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Beyond Primary energy: The energy transition needs a new lens

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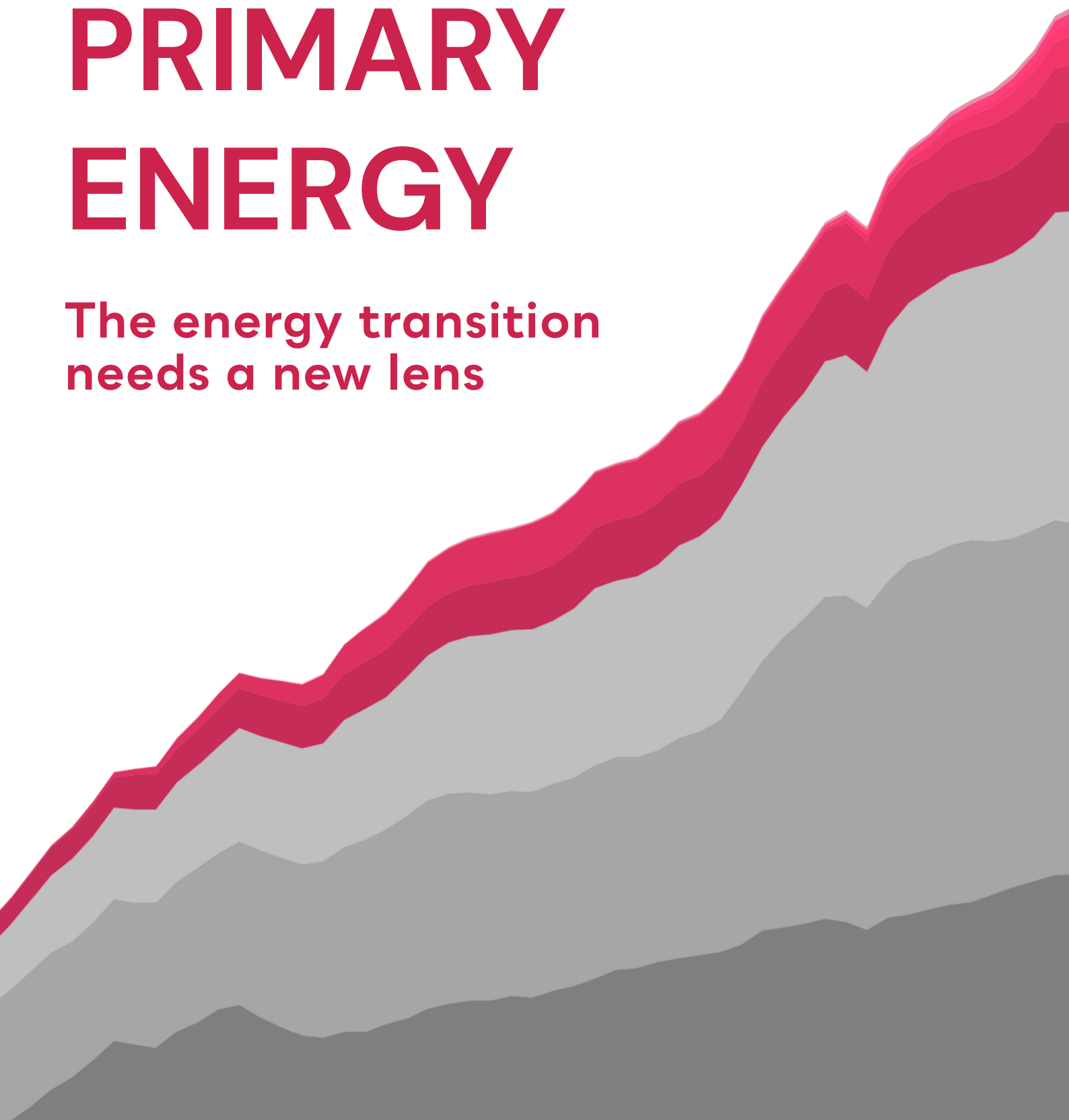
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BEYOND PRIMARY ENERGY

The energy transition
needs a new lens



INTRODUCTION

Measuring energy, whether supply or consumption, is crucial to define policy, or evaluate energy transition scenarios. To accomplish this, a reliable measuring instrument is essential. Primary energy is an important metric today, as it describes the supply to our energy system and its evolution. However, what worked well in a world dominated by fossil fuels is not suitable for a system that will primarily rely on renewables and electricity. It uses as a reference precisely what we are trying to move away from.

Therefore, it is a measure rooted in the past that is bound to become obsolete as conventions used are not based on a physical reality and it fails to capture the impact of switching to more efficient technologies. In practice, primary energy heavily favors fossil fuels, which can create a discouraging impression that the transition to renewables is an unattainable goal. Moreover, from a methodological standpoint, the definition of primary energy is problematic and varies significantly among different organizations in various studies and reports that aim to shed light on our energy future.

In this report, we aim to provide a more detailed examination of these flaws. We want to emphasize the central role of electrification in the energy transition, which is crucial for both decarbonization and energy efficiency. Focusing on final and useful energy measurements can offer a more accurate description of these dynamics.

