

BIO 472

Göteborgs universitet

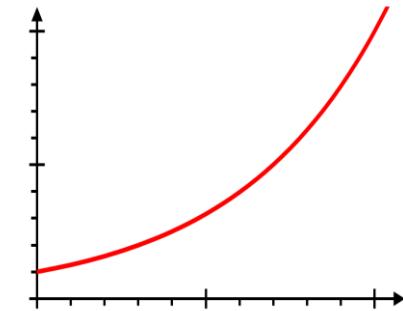
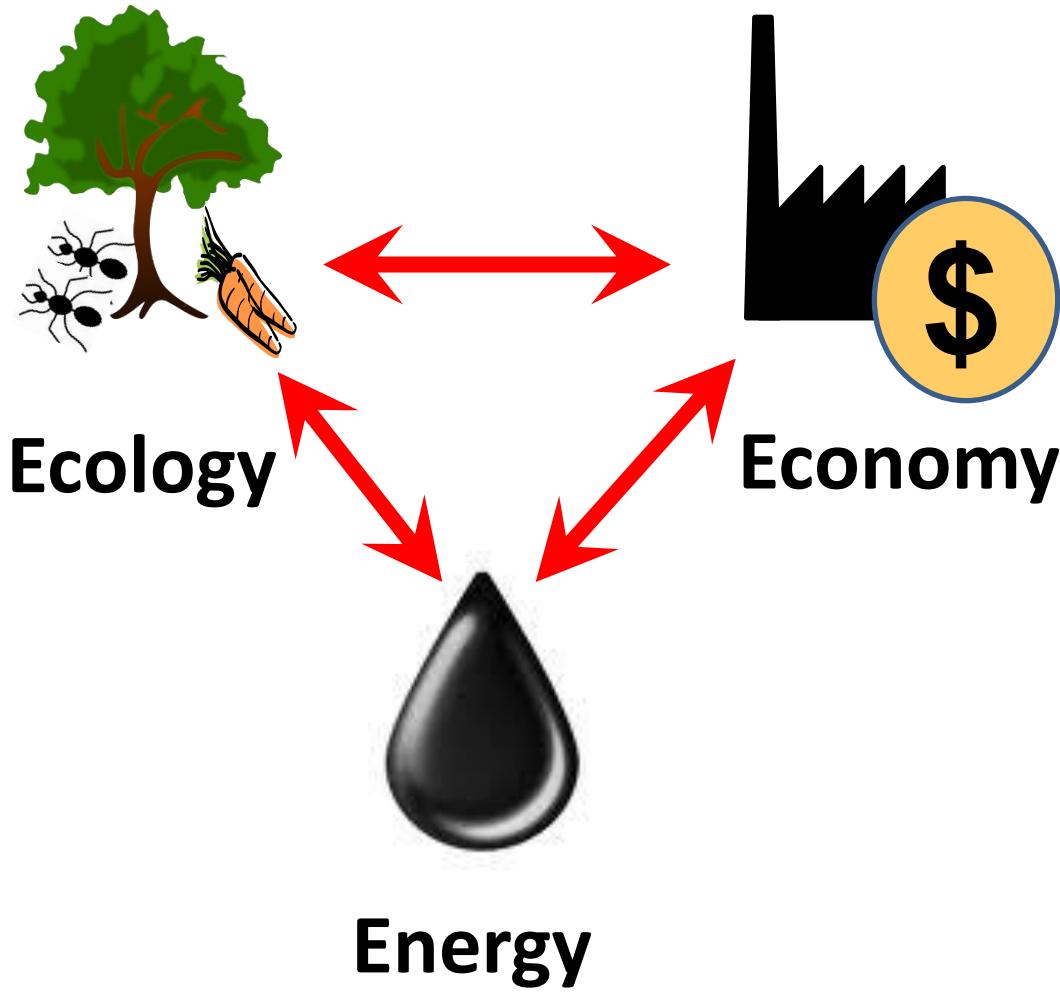
2023-03-28

Stellan Tengroth



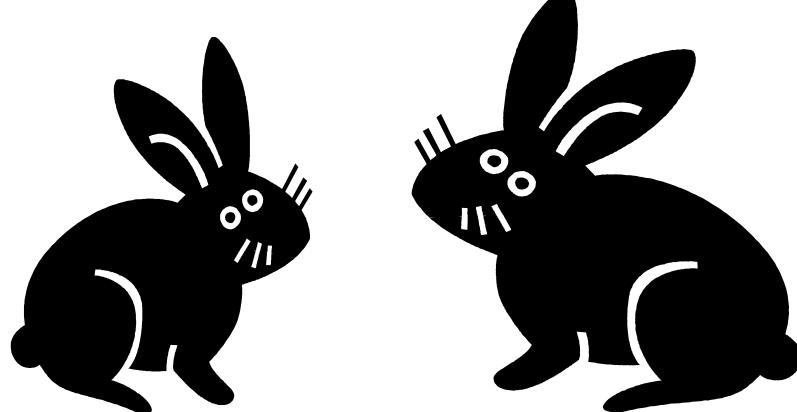
- Civilingenjör
- Författare
- Föreläsare

3 E + 1 G



1. Growth and feedback
2. The ecological limits
3. Addicted to fossil fuel
4. Peak Oil is a reality
5. Sun and wind will not save us
6. Green growth is an illusion
7. How to cope with the perfect storm

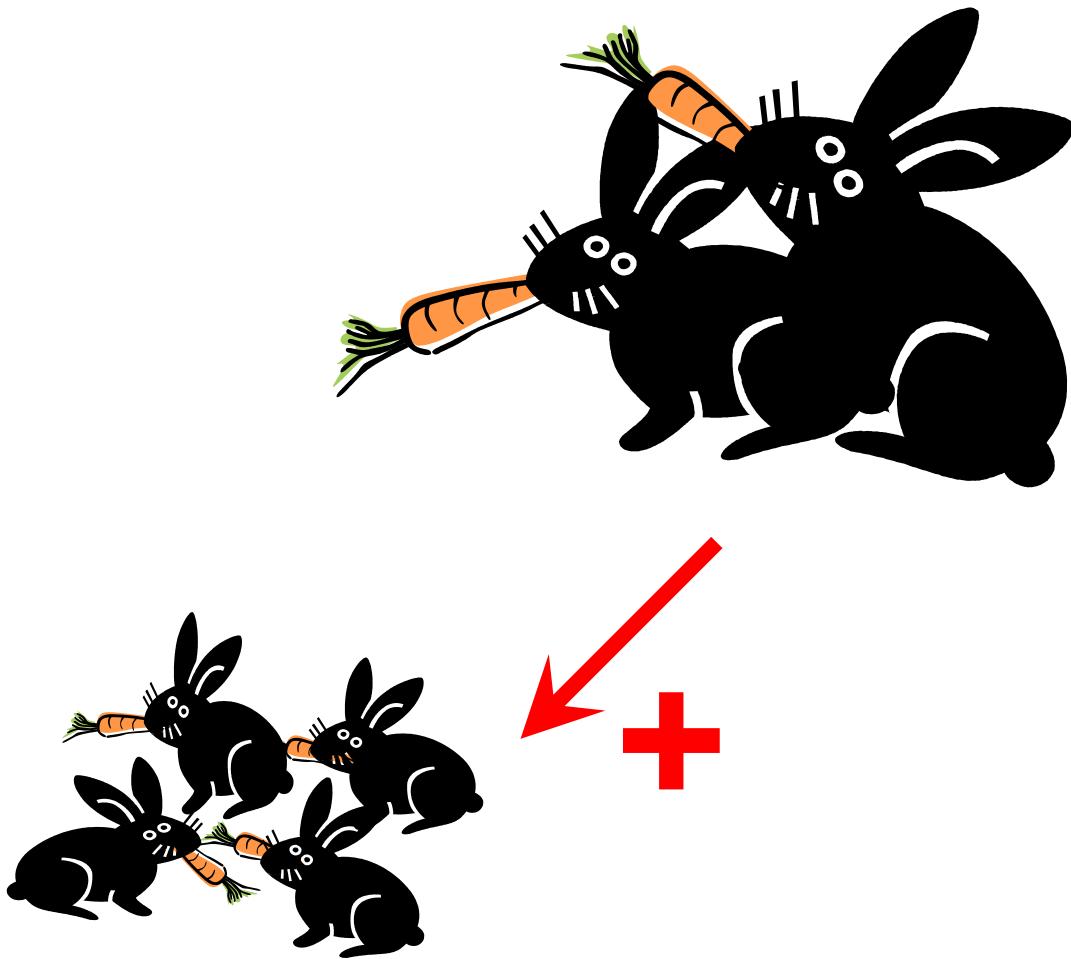
Rabbits



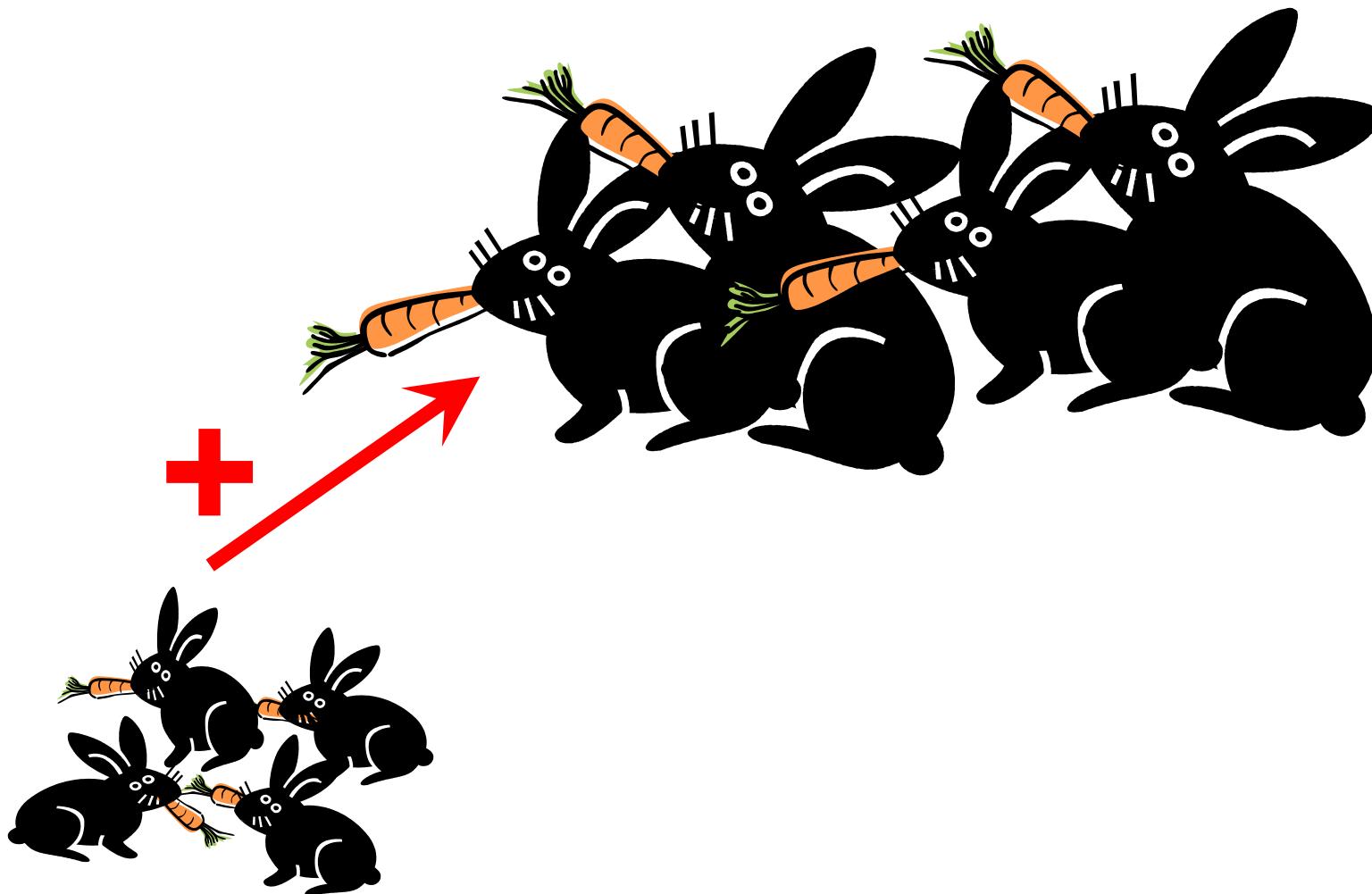
Rabbits and Carrots

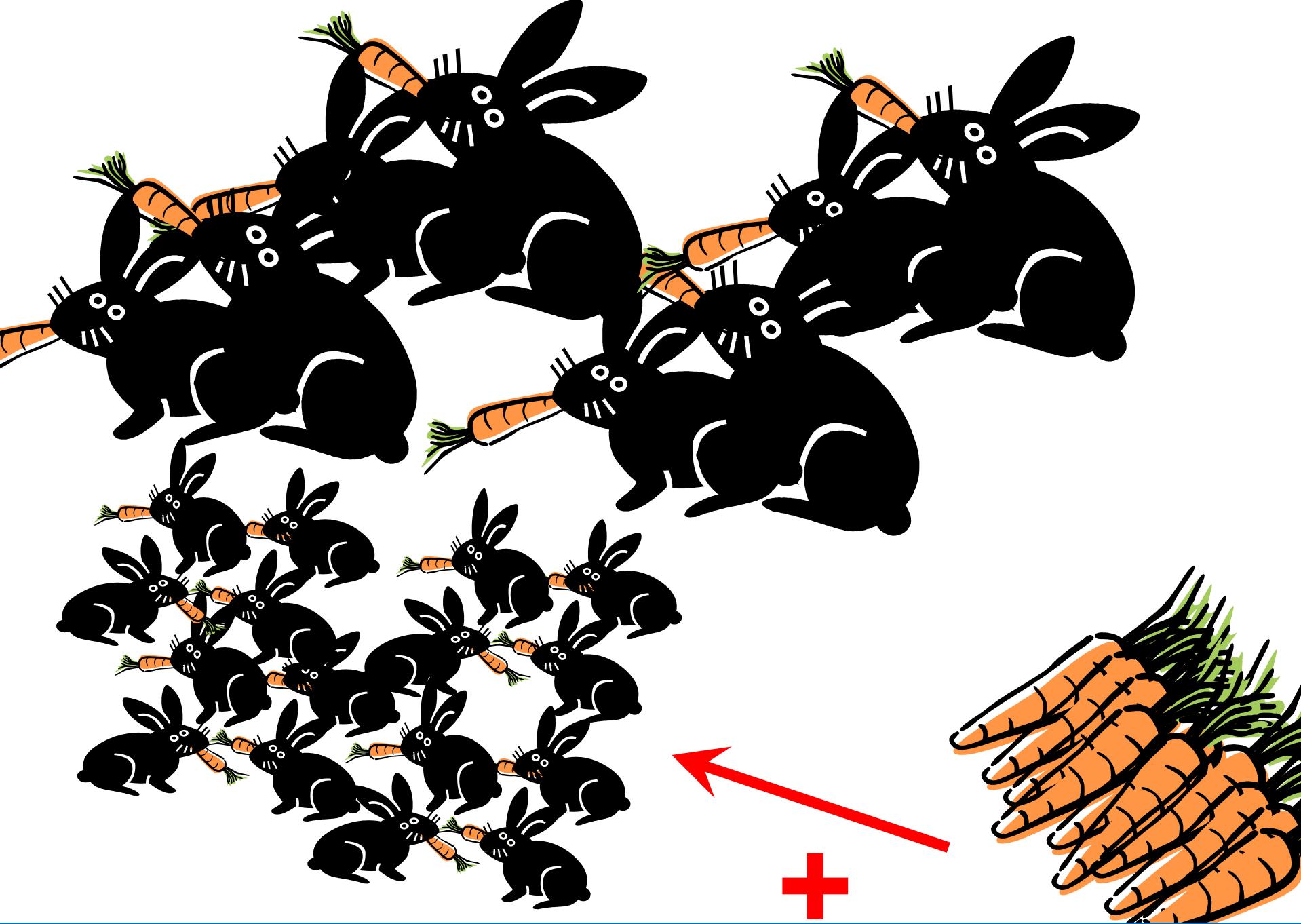


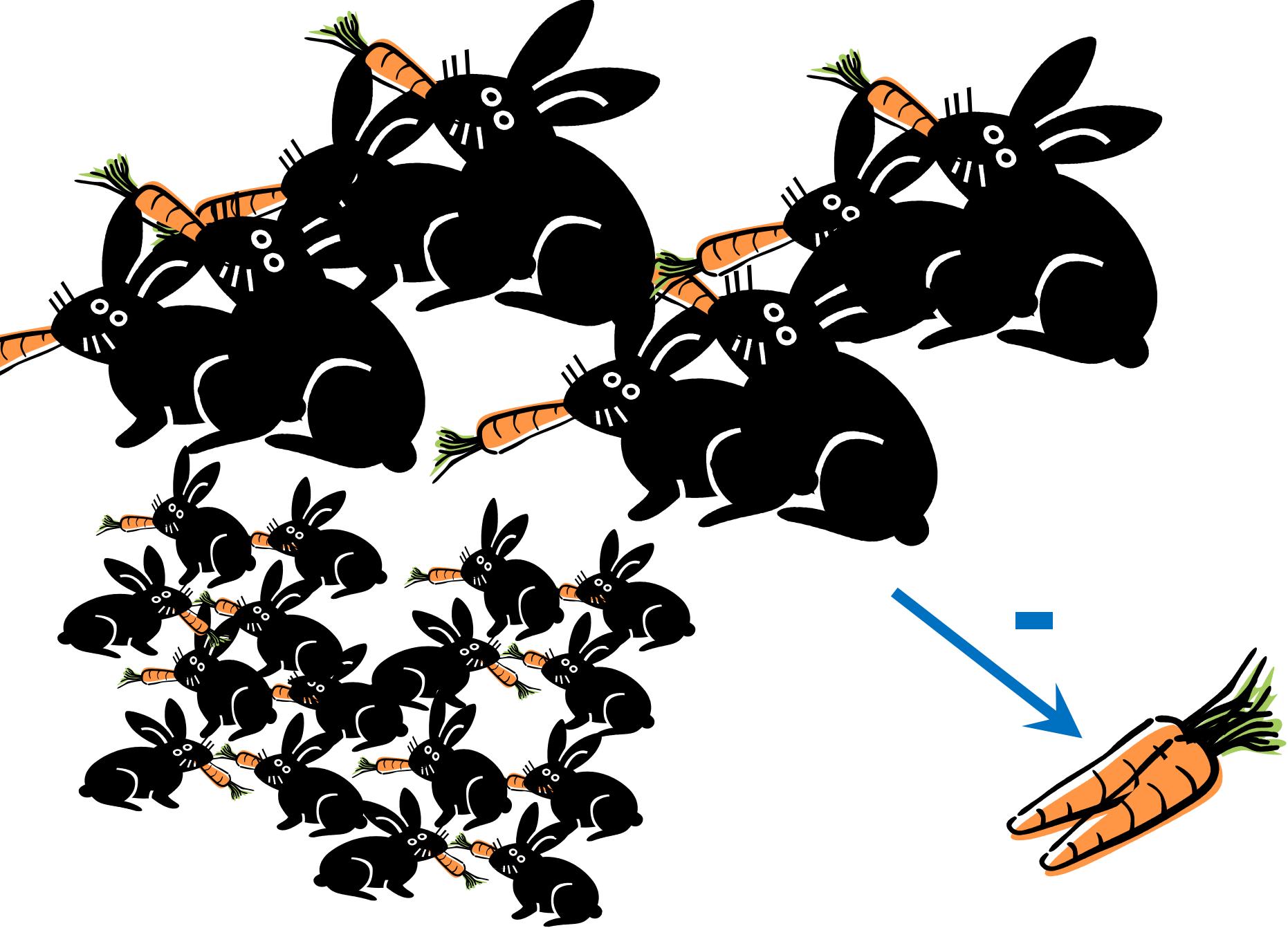
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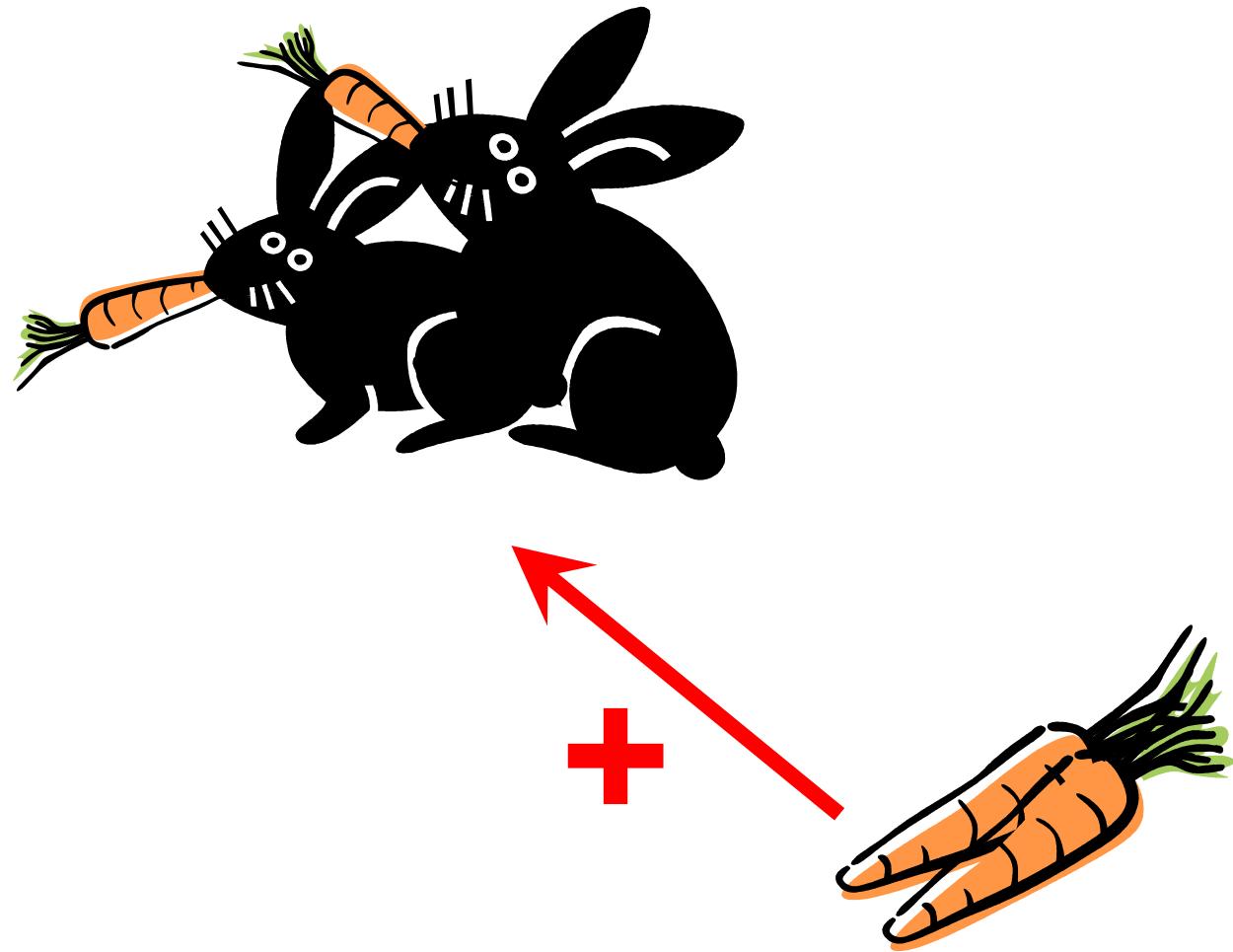


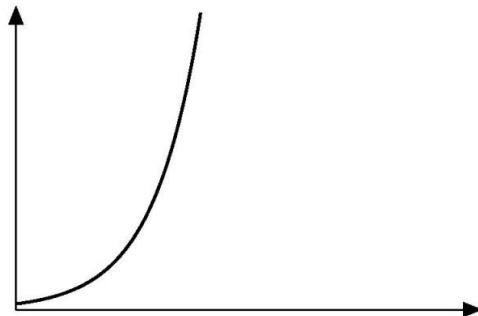
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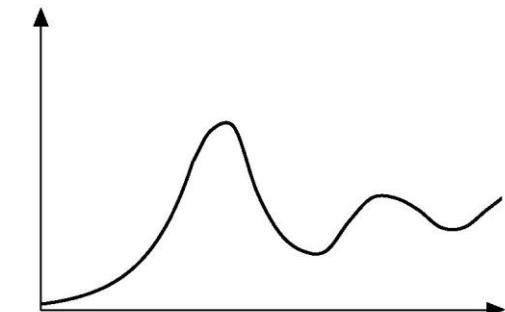




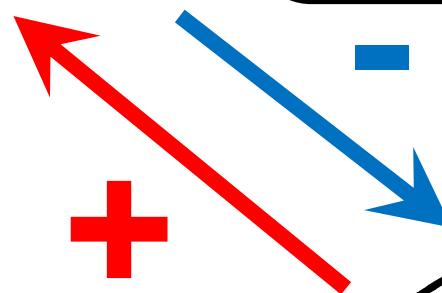
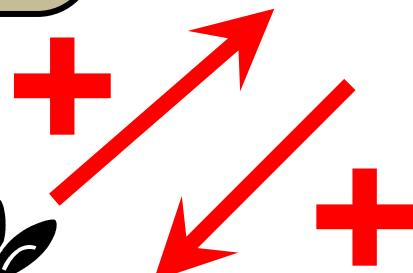
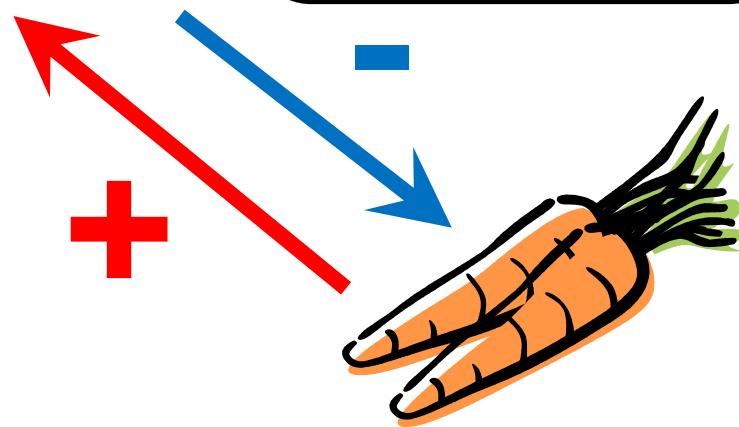
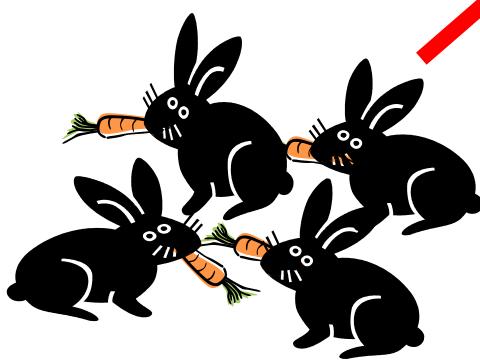


