

Advanced Research Workshop
Unravelling The Cyber-Physical-Social Infrastructure Climate
Change (CPSICC) Nexus



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**Waste heat is an inexplicably neglected environmental problem
and at the same time an unused energy treasure**

Fero Simančík



institute of materials & machine mechanics

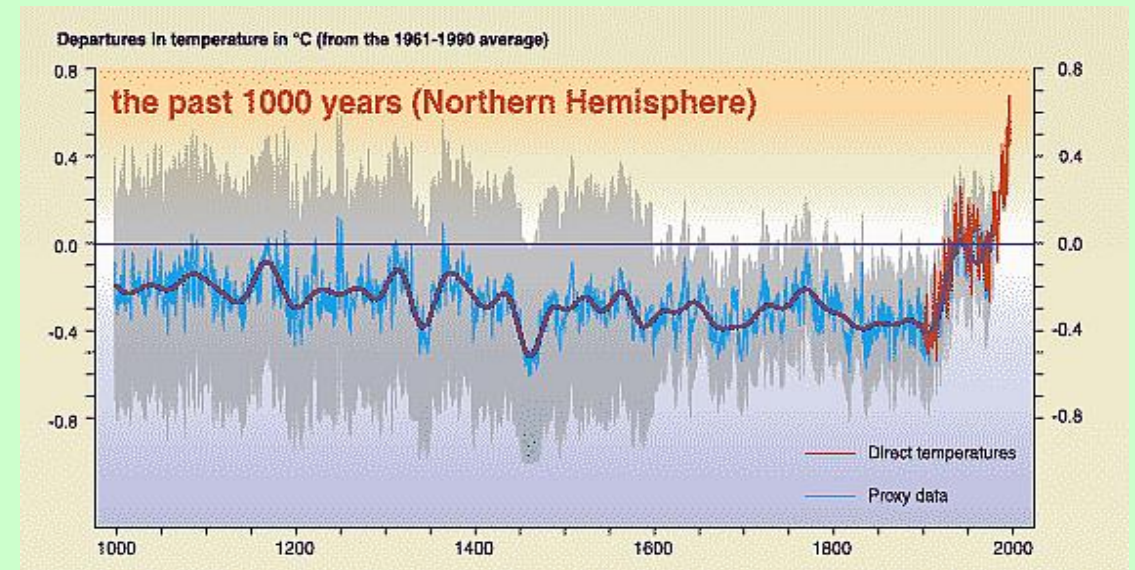
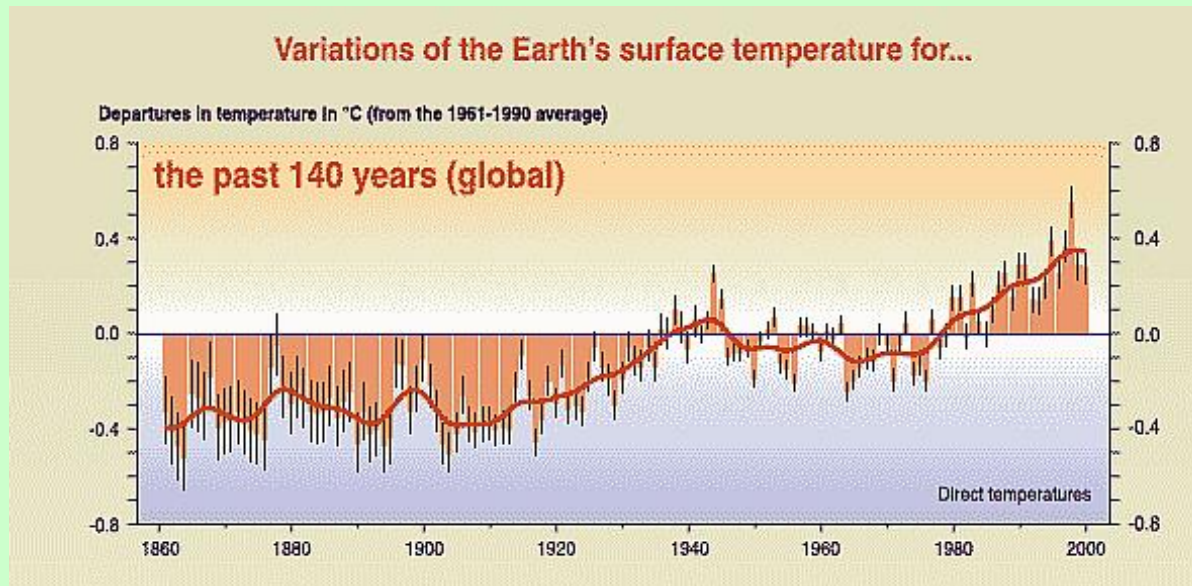
slovak academy of sciences

IMSAS - Dúbravská cesta 9/ 6319, 845 13 Bratislava, SK, frantisek.simancik@savba.sk