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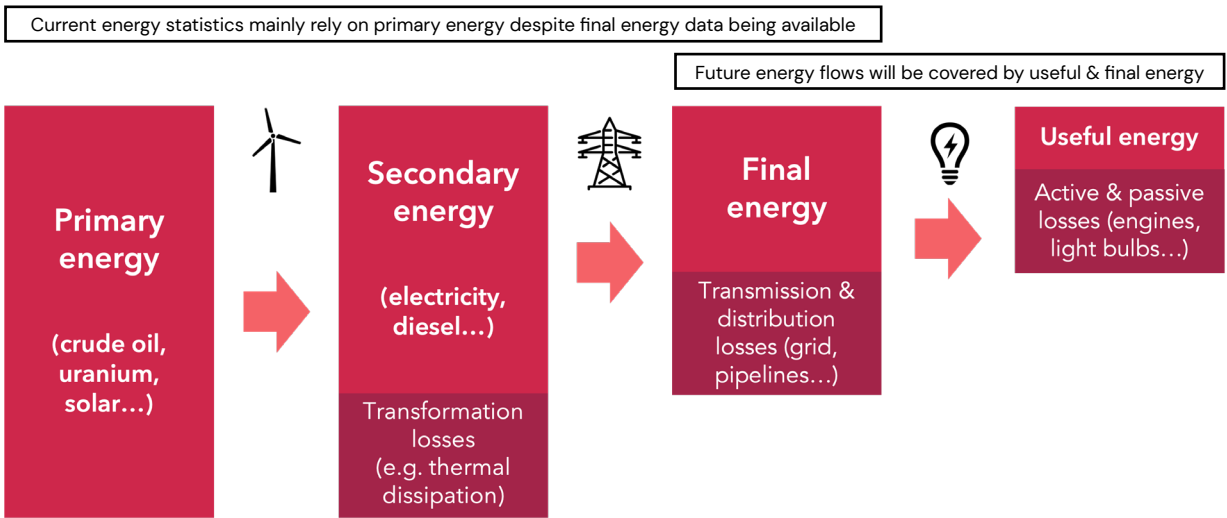
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A VISUAL SUMMARY

The way energy balances are quantified will change.

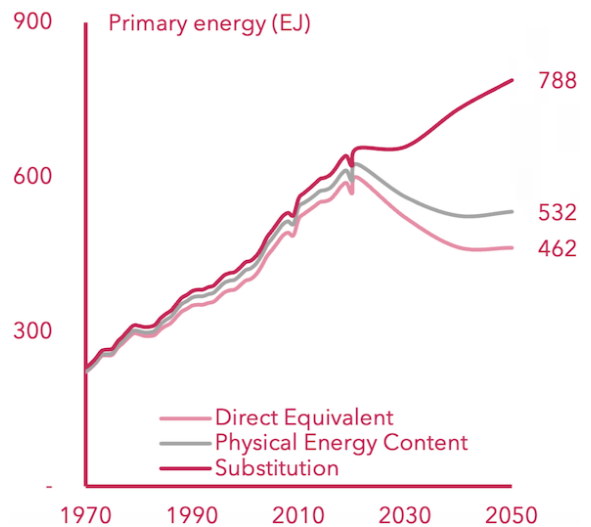
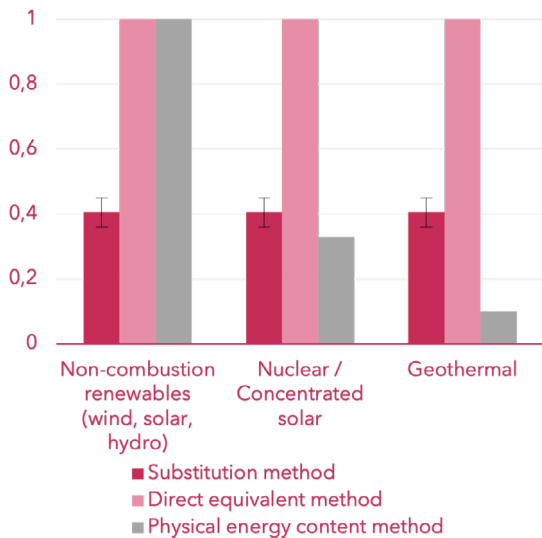
The scope of study of energy flows within an energy balance is set to change



Primary energy is outdated.

Impact of different primary energy accounting methods on primary energy demand and on primary energy to electricity conversion factors

IEA Net-Zero by 2050 scenario for primary energy statistics. IEA, UN IRES & BP statistics for conversion factors



Electrification leads to a reduction of final energy consumption.

Final energy is set to be impacted by heavy electrification of the energy system. IEA World Energy Outlook 2022

