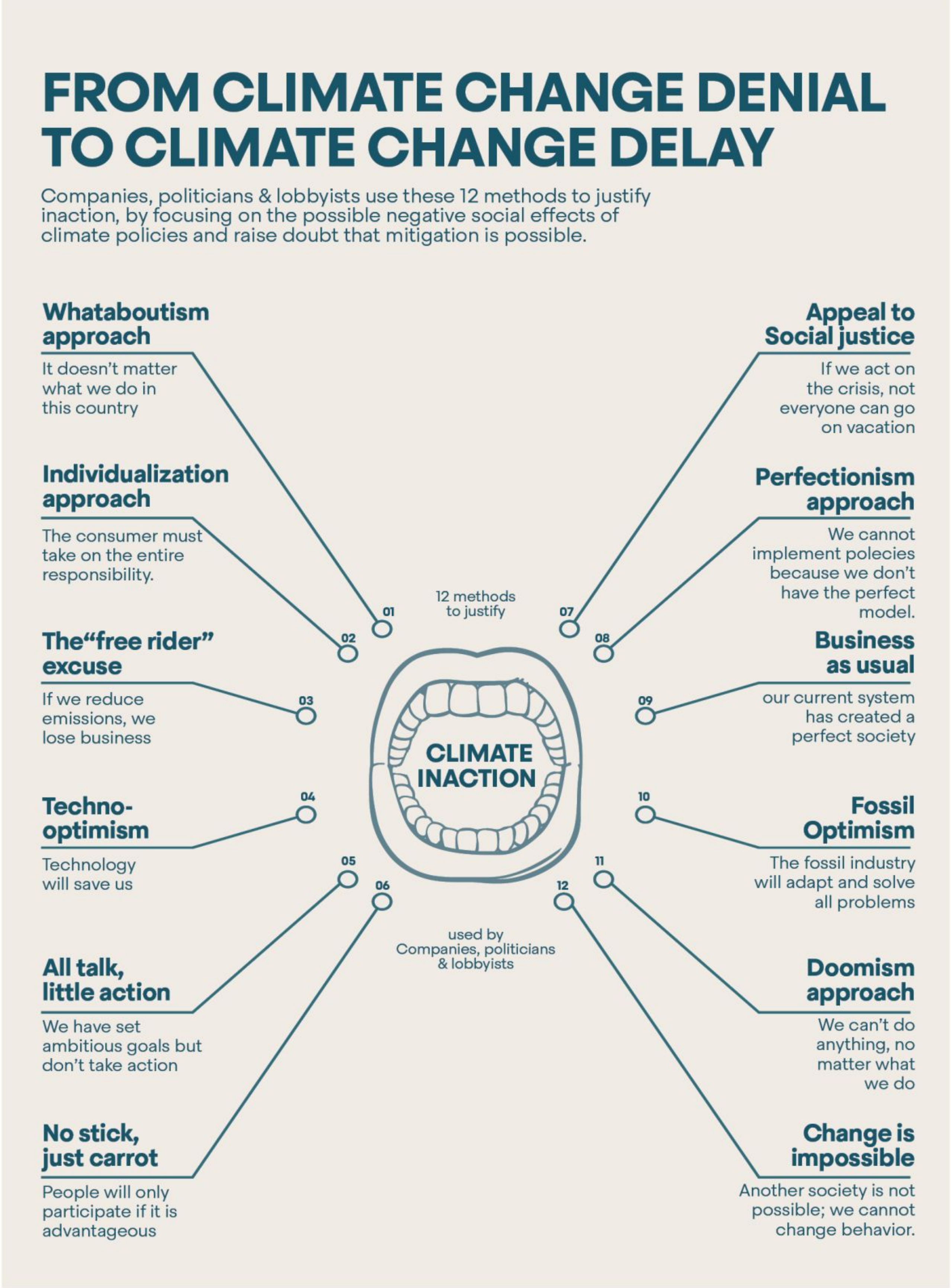
THANK YOU FOR YOUR UNDERSTANDING

eurizon

European network
for developing new horizons for RIs

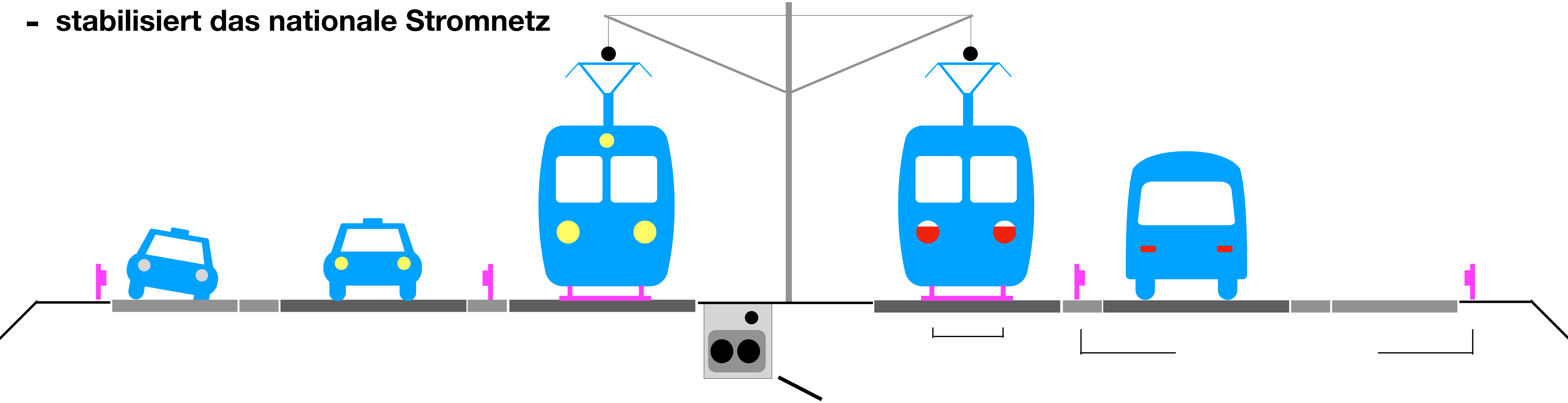
Backup



Source: Lamb, W., Mattioli, G., Levi, S., Roberts, J., Capstick, S., Creutzig, F., . . . Steinberger, J. (2020). Discourses of climate delay. *Global Sustainability, 3*, E17. doi:10.1017/sus.2020.13

Schnellstraßenbahn auf der Auto-Bahn

- mehr Komfort als Autos: fährt „on Demand“ von Stadtteil zu Stadtteil und Dorf zu Dorf
- 130 km/h ohne Zwischenhalt auf Autobahnen
- kein neuer Flächenverbrauch
- stabilisiert das nationale Stromnetz



