Beyond a Usage Threshold, NO Form of Energy is Green

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Singular Lopsided focus only on **Supply**

- Supply of sustainable green energy has been extensively investigated by many researchers (ex: see John David Mackay's great work, ref No. 3 in the paper; url www.withouthotair.com)
- Only supply side focus ignores what happens to the energy after we use it….
- This work: Earth/Ocean has limited capacity to dissipate energy and we're getting perilously close to that limit….

must also curtail **demand** or else …

- The implications are obvious:
  - Cannot use unlimited amounts of energy in ANY form; no matter however green it seems to be
- Must also restrict/control the demand for and the usage of energy…

- Otherwise ?

  Potentially perish in our own entropy ….

Mirroons ?

- Hypothetical question:
- Suppose humans become capable of getting more sunlight by constructing ultra-ultra thin spheres/objects to reflect more sunlight onto the earth (we call these “mirroons” a combination of the words mirrors and moons).

- Should we put up the mirroons ???

What happens to used energy ??

- High school physics: **Energy cannot be created or destroyed, it merely changes form** (from matter into energy in nuclear reactions. However, the reverse, from energy into matter is not yet not feasible beyond the tiny, ephemeral matter-anti matter pairs that arise in modern particle colliders. But the anti-matter tends to re-combine with matter and turn back into energy as per NASA. (imagine.gsfc.nasa.gov/ docs/ ask_astro/answers/970724a.html).

only low temp sink = earth's surface

- Fundamental laws of thermodynamics apply.
- Almost all processes that involve energy exchange can be modeled at an abstract level by a Carnot-cycle ⇒ must dissipate unused part as waste-heat into a low-temperature reservoir or sink.

- But there is only one low-temp reservoir we all share: = the surface of planet ocean
  - **mistakenly called earth… the oceans of liquid water set us apart from gazillion other planets**

All used energy becomes entropy …

- ∴ all used energy eventually turns into waste-heat/entropy/disorder on the surface of the earth.
  - An example of how this is true of all the energy spent in transportation is in the paper.
  - Similar arguments apply to all other human energy consumption scenarios…..
  - Look up any textbook on engineering thermodynamics (ex: Moran et. al., 5th reference in the article) to convince yourself….

Worse than waste in “matter” form ?

- waste products in matter (solid/liquid/gas) forms at least allow a separation into different streams (ex: bio-degradable, highly toxic material such as spent nuclear fuels…etc.); with the possibility of long term sequestration (at least in principle)

- With energy we are out of luck: all forms of used energy turn into waste-heat/entropy …

Irreversibility, Quality of energy

- Consequence of 2nd law of thermodynamics : Energy of higher quality can be readily converted into energy of lower quality by spontaneous processes. The resulting degradation in the quality of energy can be measured by the "Irreversibility".
- As the name implies, the reverse, i.e., converting low quality energy into higher quality energy is not feasible without spending (substantially higher amounts of) higher quality energy.

Non-viable(non-sensical) solutions

- Waste-heat or entropy is the lowest grade/form of energy
- It is therefore not possible to "get rid of excess heat" by converting it into EM waves and building huge antennas to radiate it away or convert it into laser beam to send it away, or "somehow send it into space by convection/heat plumbing …."
  - All humanly constructible mechanisms (known as of today) fail to get the excess entropy out of the earth….

Only way out: thermal/**black-body** rad.

- Half of the earth is always facing the Sun ⇒
- Earth is continually getting substantial amount of energy. Yet there has been thermal equilibrium (on the average) over eons.
- This happens because the earth also radiates energy (via thermal or black-body radiation) into space.
- Amount radiated (almost exactly) equals the energy continually absorbed from the sunlight setting up a delicate balance as seen in Fig. 1