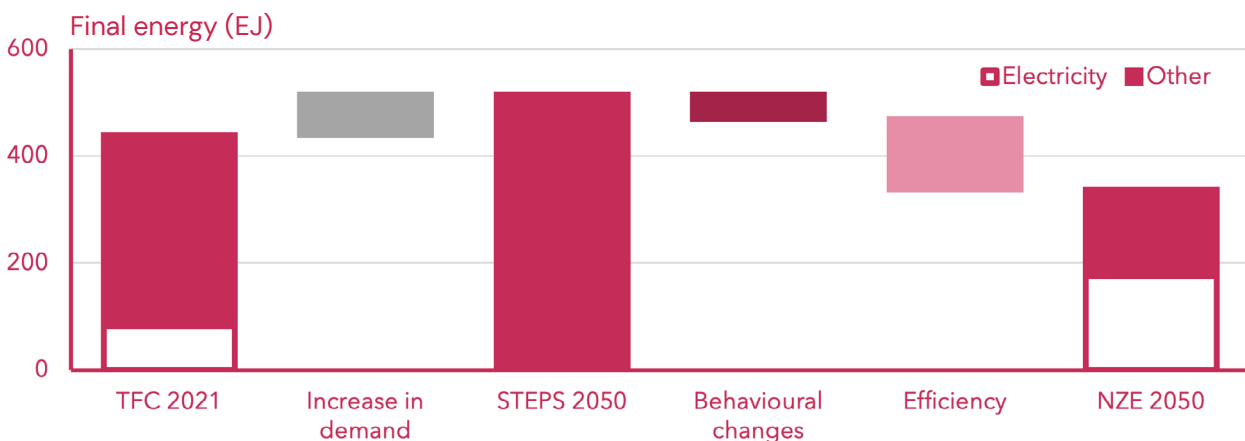


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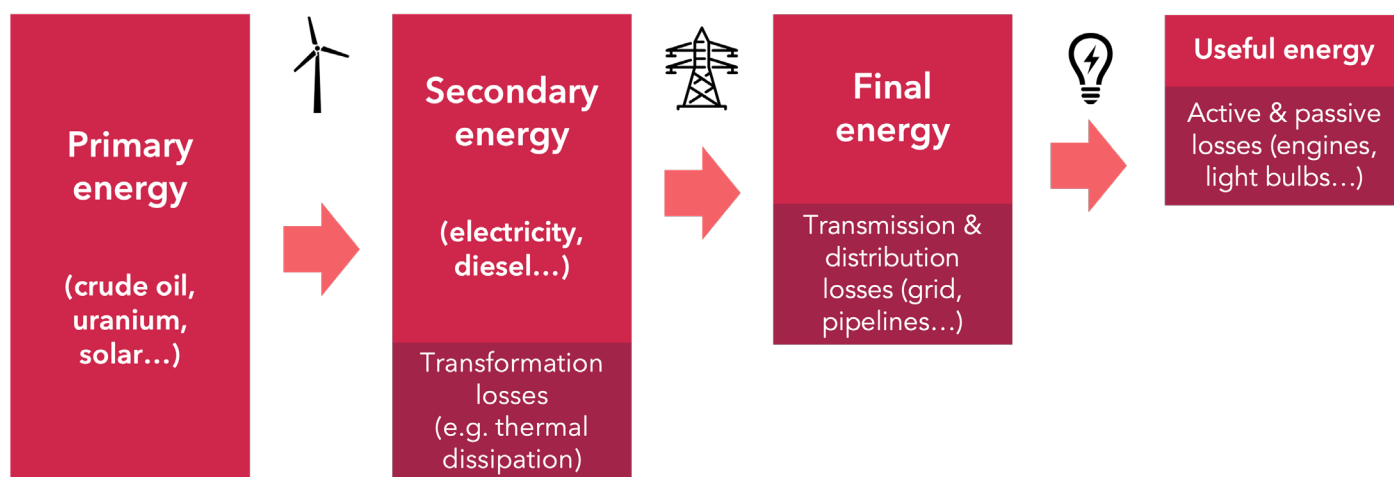


Figure 1. Simplified diagram of the energy system and the different layers of energy

The energy system comprises all components related to the production, conversion, and use of energy. To fully understand holistically the energy system that governs our societies, a common conceptual and terminological framework is required. Once put in place, this framework allows to examine in great details different aspects of the system. This framework is known as the energy balance.

WHAT IS AN ENERGY BALANCE?

The energy balance is the most comprehensive statistical accounting tool of energy products and their flow in the economy. It allows users to see the total amount of energy extracted from the environment, how it is transformed and finally how all energy vectors are ultimately used.

These statistics are needed to estimate territorial emissions, study energy transformation efficiencies, or develop several aggregated indicators. Looking at Figure 2, which shows the data for the USA, one can understand how much and what type of energy a sector consumes for a specific period. As an example, the residential sector (households) used about 14% of the 36.6 PJ of the US electricity.

Using Figure 1 as support, energy balances can be decomposed into three main layers: primary energy, final energy, and useful energy. These metrics capture the energy losses along the conversion pathway until the end-user as well as how energy is consumed and transformed.

Yet, it is crucial to understand that an energy balance is an accounting framework – as such it needs to be looked at as a whole. Individual energy metrics for each stage of the energy balance provide clear insights but using data without reference to the framework requires careful understanding.

Looking at the global energy balance shows that our current energy systems are highly inefficient (i.e., most energy is rejected at the end-user level). Looking at the United States in 2021 as an example, **67% of the energy is lost without serving any purpose**. This is equivalent to stating that **for every joule of energy used, 2 joules go to waste!** This suggests that important efficiency gains are possible to reduce energy consumption and hence reduce environmental footprints.