There is no doubt: it's getting hotter



There is no doubt: it's getting warmer



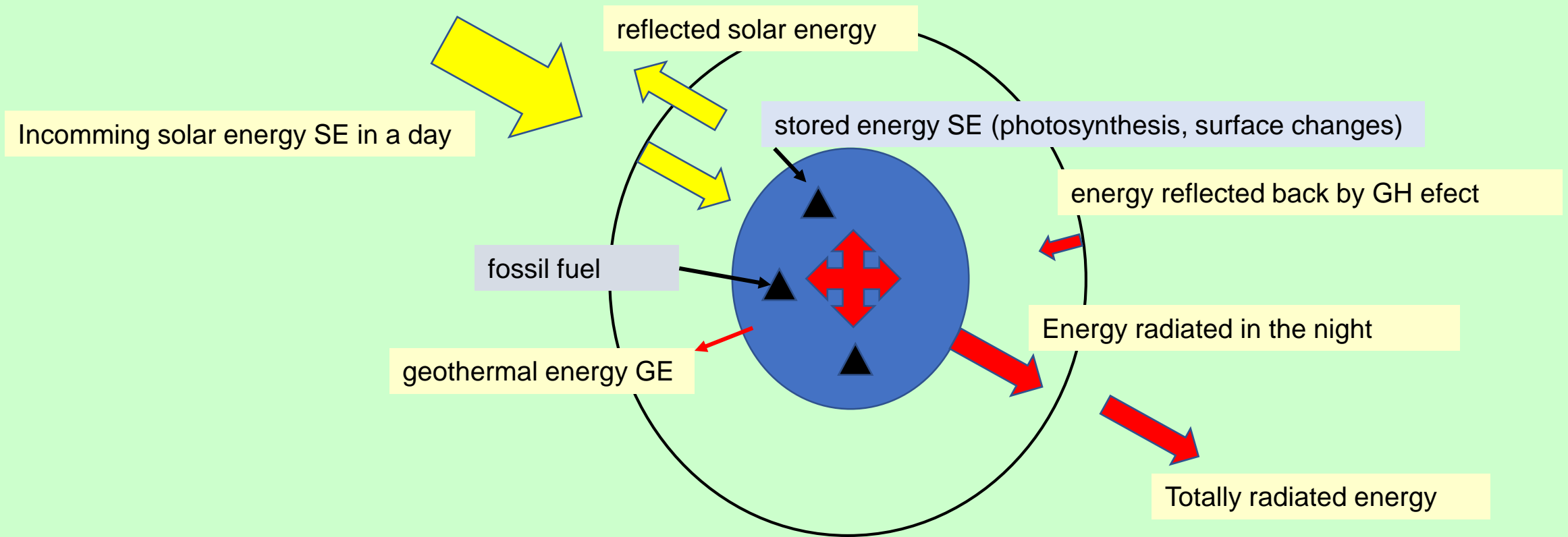
Source: IPCC Fourth Assessment Report: Climate Change 2007, Intergovernmental Panel on Climate Change.
<http://whatsyourimpact.org/greenhouse-gases/carbon-dioxide-emissions>



**Why is it getting warmer?
Is human civilization really contributing to global warming?**

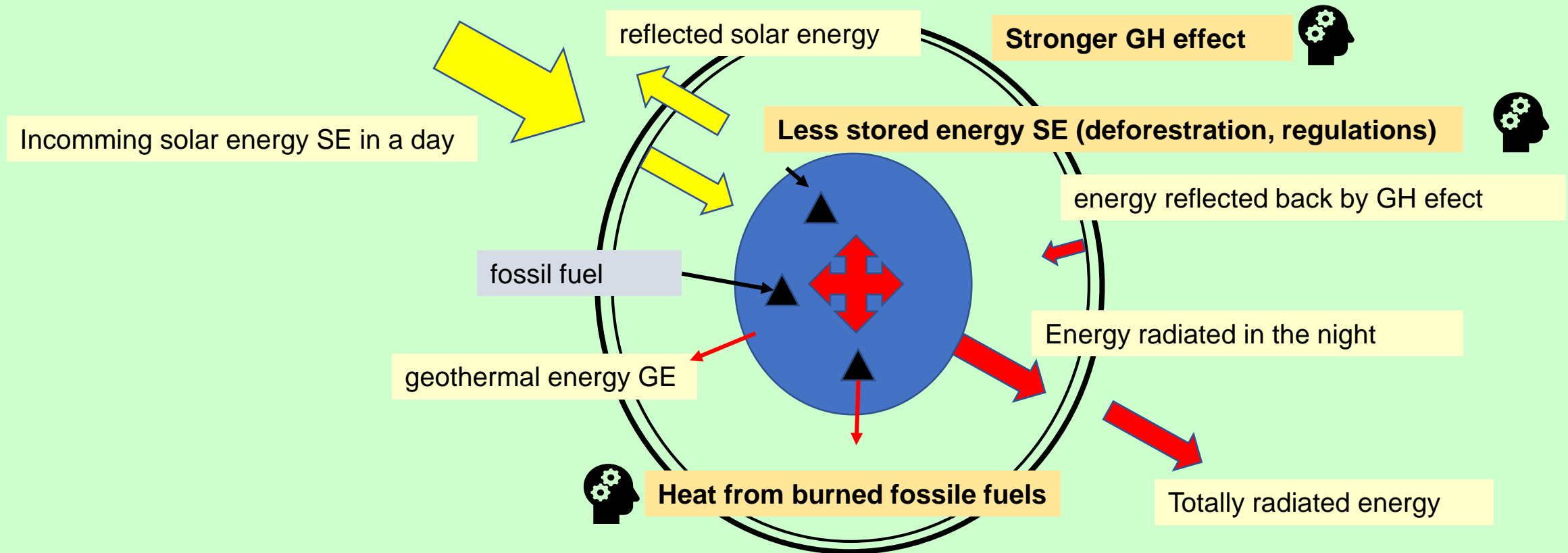
Energy balance without human civilisation

