Climate change and energy balance on Earth

This is not a study, but rather a brainstorming exercise.
I have attempted to organize the available information according to a new point of view.

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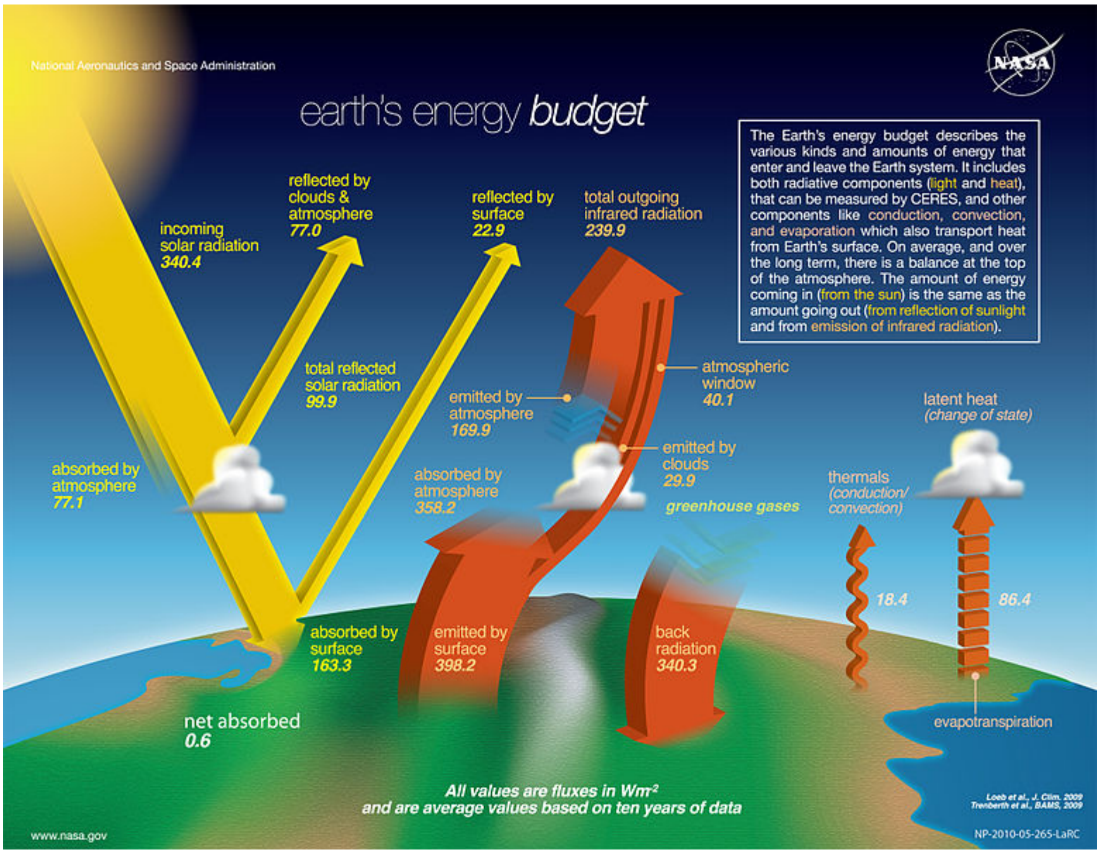
Contents

Climate change as a result of the upset energy balance of the Earth

The current situation

Nowadays, the major issue confronting us is that of climate change. It governs our everyday life, and so discovering its causes is intrinsic to combatting it in the future. There are several mathematical models for describing the situation but these algorithms treat climate change as a meteorological phenomenon affecting only the atmosphere.

It would appear that the change has been more rapid than the model-predicted value. According to the models, the major reason for global warming is the increasing emission of greenhouse gases. Since the Industrial Revolution, the amount of carbon dioxide emitted has been growing rapidly and animal husbandry has also been adding increasing quantities of methane. These gases trap the heat that should have been released into space.



Source: The-NASA-Earth's-Energy-Budget-Poster-Radiant-Energy-System-satellite-infrared-radiation-fluxes

Energy balance

The above table provides an important view of energy balance. A small fraction of incoming solar energy has been converted to chemical energy, the products of which are coal, oil and natural gas. The data may appear insignificant, but this conversion has occurred over billions of years. Due to human activity, we have been releasing this accumulated energy over some hundred years! The speed of release is faster by at least six orders of magnitude! That means that the seemingly low fraction of energy balance has a higher effect by an order of magnitude of six!