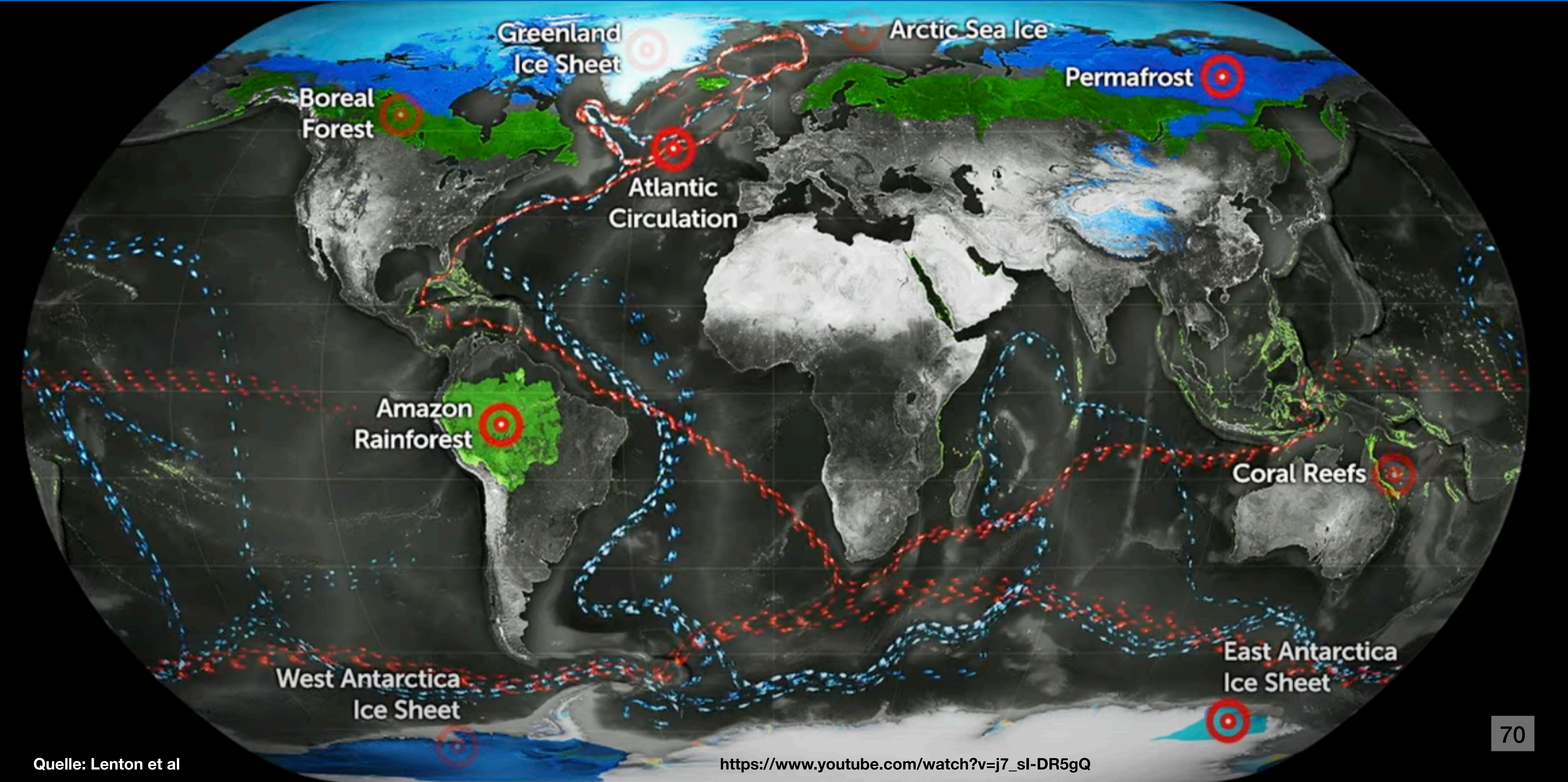
Global direct primary energy consumption
https://ourworldindata.org/grapher/global-primary-energy
Input from Our World in Data

Direkt

convert TWh/Jahr in GW 0,11416

Input für 2021	TWh/a	GW									
bio	1140	130									
other	763	87									
solar	1033	118									
wind	1862	213									
hydro	4274	488									
nuclear	2800	320									
gas	40375	4609									
oil	51170	5841									
coal	44473	5077									
traditional	11111	1268									
Sum	**159001**	**18151**	50% CO_2			50% CO_2, 12x CO_2-free			50% CO_2, 3x CO_2-free		
same as above but grouped:			Factor	2030	GW	Factor	2030	GW	Factor	2030	GW
fossil	136018	15527	0,5	68009	7764	0,5	68009	7764	0,5	68009	7764
CO_2-free w/o hydro	7598	867	1	7598	867	12,2	93033	10620	3	22794	2602
rest + hydro	15385	1756	1	15385	1756	1	15385	1756	1	15385	1756
Sum 2021	**159001**	**18151**		**90992**	**10387**		**176427**	**20140**		**106188**	**12122**
Extrapolated to 2030:											
Sum 1965 (input)	**50571**	5773									
slope TWh/y or GW/y	1936,25	221									
Sum 2030 (extrapolated)	**176427**	**20140**									
Missing Energy	**17426**	**1989**		**85435**	**9753**		**0**	**0**		**70239**	**8018**
Saving factor needed	10%	10%		48%	48%		0%	0%		40%	40%
	1,11	1,11		1,94	1,94		1,00	1,00		1,66	1,66
Kraftwerke pro Woche					**0,0**			**26,8**			**4,8**
2,5 GeV Kraftwerke/Woche					**0,0**			**10,7**			**1,9**
					0,40			0,40			0,40