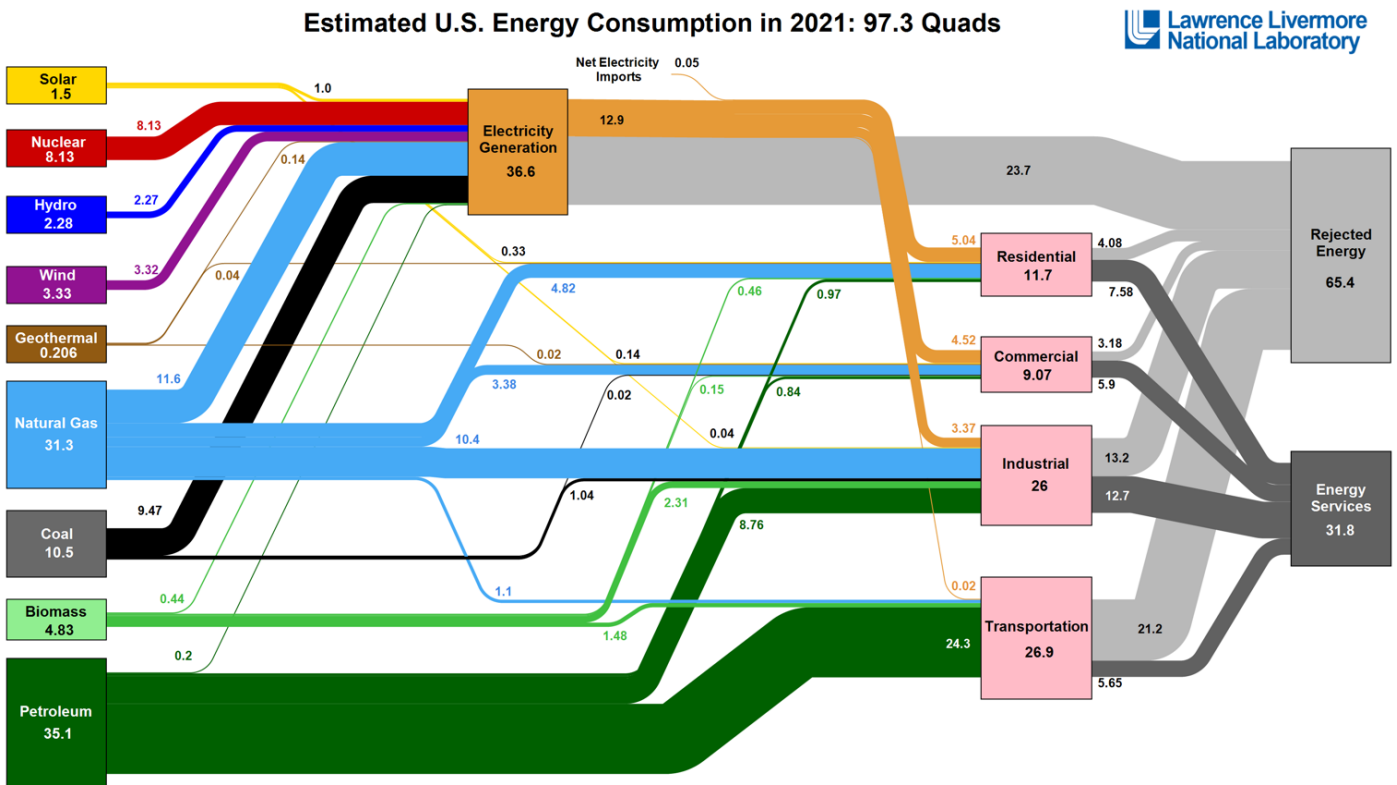


Figure 2. Energy balance of the United States, 2021¹

DIFFERENT LAYERS OF ENERGY

1. Primary energy

Primary energy represents the overall supply of energy available for use in a system before it is transformed. It is equivalent to the energy embodied in resources as they exist in the environment, or the input energy that will be used throughout the economy as it is not used directly. Its main advantage is its capacity to illustrate thermal losses of an energy system.

Primary energy cannot be directly measured. It is determined through statistical conventions to ensure the data reliability. Regarding fossil fuels and biomass, conventions are quite straightforward, primary energy is derived from the conversion of commodity balances, in physical units, defined in terms of the heating value of combustion. Choices can be made to include or not the enthalpy of water vaporization, which would affect the contained energy by approximately 5–6% for solid and liquid common fuels and 10% for natural gas².

For non-combustion energy resources (renewables & nuclear), especially for power production, different conventions with specific conversion factors exist to account for primary energy equivalents: the substitution method, the Direct Equivalent (DE) method, and the Physical Energy Content (PEC) method. The choice of convention will impact the share, or the amount of non-combustion energy resources in the primary energy supply mix.

BOX 1 | How does a convention affect the efficiency of a non-combustion technology?

Selecting a specific convention results in certain power producing technologies having different energy conversion factors, leading to different energy supply inputs⁸. Depending on the method, the conversion from electricity (final energy) to primary energy will differ.

As an example, nuclear energy has an efficiency of 0.41 (today) with the substitution method, 1 with the Direct Equivalent method and 0.33 with the Physical Energy Content method. Hence, nuclear energy which had a total electricity production of 2780 TWh in 2021⁹, would correspond to a primary energy input of 6837 TWh, 2780 TWh or 8411 TWh, using the substitution, DE or PEC conventions, respectively.

Note: For the substitution method, the efficiency of thermal power plants is expected to increase according to BP, the intervals on Figure 3 represent the efficiency in 1965 and 2050 for the lower and upper bound respectively.

Substitution

It estimates the primary energy of non-combustible sources required to produce the same amount of energy in conventional thermal plants. The equivalent primary energy is thus calculated using an Equivalent Heat Value of Combustion (EHVC) efficiency, an average indicator of current thermal power plant generating efficiencies, which evolves throughout time (to represent the progress in thermal plants' efficiency). It is mainly used by BP (and now the Energy Institute)³. This method presents difficulties regarding the choice of an appropriate thermal efficiency conversion factor as well as the display of hypothetical thermal losses for non-combustion technologies.

Direct Equivalent

It applies a conversion efficiency of 1 from primary energy to secondary energy for all non-combustible sources. Its limitations are twofold: an increase in non-conventional energy sources results in apparent efficiency improvements of the energy system as well as the fact that actual conversion efficiencies for such technologies are substantially lower than 100%. This method is mainly used in literature such as UN statistics⁴ or IPCC reports⁵.