According to a recent NASA article:

Earth's Energy Budget

Note: Determining exact values for energy flows in the Earth system is an area of ongoing climate research. Different estimates exist, and all estimates have some uncertainty. Estimates come from satellite observations, ground-based observations, and numerical weather models. The numbers in this article rely most heavily on direct satellite observations of reflected sunlight and thermal infrared energy radiated by the atmosphere and the surface.

Earth's heat engine does more than simply move heat from one part of the surface to another; it also moves heat from the Earth's surface and lower atmosphere back to space. This flow of incoming and outgoing energy is Earth's energy budget. For Earth's temperature to be stable over long periods of time, incoming energy and outgoing energy have to be equal. In other words, the energy budget at the top of the atmosphere must balance. This state of balance is called radiative equilibrium.

About 29 percent of the solar energy that arrives at the top of the atmosphere is reflected back to space by clouds, atmospheric particles, or bright ground surfaces like sea ice and snow. This energy plays no role in Earth's climate system. About 23 percent of incoming solar energy is absorbed in the atmosphere by water vapor, dust, and ozone, and 48 percent passes through the atmosphere and is absorbed by the surface. Thus, about 71 percent of the total incoming solar energy is absorbed by the Earth system.

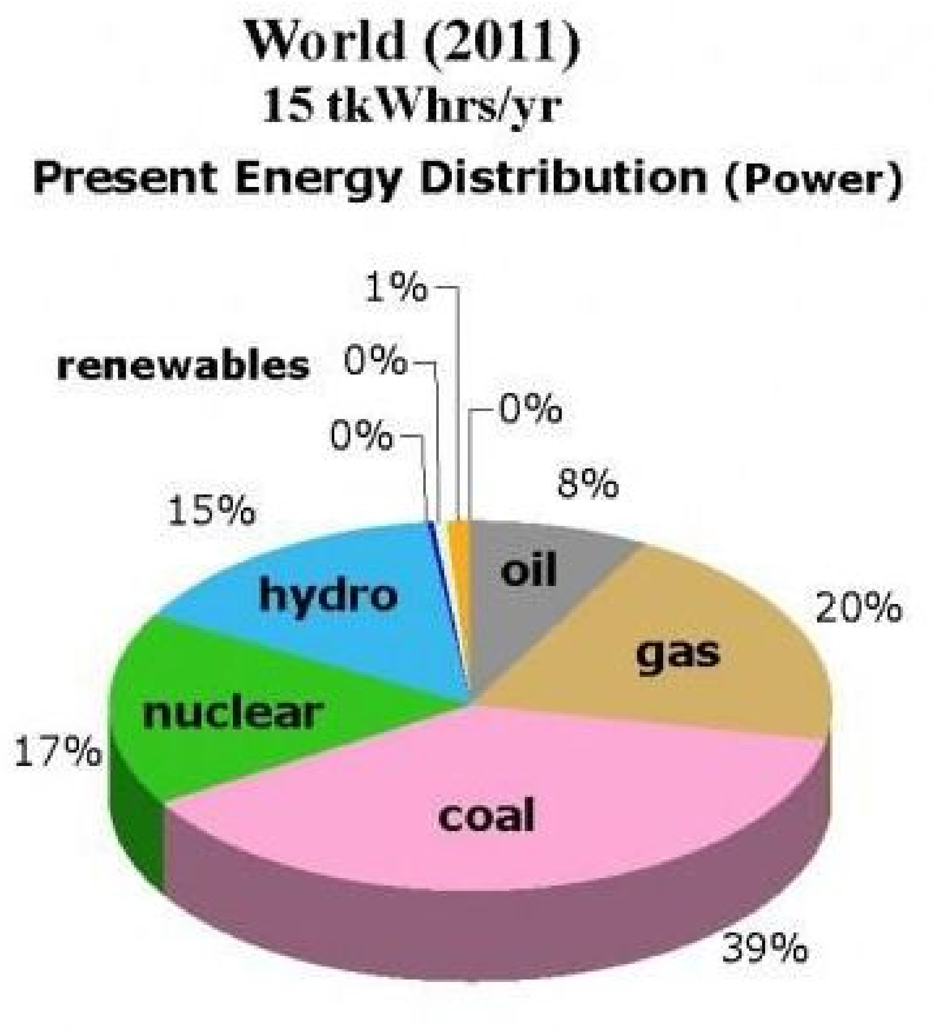
Source: earthobservatory.nasa.gov/features/EnergyBalance