$$(SE_{inc.} - SE_{refl.} + GTE_{gen.}) \quad \text{vs.} \quad (GE_{radiated} - GE_{refl. \text{ back by GHE}} + E_{stored})$$



Energy balance with human civilisation

$$(SE_{inc.} - SE_{refl.} + GTE_{gen.} + \text{Heat}_{gen.}) \quad \text{vs.} \quad (GE_{radiated} - GE_{refl. \text{ back by GHE}} + E_{stored})$$



Energy balance comparison

Without human civilisation

$$(SE_{\text{inc.}} - SE_{\text{refl.}} + GTE_{\text{gen.}}) = (GE_{\text{radiated}} - GE_{\text{refl. back by GHE}} + E_{\text{stored}})$$

stable global temperature established for long time

With human civilisation

$$(SE_{\text{inc.}} - SE_{\text{refl.}} + GTE_{\text{gen.}} + \text{Heat}_{\text{gen.}}) > (GE_{\text{radiated}} - GE_{\text{refl. back by GHE}} + E_{\text{stored}})$$

~ 1500 EJ

~ 600 EJ

more energy reflected

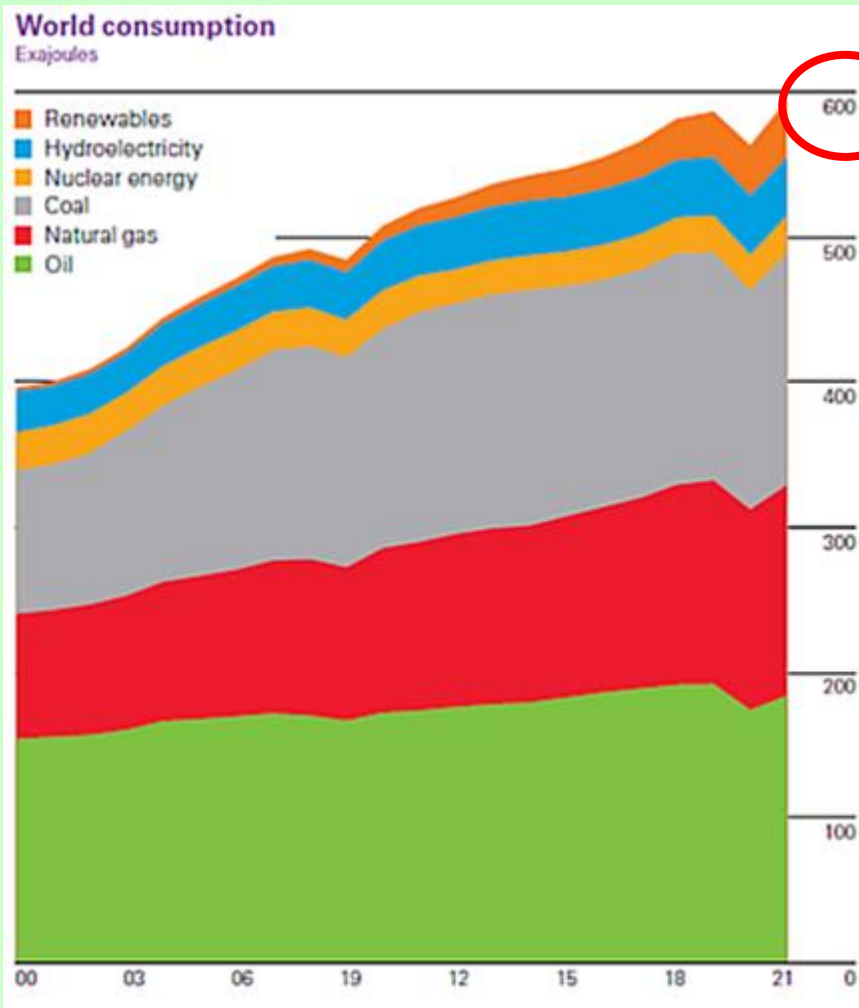
~ less energy stored

use of energy for our comfort increases global temperature

we are improving our greenhouse and additionally we produce more heat in it



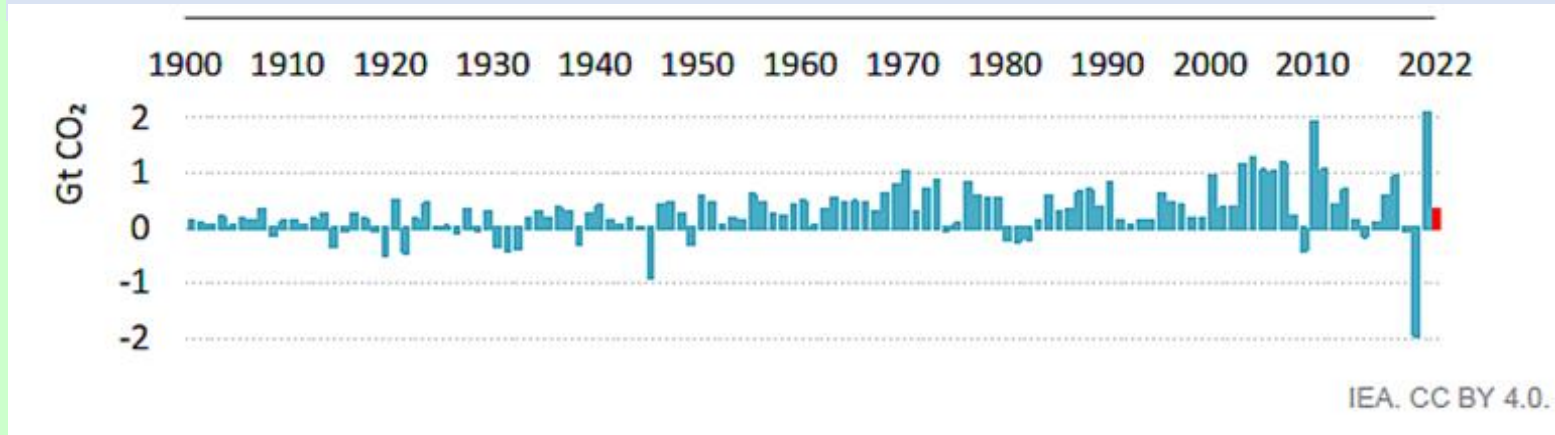
1st problem: We are steadily increasing our energy needs on available primary energy (we steadily produce more heat)



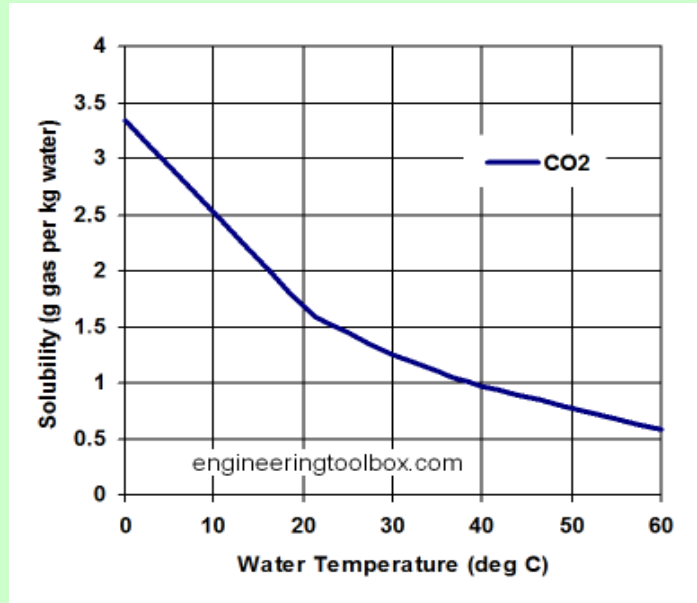
Practically all of this energy is transformed into heat, which would not be generated without human activity

"Thanks" to the pandemic, the largest reduction in CO₂ emissions since 1945 was achieved in 2020.

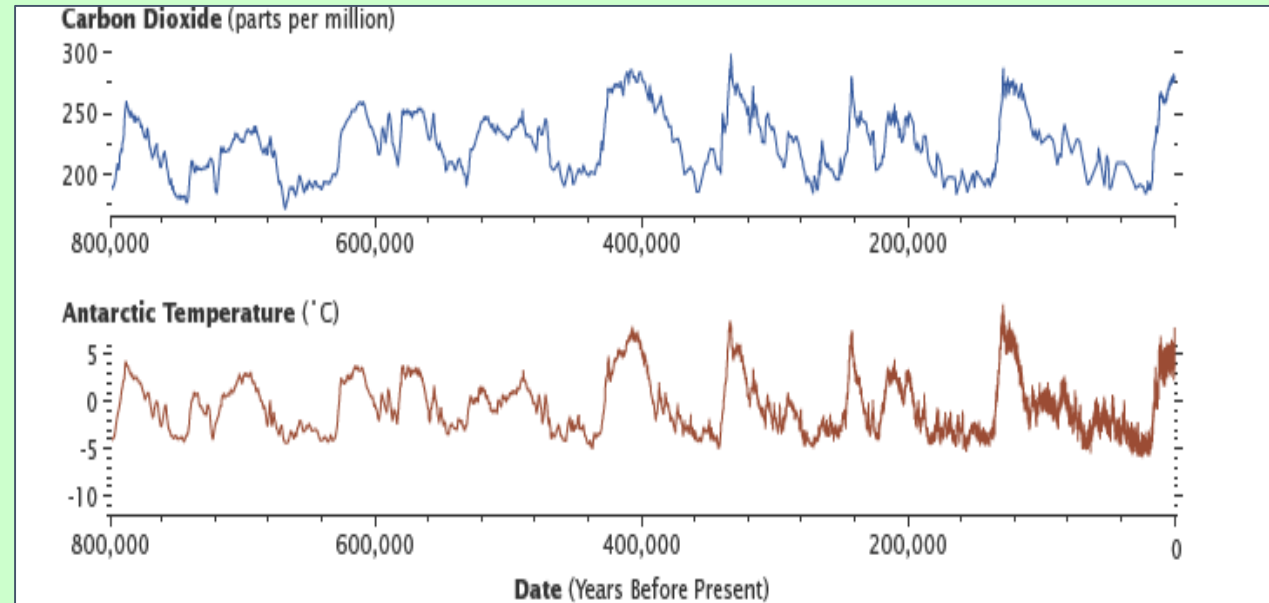
However only a level of emissions comparable to 2011 was reached, despite 80% reduction in air traffic and radical industrial recession