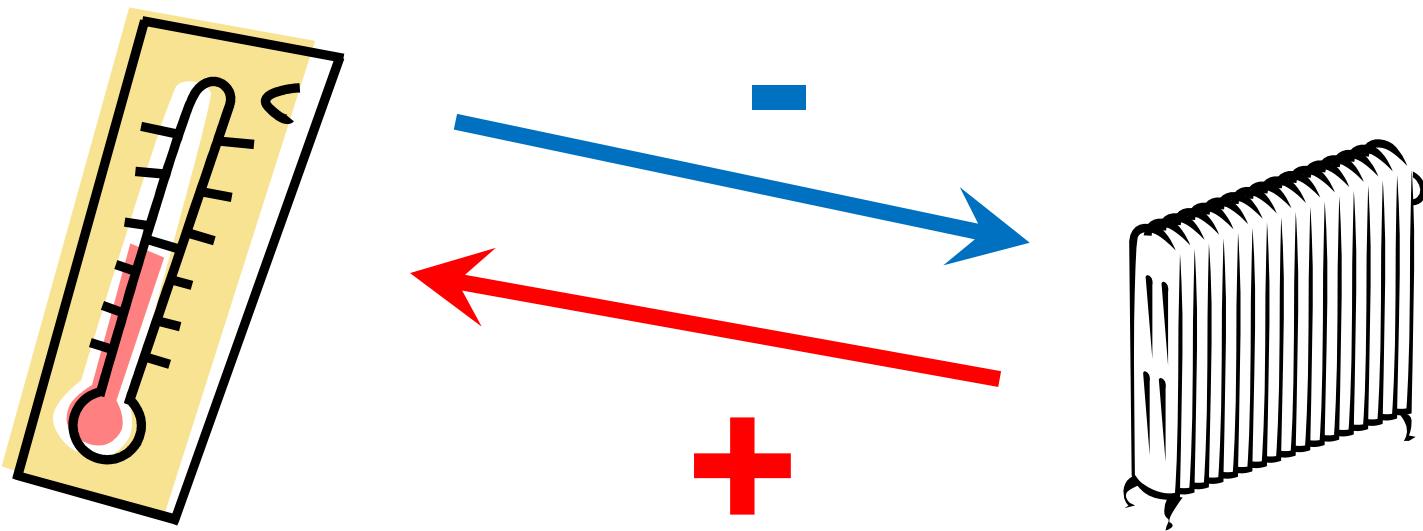


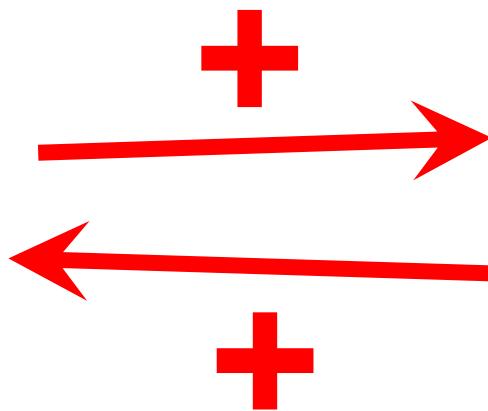
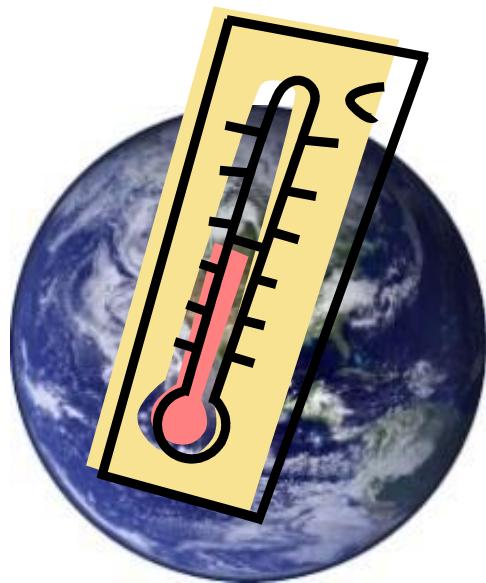
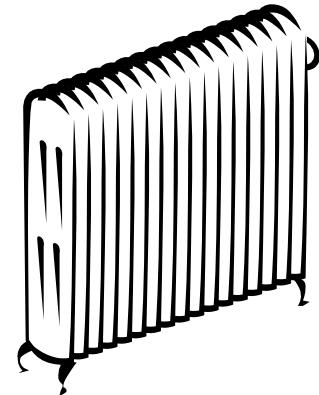
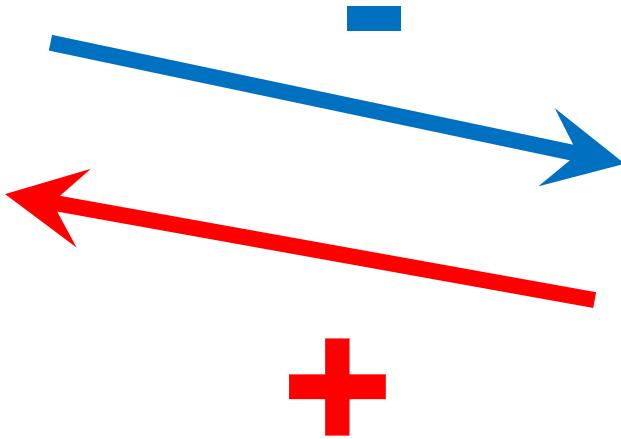
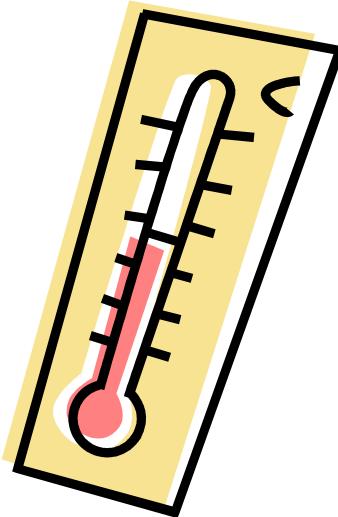
**Positive
feedback**
(amplifying)



**Negative
feedback**
(balancing)

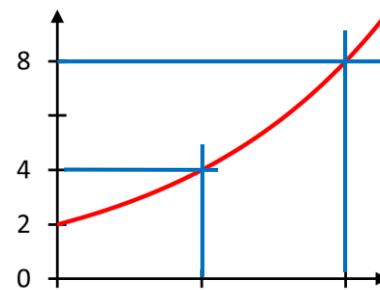






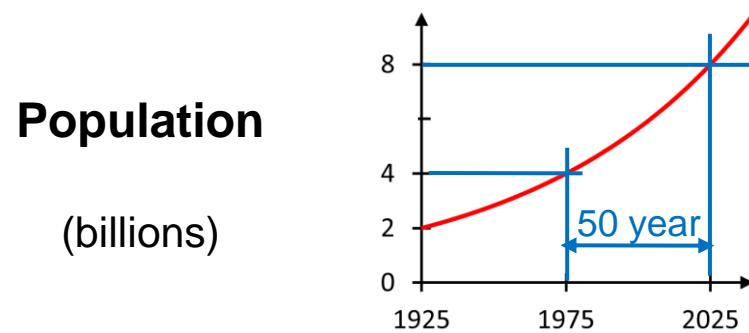
Exponential growth

- At undisturbed positive feedback the conditions for growth will always be the same.
- The growth expressed in percent will be constant over time.



- Exponential growth is characterized by a constant time between each doubling.

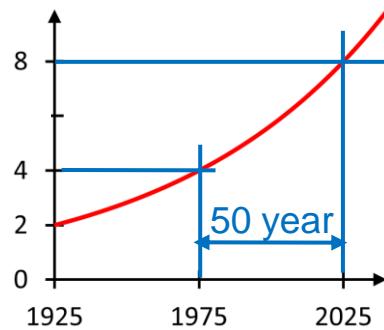
Three examples – same pattern



Three examples – same pattern

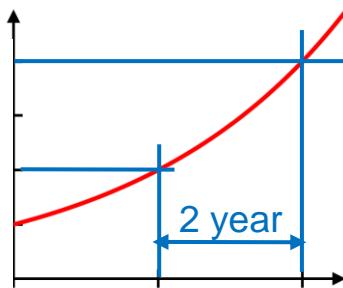
Population

(billions)



Moore's law

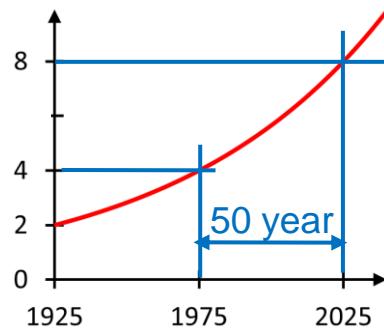
(computer performance)



Three examples – same pattern

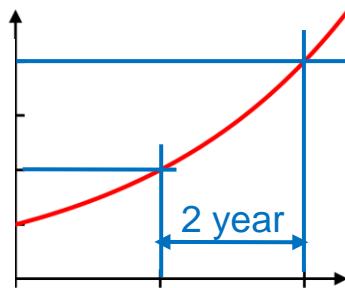
Population

(billions)



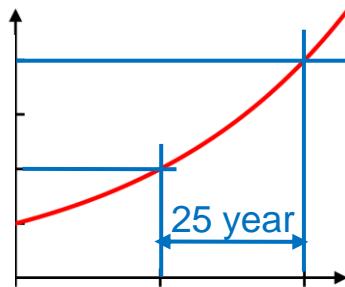
Moore's law

(computer performance)

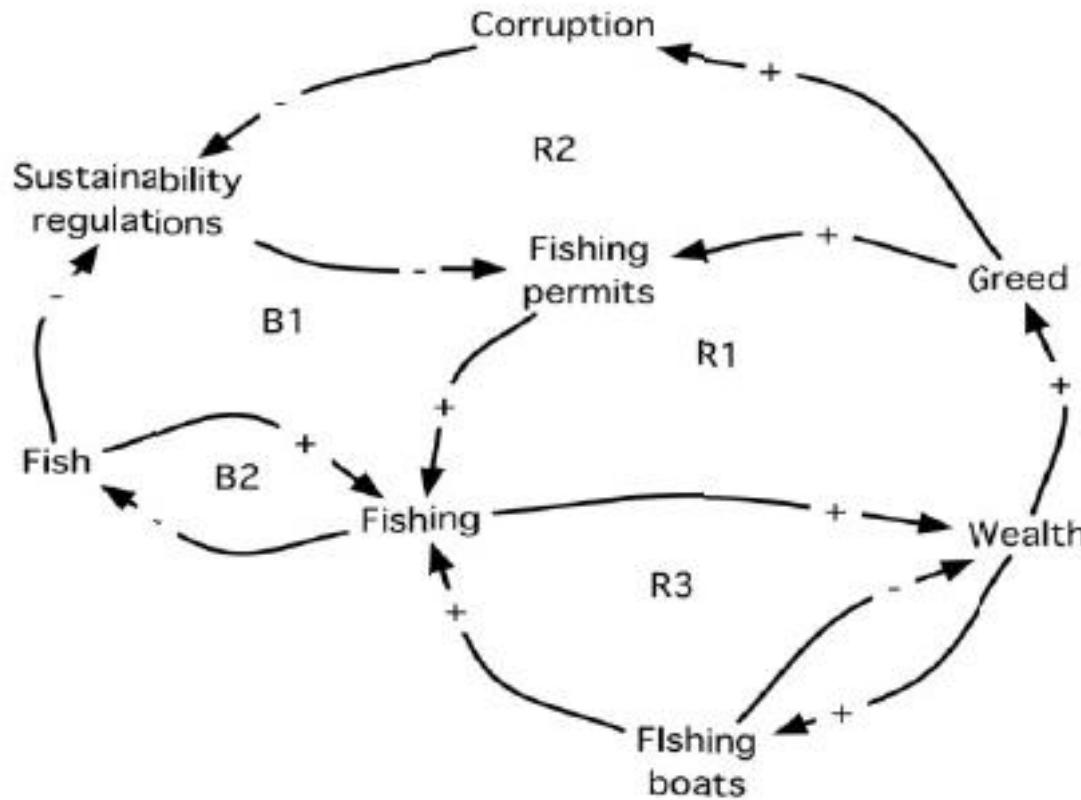


GDP

(value of all production)



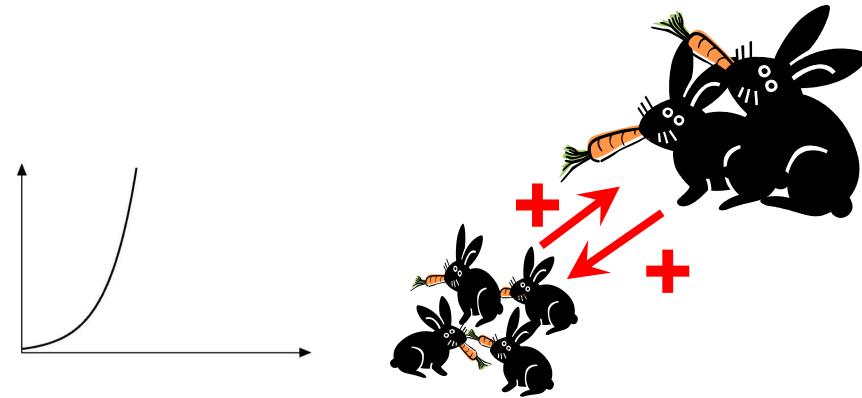
The world is complex ...



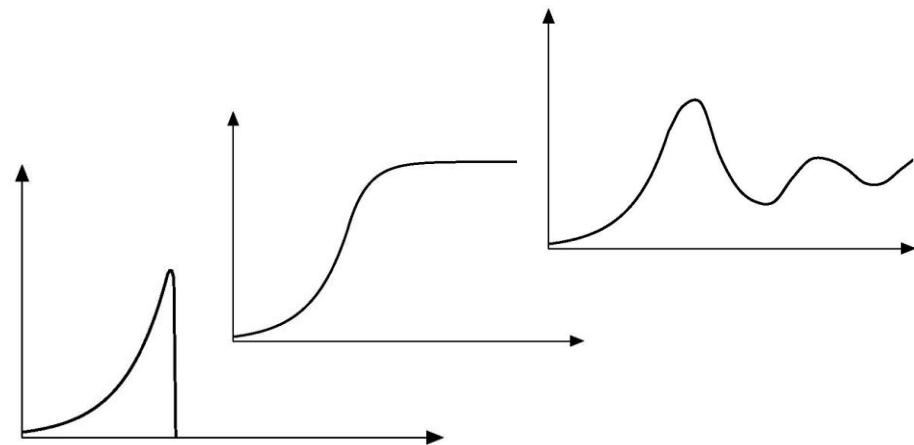
Källa: Sverdrup, Koca & Ragnarsdottir: *Peak Metals, Minerals, Energy, Wealth, Food and Population: Urgent Policy Considerations for a Sustainable Society*

Two realities

- Exponential growth requires positive feedback.



- Growth will never last for ever.



1. Growth and feedback

2. The ecological limits

3. Addicted to fossil fuel

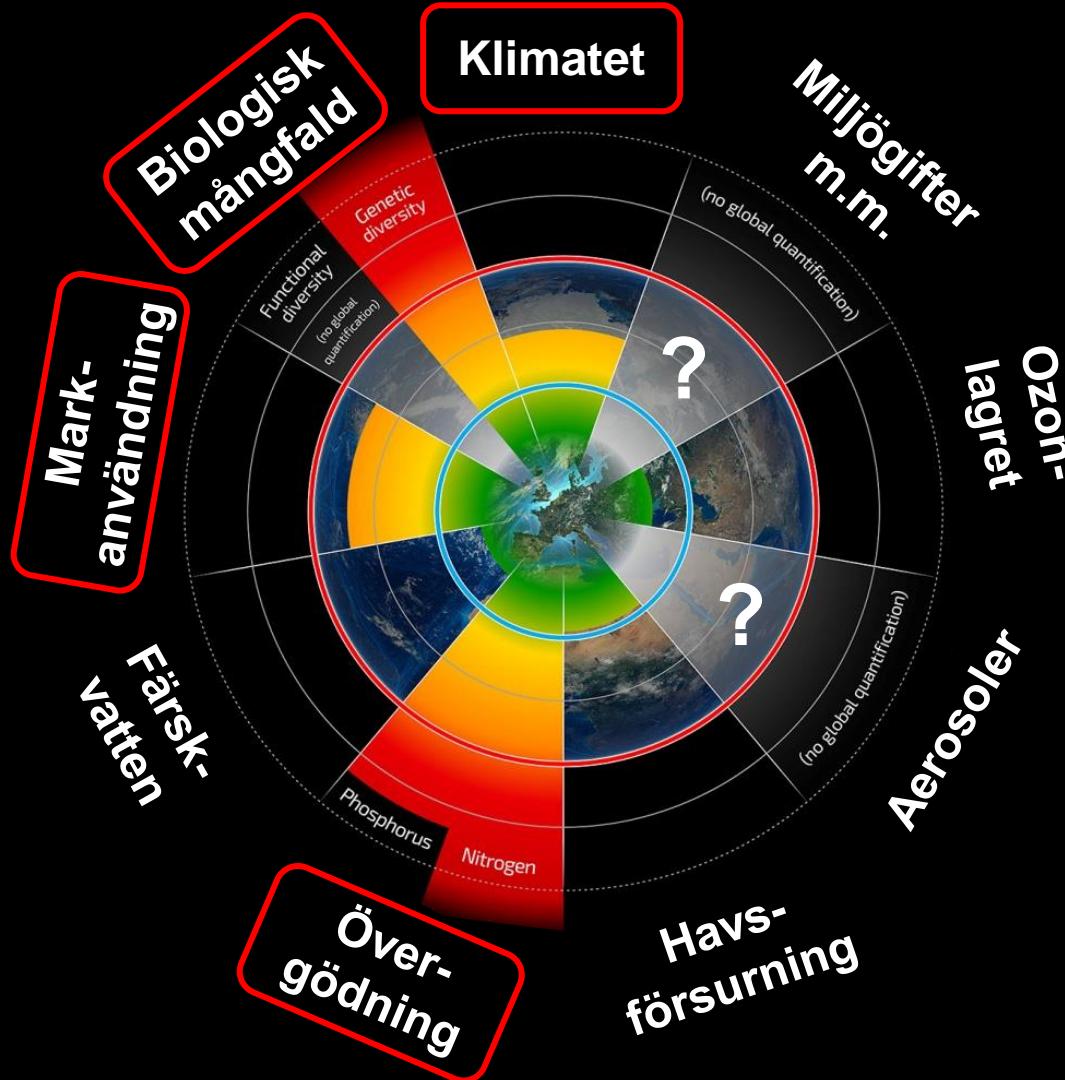
4. Peak Oil is a reality

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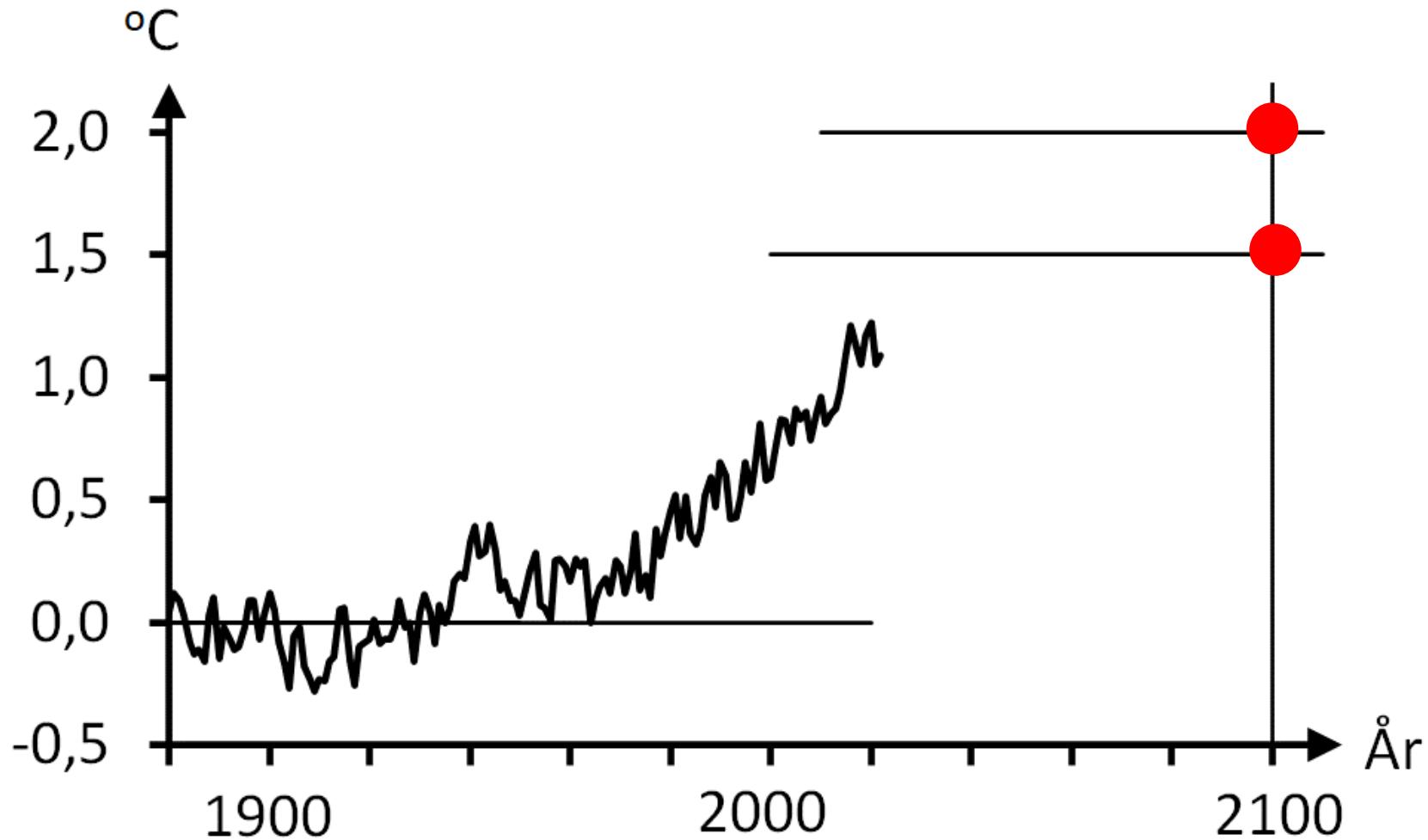
7. How to cope with the perfect storm

Planetära gränser



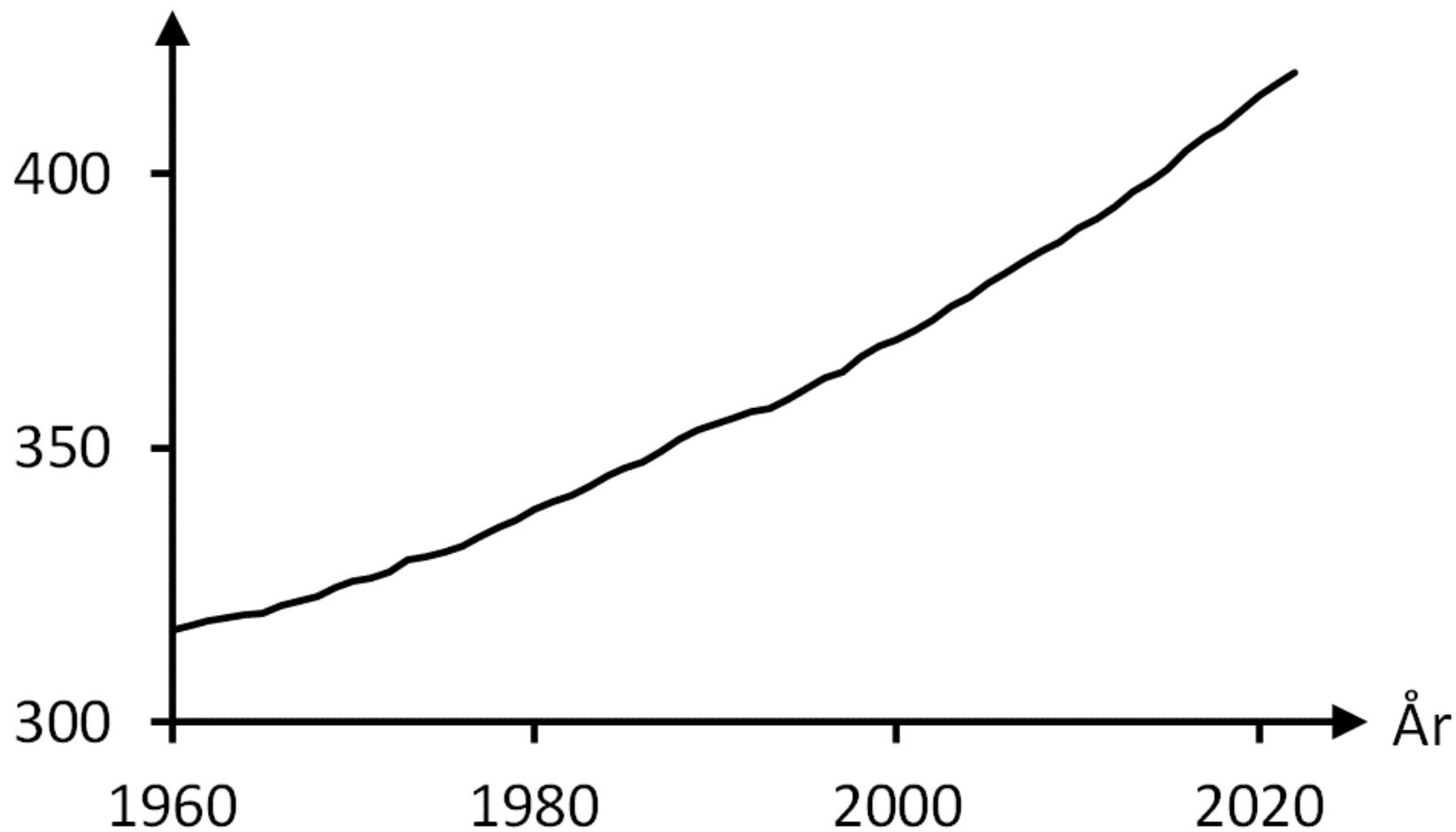
Källa: J. Rockström m.fl. (2015): Planetary boundaries,
Guiding human development on a changing planet

Global warming



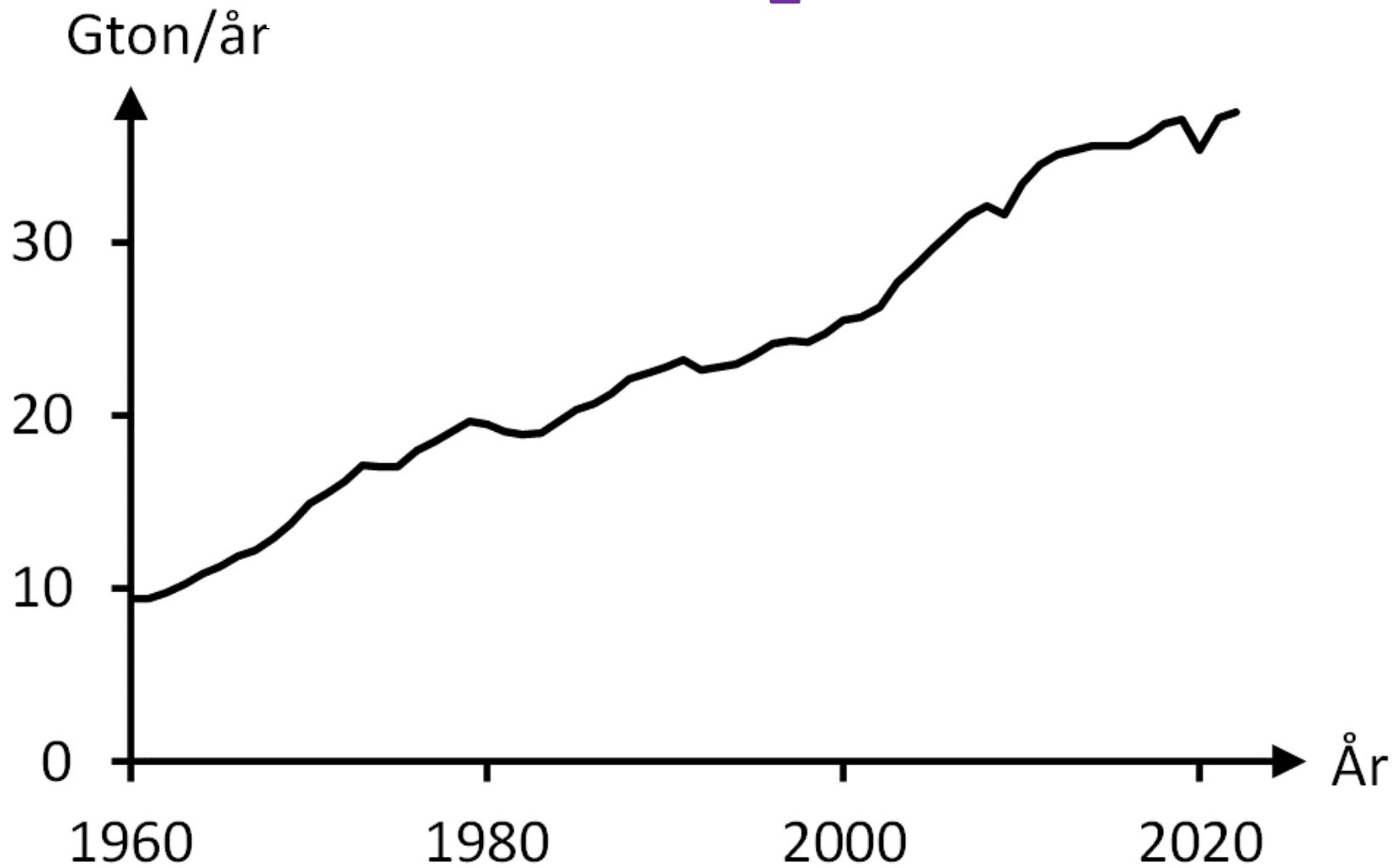
Källa: NASA (data t.o.m. 2022) <https://www.esrl.noaa.gov/gmd/ccgg/trends/data.html>