Notwithstanding the meteorological considerations, we should also monitor other aspects of the thermal balance on Earth. Besides measuring incoming solar energy, we should add the amount of energy generated by human activities. **A rise of 1.5 - 2.2 % on the Kelvin scale would not appear very significant, but if we project the same value to the "habitable" temperature range, the same absolute value will result in a rise of at least 5 % or higher!**

The Industrial Revolution

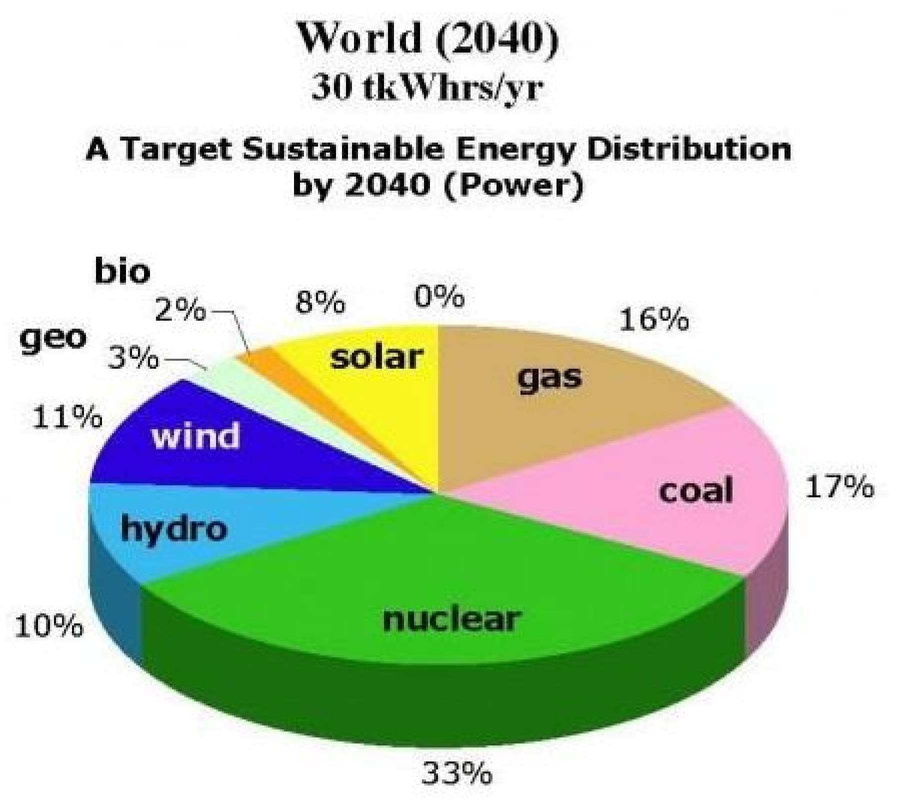
Before the Industrial Revolution, the incoming solar/heat energy and the outgoing, radiated energy produced a thermal balance at a definite surface temperature. The increasing industrial and other human activities not only produced more greenhouse gases, but also generated extra heat. By using fossil energy, we release the solar energy that has been converted to chemical energy and preserved over billions of years, millions of times faster, that is, in a period of only some hundred years. The full energy content of the mined and used fossil fuels will be added to the amount of incoming solar energy.

The present energy mix as identified by Forbes shows the following distribution of energy:



Source: Earth_energy_mix_Forbes

Present mathematical models only calculate with the emitted greenhouse gases but do not calculate with the excess energy and heat that is produced. Furthermore, the medium-term prediction suggests very similar figures.



Source: Earth_energy_mix_Forbes

The new balance, with locally generated energy added to incoming solar energy, results in a higher surface average temperature, which is the major cause of global warming.