9 aktive Kipp-Elemente



Quelle: Lenton et al

https://www.youtube.com/watch?v=j7_sI-DR5gQ

4 steps towards the speed tram

1. Bus:
(on demand)

2. O-Bus:
(Oberleitung)

3. Autonomous Rail Rapid Transit (ART)
(virtuelle Schienen)

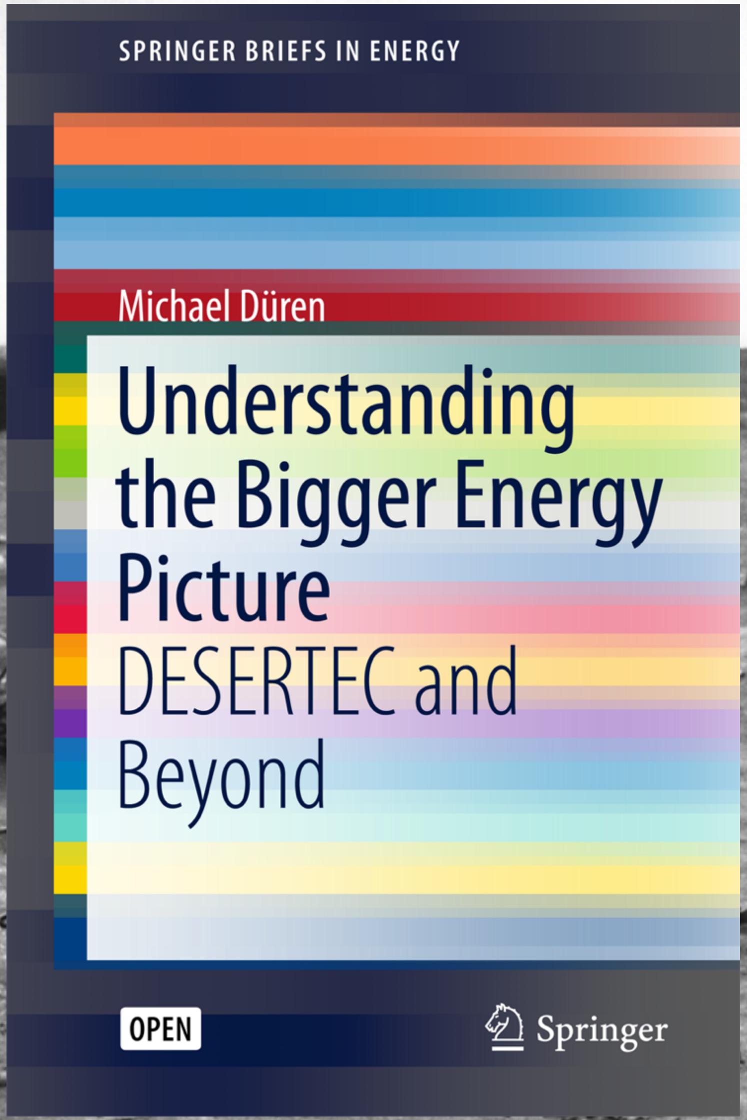
4. Schnellstraßenbahn
(beste Energieeffizienz
+ Netzstabilisierung)