2nd problem: a warmer Earth releases more natural CO₂ emissions



Source: www.engineeringtoolbox.com/gases-solubility-water-d_1148.html



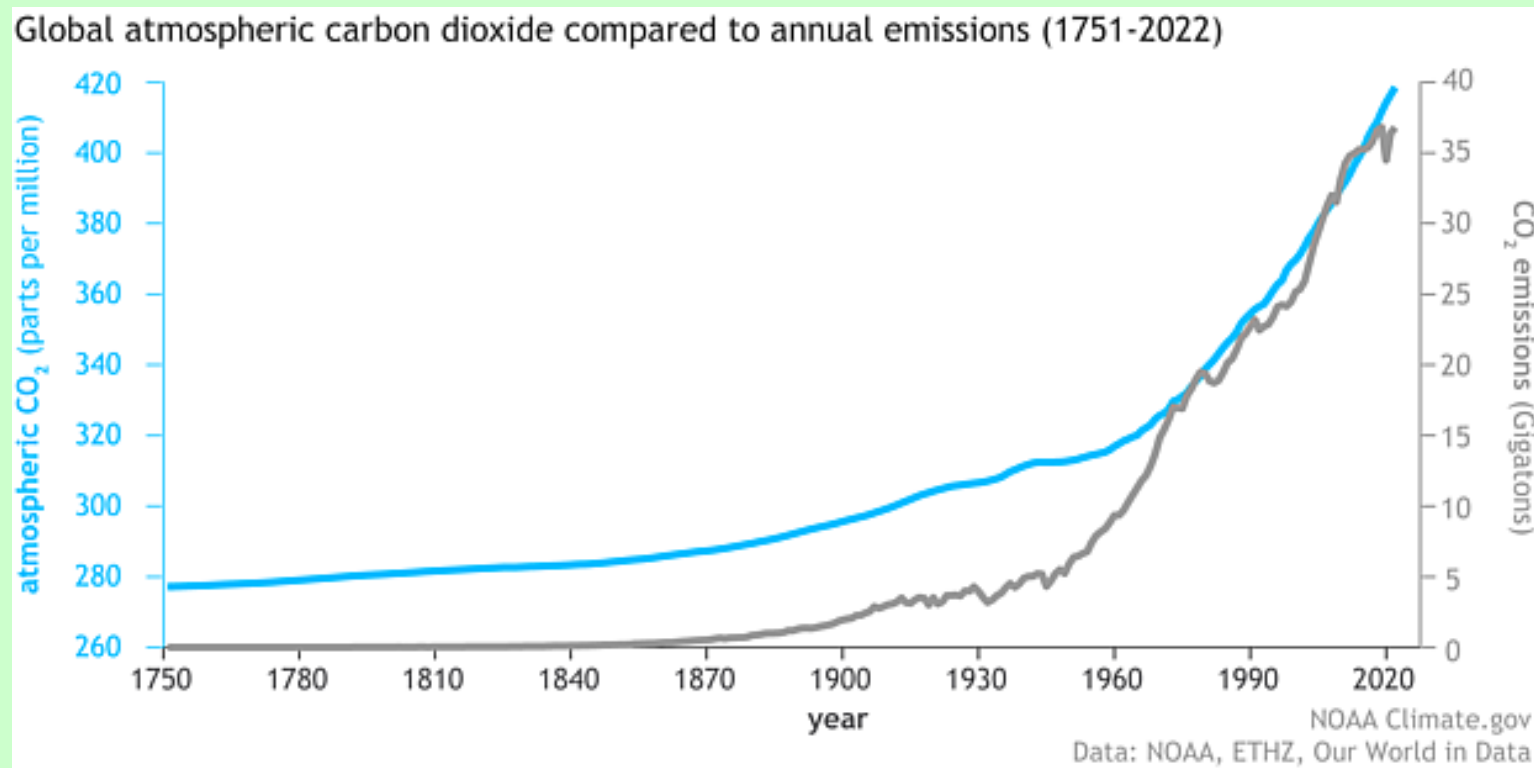
Graphs by Robert Simmon, using data from Lüthi et al., 2008, and Jouzel et al., 2007.