Being carbon-neutral is not enough; We must also be energy-neutral!

If we really intend to combat global warming, we must omit the use of both fossil and nuclear energy. Although we generate energy, we should also convert, store and re-distribute solar energy.

Efficiency

It is well known that using natural gas, oil or coal generates greenhouse gases, but we should also calculate with the released energy. According to the laws of thermodynamics, all released energy will eventually be converted to heat! In addition, the efficiency of heat engines is lower than 40 %. It means that if you generate 1 kWh of “useful” energy, you should calculate an additional heat loss of 1.5 kWh, so the total heat load will be 2.5 kWh! If you want to know the exact value of the additional heat load, you should add the full energy content of mined fossil energy sources!

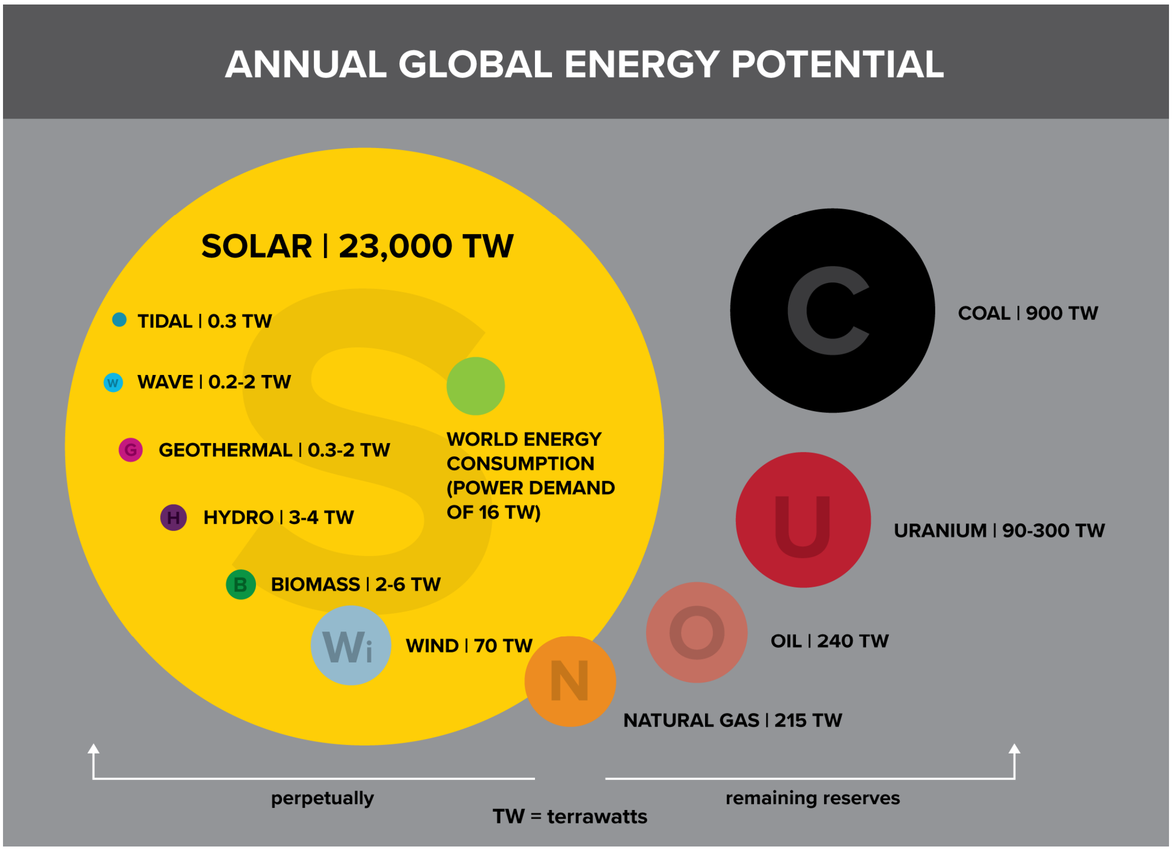
Nuclear energy

The situation with nuclear power plants is the same. As nuclear plants do not generate or emit greenhouse gases, their effect can remain hidden temporarily. Their well-known drawbacks are the potential dangers of radiation and the long-term effects of nuclear waste. In addition, nuclear plants are also heat engines, which are fuelled with released nuclear energy. **The pitfall is that nuclear plants, especially the fusion plants of the future, may provide unlimited amounts of energy, which would result in unlimited heat emission!** The predictable energy mix calculates with only 32 % of the amount of renewable energy used by 2040 and with double the amount of nuclear energy.