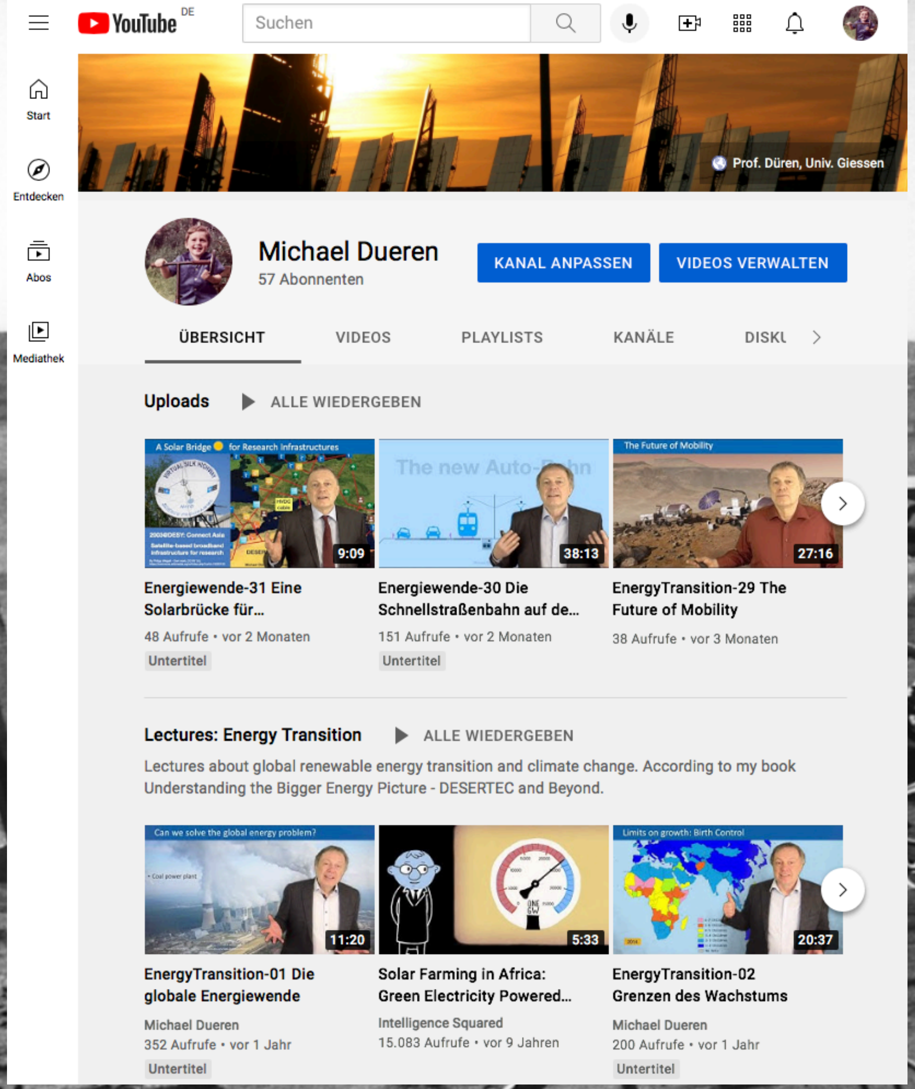
Schnellstraßenbahn =
Schienen + Batterie + Oberleitung +
Cargo + Autonom + „on Demand“

ps://
705932

Michael Düren, Univ. Giessen

Publications





ROBERT-WICHARD-POHL-PREIS

Das Ende der Autobahn

Energie und Mobilität aus Sicht eines Physikers

Michael Düren

Der Klimawandel verlangt grundsätzliche und schnelle Veränderungen unserer Gesellschaft. Die Energie- und Verkehrsinfrastruktur spielen dabei eine Schlüsselrolle. Eine Umwidmung der Autobahnen für eine sogenannte Schnellstraßenbahn könnte eine völlig neue Ära der Mobilität einläuten.

Mit dem anthropogenen Klimawandel habe ich mich erstmals in den 1980er-Jahren beschäftigt, als mein Aachener Professor mich zum Arbeitskreis Energie der DPG einlud. Als Kern- und Teilchenphysiker habe ich natürlich zunächst über neuartige Kernreaktoren nachgedacht. Abstand davon nahm ich letztlich aufgrund folgender Überlegung: Der globale Primärenergiebedarf beträgt in jeder Sekunde im Mittel etwa 18 000 GW [1], was einer Leistung von etwa 18 000 Kernkraftwerken entspricht. Wenn also Kernenergie einen signifikanten Anteil der Primärenergie liefern soll, so sind tausende Reaktoren auf allen Kontinenten nötig. Aufgrund der damit einhergehenden Risiken erzeugt die Kernenergie mehr Probleme, als sie löst – insbesondere bei Terrorismus und Proliferation. Damit war für mich das Kapitel Kernenergie abgeschlossen, auch wenn viele meiner Kollegen entgegengesetzter Ansicht sind [2, 3]. Doch wie lässt sich der immense Energiehunger unserer modernen Gesellschaften stattdessen stillen?