Physical Energy Content

It employs a hybrid method with a direct equivalent approach for all non-thermal energy conversion devices. Non-combustion thermal power plants (solar thermal, nuclear, geothermal) will be given conversion efficiencies accordingly whereas non-thermal plants have an efficiency of 1. It is used by agencies such as the IEA⁶, OECD⁶, and Eurostat⁷.

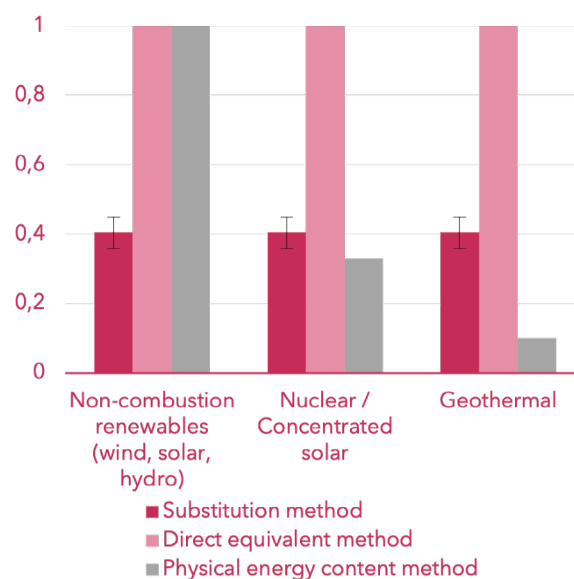


Figure 3. Efficiency factors for non-combustion technologies, according to primary energy accounting method^{3,4,6}

BOX 2 | Impact of accounting on the energy mix

Given the significant differences in primary energy accounting, care is required when using and comparing reported primary energy data across different statistical sources. The share of fossil fuels in a country's energy supply mix can greatly vary depending on the accounting method (especially for countries with a high share of hydropower or nuclear power such as France or Sweden). This can lead to biases regarding energy supply objectives, notably on the share of fossil fuels in primary energy.

Looking at figure 4, we can notice that according to the selected primary energy convention, the share of renewables (or fossils) greatly varies. This can be penalizing if policy measures include for example a specific share of renewables in a country's primary energy supply mix as an objective for climate change mitigation rather than emissions abatement.

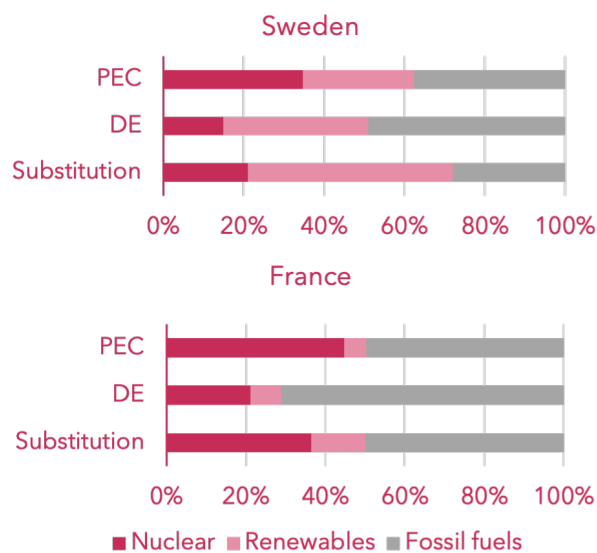


Figure 4. Energy mix for selected countries, according to primary energy accounting method. Data reworked from BP Statistical Review of World Energy¹⁰

2. Final energy

Final energy is what consumers refer to when they speak about energy. It is the energy they pay for, be it the metered electricity at home, or the gasoline at the service station. Final energy is the one distributed at the point of retail but can also be directly collected by end-users (like firewood for example). In this case, final energy and primary energy are similar¹¹.

The energy carrier for final energy is most often chosen for its energy density, its ease of transport and distribution, and finally for its versatility. Electricity is one of the best energy carriers as it can efficiently be converted into other forms of energy and is also very easy to transport.

Final energy is not used directly but converted to provide the required service by specific end-use technologies.

3. Useful energy

Useful energy is obtained after the conversion of final energy by end-use technologies- it is therefore the energy providing the required service. Cooking a meal with an electric stove uses final energy (electricity) and converts it into heat (useful energy). It is thus measured as the output of these end-use technologies. Due to its decentralized nature, however, and the diversity of machines, useful energy consumption is difficult to quantify on a global scale.

At the very end of the energy system are **energy services**, qualified as the application of useful energy to satisfy human needs, namely: illumination, thermal comfort, cooking... One could have a chimney with lots of firewood to burn but still have thermal discomfort because of the bad insulation of the house. In this, energy services differ from useful energy because they give an **indication on the quality** of the provided service.

Energy services are even more difficult to quantify as they "are the result of a combination of various technologies, infrastructures (capital), labour (know-how), materials, and energy forms and carriers"¹². From the consumer's perspective, the important issues are the **quality and cost** of energy services. It often matters little which energy carrier or "upstream" primary energy resource served as input.

As Amaury Lovins once said, "people don't want energy; they want hot showers and cold beer"¹³. Useful energy and energy services define exactly that. Quantifying useful energy and energy services is hence particularly important as it conditions our **ability to transform our environment** and ultimately do things. The available useful energy depends on the level of final energy available but also on the efficiency of the systems. Improving their efficiency leads to maximizing the quantity of useful energy available with the same quantity of final energy. Or it can be the other way around, by guaranteeing the same energy services while decreasing final energy consumption.

The current energy system is **service driven** whereas energy flows from primary state are driven by **resource availability** and **conversion processes**. This is key to understand that energy systems cannot be analysed in isolation.