By way of an example, if we have a 2000 MW nuclear plant with 40 % efficiency (in reality this is somewhat lower), the 2000 MW will be used and converted to heat at the location of the end users; thus an additional 3000 MW of heat will be directly emitted by the cooling system of the power plant. That heat will result in a definite rise in the local surface temperature.

Meeting energy demand

The incoming solar energy could safely meet the energy demand of the world's population, now and in the future:



Source: solar-prevalence_UCDavis_edu

According to this table, the current global power demand is approximately 16 TW. This only represents the efficient part of the energy. If we add the losses, multiplying this value by 2.5, the real demand is nearer 40 TW. The available solar energy is 575 times higher! If the efficiency of solar – electricity conversion is only 20 %, the available solar energy is approximately 120 times higher than the real demand!

Convert, not generate!

Meeting the entire energy demand from solar energy can only be accomplished with strong cooperation at a global level!

Renewable sources

At present, we rely on the following renewable sources:

- tidal
- wave
- geothermal
- hydro-
- biomass
- wind
- solar

We should be careful when mentioning these sources, as some are not genuinely renewable, and others may contain hidden dangers.

Tidal and wave plants

The mechanical construction of tidal and wave plants can be somewhat sophisticated and would require regular maintenance, so the question is whether their operation could be rentable by the energy companies.

Geothermal plants

Geothermal plants represent a pseudo-renewable source. On one hand, if you scatter an area with numerous geothermal plants, the accessible amount of energy will decrease. On the other hand, those plants conduct heat to the surface from the lower layers of the Earth, and hence geothermic plants add heat to the surface, thus increasing the surface temperature and contributing to global warming.

Hydroelectric plants

Hydroelectric plants represent a well-known technology with several decades of experience. The environmental and social effects are worth consideration.

Biomass plants

Biomass plants represent renewable sources of energy but those generate carbon dioxide and might be some unpleasant side effects in the closer environment.

Wind farms

Winds represent critical elements of the meteorological system. Winds transfer heat and move clouds. If we remove kinetic energy from the wind systems, it will cause slow but long-term changes in the weather system. I would not recommend large-scale wind farms.

Solar plants

Solar plants appear to be the most environmentally friendly solution. If there is no solar panel on a given area the Sun heats the naked surface. If the solar panel covers the surface some of incoming solar energy will be directly converted to electricity, and it will be transferred to the users. The local warming will be somewhat lower, due to the energy being diverted. The generated electricity can be used immediately or stored.

Storing electricity

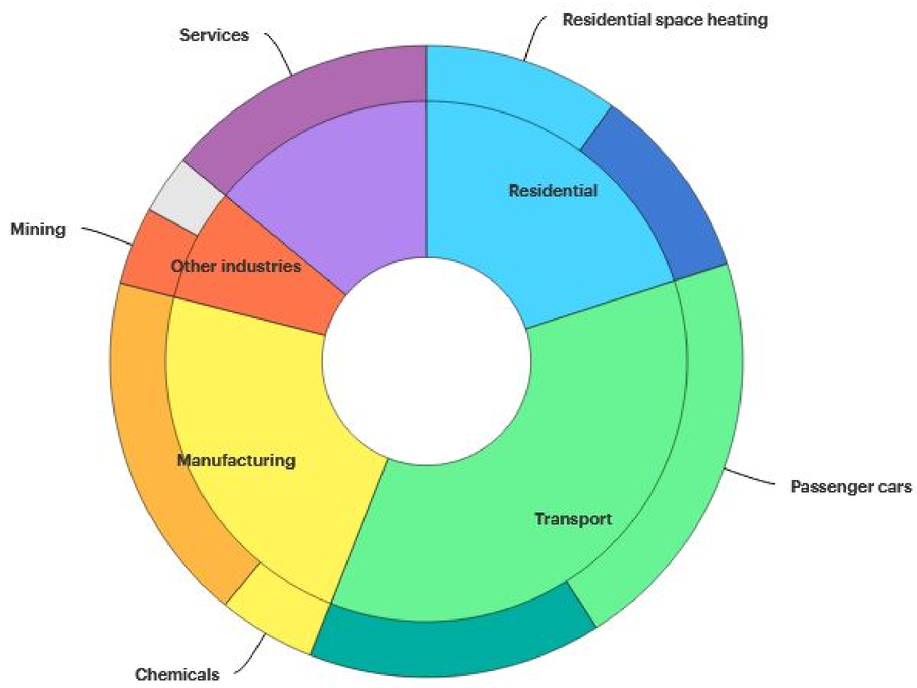
At present, the most important problem lies in the use of different types of periodically available renewable energy. Energy usage is almost continuous, so we should store the unused energy for the periods of peak demand. The currently used batteries are heavy, and their capacity can only be sufficient for serving a family or a smaller community. Pumped-storage hydroelectric plants offer an industrial level solution and are compatible with the present SCADA (*Supervisory control and data acquisition)* systems, so their use does not necessitate learning a new technology. The drawback is that those plants require special geographical conditions and considerable investment.