CO₂-level in the atmosphere



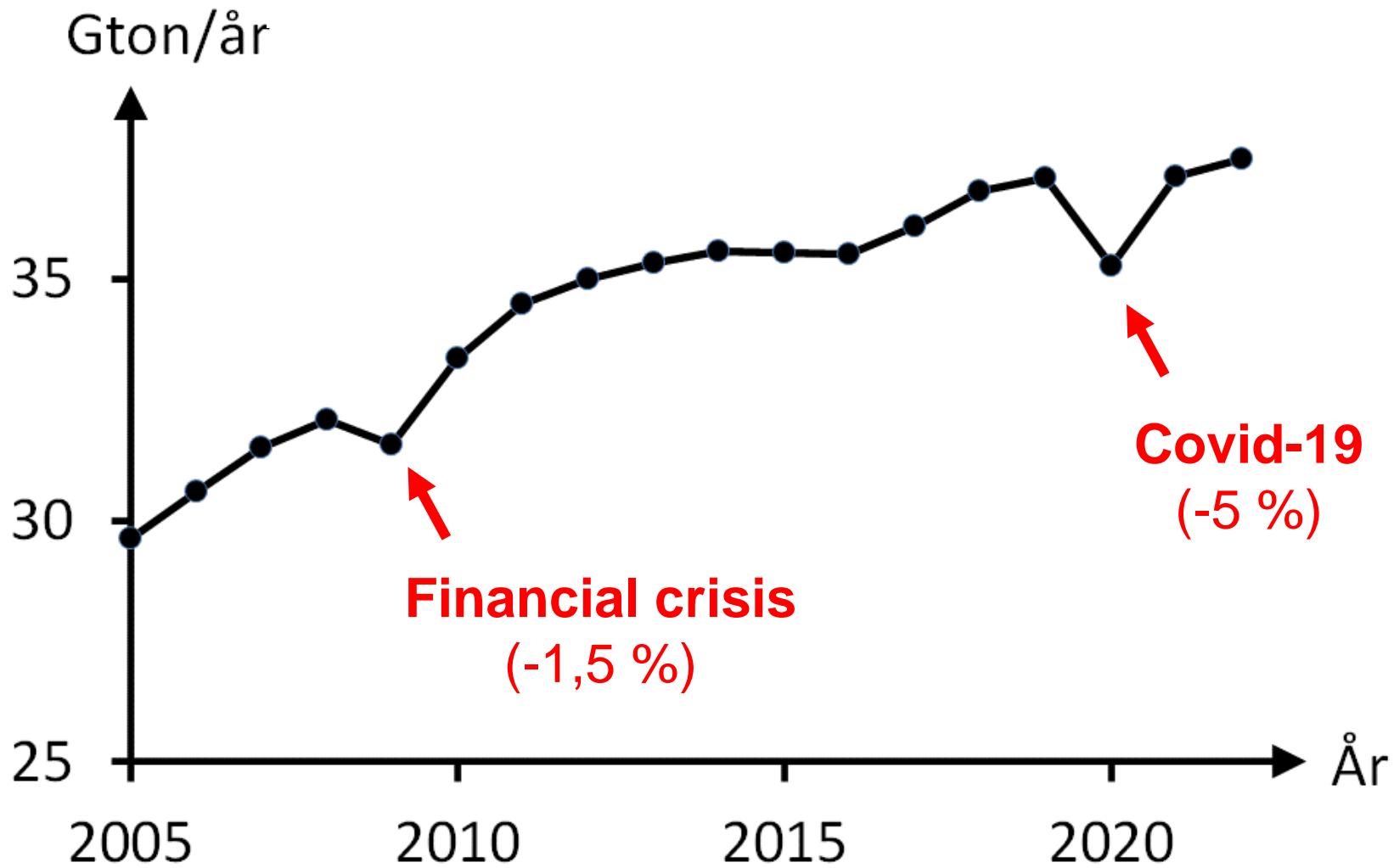
Källa: NOAA, årsmedelvärden uppmätta på Mauna Loa, Hawaii (data t.o.m. 2022)

Yearly CO₂-emissions



Källa: *Global Carbon Project*, 2022 (data t.o.m. 2022). <https://www.globalcarbonproject.org/carbonbudget/>

Two small dips

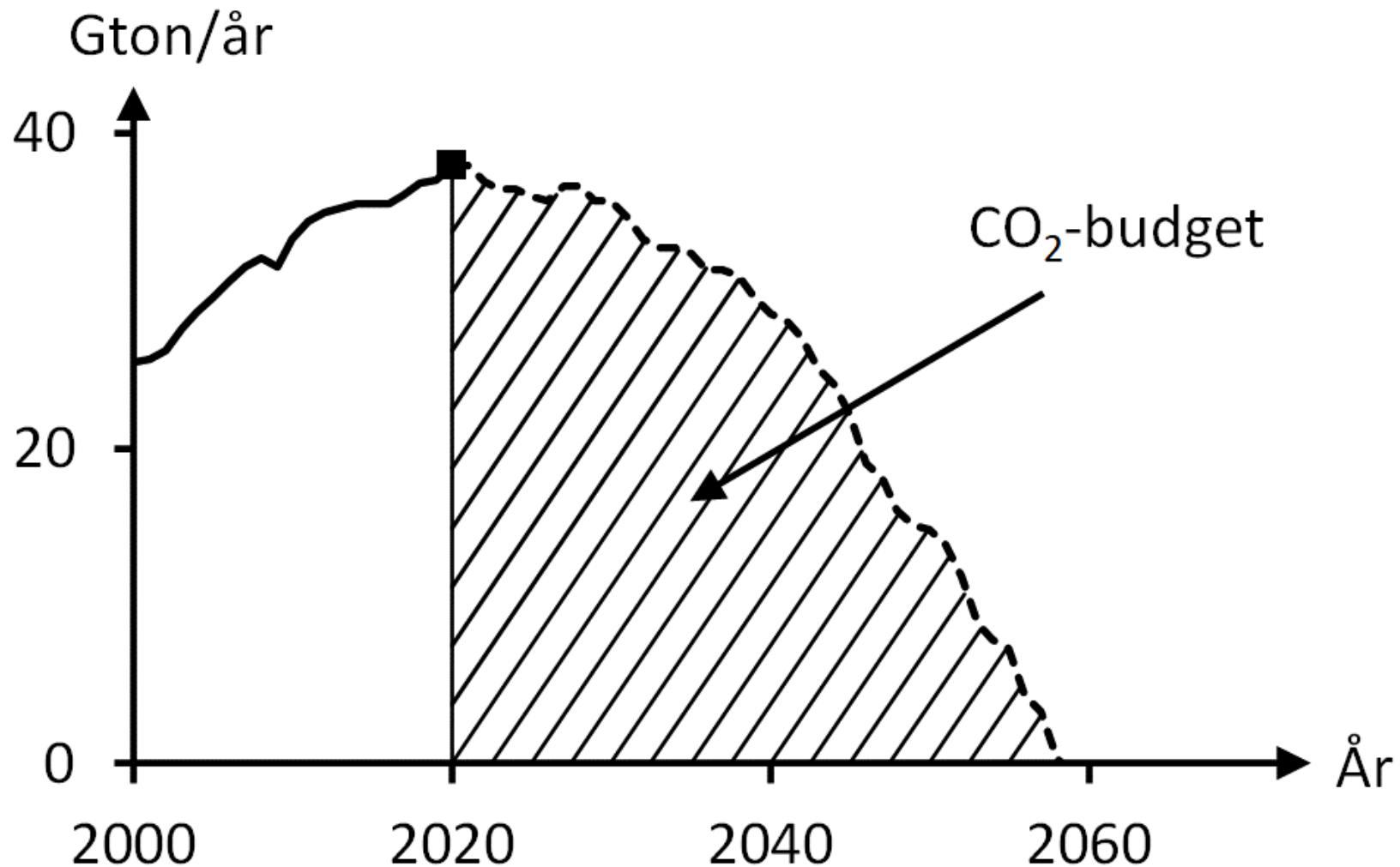


Källa: Global Carbon Project, 2022 (data t.o.m. 2022). <https://www.globalcarbonproject.org/carbonbudget/>

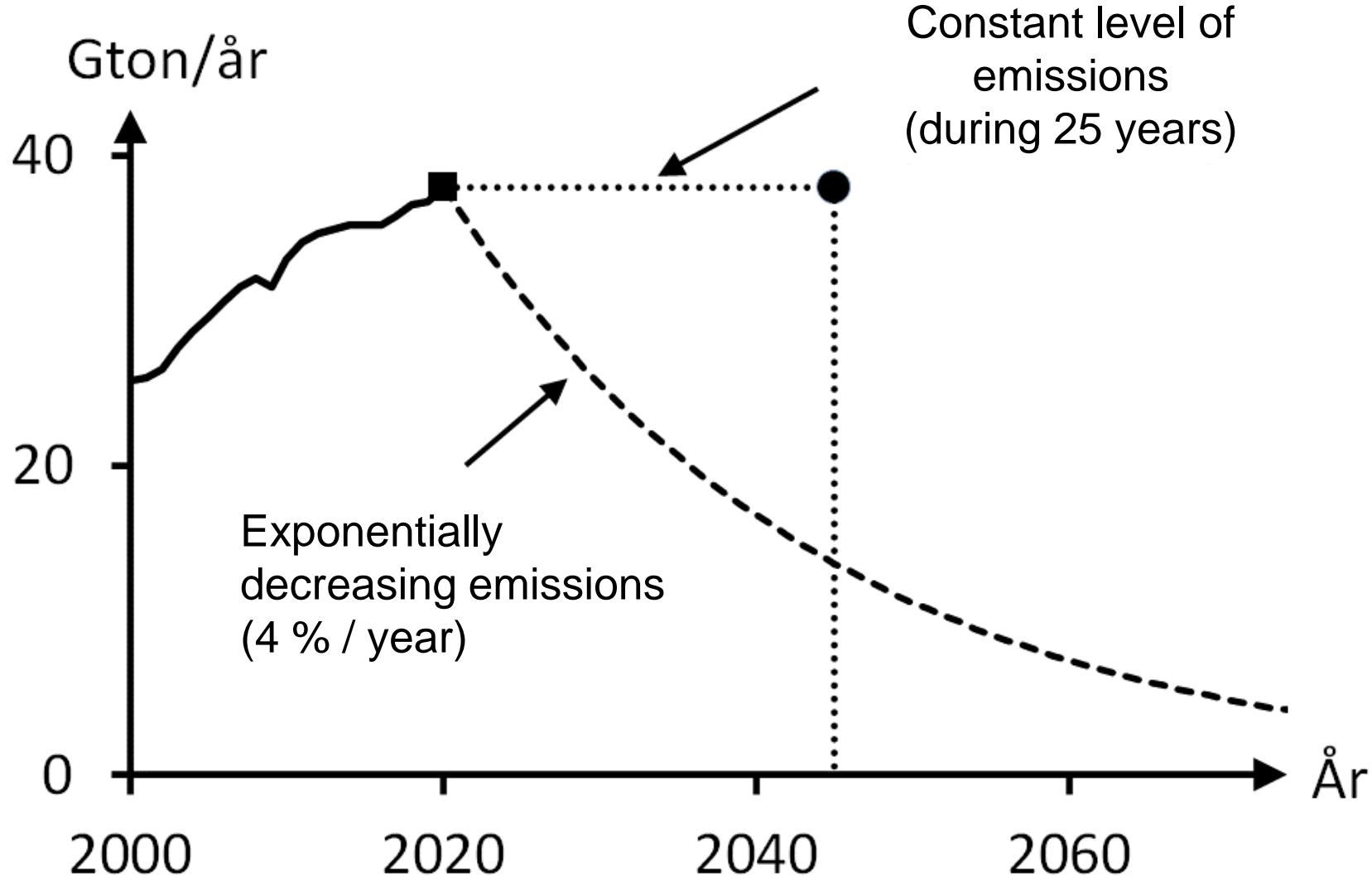
CO₂-budget

- A CO₂-budget is an estimate of the total amount of CO₂ that may be emitted without severe consequences.
- The concept pay no attention to the distribution in time.
- Despite large uncertainties it could be an excellent tool to monitor the progress to reduce the CO₂-emissions.

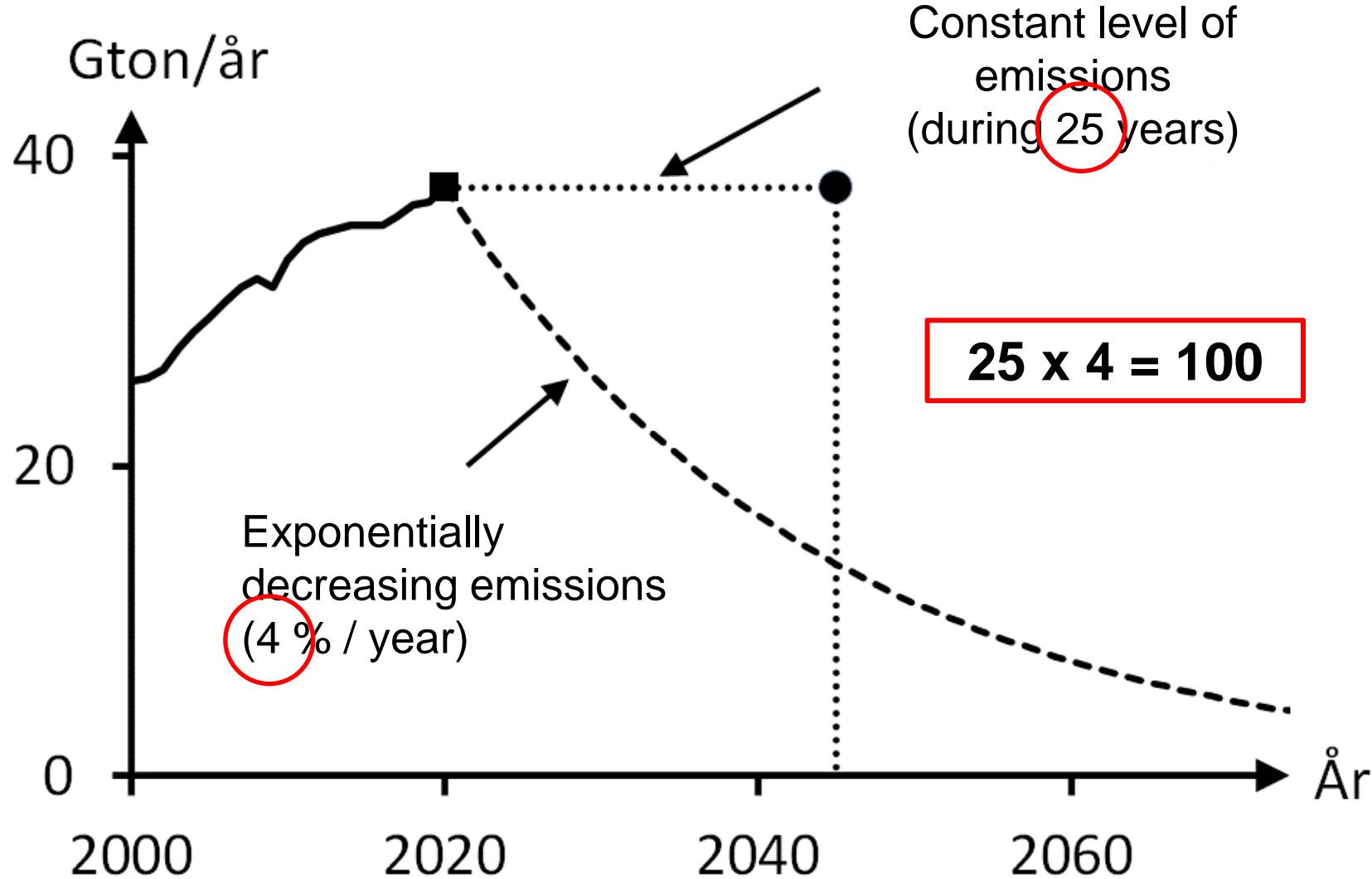
The concept



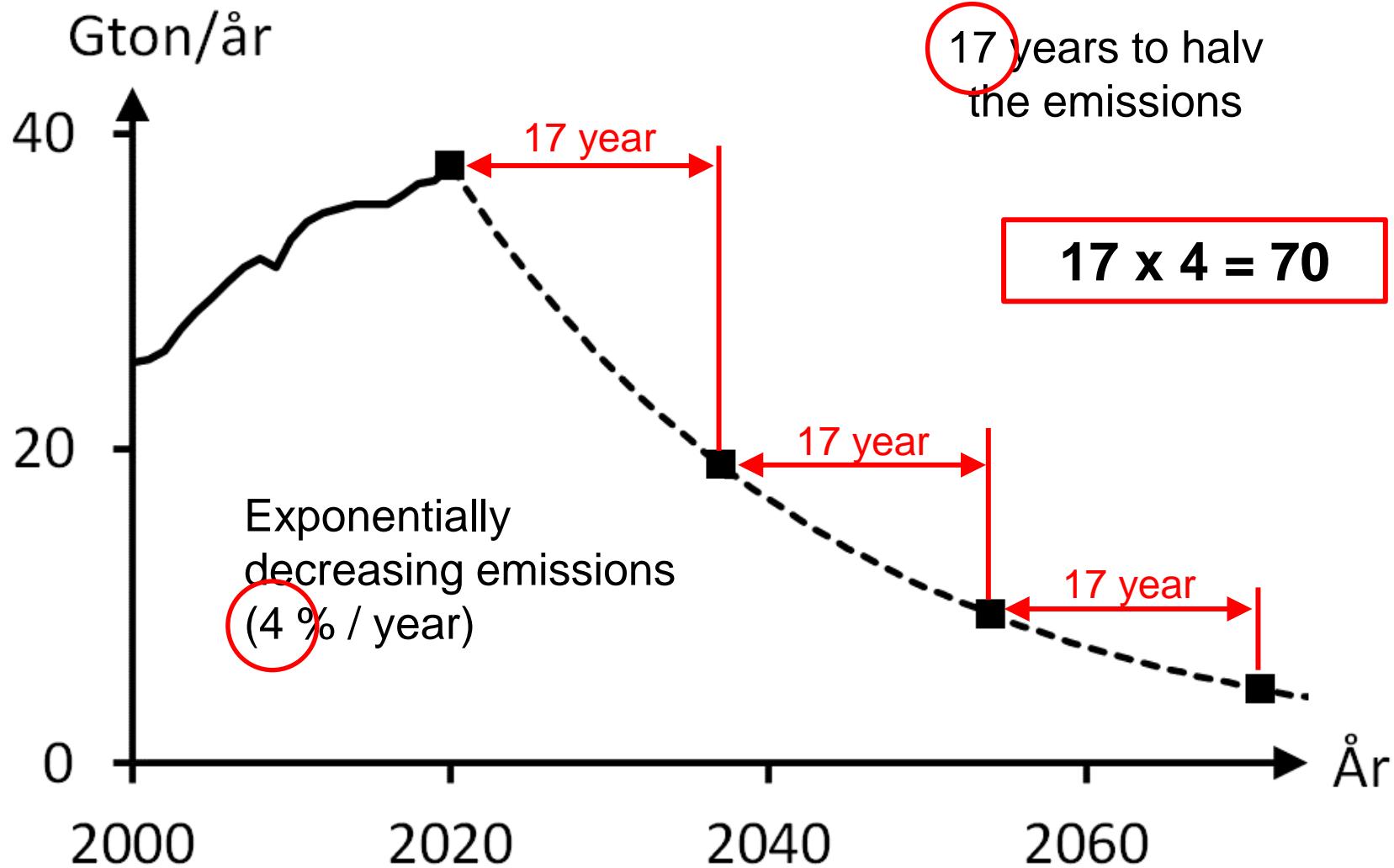
Two ways – same budget



The 100-rule



The 70-rule

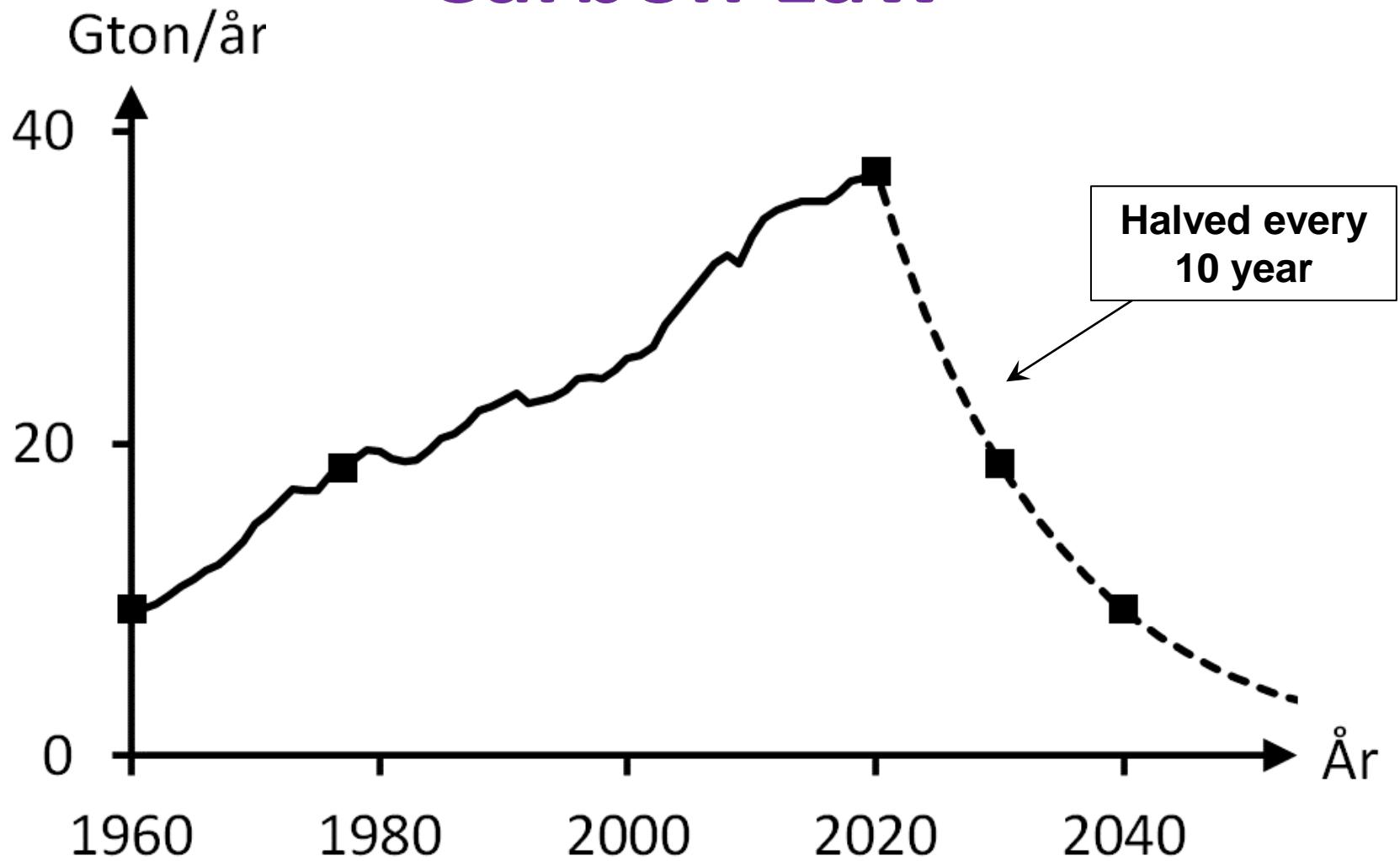


Two "Rules" gives one "Law"

An estimate from Johan Rockström and some others:

- If the future CO₂-emissions do not exceed 600 Gton the probability is 75 % to keep the global warming below 2 degrees.
- With the current emissions being 40 Gton this corresponds to 15 years with emissions on todays level ($600/40=15$).
- From the "100-rule" one find that the emissions should decrease by 7 % annually ($7 \times 15 = 105$).
- The "70-rule" gives the time to halv the emissions ($7 \times 10 = 70$).
- **The "Carbon Law": emissions should be cut to half every 10 year.**

Carbon Law



Källor: Global Carbon Project, 2022 (data t.o.m. 2019). <https://www.globalcarbonproject.org/carbonbudget/>
Rockström m.fl. 2017: A roadmap for rapid decarbonization

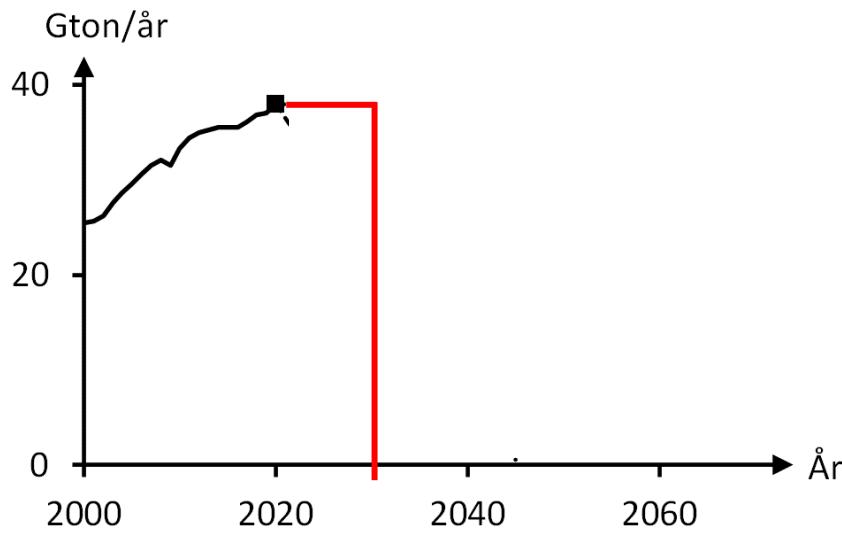
Another CO2-budget

DN:

UTSLÄPPEN MÅSTE SLUTA HELT OM:

6 år, 291 dagar, 14 timmar, 10 min, 20 sek

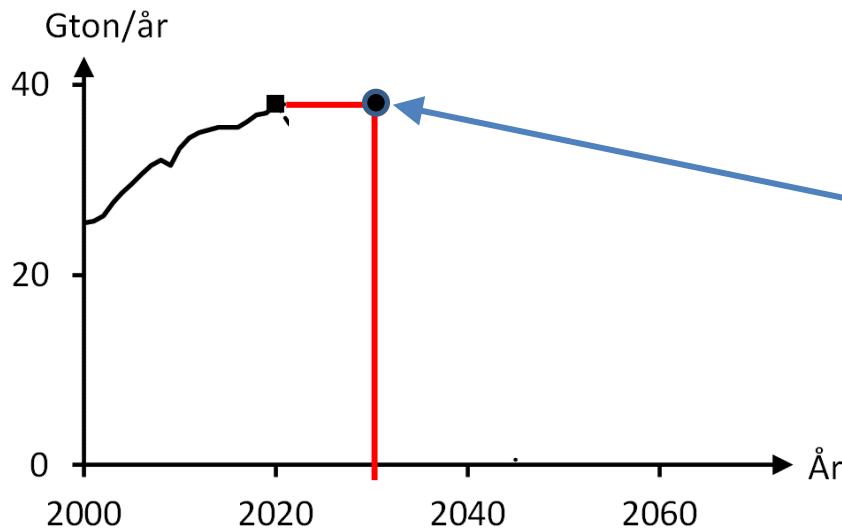
för att uppvärmningen ska begränsas till max 1,5 °C - om vi fortsätter som i dag



- Ok to question the size of the budget.