There is a clear correlation between natural CO₂ emissions and temperature:

- **Increased temperature releases higher amounts of natural CO₂ (and also methane as a potent GHG)**
- **Higher CO₂ emissions cause a GH effect, thereby increasing the temperature of the earth's surface**

The proclaimed cause of warming is at the same time its consequence !!!

Consequence: The CO₂ content (ppm) in atmosphere steadily rises



Reduction of our CO₂ emissions is insufficient, we need to reduce also produced heat.
Reduction of the global need for primary energy will also automatically lead to a reduction in emissions. It does not apply the other way around!!!



Excessive consumption of primary energy = humanity's biggest contribution to climate change

- The human population (8 billion) needs **~24.1 EJ/year** of energy in food to survive (2000 kcal/day, 8.4 MJ/day, 365 days/y)
- for civilization comfort, we transform approximately **600 EJ/y** of primary energy, mostly from fossil fuels (~80%)
- **Most of this energy is ultimately converted to heat**
- From this energy **we efficiently use only about one third** (most of it is uselessly wasted as heat)
- not only CO₂ but **also released heat is a problem**
- The heat released by human race is at the level of ~40% of the flow of geothermal heat through the earth's crust (~1500 EJ, $47 \pm 2 \text{ TW}^1$)

¹Source: J. H. Davies and D. R. Davies. Earth's surface heat flux. Solid Earth, 1, 5–24, 2010. www.solid-earth.net/1/5/2010/

**No other creature on Earth does such a waste of energy.
From this point of view, man is extremely unadapted to the available resources.**



How is it with the use of primary energy per year in Slovakia (population 5,5 mil., PE ~ 240 TWh/y)

- Electricity production: ~ 28.9 TWh, of which ~ 24.4 TWh from heat with an efficiency of ~ 30%:

Residual waste heat ~ 50 TWh

- Transport: ~ 30 TWh of liquid fuels, combustion engines with an efficiency of ~ 30%:

Residual waste heat ~ 20 TWh

- Industry: heat from gas and electricity (electric melting furnaces) ~ 40 TWh:

Residual waste heat (unused) ~ 30 TWh

~ 100 TWh is wasted without any benefit



**We convert additional ~ 20.8 TWh of primary energy for household heating !!!!
of which ~ 4.8 TWh is heat produced by burning poor quality solid fuel**



Why not use the wasted heat for heating of households?

- 20% of the waste heat from industry, transport or electricity production is fully sufficient to heat all households in Slovakia,
- If we used the waste heat (residual) to heat homes, approximately 4.8 megatons of CO2 emissions would be saved, which is more than the emissions from the entire transport by passenger cars (~ 2.5 Mt CO2/y) or almost 2/3 of the emissions from all land transport (approx. 7.5 Mt CO2/y)
- In addition, ~ 20 TWh of heat would not be released but would remain stored in the unburned fuel
- If we let out today's residual heat through the buildings, we wouldn't even have to insulate them (further enormous cost and energy savings, minimization of problems with energy imports, etc...)



Heat can be easily transferred and stored

Heat can be easily stored in thermal batteries and transported by truck or by train.

There is no need to build an expensive pipeline with large energy losses.

A freight tank train with 20 wagons each with a volume of 60 m^3 transports 120 MWh of heat in hot water. At the same time, it consumes less than 10 MWh of electricity per 100 km.

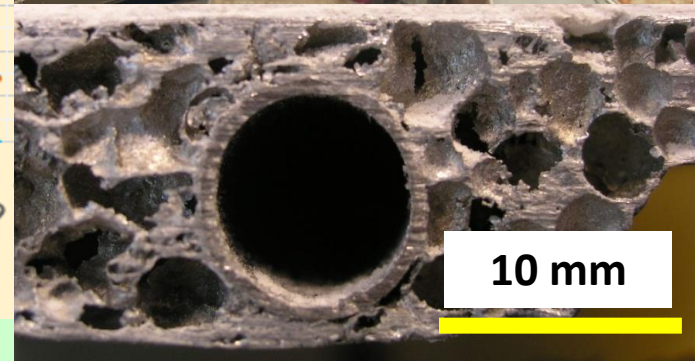
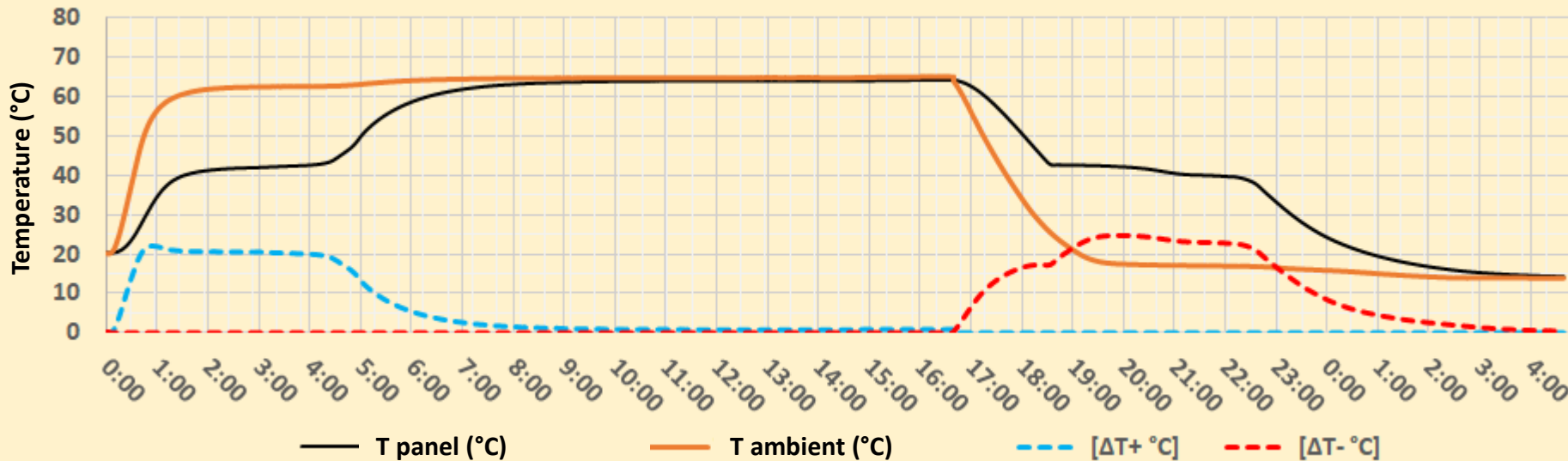
A cargo tank with a volume of 10 m^3 of hot water (95°C) will transport 1MWh of heat at a time, with a total weight of approx. 16 tons.