The available excess electricity can be used for the electrolysis of water. The oxygen that is produced can be released or compressed and used on other locations, and the hydrogen can be compressed, liquefied, delivered, and stored. It can be used, for example, in fuel cells or in several other ways. Delivery chains can be established with relative ease. The hydrogen can easily be used, both in the home and on an industrial scale. The existing delivery systems developed for transferring natural gas can also be modified for transporting hydrogen with relative ease.

Solar energy that is converted and distributed at the existing technological level can meet the needs of the World. The method of conversion should be environmentally friendly. It would appear that the water – hydrogen – water cycle that is supplied with photovoltaic energy may be suitable**. The first to invest in the large-scale distribution and use of hydrogen will be the long-term winner of the economy.**

Saving available energy

Here, energy-efficiency is a key question.



Source: IEA, *Largest end uses of energy by sector in selected IEA countries, 2018*, IEA, Paris https://www.iea.org/data-and-statistics/charts/largest-end-uses-of-energy-by-sector-in-selected-iea-countries-2018-2

The following represent the most significant areas of use:

- transport
- manufacturing
- residential consumption
- services

Manufacturing

In the manufacturing sector, decreasing the use of energy is a familiar and rather well-performed aim. Lower use of energy results in lower costs and higher profits. This is a self-propelling process. Most cutting technologies are replaced with precision moulding solutions, which enables companies to save both material and energy.

Transport

In the area of transport, the situation is very similar. In air transport, decreasing the cost of fuel is essential:

According to Davis Chhoa of Stanford University:

Increasing Efficiency

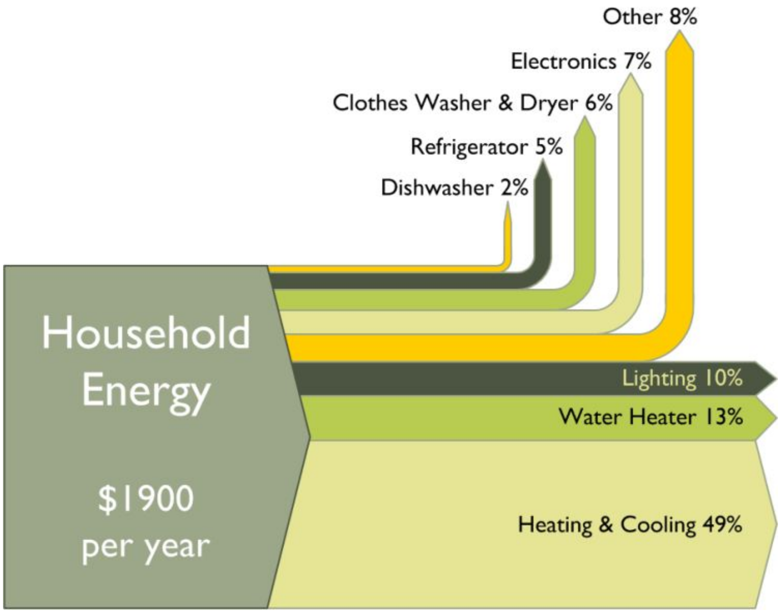
According to historic trends in measurements of aircraft fuel usage per seat, modern aircraft are approximately 80% more fuel efficient than aircraft of the 1960s through a combination of increased passenger capacity and technological improvements to improve fuel usage. [4] The rate of fuel efficiency improvement was quite variable throughout the past half century due to different developments in turbo engines, fuel consumption, and aircraft design. Between the 1960s and 1980s, the rate of fuel efficiency increased by an average of 3% annually, as determined by the International Civil Aviation Organization's calculated metrics, while there was essentially no increased fuel efficiency between the 1970s and 2000s. [3] However, as a result of recent fluctuations in fuel prices and the fact that fuel expenses comprise a significant amount of an aircraft's operating expenses, engineers have been working on improving aircraft fuel efficiency. [5] Furthermore, aircraft are incredibly energy efficient vehicles once they are up in the air. In fact, the faster the aircraft are able to travel, the more efficient they become. Since aircraft travel long distances and carry a limited quantity of fuel before needing to be replenished, engineers are working on improving the fuel efficiency of aircraft in order to fly longer distances with reduced amounts of fuel. The Airbus 320neo, shown in Fig. 1, is one of the most recent aircraft developed. It claims a reduction in fuel usage of approximately 15 percent compared to previous the previous Airbus 320 model. [6] The "neo" in the new aircraft's name refers to the use of a new, more fuel-efficient engine, demonstrating an example of the relationship between technology and efficiency improvements.