Planetarisches Denken

Als junger Student am CERN in Genf habe ich gelernt, wie wissenschaftliche Ziele Menschen zu ungeheurem Einsatz motivieren können und Hierarchien und kulturelle Unterschiede an Bedeutung verlieren, wenn alle am gleichen Strang ziehen. Bereits zu der Zeit, als man noch sein Magnetband mit den neuesten Daten seines CERN-Experiments über die Grenze nach Deutschland schmuggeln musste, um die Wartezeit beim Zoll zu sparen und es

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

Videos: YouTube Channel: Michael Dueren

kostenlos!

Physik Journal August/Sept. 2021

https://www.pro-physik.de/restricted-files/155228

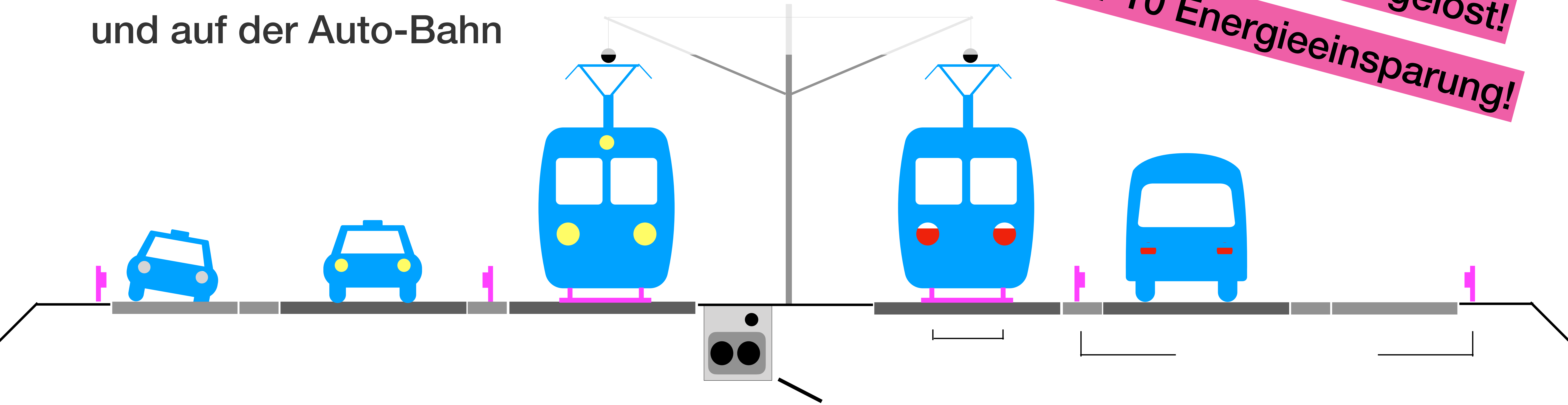
Vielen Dank für Ihre Geduld

1: Reduktion des Gütertransports
2: Reduktion des Personenverkehrs
3: Kurze Strecken zu Fuß + leichte Fahrzeuge
4: U-Bahnen in Großstädten
5: Schnellstraßenbahn in Dorf, Stadt
und auf der Auto-Bahn

Umwidmung der Auto-Infrastruktur für Züge und Kabel

Blackout Problem gelöst!

Faktor 10 Energieeinsparung!