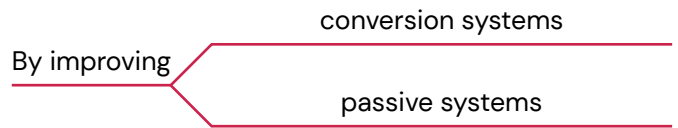
THE IMPACT OF EFFICIENCY ON ENERGY BALANCES

Efficiency is the ratio of the energy output over the energy input of a system. It arises from the first principle of thermodynamics, which states that energy is never lost nor created but only converted from one form to another- each conversion being associated with losses. Looking at the global energy system (fig. 5) shows that the useful to primary energy efficiency is only 35% i.e. 2/3 of the consumed primary energy is lost in various conversions¹⁴.

Historically, efficiency gains allowed the development of more powerful machines to provide **better or new services** that were not available before. For example, the efficiency improvements on plane engines have made long-haul travel possible, and improvements on microchips and LCD panels allowed the emergence of the smartphone, a device that fits in a pocket substituting for over 15 different end-use devices (camera, phone, calculator...) while consuming close to 100 times less energy¹⁵.

Improving the efficiency at all stages of the energy system is generally regarded as **one of the most effective means to reduce final energy consumption** while maintaining the same quality of energy service at the end, hence reducing humanity's impact on the environment (fewer fossil fuels burnt, less infrastructure to build...).

Better efficiency can be reached in two ways¹⁶:



What is also important is not only the efficiency of the energy converting device or process but rather the efficiency of the **full energy chain**, from primary energy to energy service.

Conversion devices

Electrification is a very effective way to improve energy efficiency of conversion devices in addition to **reducing GHG emissions** because electricity can be produced from low-carbon sources. For example, due to the better efficiency of electric engines compared to internal combustion engines, providing the same drive power as today would require much less final energy. Figure 5 shows the evolution of the energy efficiency of different types of engines.

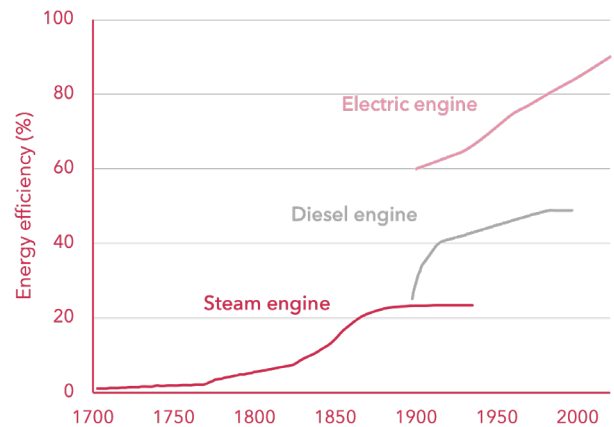


Figure 5. Comparison of historical efficiencies (tank to wheel) of steam, gasoline, diesel and electric engines^{17 18 19}

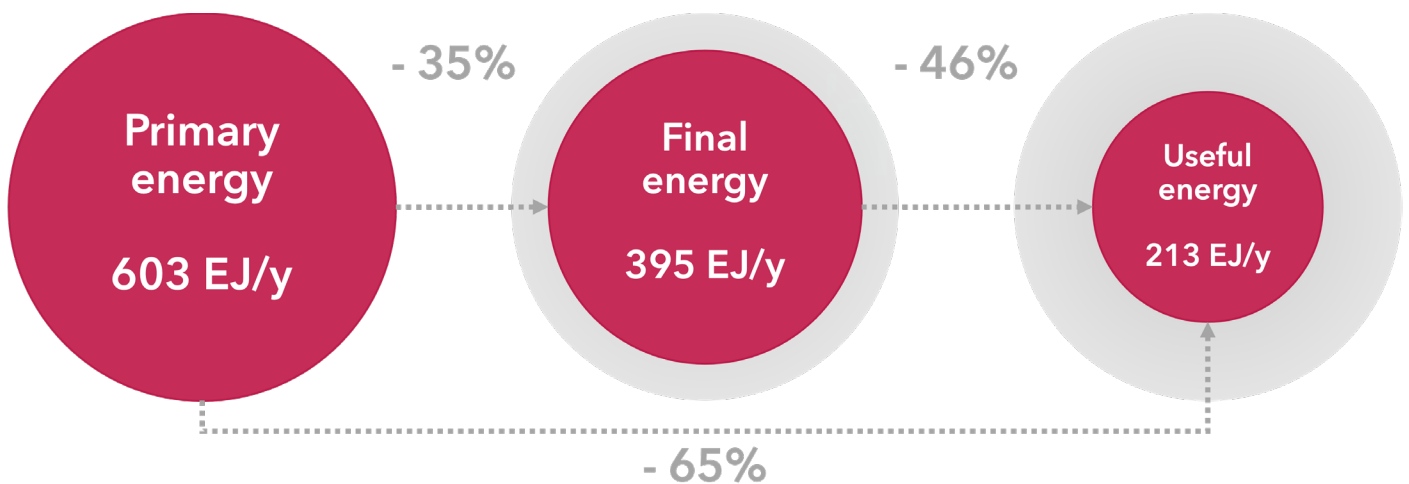


Figure 6. World primary, final and useful energy consumption in 2014¹⁴

To better grasp the impact of electrification, and the associated decrease in energy consumption, one can compare the final energy consumption of the transport sector globally in 2021 with its projected value from the Net Zero by 2050 scenario from the IEA updated in the World Energy Outlook 2022 (fig. 7)⁹.