Another CO2-budget

DN:



- Ok to question the size of the budget.
- **But, this point should never be reached**
- **The message should rather be:**
 - annual reduction by 14 %
 - to be halved every 5 year

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The Eiffel Tower

- 1 step/second = 28 minutes to the top
- Repeat every hour during one working day (8 times)
- All working days the year around



The Eiffel Tower

- 1 step/second = 28 minutes to the top
- Repeat every hour during one working day (8 times)
- All working days the year around



Men or Machine

200 kWh	 A photograph of the Eiffel Tower in Paris, France, showing the tower against a clear blue sky with some clouds. The tower is viewed from across a green lawn and a path.	1 year of work
	 A large, dark, teardrop-shaped graphic representing a drop of oil or petrol.	20 liter petrol

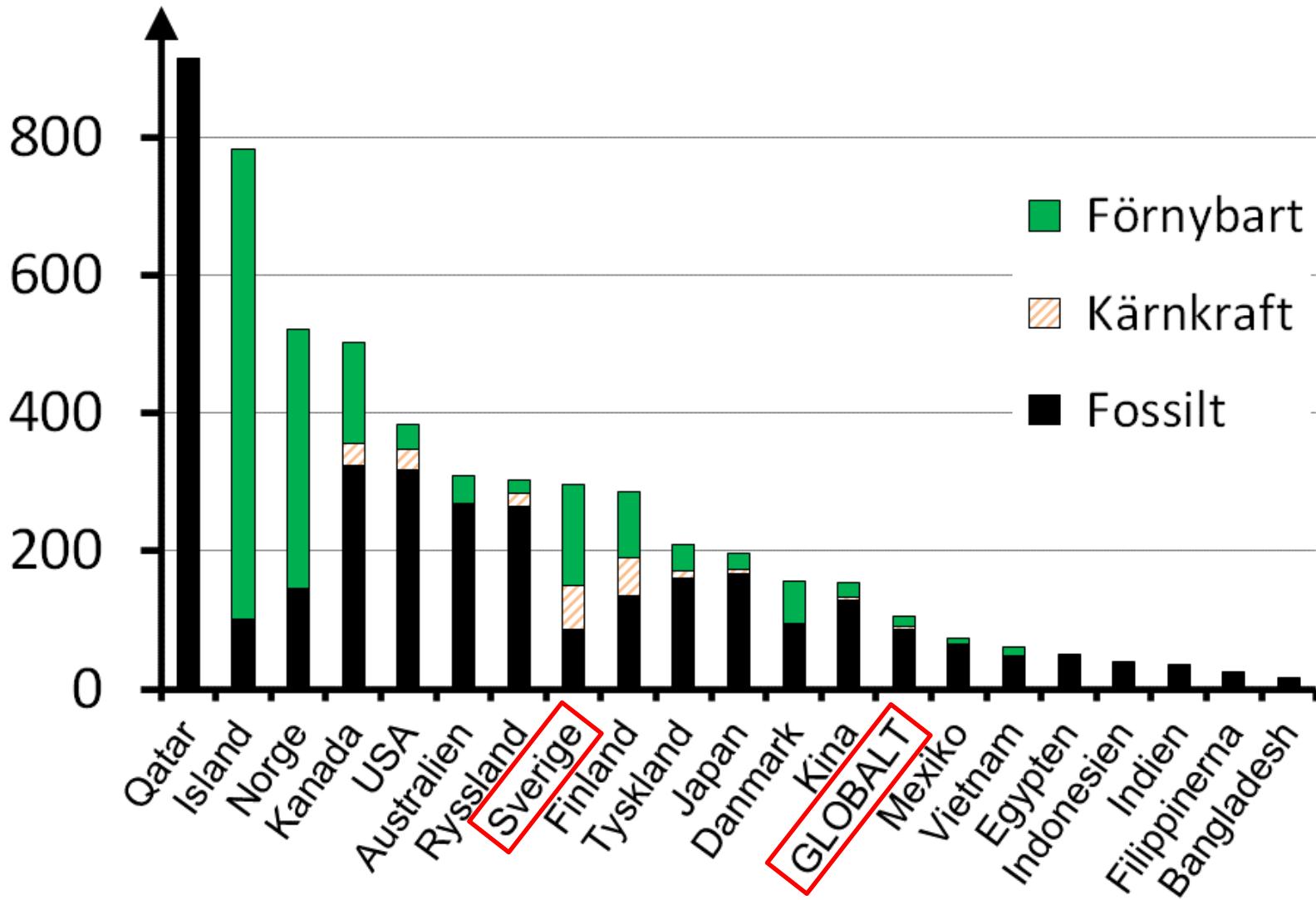
Men or Machine

200 kWh	 A photograph of the Eiffel Tower in Paris, France, showing the tower against a clear blue sky with some clouds.	1 year of work	25 000 kr/month
	 A graphic illustration of a single, dark, teardrop-shaped droplet, representing a unit of petrol.	20 liter petrol	15 kr/liter

Men or Machine

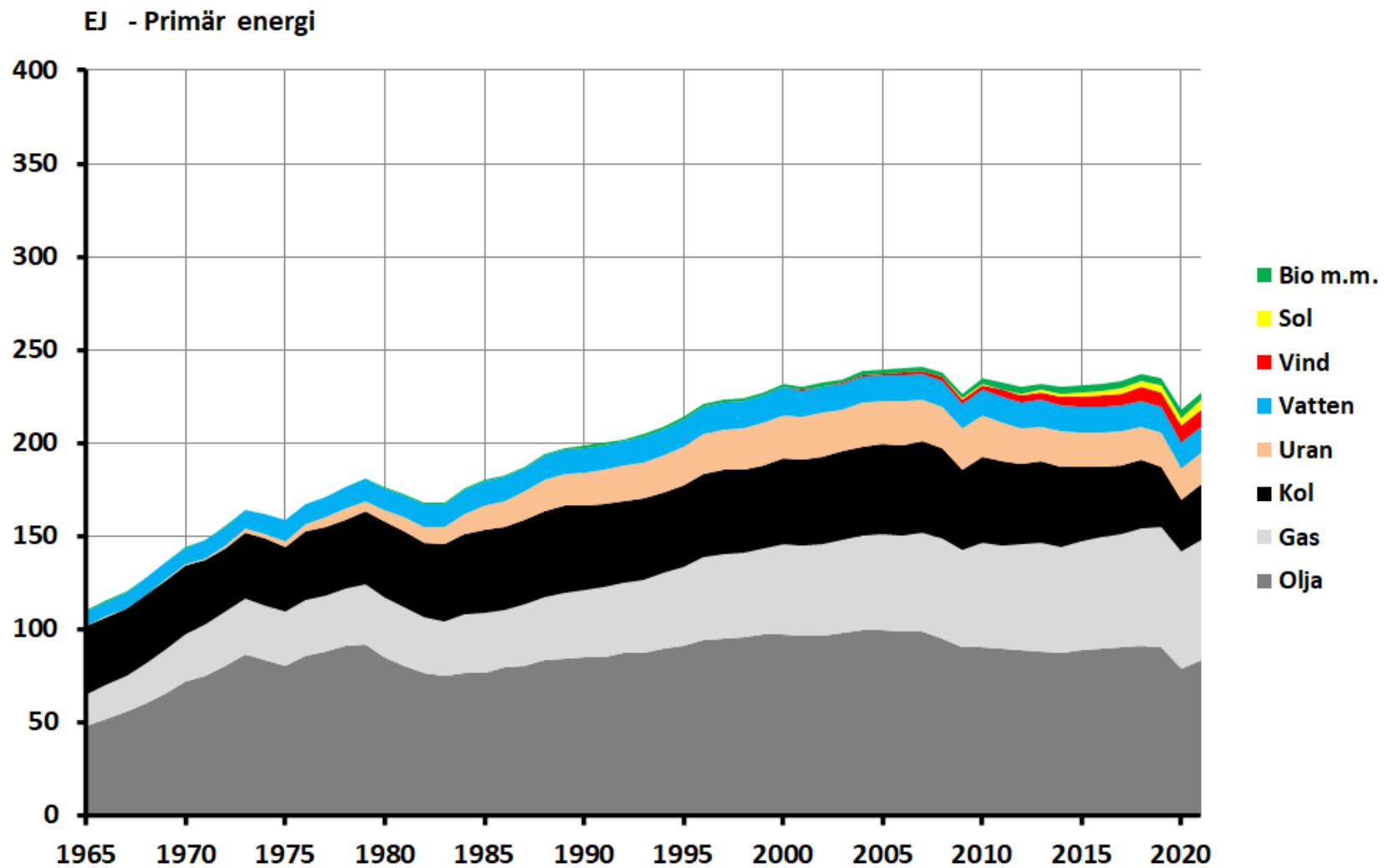
200 kWh	 A photograph of the Eiffel Tower in Paris, France, viewed from across a green lawn and a path.	1 year of work	25 000 kr/month	300 000 kr
	 A graphic illustration of a single, dark, teardrop-shaped droplet of oil or petrol.	20 liter petrol	15 kr/liter	300 kr

“energy slaves”/capita



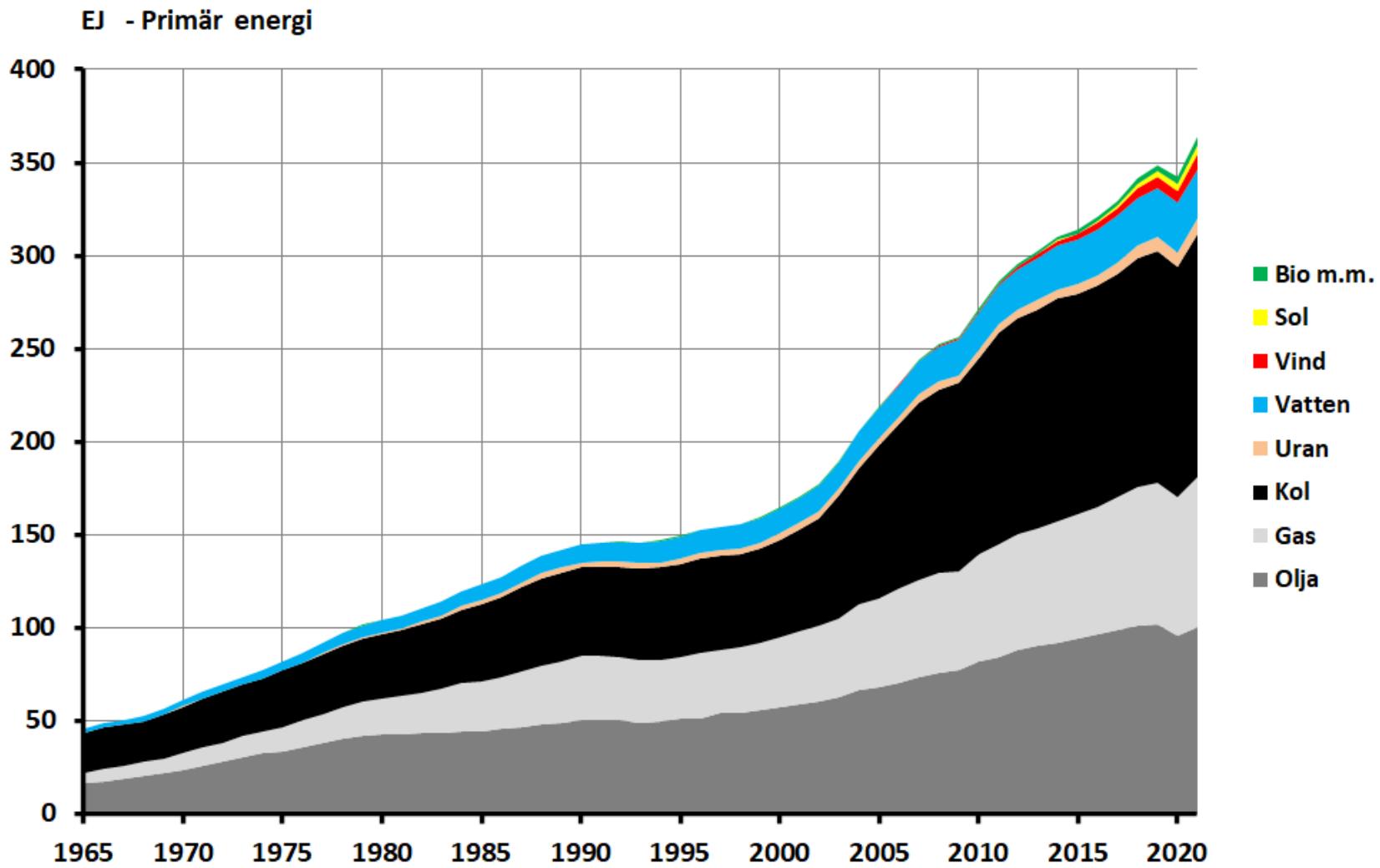
Källor: *BP Statistical Review of World Energy 2022* och *World Bank*

OECD – 1,4 billions in 38 countries



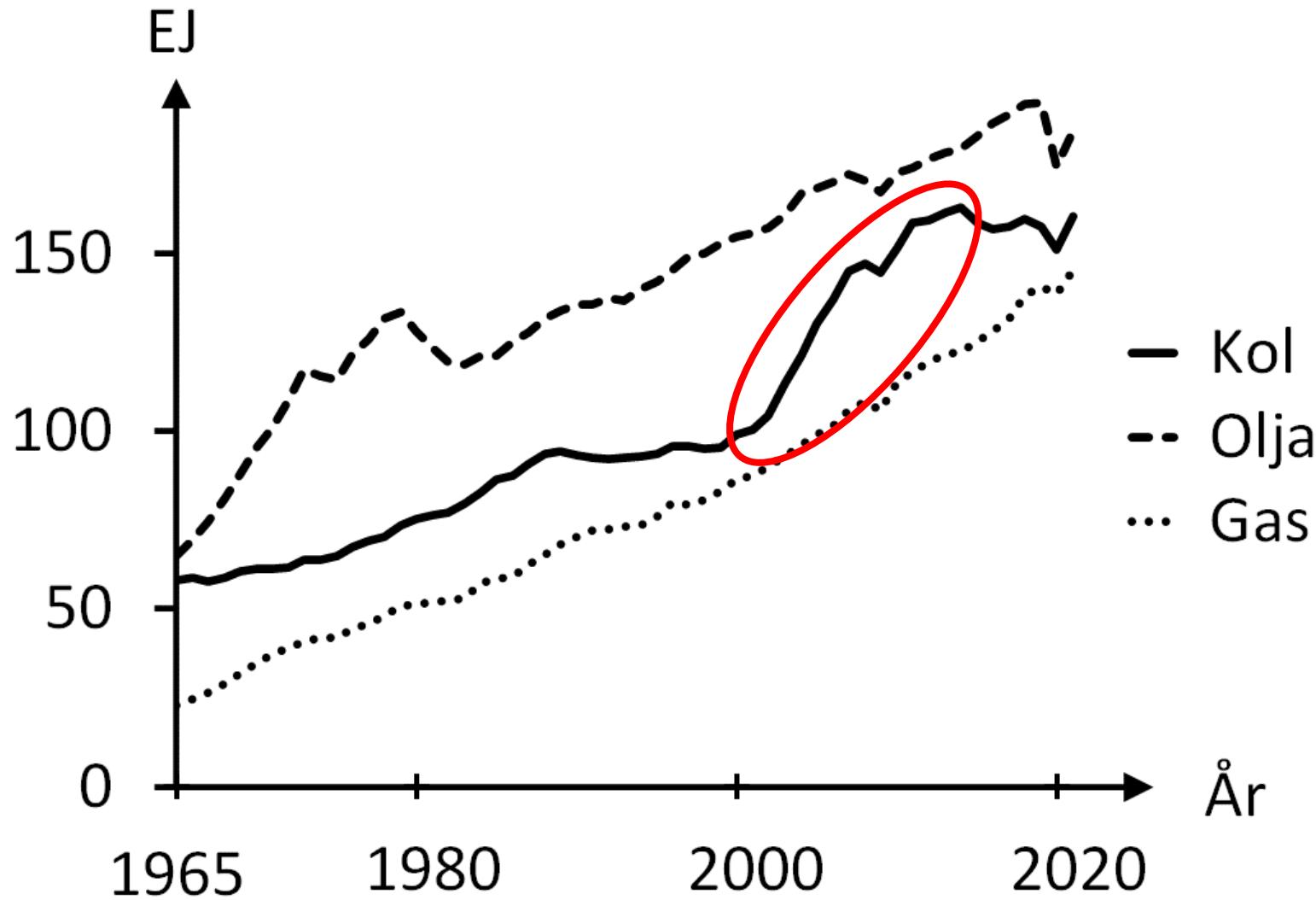
Källor: *BP Statistical Review of World Energy 2022*

Non-OECD – 6,5 billions



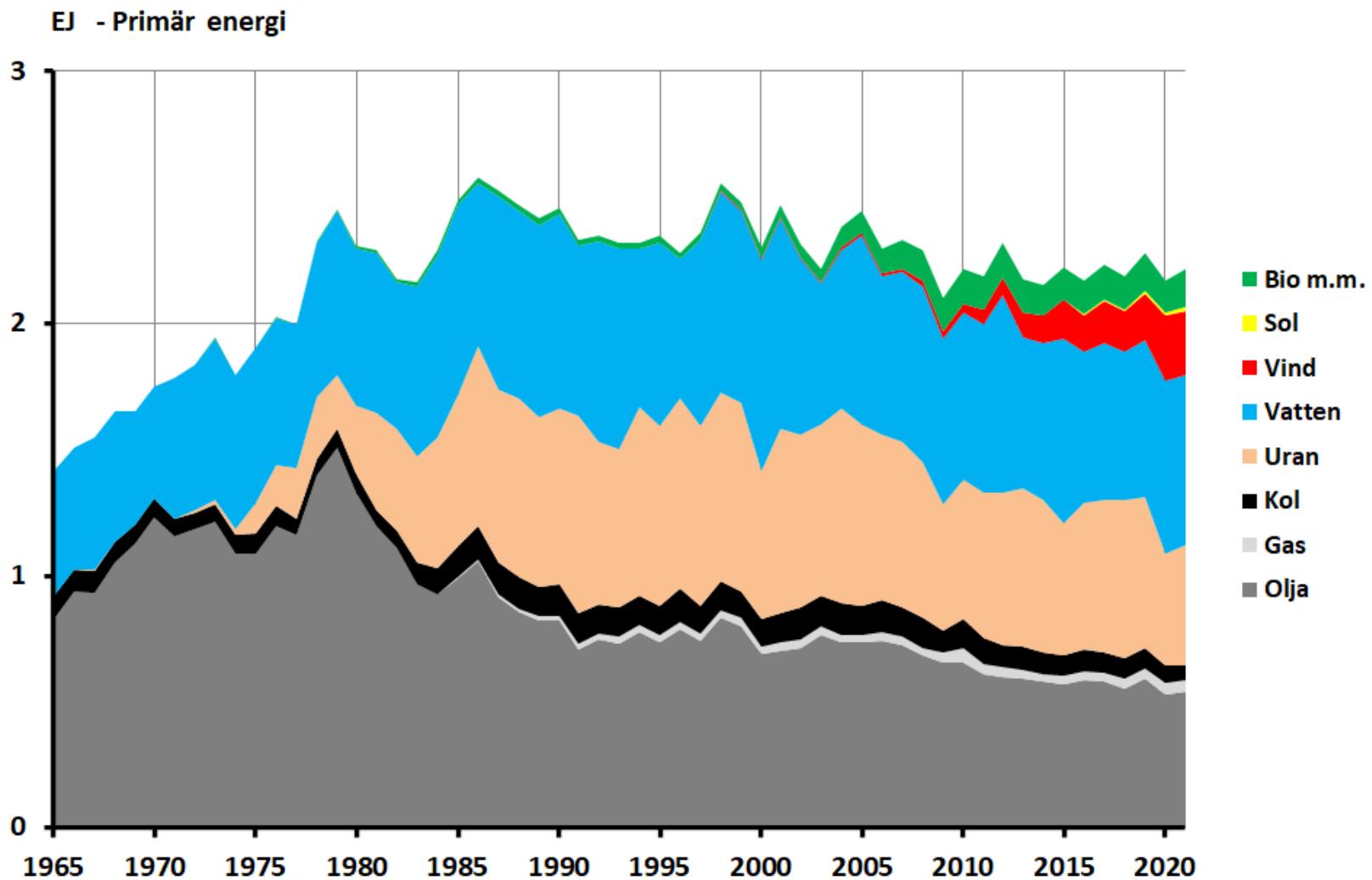
Källor: *BP Statistical Review of World Energy 2022*

The second big expansion for coal



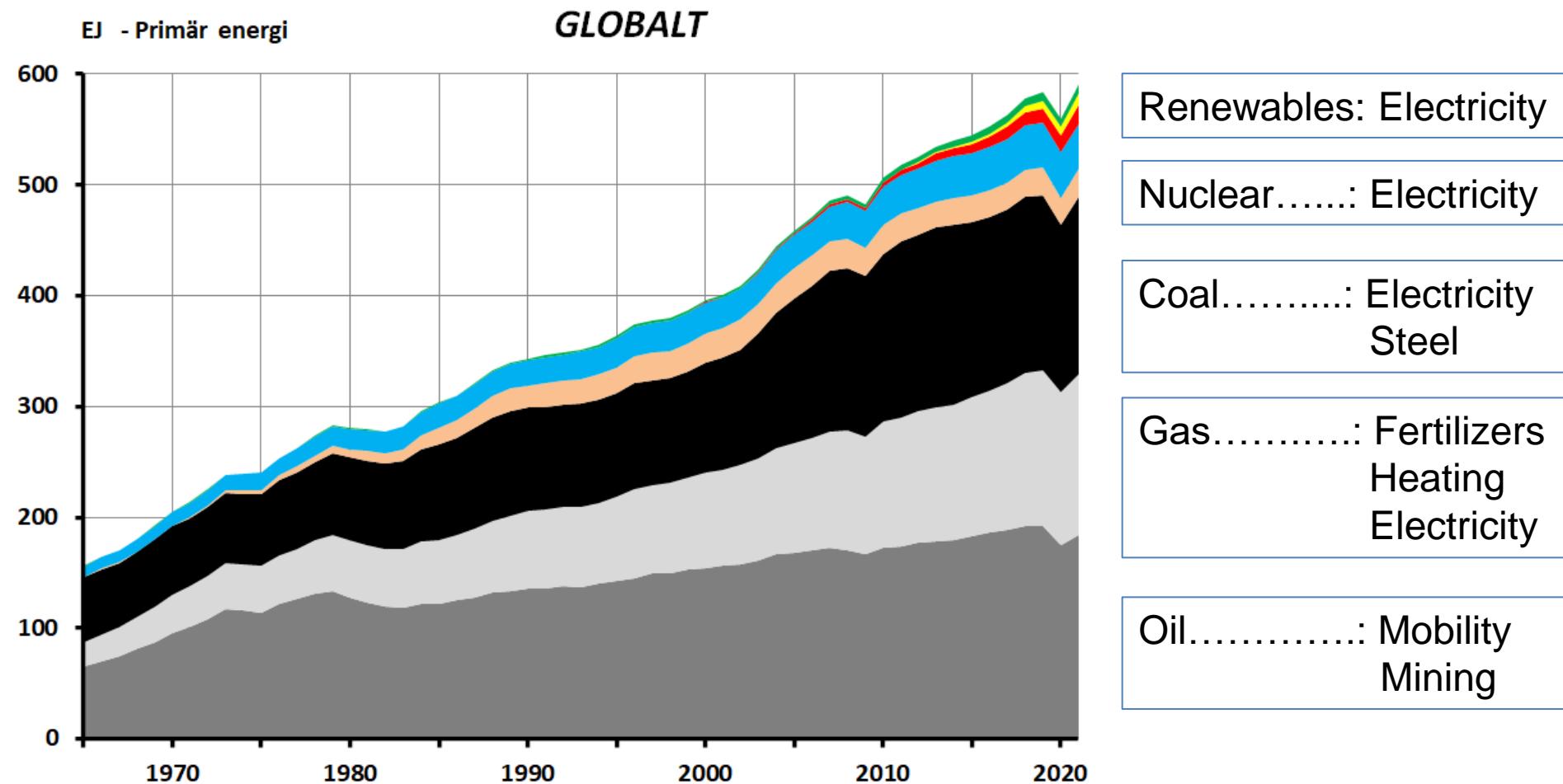
Källa: *BP Statistical Review of World Energy 2022*

Sweden – 10 millions



Källor: BP Statistical Review of World Energy 2022

Energy, but of diffent kind



Källa: *BP Statistical Review of World Energy 2022*

Oil is more than energy

Adhesive	Fan belts	Luggage	Skis
Air mattresses	Fishing boots	Model cars	Soft contact lenses
Antifreeze	Floor wax	Motorcycle helmets	Solar panels
Antiseptics	Food preservatives	Movie film	Solvents
Asphalt	Footballs	Nail polish	Sports car bodies
Aspirin	Fuel tanks	Noise insulation	Sunglasses
Backpacks	Glue	Nylon rope	Swimming pools
Balloons	Golf bags	Oil filters	Synthetic rubber
Boats	Golf balls	Paint brushes	Telephones
Cameras	Guitar strings	Pajamas	Tents
Candies	Hand lotion	Parachutes	Tires
Car battery cases	Hearing aids	Perfumes	Tool boxes
Cell phones	Heart valves	Pharmaceuticals	Toothbrushes
Clothes	House paint	Plastics	Toothpaste
Computer keyboards	Ink	Plywood adhesive	Transparent tape
Computer monitors	Insecticides	Roller skate wheels	Trash bags
Cortisone	Insulation Kayaks	Roofing	Truck parts
Credit cards	Laptops	Rubber cement	Tubing
Dashboards	Life jackets	Safety glasses	TV cabinets
Deodorant	Light-weight aircraft	Shampoo	Umbrellas
Electric blankets	Lipstick	Shoes	Vinyl flooring
Enamel	Loudspeakers	Shower curtains	Water pipes
Eyeglasses	Lubricants	Skateboards	Wind turbine blades

Oil is more than energy

Adhesive	Fan belts	Luggage	Skis
Air mattresses	Fishing boots	Model cars	Golf contact lenses
Antifreeze	Floor wax		Car panels
Antiseptics			Events
Asphalt			Parts car bodies
Aspirin			Sunglasses
Backpacks			Swimming pools
Balloons			Synthetic rubber
Boats	Golf balls	Paint brushes	Telephones
Cameras	Guitar strings	Pajamas	Tents
Candies	Hand lotion	Parachutes	Tires
Car battery cases	Hearing aids	Perfumes	Boxes
Cell phones	Heart valves		Rushes
Clothes			Gum paste
Computer keyboards			Transparent tape
Computer monitors			Trash bags
Cortisone			Truck parts
Credit cards			Tubing
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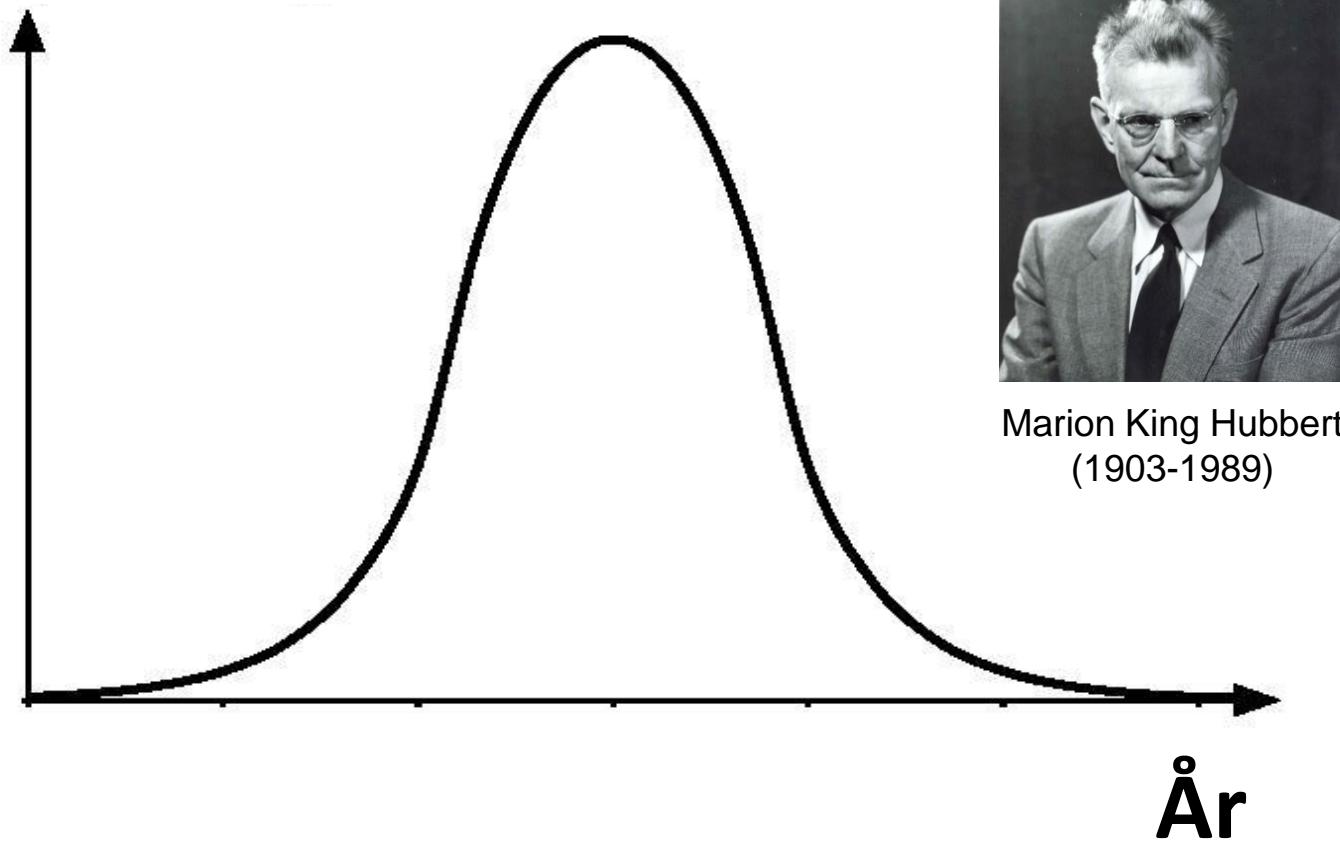
All of them are not necessary,
but many are vital for our society.