A well-insulated tank cools down by less than 3°C in 24 hours.

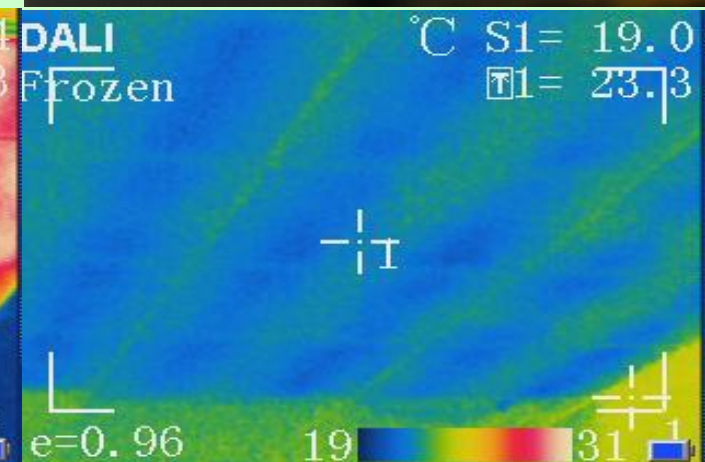
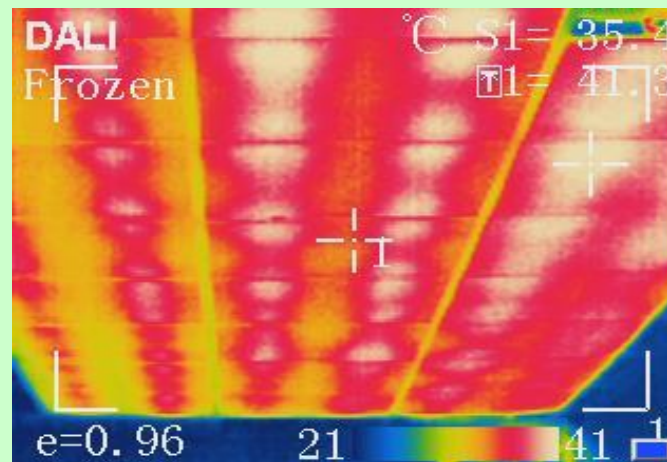


Also low potential heat can be stored and later used....

Thermal battery panel PCM RT44HC (dT±20°C)



- The PCM thermal battery can be charged and discharged at $\pm 4^\circ\text{C}$ during phase change of filler
- no critical raw materials are required
- 3-5 times cheaper than an electric battery with the same energy capacity



A lot of unused heat is in traffic around us

Example

With a diesel consumption of 30 l/100 km and an engine thermal efficiency of 40%, a truck will produce around 180 kWh of waste heat on a 100 km route.

It is easy to capture 50% of this waste heat (e.g. in a 1 m³ tank – 1000 kg), while the cold water (15°C) is heated to 93°C.

1000 kg of water in addition to the normal load will increase consumption on a 100 km route by 4.3 kWh of primary energy.