Thanks to the rise of EV mobility, electricity will account for more than 48% of the final energy consumption of the sector in 2050 compared to only 1% in 2021. Due to the better efficiency of electric vehicles, CO₂ emissions and final energy consumption decline even with rapidly rising passenger travel, which nearly doubles by 2050, and rising freight activity, which increases by two-and-a-half-times from current levels, and an increase in the global passenger car fleet from 1.2 billion vehicles in 2020 to nearly 2 billion in 2050.

Hence, useful energy and energy services available in the transport sector increase while final energy decreases because of electrification. However, electricity consumption will be much higher in 2050 (37 EJ vs only 1 EJ in 2021), hence the need to rapidly deploy new low-carbon electricity production capacities to meet the demand.

Passive systems

Apart from electrification and the efficiency of conversion devices, efficiency gains can also materialize when considering an **integrative approach of systems** and focus on passive systems.

Passive systems are all the systems linking the conversion devices between them (transport of the energy carrier) and where useful energy is delivered.

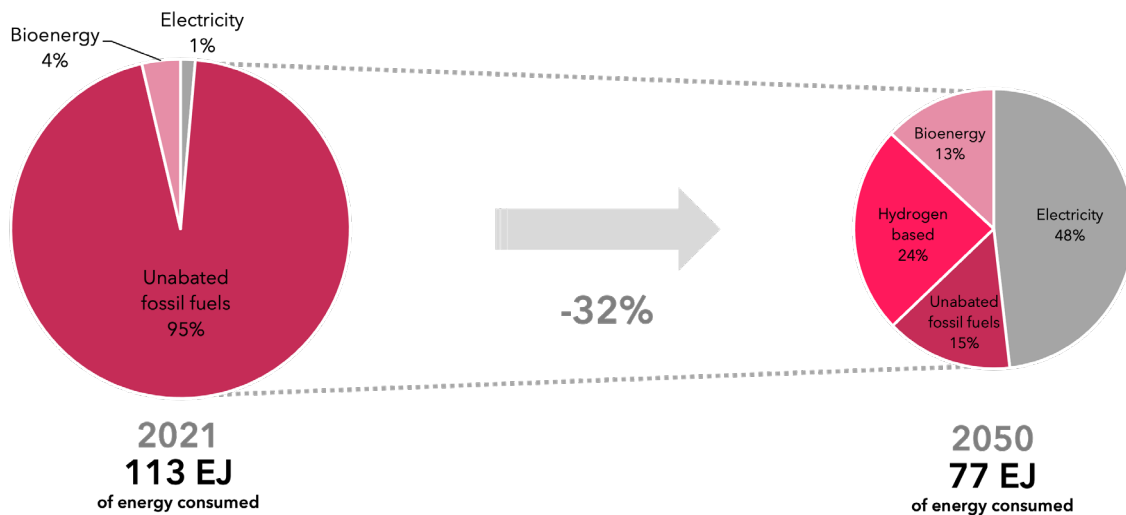


Figure 7. Comparison of final energy demand for the transportation sector between 2021 and 2050⁹

BOX 3 | Different efficiencies of conversion technologies

Electrification will result in even bigger efficiency gains for the provision of heat than for transportation. Indeed, heat pumps are much more efficient than the current best in class gas boilers, reaching efficiencies as high as 400%, compared to 90% for gas boilers²².

Even when comparing low carbon technologies, efficiency is primordial. Replacing all the electric heaters in France by heat-pumps - whose average Coefficient of Performance (COP) is around 2.3 using 2020 figures²⁰ - would save 30% of the electricity dedicated to space heating. Even more flagrant: considering that hydrogen is produced via water electrolysis powered by renewable electricity, heating a house with hydrogen would require nearly 6 times more electricity than a heat pump.

Concerning lighting, the global average efficiency of energy use in light devices is calculated to be 4%, still far below advanced technologies such as CFL and light emitting diodes (LED) with efficiencies above 20%²¹.

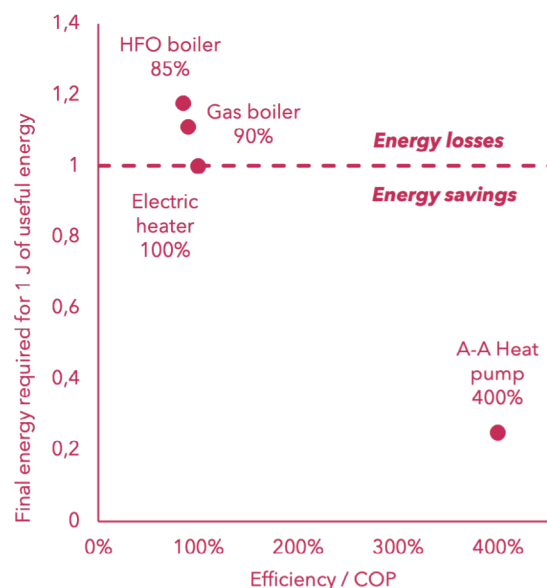


Figure 8. Efficiencies and final-to-useful energy ratios for different typical heating technologies²³

THE FUTURE OF ENERGY BALANCES IN THE ENERGY TRANSITION

1. Primary energy is outdated

The concept of primary energy is limited by its accounting methods. The different primary energy accounting methods described above outline differences in how non-combustible energy sources are accounted for in statistics. As the variations are significant for nuclear and renewables, the accounting method has an impact on how primary energy is structured. This itself is a crucial limitation in the primary energy metrics.