Most of them can not easily
be made from other sources.

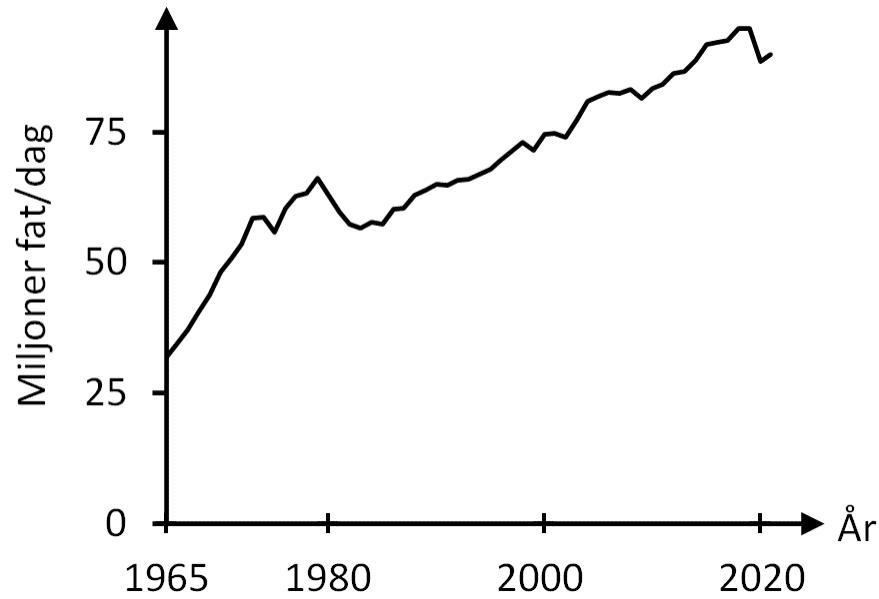
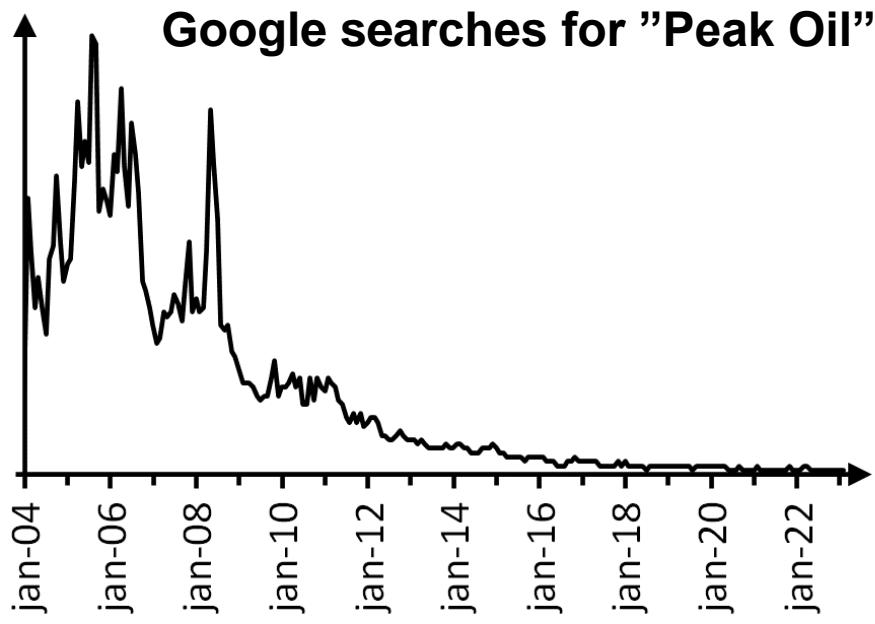
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Peak Oil

Oil production



A false alarm?



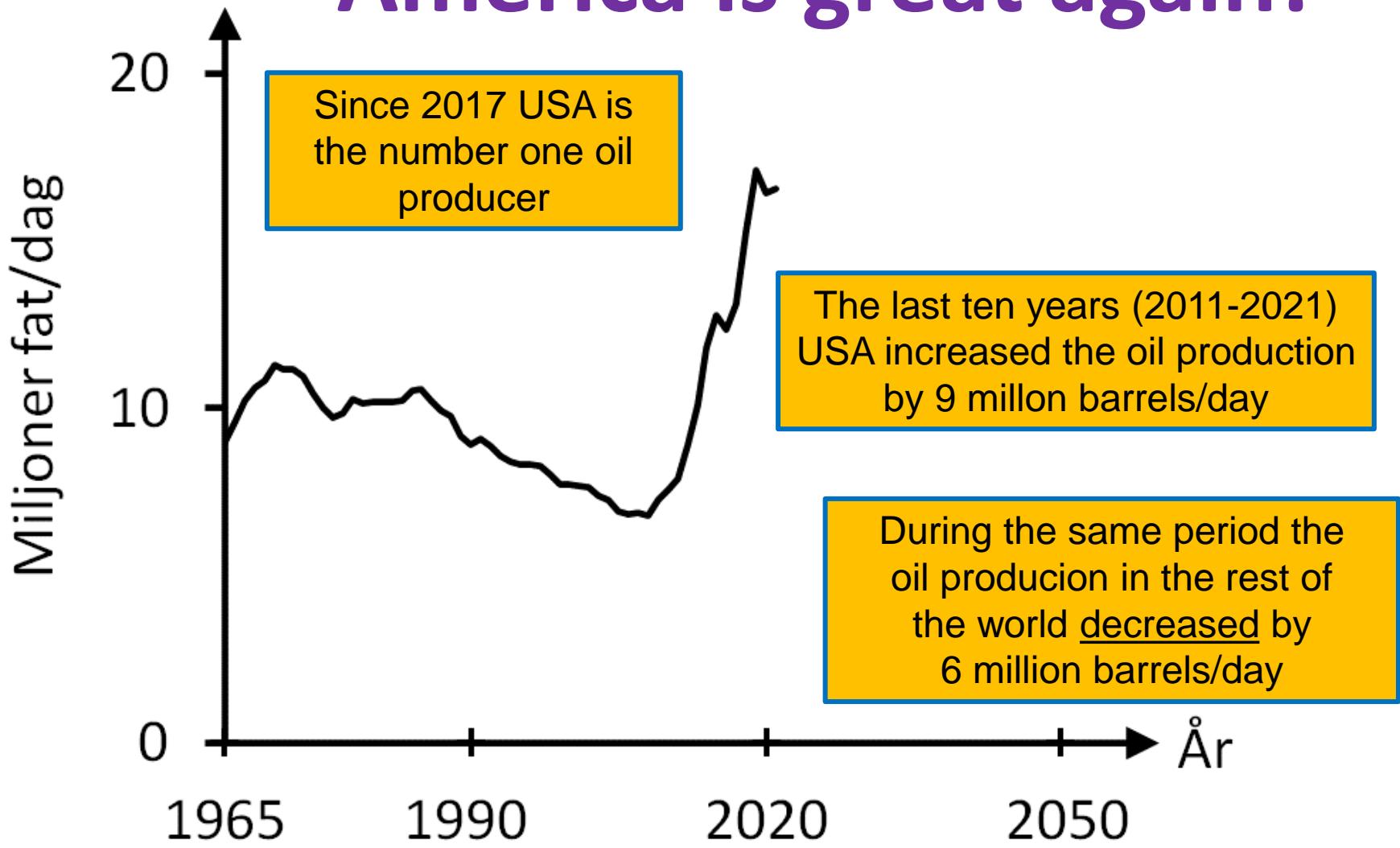
The interest for "Peak Oil" has reached a peak.

Until 2019 no signs of a peak.

--
Covid-19 was a temporary disturbance?

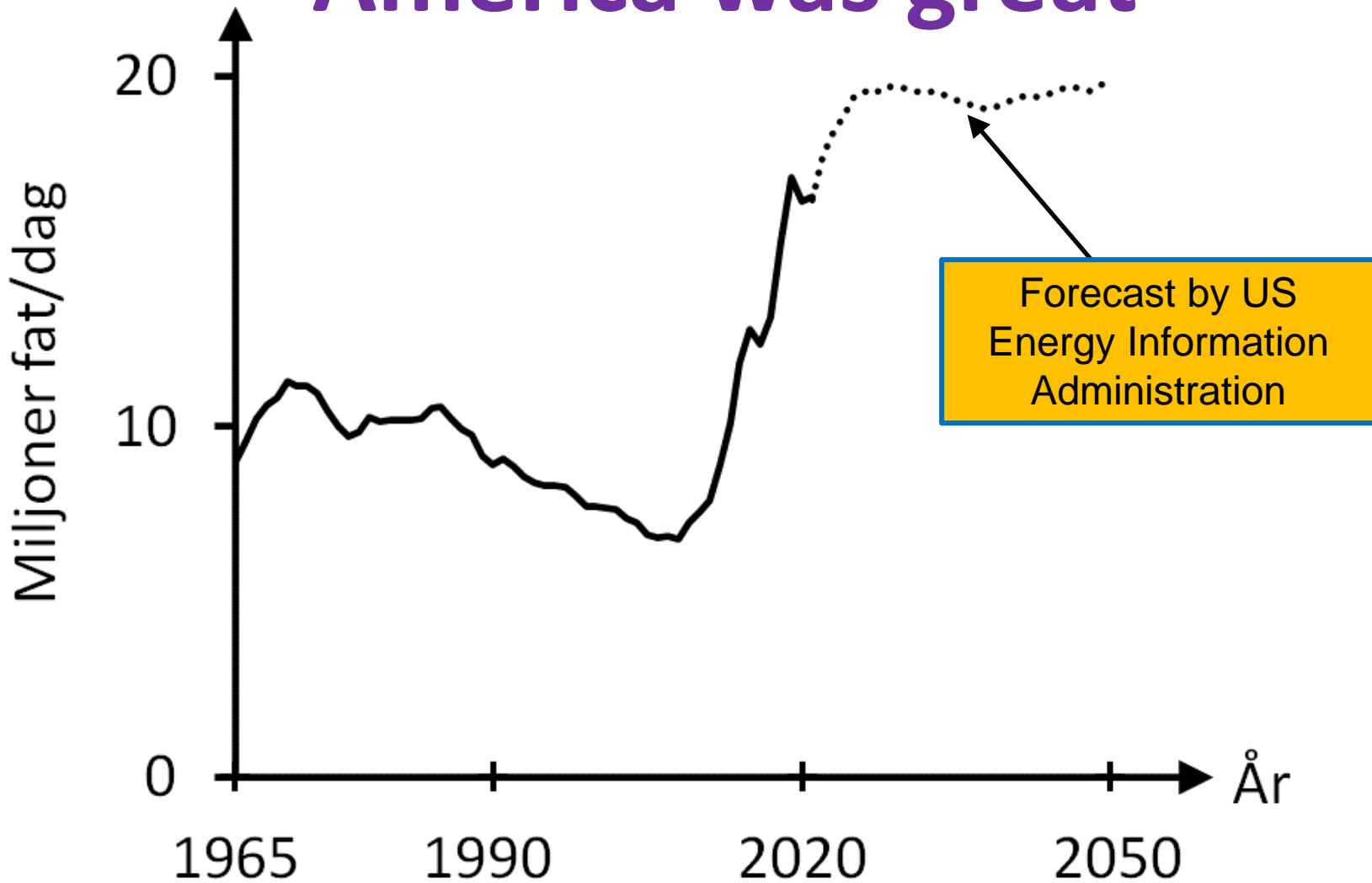
Källor: *BP Statistical Review of World Energy 2022* och *Google Trends*

America is great again!



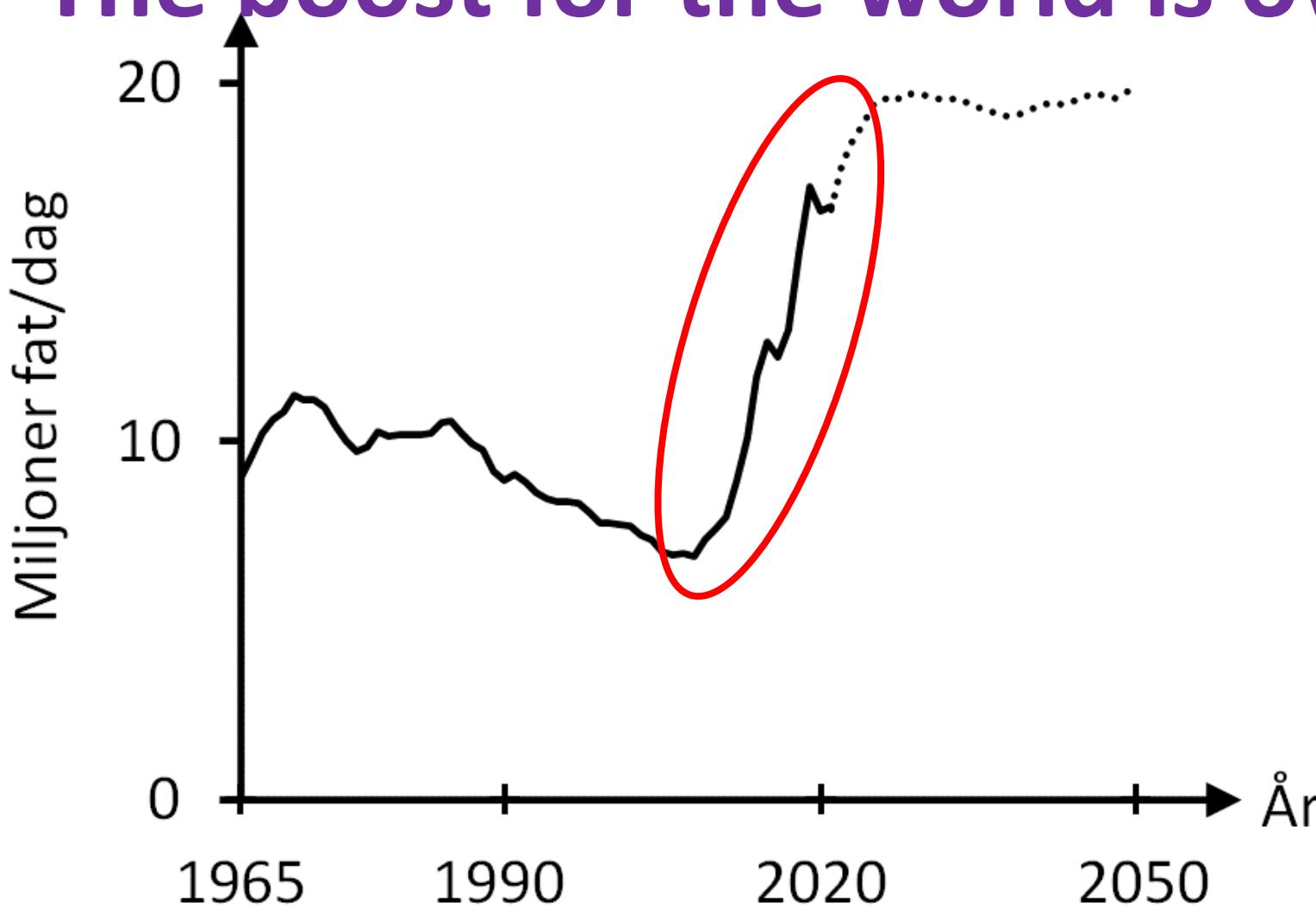
Källa: *BP Statistical Review of World Energy 2022*

America was great



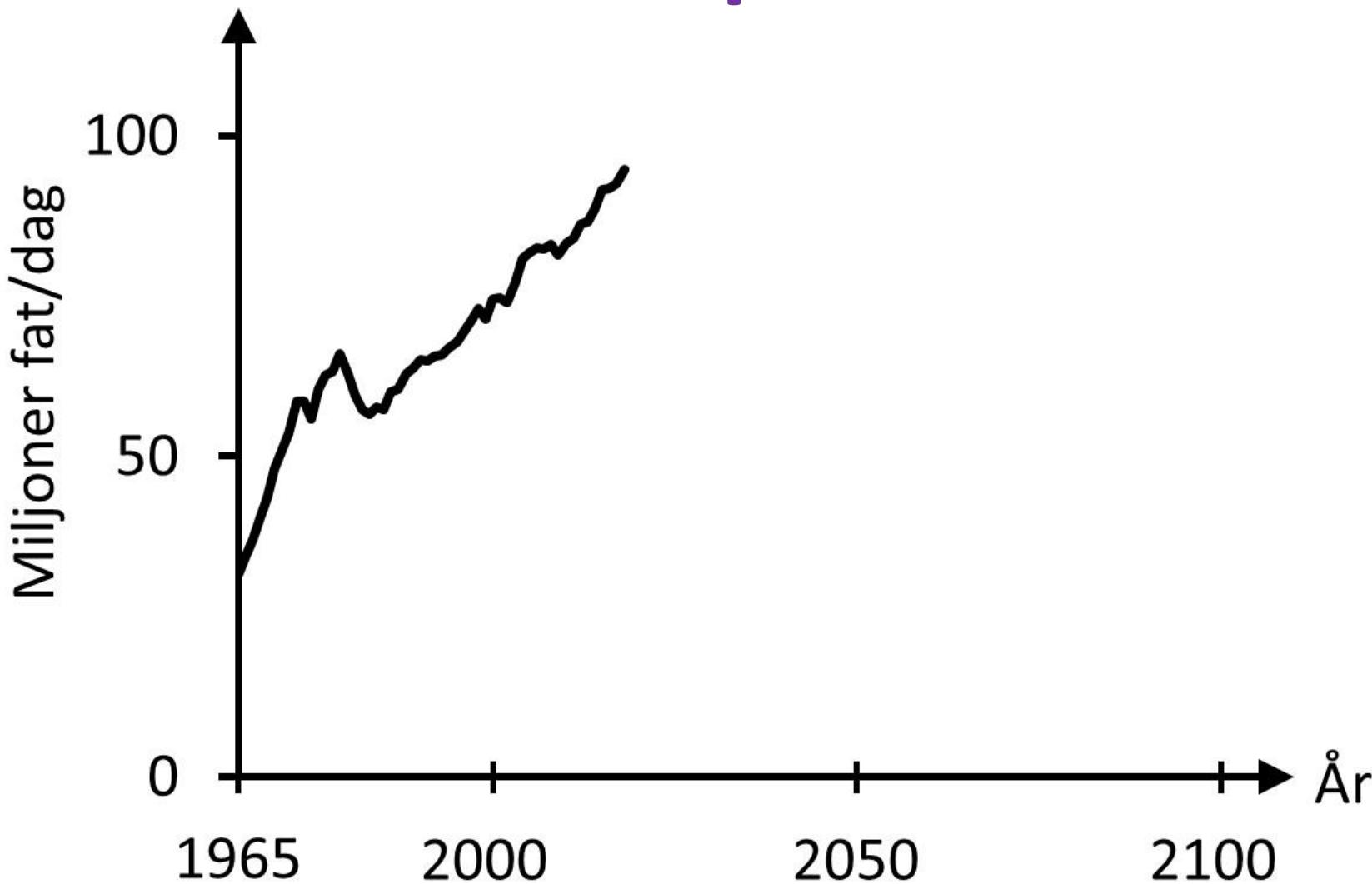
Källor: *BP Statistical Review of World Energy 2022* och
EIA, Annual Energy Outlook 2022 with projections to 2050

The boost for the world is over



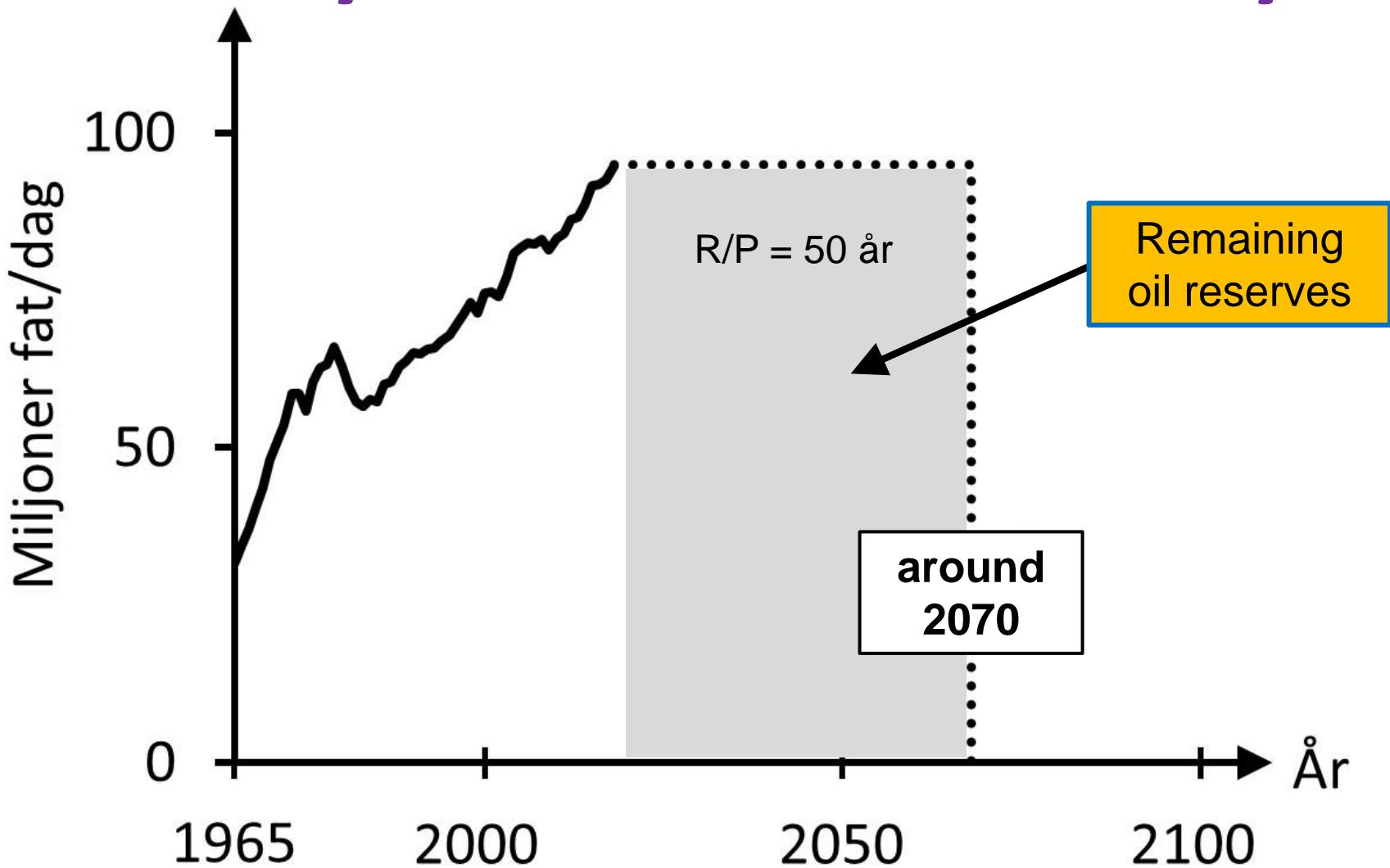
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Global oil production



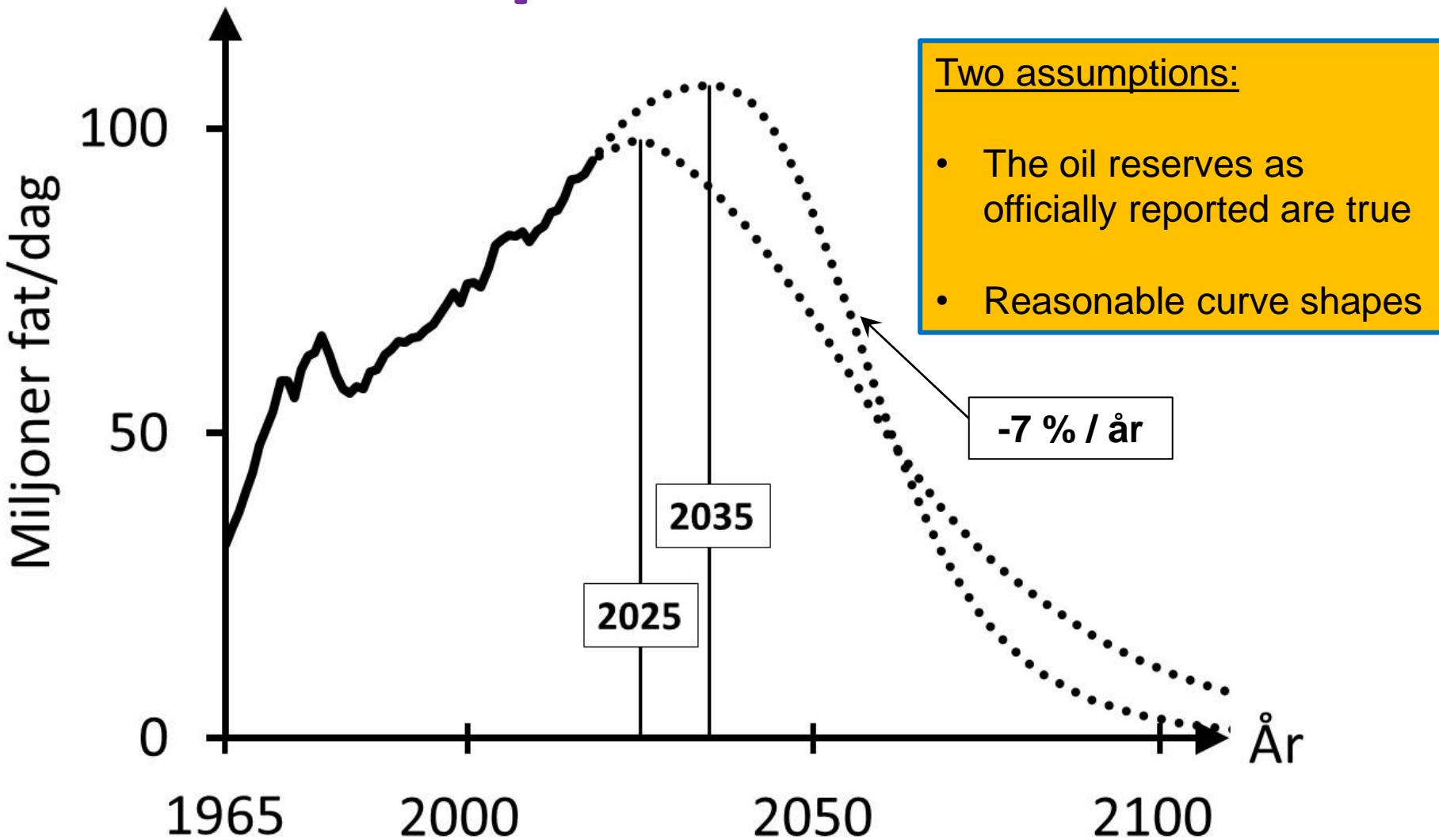
Källa: *BP Statistical Review of World Energy 2019*

On todays level – another 50 year?