Source: http://large.stanford.edu/courses/2017/ph240/chhoa1/

Public transport can rather easily be biased towards electric vehicles. With private transport it seems to be a similar situation. Electric cars have started to be more affordable and usable, and hybrid cars (not the so-called “mild hybrid” vehicles) may provide a satisfactory transition.

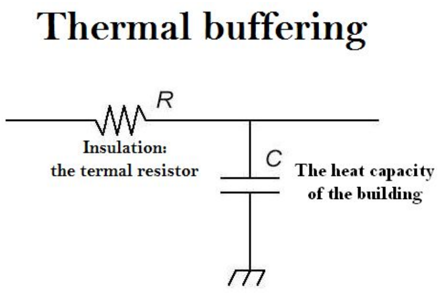
Residential use

This seems to be the most critical area.

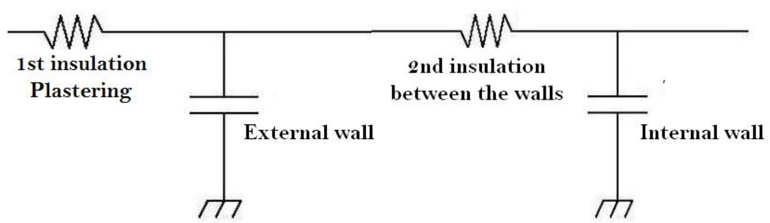


Source: https://www.sankey-diagrams.com/wp-content/gallery/x_sankey_004/cache/home-energy-use-sankey-diagram.png-nggid03368-ngg0dyn-500x0x100-00f0w010c010r110f110r010t010.png

Heating and cooling systems use approximately half the available energy. In addition, cooling results in an immediate rise in temperature in the local environment. Thermal insulation of the external walls of buildings can decrease the energy demand of heating and cooling, but we should pay more attention to the efficiency of household energy use. We can increase the heat capacity of the buildings by way of thermal buffering, which is described as follows:



This solution can mitigate thermal peaks, both warm and cold ones. Old brick or stone buildings can remain significantly cooler in summer because the heat capacity of the walls is relatively high. The daytime warming is not enough to warm up the entire wall, and at nighttime the external surface will reradiate a significant amount of the collected heat. Light, modern building materials do not have the necessary heat capacity. We should use the old, heavy materials, at least for the external walls. Another method, which is used in Belgium, is to build with double brick masonry, with a layer of insulation between the inner and outer walls, and finally add a layer of external insulating plaster. This solution results in “double thermal buffering”.



Summary:

Being carbon-neutral is not enough. We must also be energy neutral.

We should not generate excess energy on Earth. Rather, we should only convert and use available solar energy.

By returning to the use of heavy building materials in construction, we can reduce heating and cooling demands.