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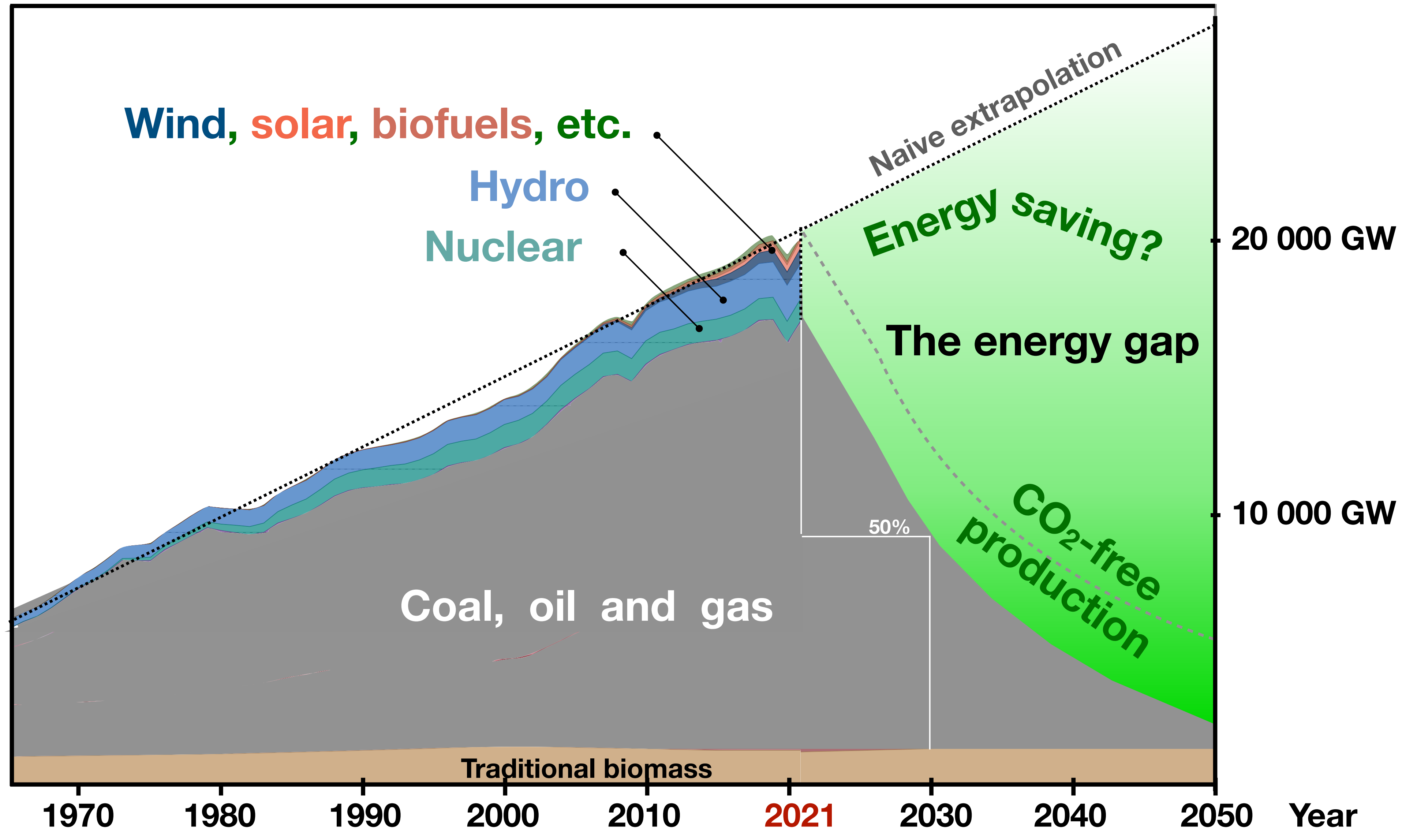
https://www.tunur.tn/project/tunur-italy-transmission-line-2/

CO_2 emissions trigger tipping points (irreversible)

Global primary energy consumption per second



Sources: energy demand: Our World in Data based on Vaclav Emil (2017) and BP Statistical Review of World Energy / CO_2-saving requirement from IPCC; Graphics: M. Düren

Required reduction: 50% in ~7 years

Scenario:

50% CO_2 reduction will not be done in 7 y (strict energy saving would be required)

↓

Tipping points will enforce climate change

↓

Agriculture will fail to feed the world

↓

Hunger, migration, wars of >10% of population (Billions)

↓

Escalation of wars and pandemics

↓

Cascades of tipping points

↓

Our children will have a life in despair

Prediction with confidence level = x

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x=80%?