The obtained 90 kWh of heat is a 20-fold energy gain compared to the increased consumption



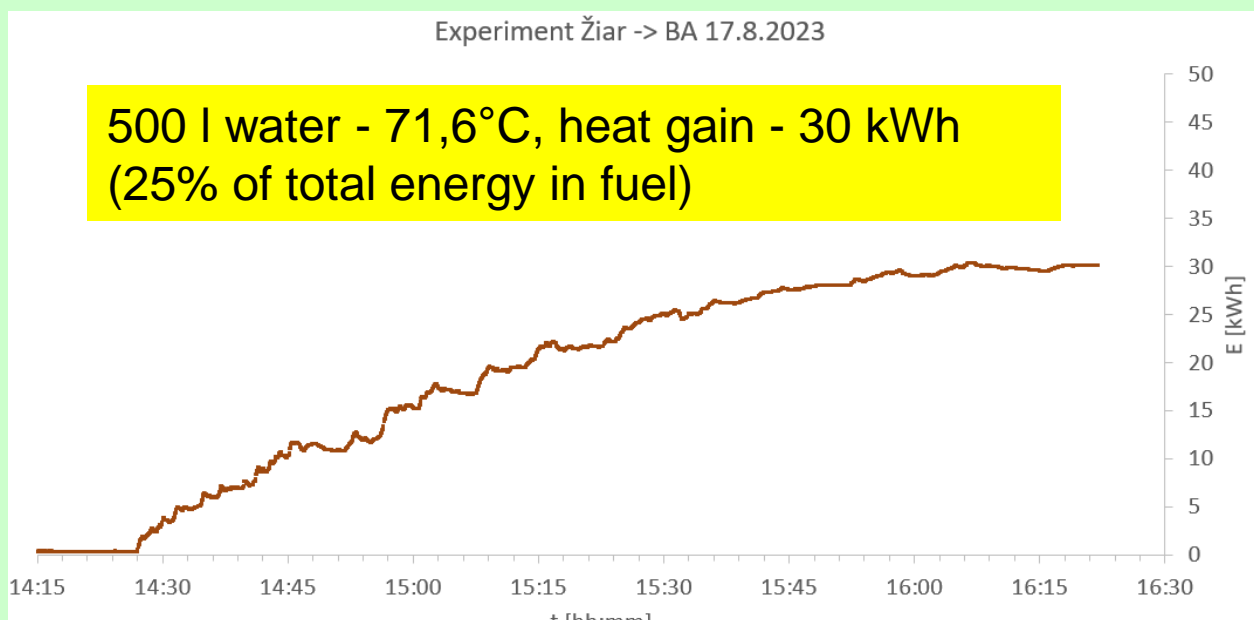
Heat directly from car: experiment (route 130 km)



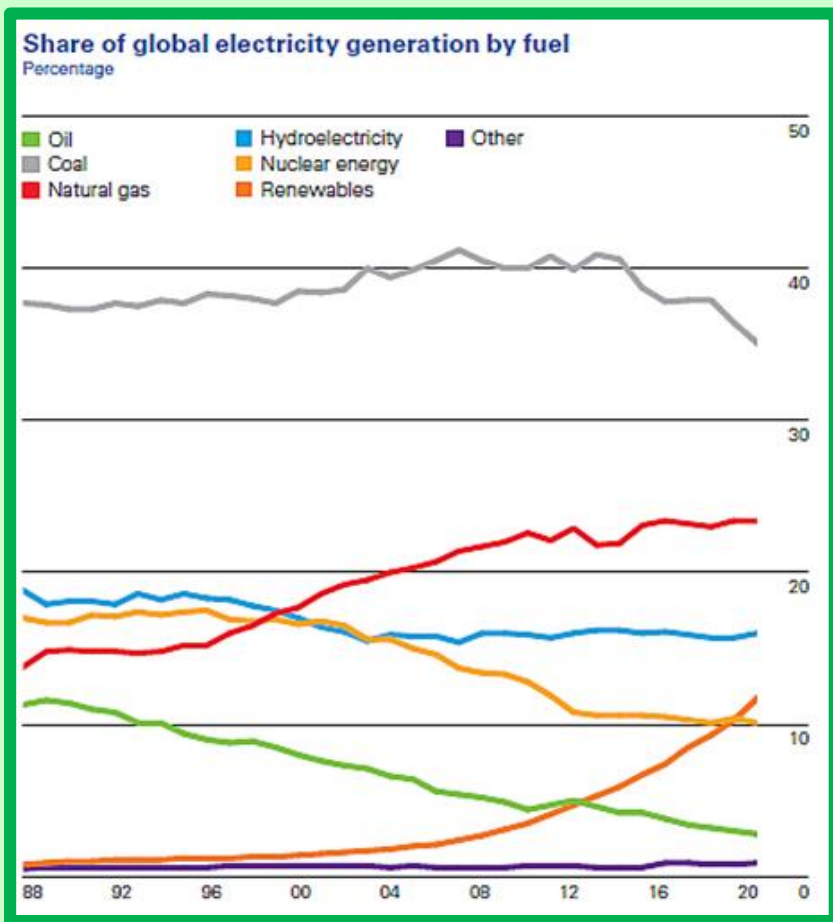
Insulated water tank 500 l



Heat exchanger mounted between engine and cooler



Global electrification does not yet appear to be a successful solution in the near future



Global electricity production still requires more than 60% of fossil fuels (coal, gas, oil)

Source: BP statistical review of world energy 2022

Use of RES for electricity production increases the total consumption of primary energy because of less efficient processes

There is no alternative primary energy that humanity can simply take to cover its comfort.

There are always some consequences for the natural cycle of processes on Earth, that has been created by long-term evolution

A change in the energy strategy is vital and also inevitable!!!