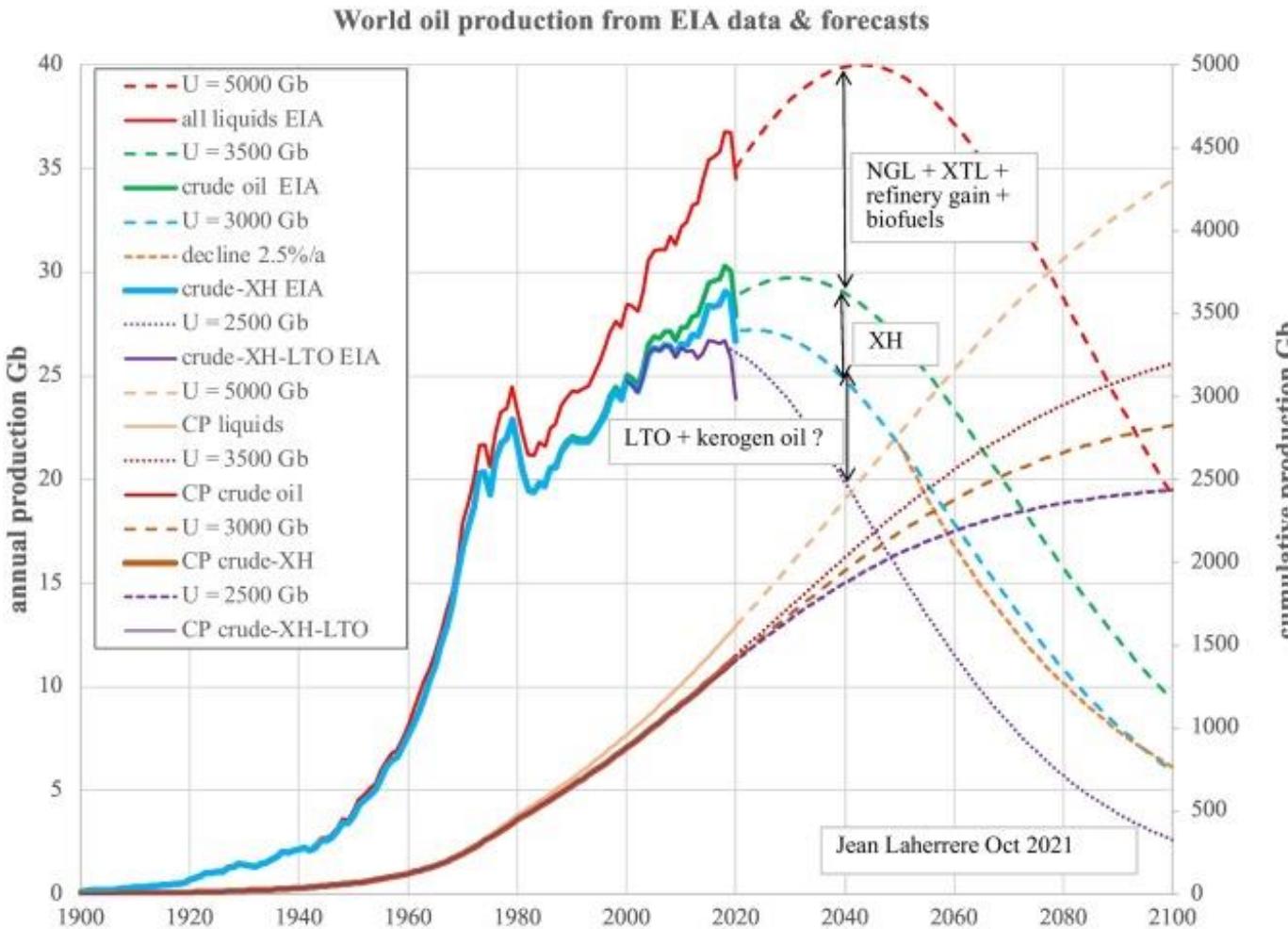
Källa: *BP Statistical Review of World Energy 2019*

Two possible cases



Källa: *BP Statistical Review of World Energy 2019*

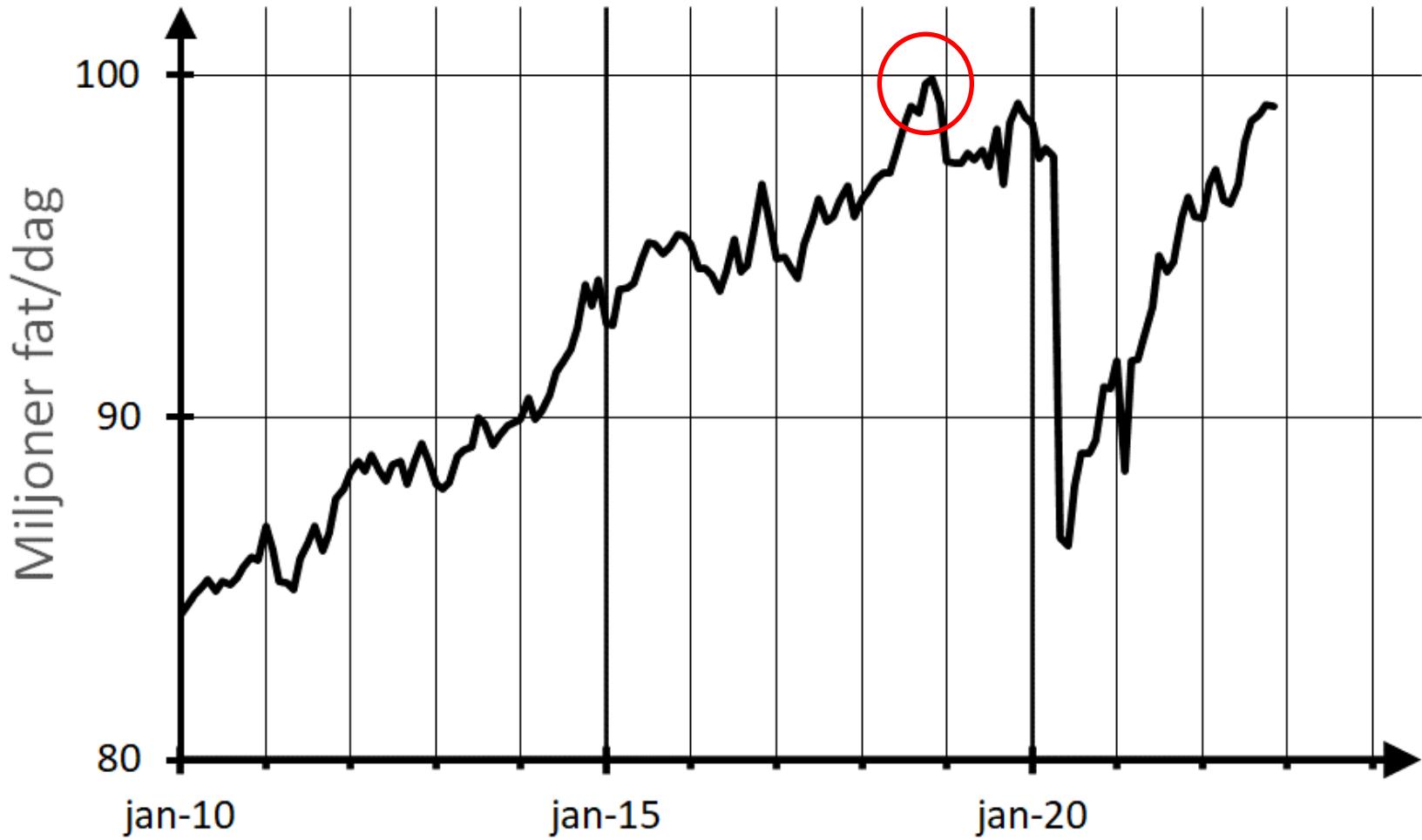
The same message ...



The peak
estimated to be
in the interval:
2020 - 2040

Källa: Jean Laherrère et. al: *How much oil remains for the world to produce? Comparing assessment methods, and separating fact from fiction.*

The most recent picture



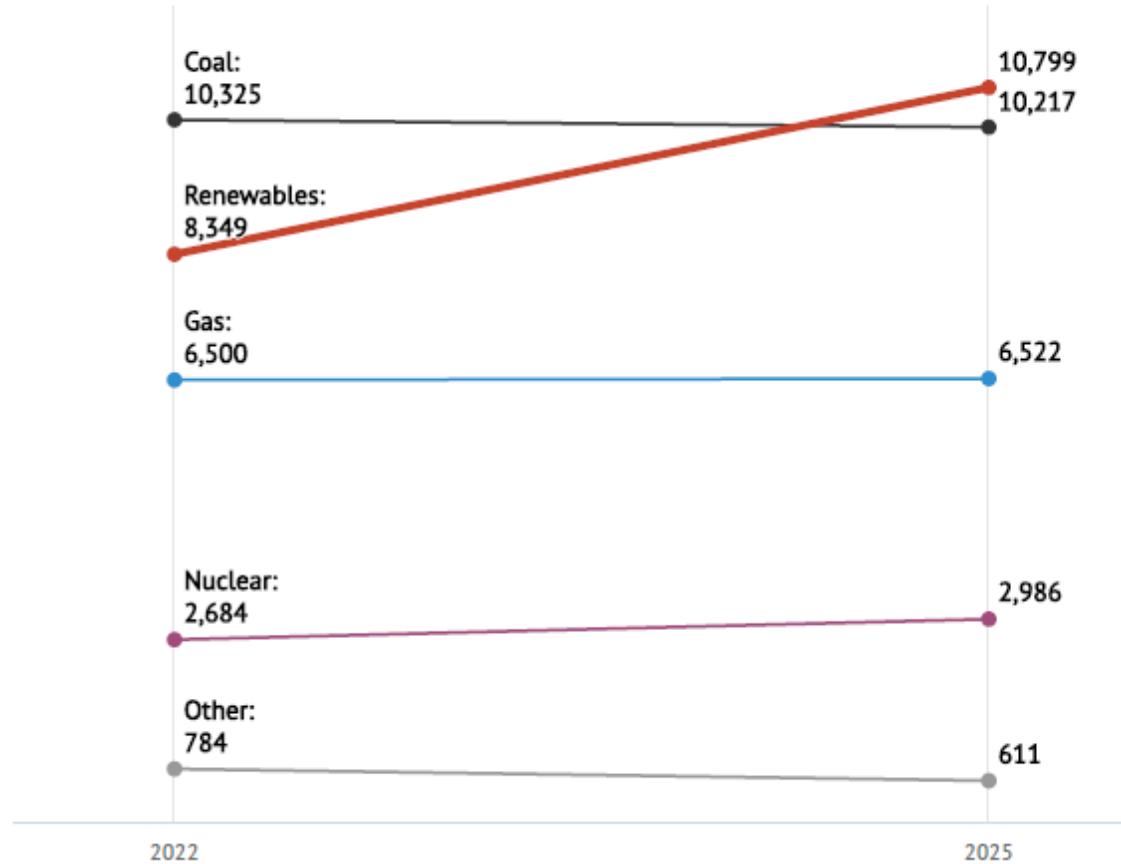
Källa: U.S. Energy Information Administration (data t.o.m. november-2022)

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IEA shows a green future

Renewables will become world's largest electricity source within three years, IEA data reveals

Global electricity generation by source, 2022-2025, TWh

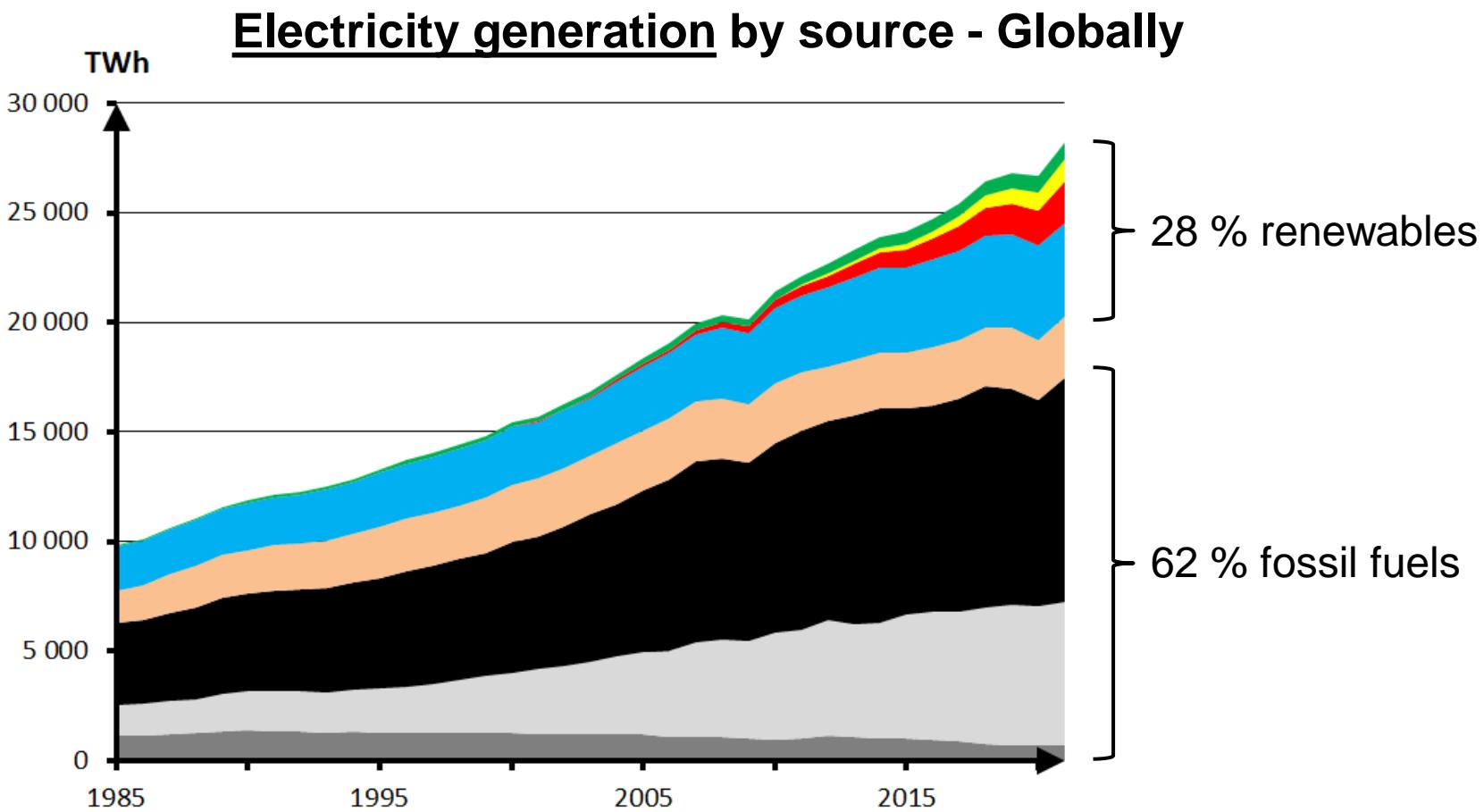


Källa: IEA: Electricity Market Report 2023

Stellan Tengroth

www.tillvaxtreflektora.se

Where we stand today – 2021

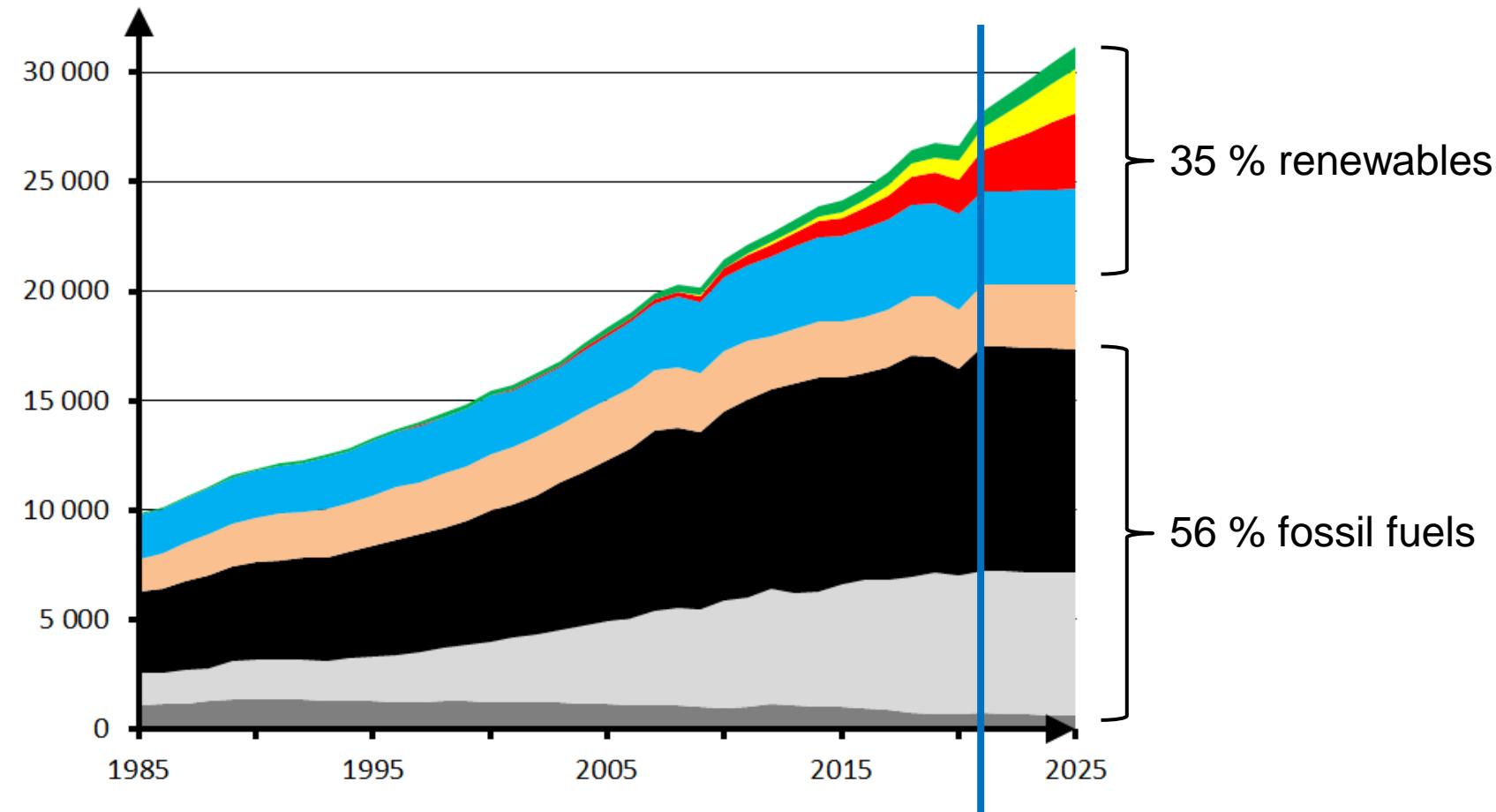


Källa: *BP Statistical Review of World Energy 2022*

IEA:s prediction – 2025

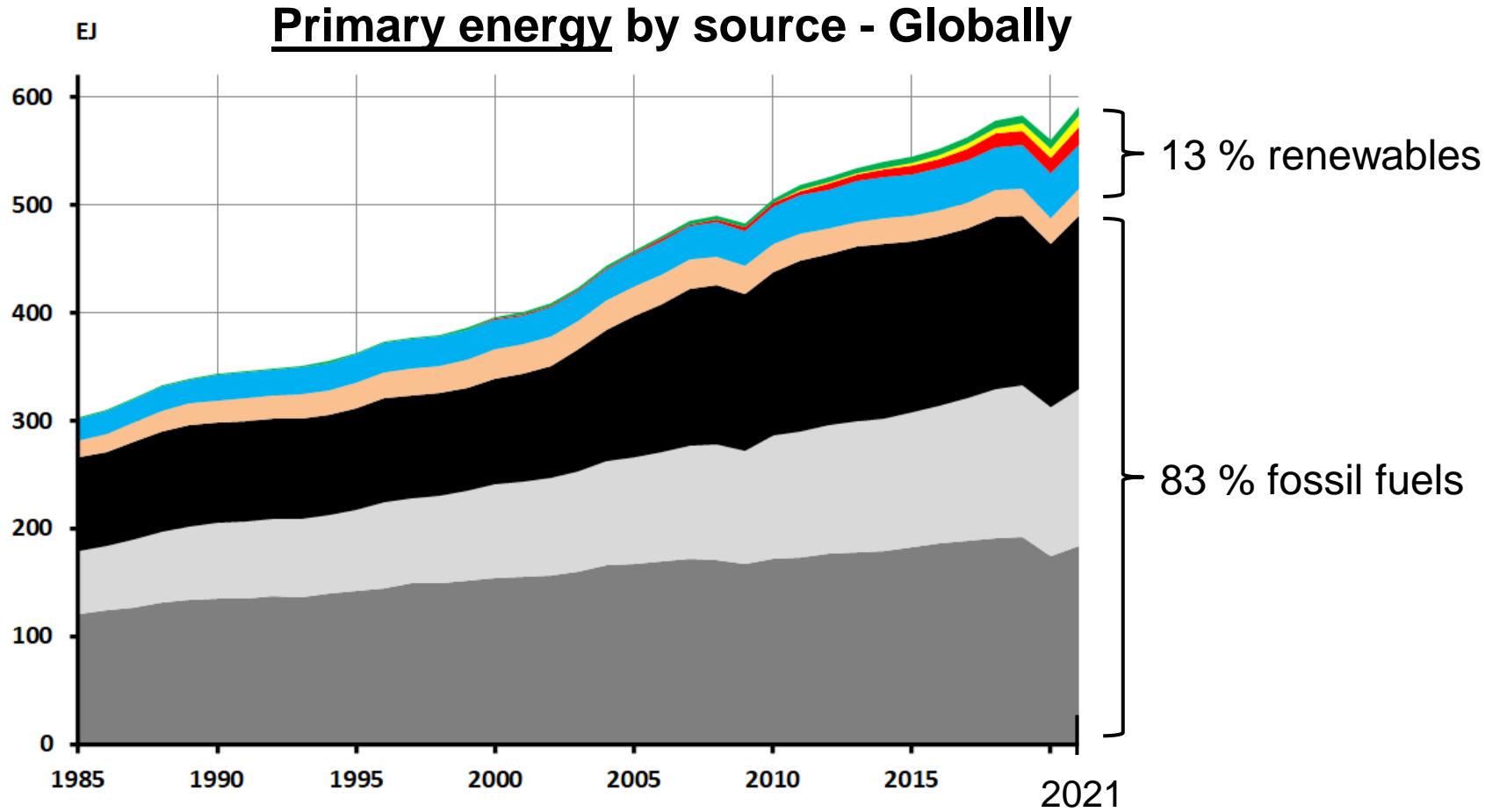
TWh

Electricity generation by source - Globally



Källa: *BP Statistical Review of World Energy 2022*

Electricity is only part of the story

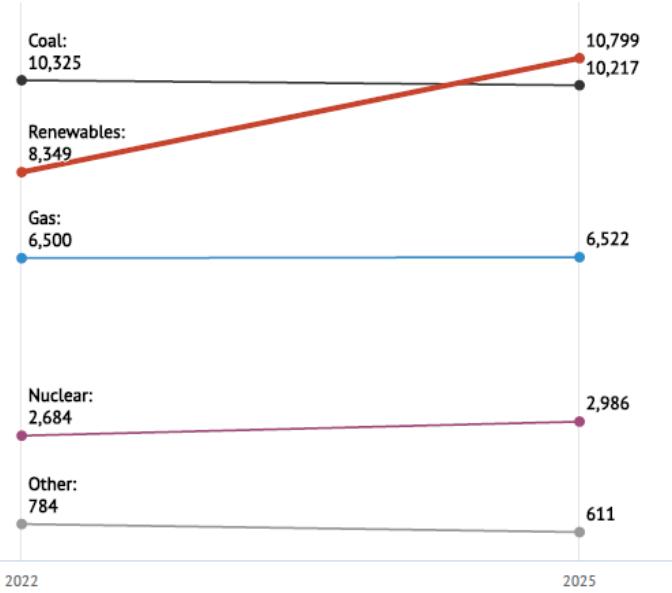


Källa: *BP Statistical Review of World Energy 2022*

Sorry IEA – it's not enough

Renewables will become world's largest electricity source within three years, IEA data reveals

Global electricity generation by source, 2022-2025, TWh



- It's possible that hydro, wind, sun and bioenergy together will overtake coal as the main source for electricity.
- But, this is of minor importance when fighting global warming.
- And, it's not enough to avoid the consequences of "peak fossil"

Källa: IEA: Electricity Market Report 2023

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Exponential growth of renewables?