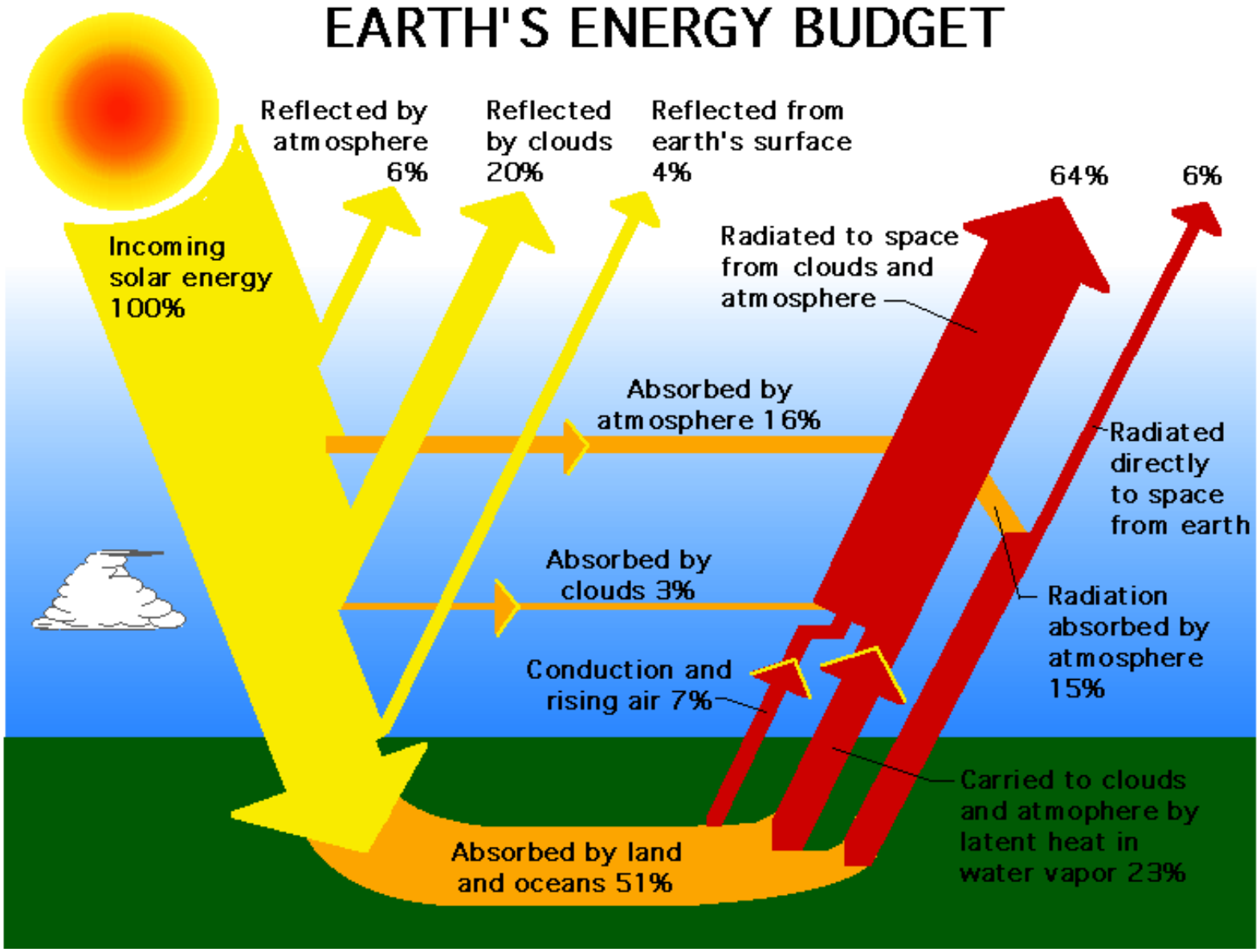

Fig 1: Earth's Energy Budget (Pic from NASA)

Black-body radiation: brief summary

$$P \propto A \left[(T_b)^4 - (T_s)^4\right]$$

Where P = Power radiated

A = Area of the black-body (bb)

T_b = *Temp of bb in Kelvins and*

T_s = *Temp of surroundings in Kelvins*

Since Area is constant (approximately);

The only way to radiate more power is by increasing the surface temp of the bb (earth) with respect to the surrounding (space)

Implications

- Let $\{\text{☀}_E\}$ = total energy that the earth receives from the Sun on the average per year.
- If we get even a small amount of extra energy (say 1% more) via Mirroons, in 100 years, we'd require the earth to have radiated an extra amount = $\{\text{☀}_E\}$; which is feasible only if the surface temperature rises.
- This is independent of whether or not the greenhouse effect is controlled….

Better not exceed $\{\odot_E\}$ ever

- The implication is straightforward : even if greenhouse emissions are totally stopped and we get energy in the form of extra sunlight (or from some other "clean" source such as cold-fusion, assuming that we happen to conquer/bottle fusion in time (which is not at all guaranteed)), we'll still get fried if the total amount exceeds $\{\odot_E\}$
- $\Rightarrow$ Humanity's consumption must be strictly restricted ; never to exceed $\{\odot_E\}$

Slack/limit << $\{\text{✸}_E\}$

- When unpredictable phenomena such as volcano eruptions, earthquakes (which release enormous energy by moving tectonic plates against tremendous friction), meteorites, large forest fires; etc., are considered, it is clear that the "slack" available for us to dissipate is much smaller than $\{\text{✸}_E\}$
- Bottom line : our consumption must be $< f \; x \; \{\text{✸}_E\}$ where, the fraction $f << 1$

But $\{\text{✸}_E\} \approx \infty$???

- So people argue: OK, it is acceptable to not exceed or even approach the cap = $\{\text{✸}_E\}$
- But $\{\text{✸}_E\}$ is so huge that we might as well consider it to be infinite….
- If that is the case, then we can at least use all the sunlight we naturally get, without any restrictions whatsoever, because the earth must radiate that much energy; whether on the way to becoming entropy/waste-heat we use it ; or not …

Let us look at actual numbers

- Let U = energy we humans produce and consume per year (in the form of electricity; or by burning fossil fuels for transportation, direct heating, operating machinery,… etc.)
- U.S. Energy Information Administration (www.eia.gov) = an agency specifically created and responsible for tracking, publishing and analyzing energy usage data.
- Already, in 2010, the fraction $(U/\{✸_{E}\}) \approx 0.0001012664497 > 1/10{,}000$

(as per data from www.eia.gov/forecasts/ieo/)

numbers don't lie (never did, humans do)

- The usage *U* does not include the energy needed by human beings to survive (at 1500 food = Kilo calories per day x 6 billion x 365; it is the same order of magnitude as and > *U)*

- What about the energy needed by plants, corals and thousands of other species ????

More restrictions ….

- 70% of $\{\text{✸}_{E}\}$ goes into creating the weather patterns that have evolved over eons….
- It is wrong to think that sunlight falling in the desert is energy wasted…..
- If we were to cover all deserts with solar cells (to “harness” the energy supposedly being wasted) and transport the energy aggregated by the solar cells into far-away city centers and use it there; what will happen ??

Lets not play with fire ….

Diversion of energy on such a massive scale will change the "distribution of energy" on earth substantially => weather patterns will likely change drastically => millions or billions could perish because rains fail/change permanently (see the example in the paper).

Closer to home: what if California becomes like sahaaraa : totally not habitable ???

Conclusions

- Unless we curtail/control our demand for and usage of energy, we seem headed into unknown, potentially disastrous realm ….
- This will happen even if we totally stop using fossil/greenhouse effect generating fuels… (obviously, if we don't control greenhouse emissions, then we'll fry the earth much faster….)
- **Can we call ourselves "intelligent" species if we let that happen** ????