Global level		
	Part of energy mix 2021	Annual growth 2016-2021
Wind energy	3,0 %	14 %
Solar energy	1,6 %	25 %

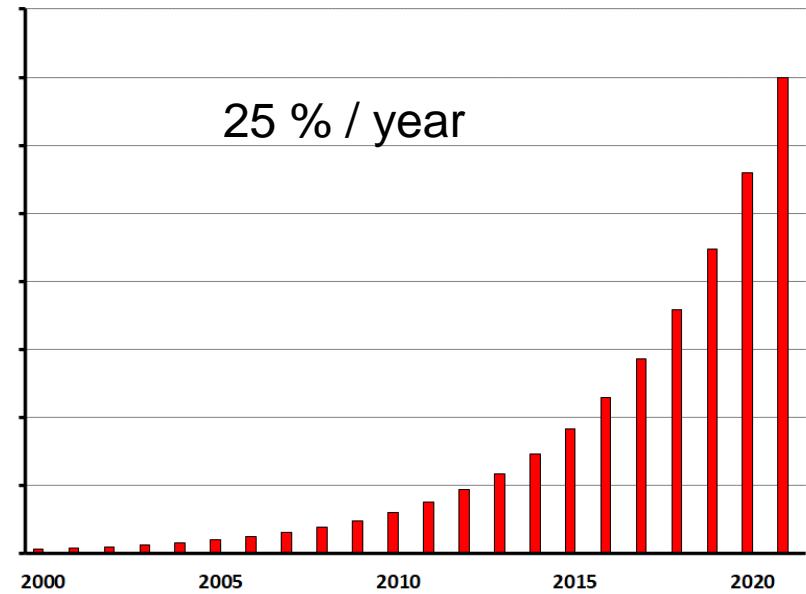
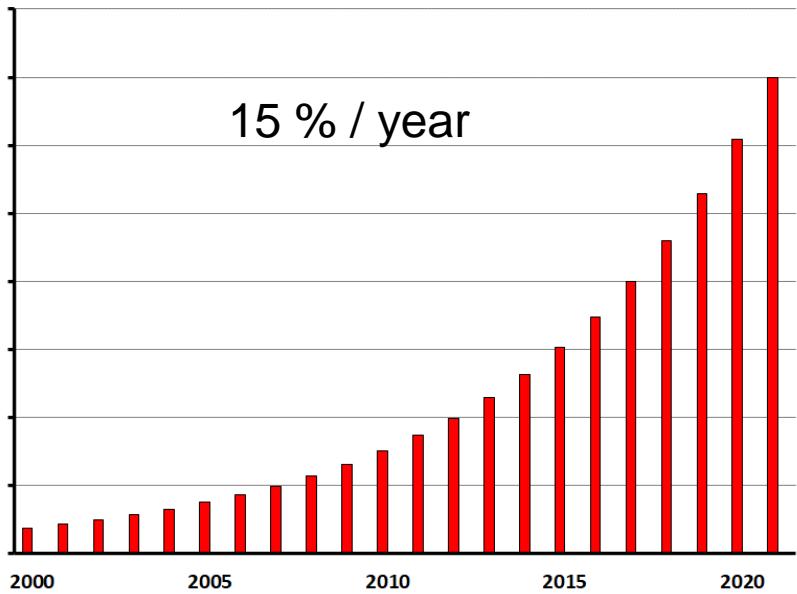
If this growth would be sustainable all our problems would be solved.

Källa: *BP Statistical Review of World Energy 2022*

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Exponential curves

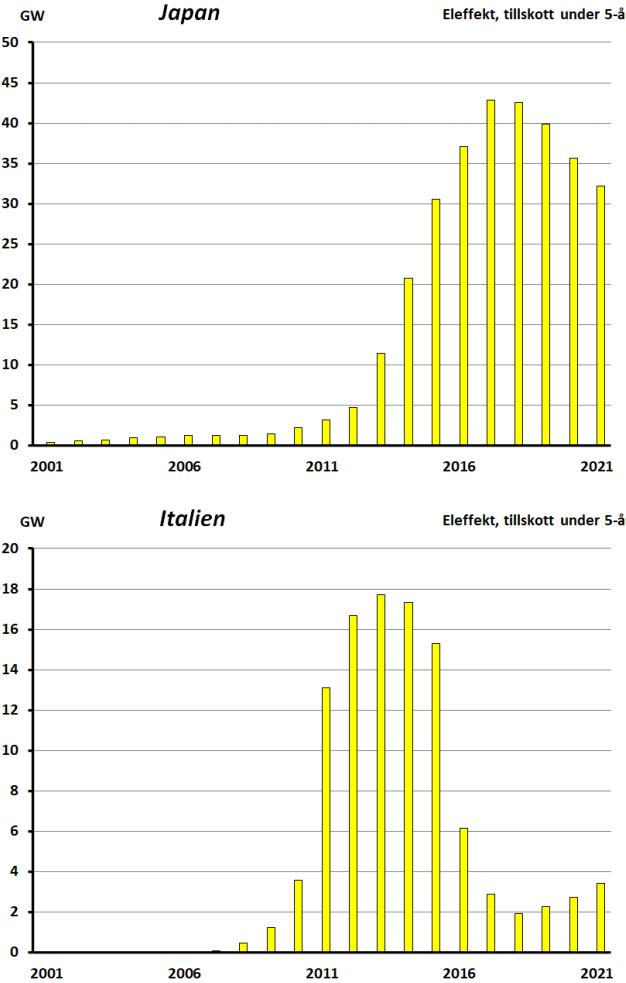


Shapes describing exponential growth

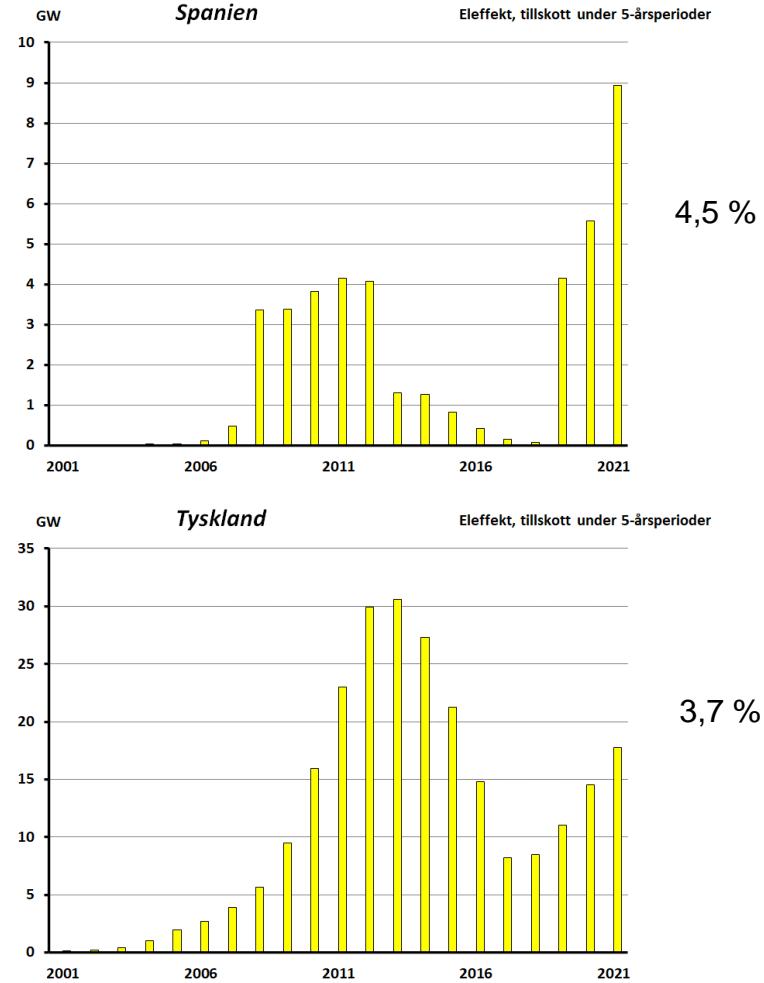
Where the solar energy is mature

Four countries with a large amount of solar energy

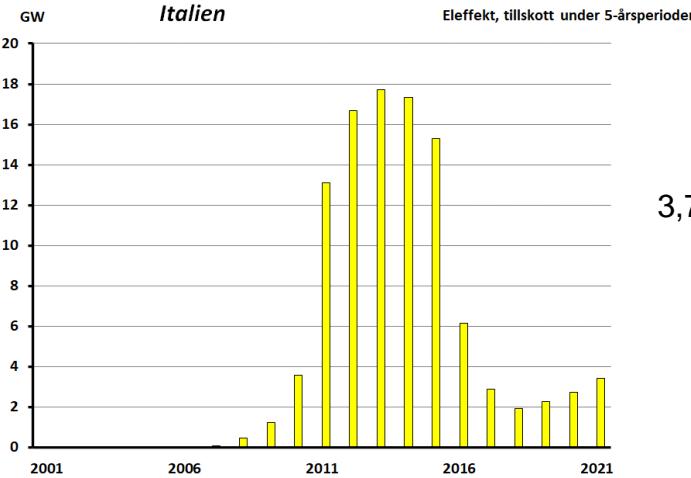
Increase in installed power during periods of 5 years



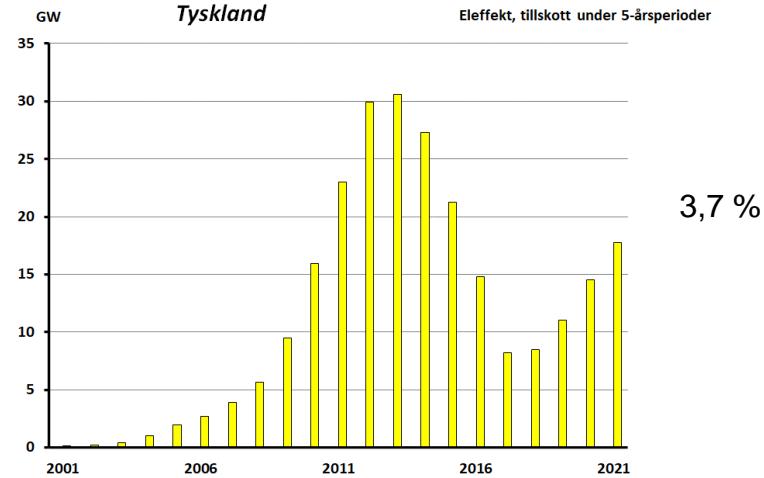
4,6 % of
energy mix



4,5 %



3,7 %



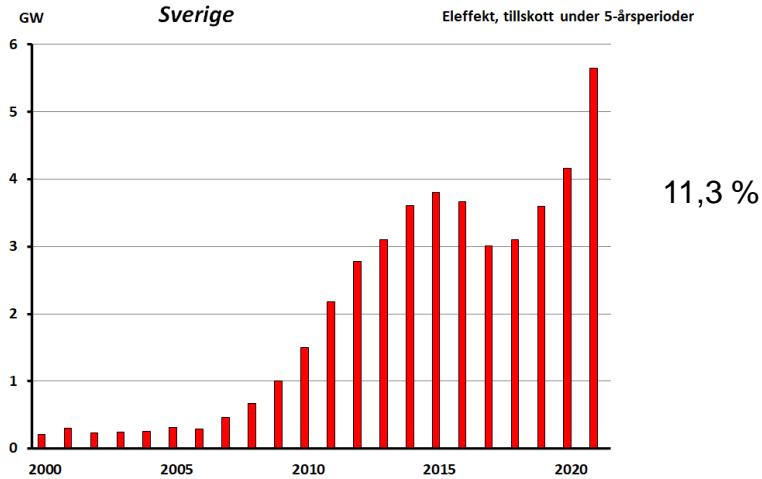
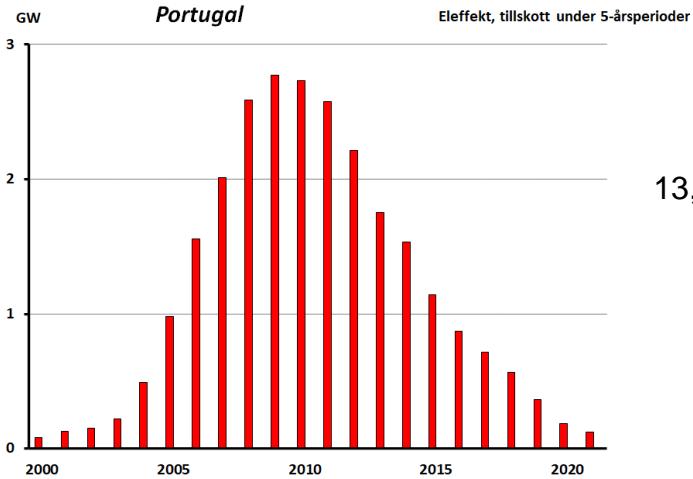
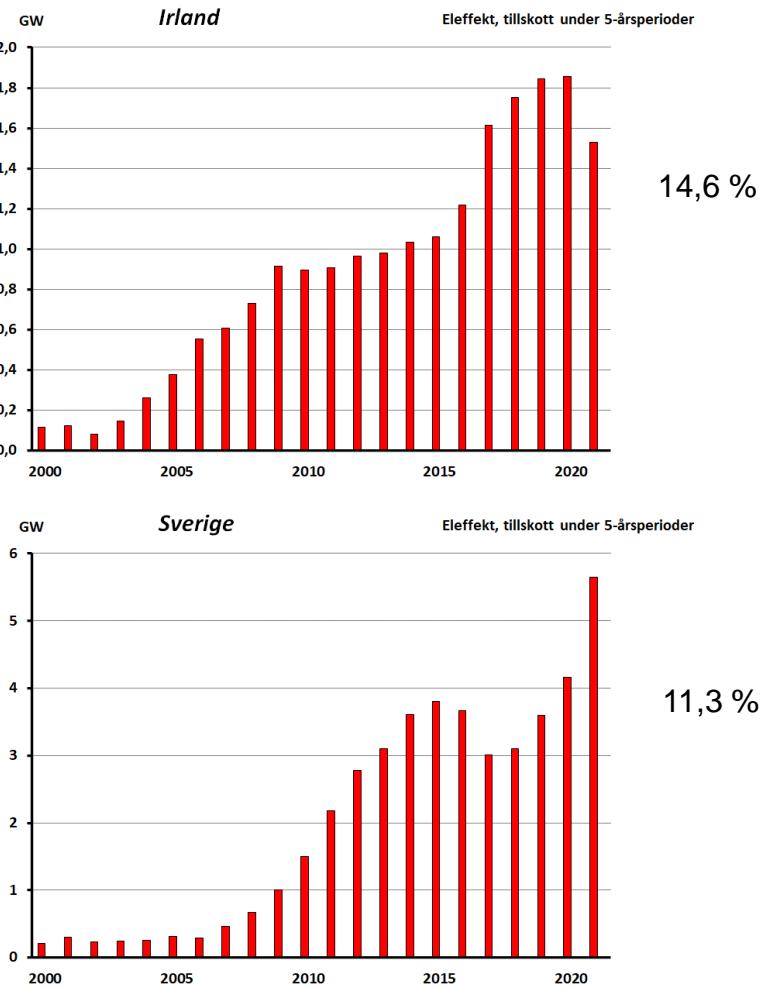
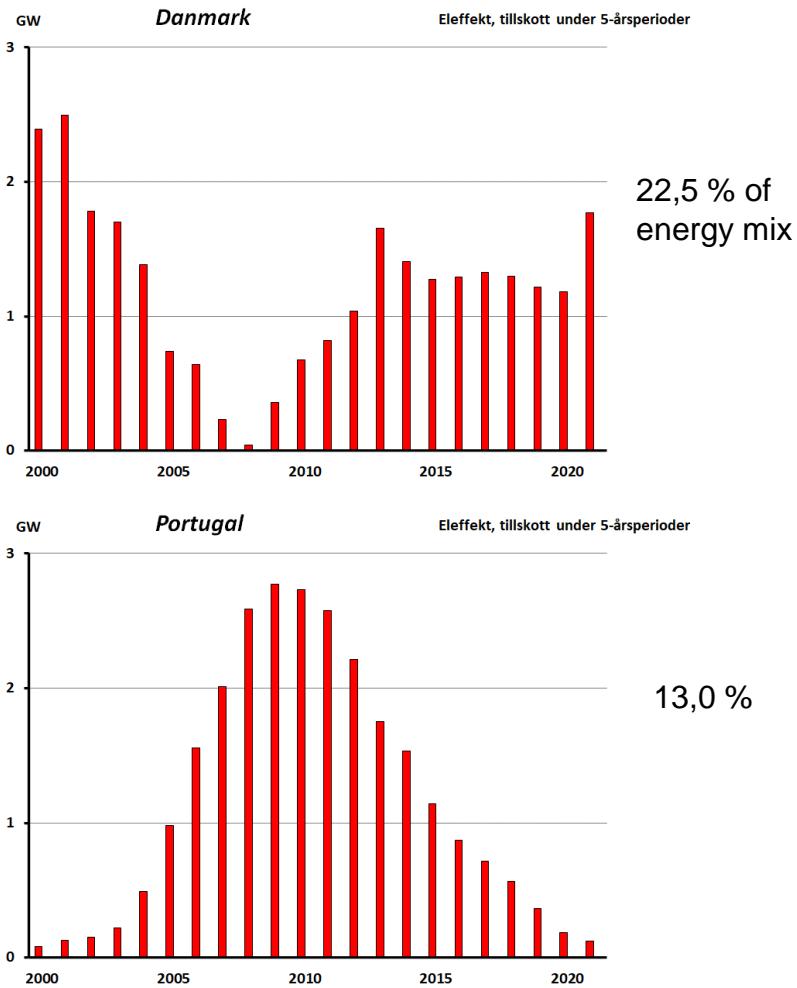
3,7 %

Källa: BP Statistical Review of World Energy 2022

Where the wind blows

The four countries with most wind in their energy mix

Increase in installed power during periods of 5 years



Källa: BP Statistical Review of World Energy 2022

Exponential growth doesn't last

- The observed expansions of wind and solar doesn't indicate any strong positive feedbacks.
- On the contrary, it's easy to find negative feedbacks:
 - The intermittent delivery of electric power.
 - The best locations are taken first. With low cost and less conflicts with people, environment and other activities.
 - Subsidies from the government is a negative feedback (tend to decrease over time).
 - Sun and wind require a lot of raw material. Will sooner or later be a problem.
- As expected: the same pattern as for the rabbits.

Electricity can't be stored

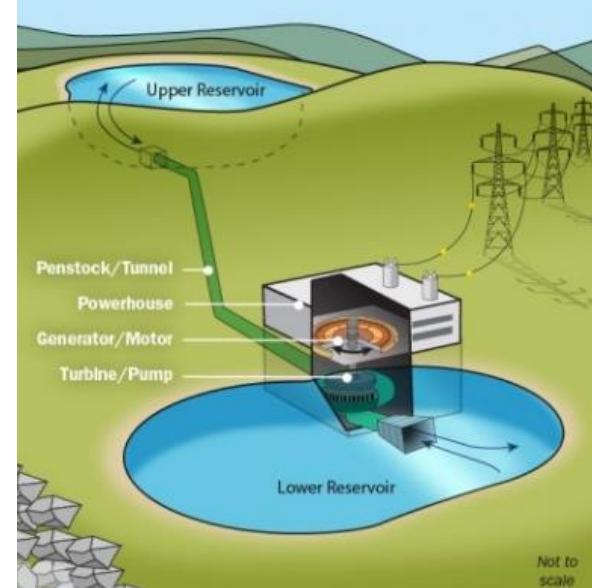
The generated power must always match the consumption.

Storage can be obtained by converting the energy to another form.

- Batteries or hydrogen are two possibilities.
 - Today in minor scale.
 - Uncertain if they can be scaled up.

The no.1 storage method

- 95 % of all storage in the world is pumped storage hydropower.
- It's a proven way to handle the variation in **demand** during the day.
- But, the storage needed to match variation in **supply** due to weather or season is a completely different task.



Storage of energy will always be a problem

Three other non-fossil

- Nuclear 4 % of the energy mix
- Hydro electric . . . 7 % ----- "
- Bio energy 1,5 % ----- "

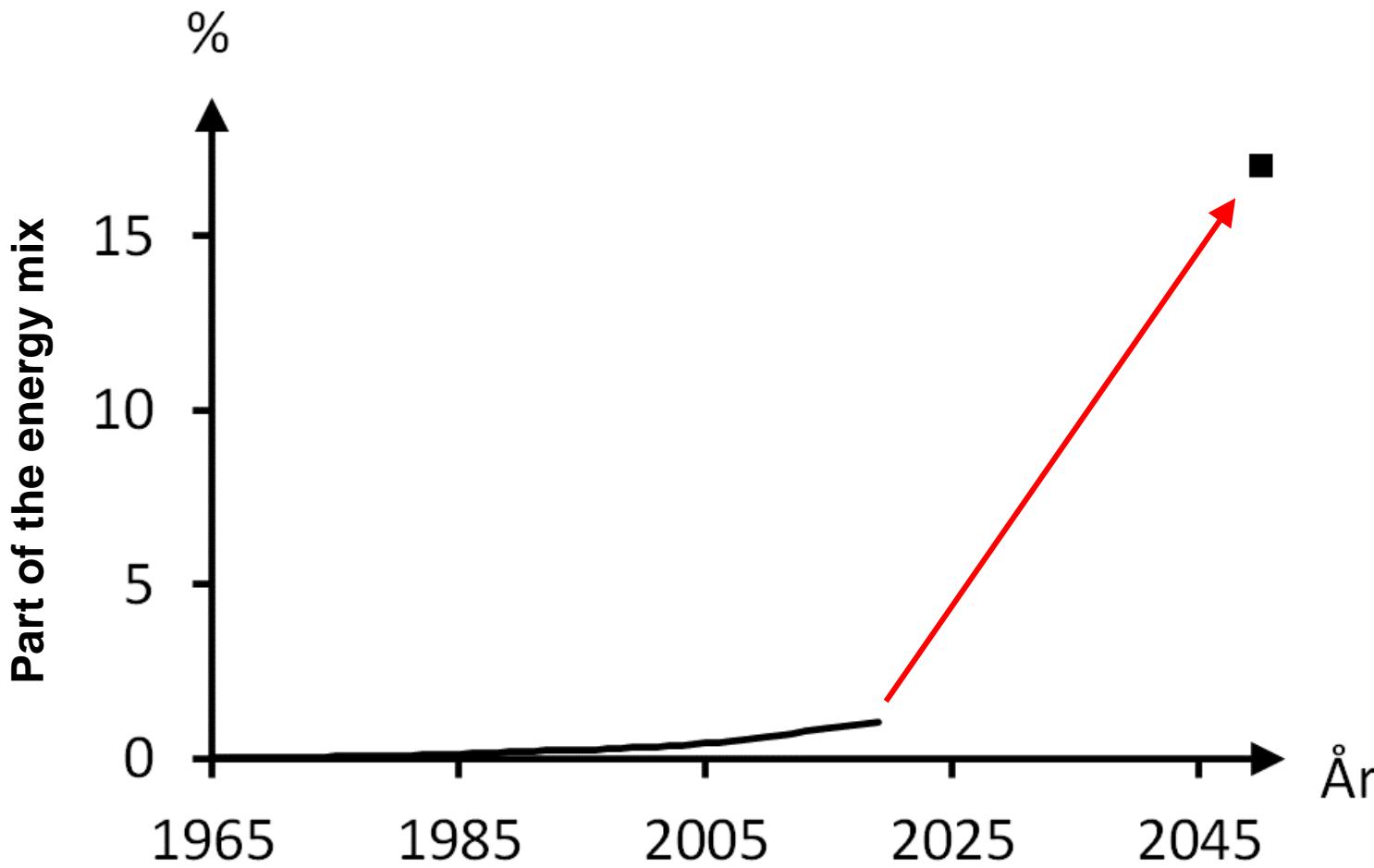
Källa: *BP Statistical Review of World Energy 2022*

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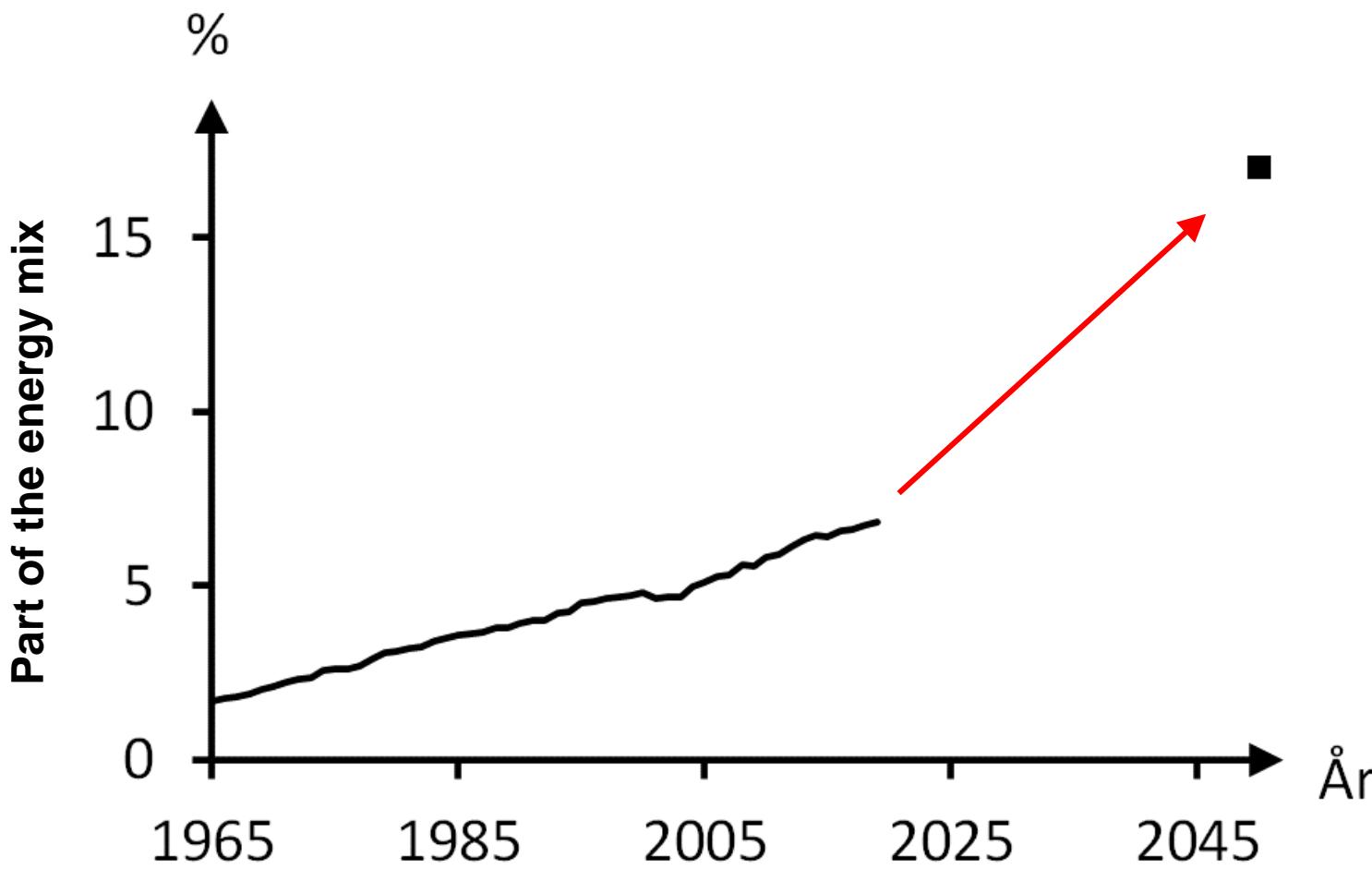
If they by 2050 could reach 15-20 % each the
"energy problem" might be close to a solution ...

Bio energy



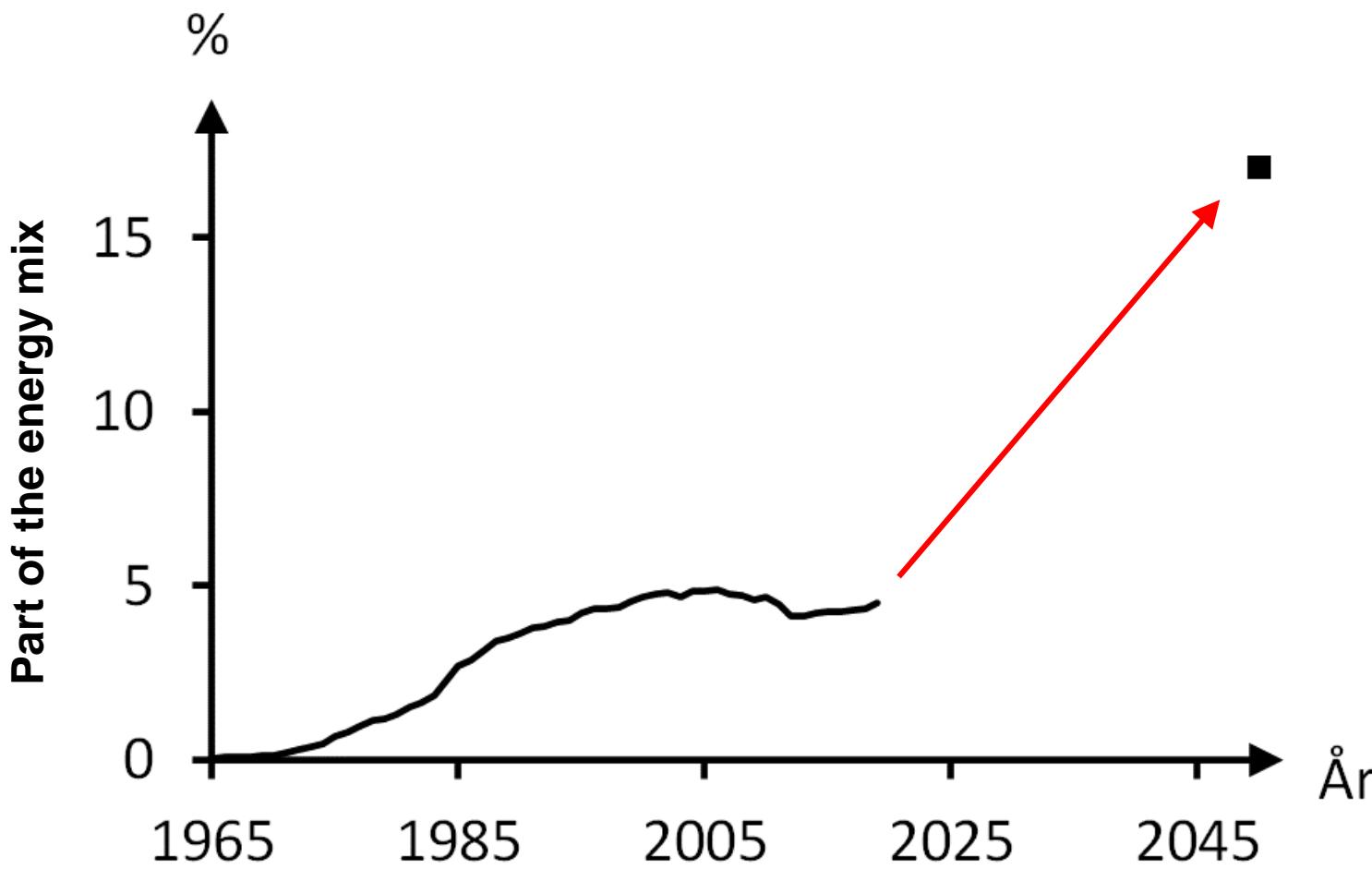
Källa: *BP Statistical Review of World Energy 2022*

Hydro electric power



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Nuclear power



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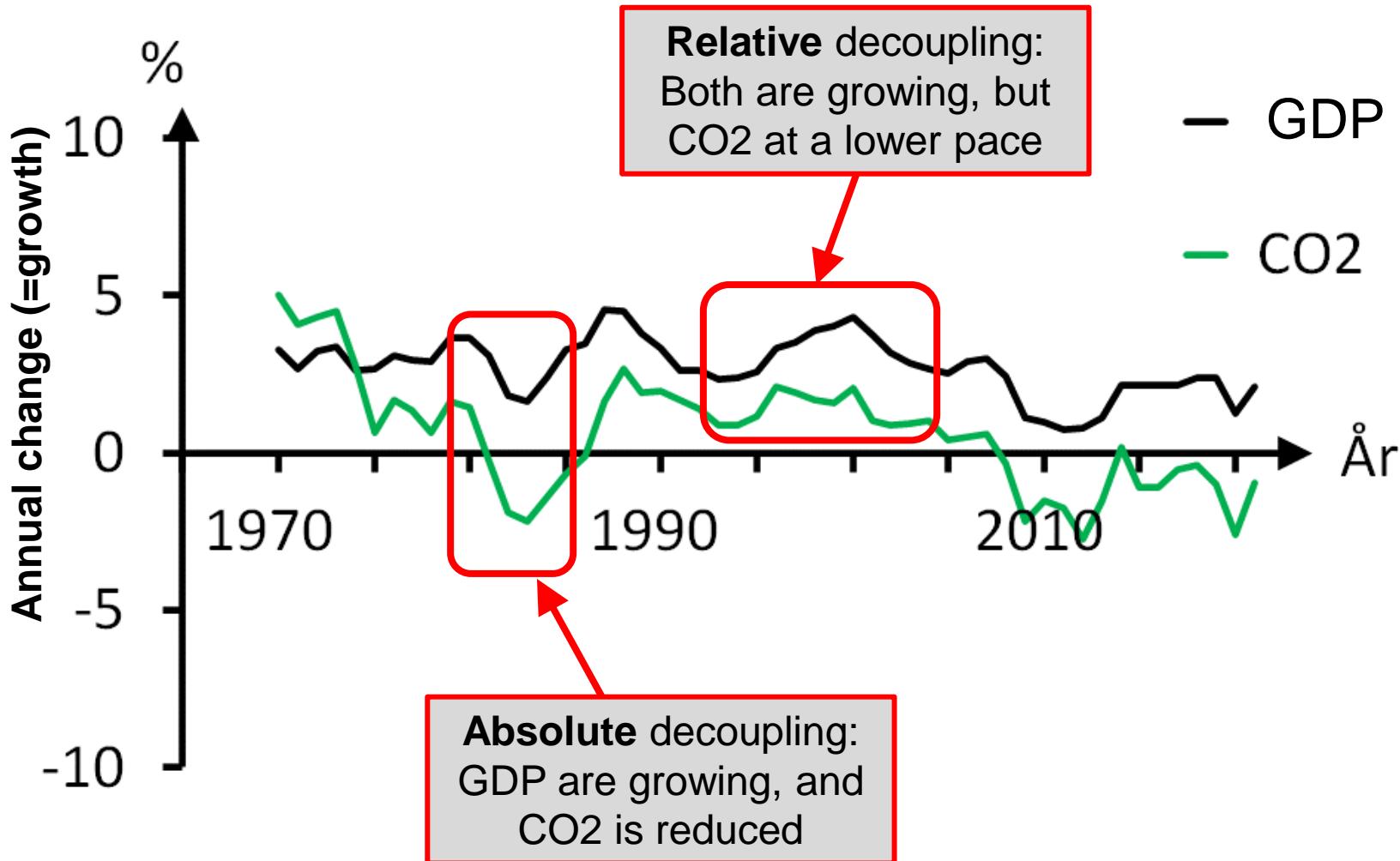
Green growth?

The idea:

Growing GDP ->
-> Technological progress ->
-> Reduce emissions

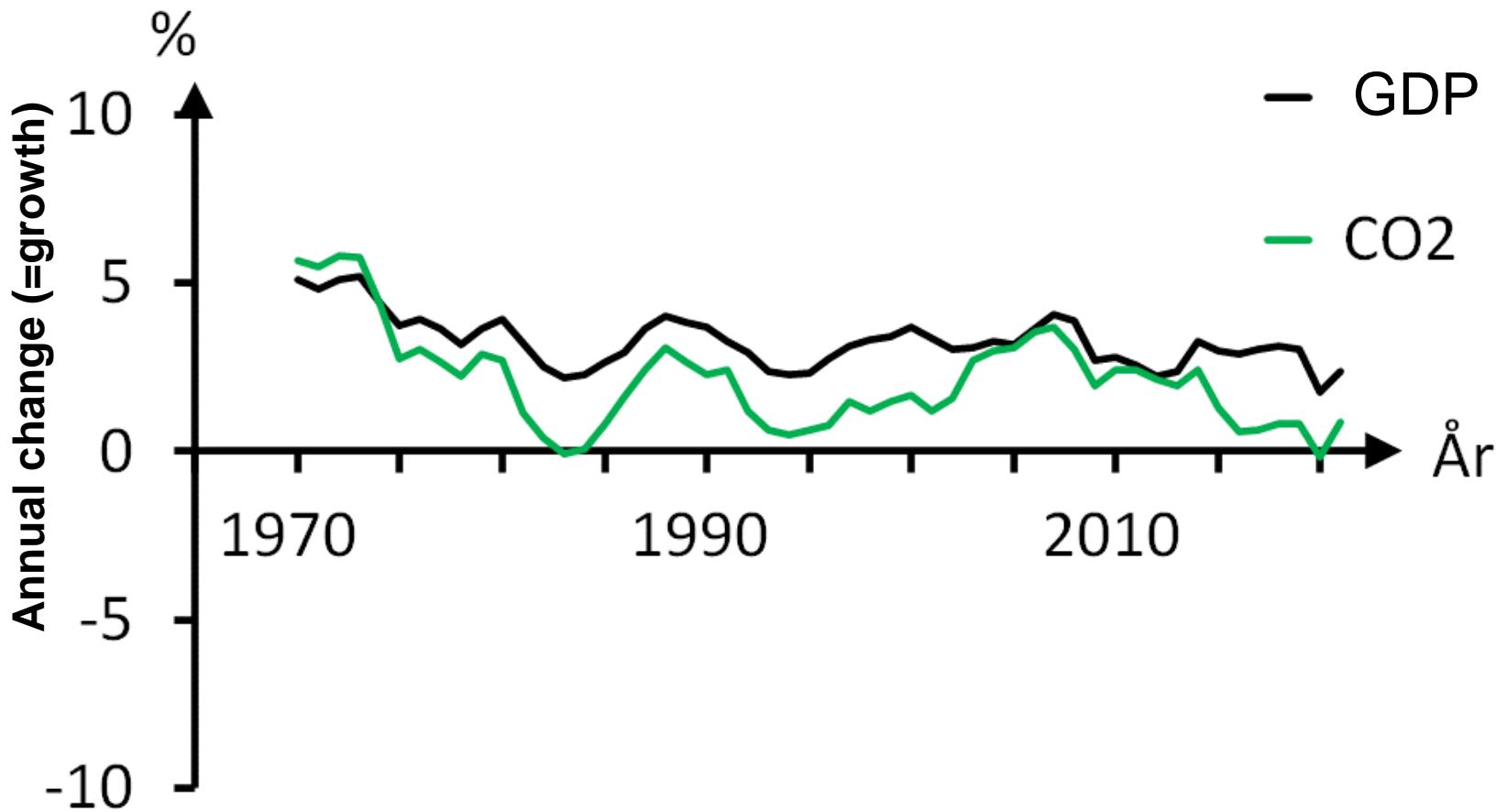
Will require a decoupling between GDP and CO₂

Two kinds of decoupling



Globally

5-years mean values



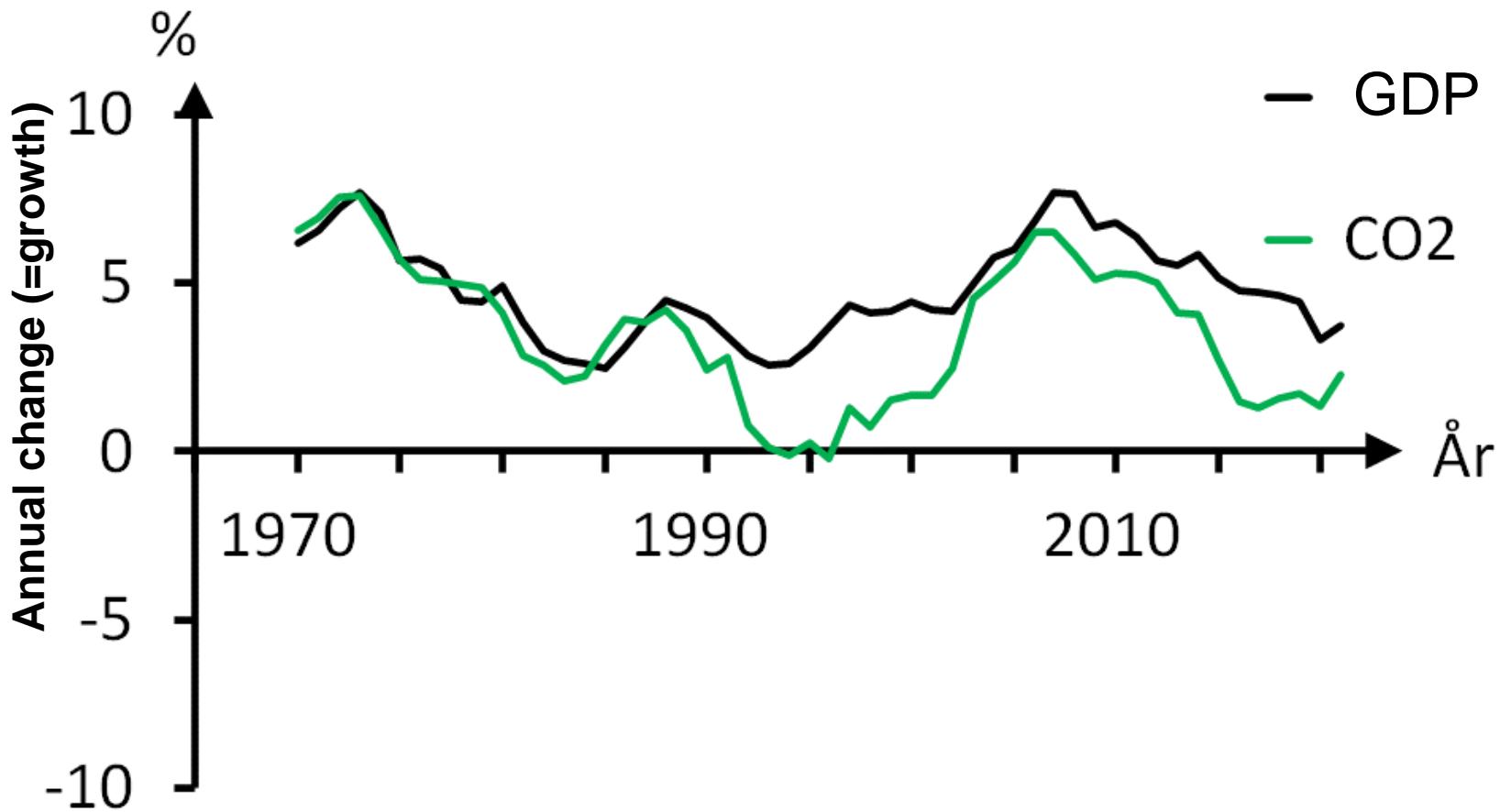
Källor: *World Bank* och *Global Carbon Project*

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Non-OECD

5-years mean values



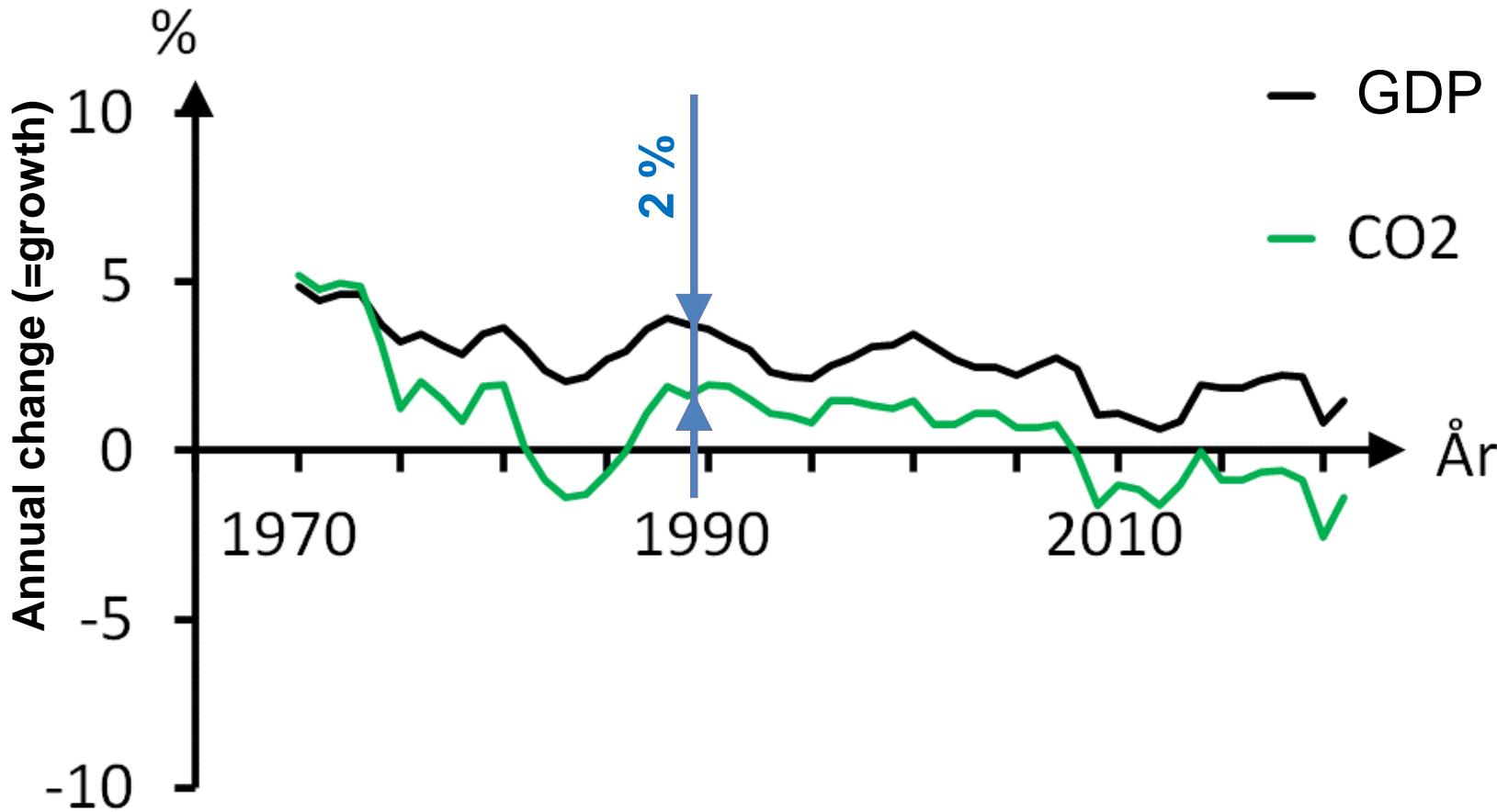
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OECD

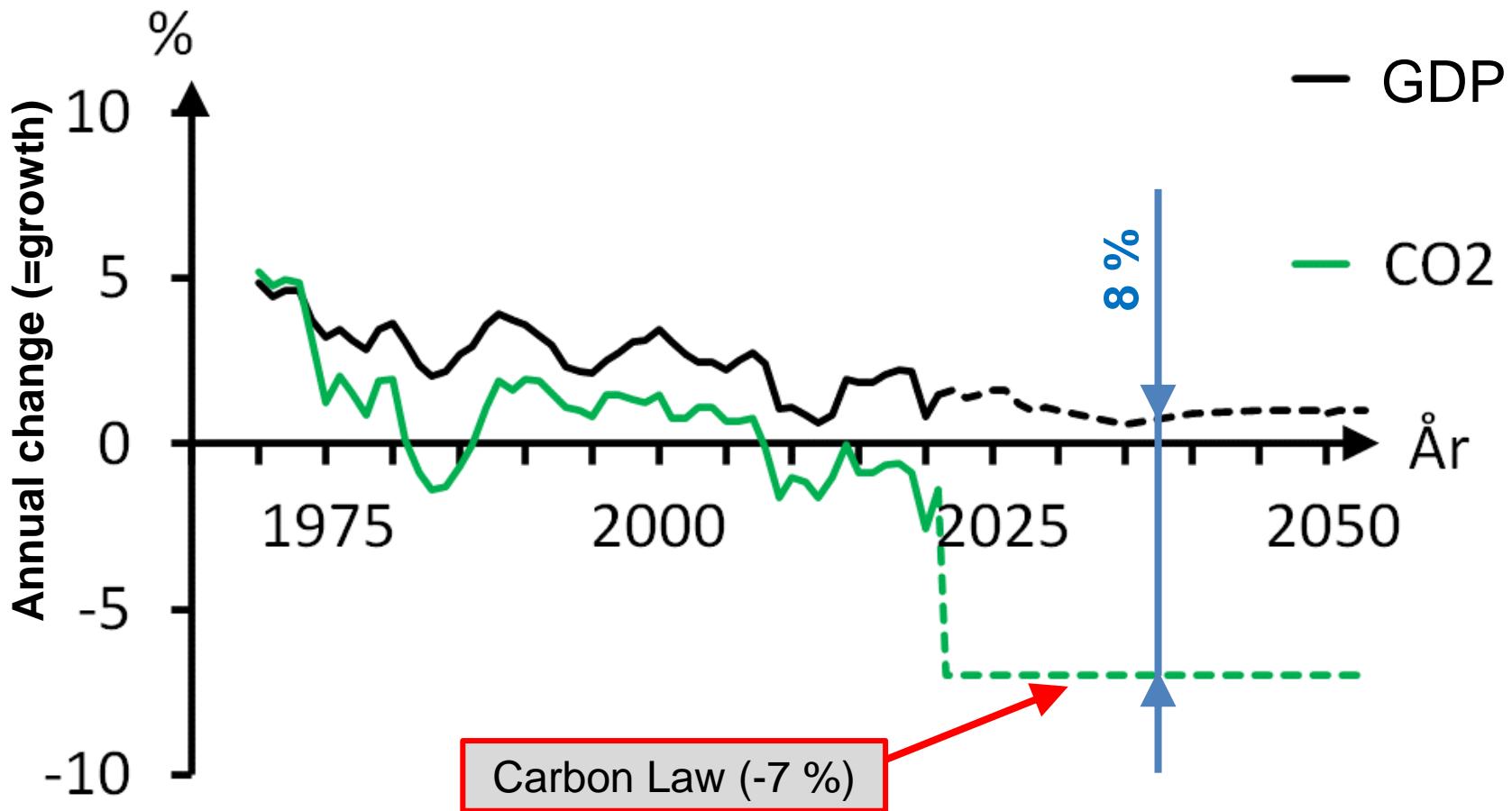
5-years mean values



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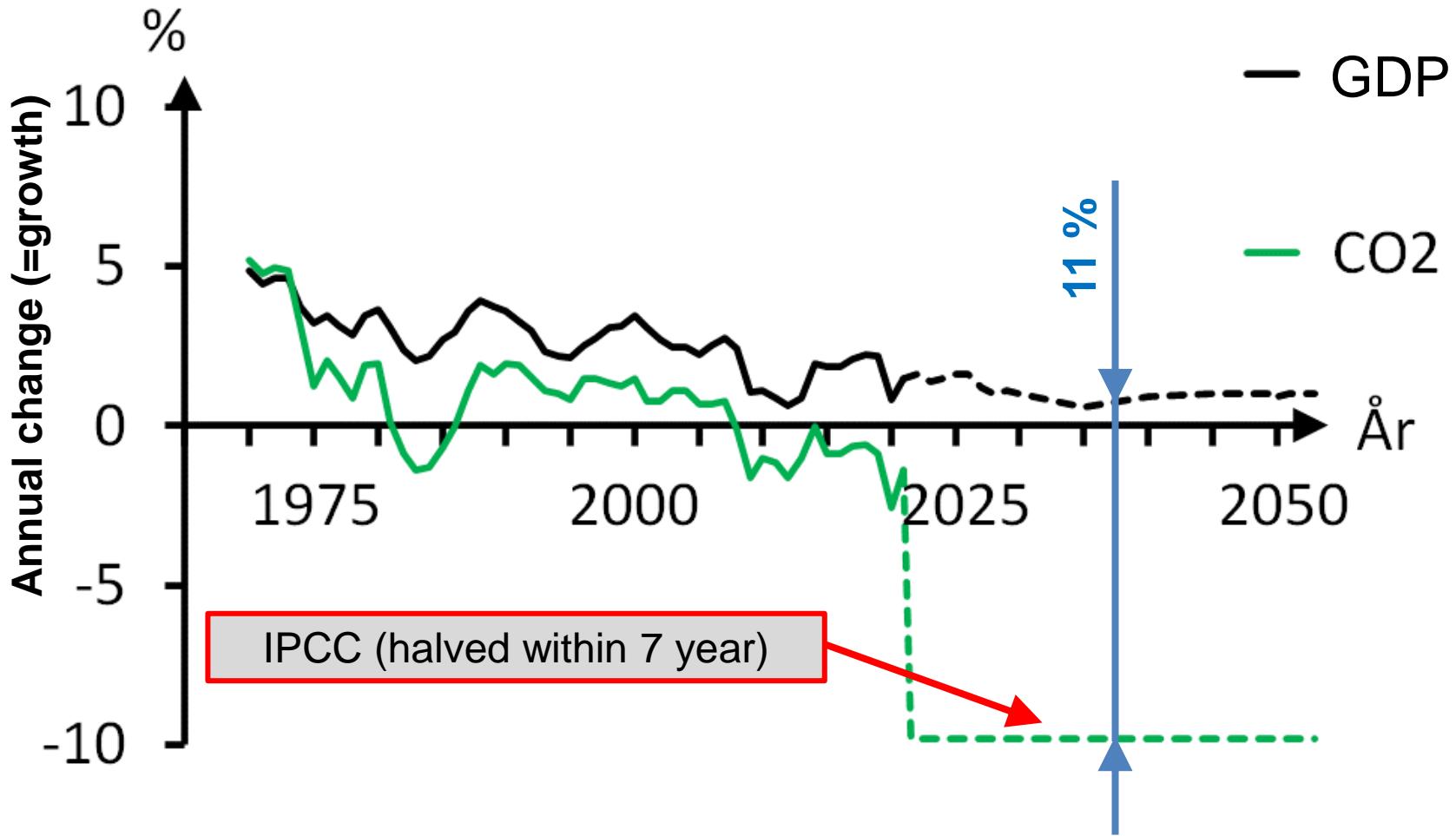
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A perfect storm

- CO₂-emissions, resource extraction and other impacts on our environment must be reduced. Today!
- Renewable energy does not seem to be the solution.
Neither for the energy problem nor the climate crisis.
- The world will be faced with lack of energy and at the same time the era with economic growth will come to an end.

The climate

- Indivual changes to the life style is not enough.
- Decisions on a national level have not been sufficient.
- UN:s climate negotiations take too small step and at a too low pace.
- Individual, regional and national actions are meaningful if they can lead to strong policies from higher levels.
- To show "good examples" can have effect, but not if they are based on unique conditions.

The economy

- Sufficient decoupling seems impossible.
- Chinas coal (2000-2010) and USA:s oil (2010-2020) have been the support for the world economy.
- A degrowing economy is not a goal, but the likely outcome.
- Plan not on more energy. The opposite would be wiser.
- Be prepared for the shrinking economy.

Don't forget Peak Oil

- Most likely close in time.
- Within the private business one may (hopefully) by own interest reduce the use of fossile fuels.
- To act on the threat from Peak Oil will be beneficial also for the climate.

Build resilience

- Be prepared for crises that can't be foreseen.
Neither of type nor in time.
- Our modern society is fragile.
Reduce the risks as much as possible.
- Can be done on all levels.
- And without all others (individuals, companies, cities, nations) doing the same.