This is indeed a major cause of confusion when comparing different statistics and analyses and can cause damage to potential policy measures related to energy, such as reduction in energy consumption, energy efficiency, or the share of fossil fuels in an energy mix.

Given future major energy transitions, low-carbon sources will provide most of the energy, and thus mainly electricity and non-combustion thermal energy. This will lead to even higher accounting gaps between the different methods as the share of combustible energy sources will decline, despite modest differences in current energy use levels. The very concept of a statistically defined primary energy that has no real physical equivalence becomes more limited as future energy systems evolve.

Figure 9 illustrates growing divergences across the three accounting methods for an identical scenario in terms of final and useful energy demand. In 2050, the level of primary energy consumption differs by a factor of 2 while the physical infrastructure is actually the same. This is a clear illustration of the limitation of primary energy use for future energy systems: No such significant accounting ambiguities affect final or useful energy (as well as the electricity mix), which are thus preferable descriptors for transformative changes in future energy systems. Furthermore, if one uses the substitution method to convert the primary energy needs for renewable technologies, a risk of inflation of needs occurs and might make the challenge seem insurmountable.

For example, a house is a passive system for heat, and is efficient if thermal energy takes time to dissipate through the walls (i.e., the house has good insulation).

Efficiency is thus not just a matter of conversion device efficiency but also of passive systems design. An electric car is a lot more efficient than a gasoline car but reducing the weight of the vehicles, improving their aerodynamics and using low rolling resistance tires are also some ways of improving the efficiency of the transportation system.

The residential sector is also a good example as a lot of energy could be saved just by improving passive systems. For example, in its WG3 6th assessment report, the IPCC estimated that, applying the Passive House standard to both new and retrofitted buildings would induce an annual heating and cooling energy demand reduction of 75% to 95% compared to conventional values²³. In the end, by applying known engineering best practice to passive systems, Cullen et al. (2011) showed that it is possible to reduce useful energy consumption by as much as 73%¹⁶. An initial assessment of the practical efficiency limits in conversion devices provides an overall global and practical estimate for the reduction potential in demand-side options, of 85%. Hence, improvements in passive systems could save a lot of energy from being used and reduce the global environmental footprint.

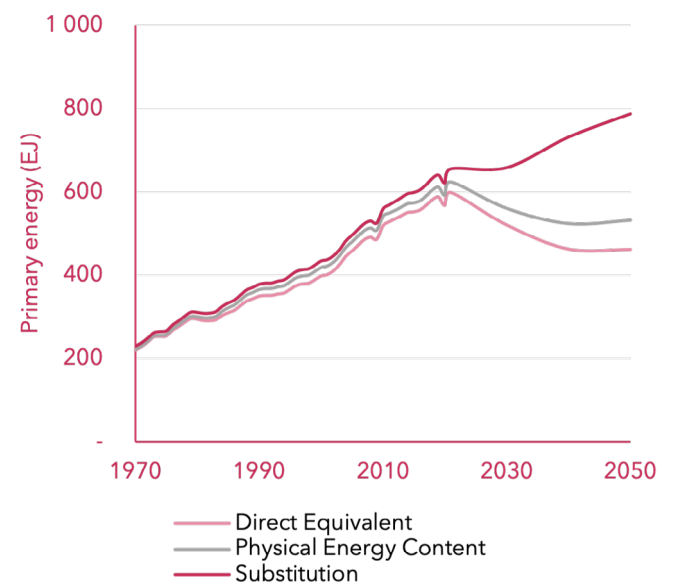


Figure 9. Evolution of global primary energy supply according to accounting method^{24 25}

Primary energy accounting underrepresents efficient technologies. Comparing demand for different energy sources in terms of units of primary energy is also misleading as they significantly underrepresent the real contributions of non-thermal renewable technologies: electrification at point-of-use. As these technologies do not rely on thermal generation, which is highly inefficient, they allow the reduction of rejected energy.

This leads to a common fallacy regarding the important share of fossil fuels in today's primary energy: it is the assumption that all the energy contained in the coal, oil, and gas that is burned today must be replaced on a 1-to-1 basis by renewables, yet it is false. **The wasted energy does not have to be replaced** and it represents a significant share of the total primary energy demand. It is why electrification is a key measure as it is more efficient than thermal generation.

This underrepresentation effect is made even worse when primary energy is determined using the substitution method. As stated previously, this method illustrates the displaced fossil fuel power generation. As the hypothetical efficiency of plants is set to increase from 40% today to 45% by 2050³, a growth rate of more than 0.5% would be required to just substitute the same fossil production. This **dwarfs any progress set by renewables** and makes the problem seem unsolvable, despite renewables having an exponential growth rate in energy supply, as supported by figure 10⁹.

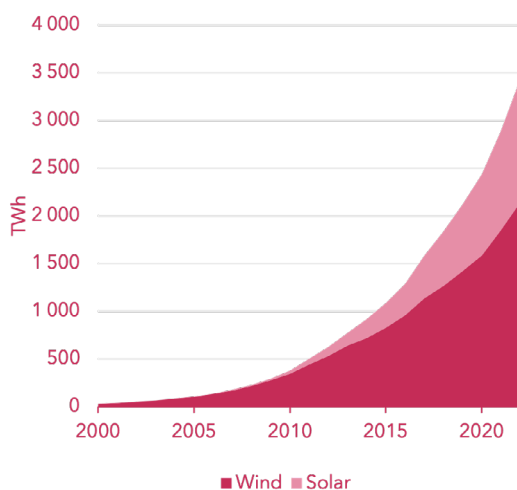


Figure 10. Global electricity generation from wind and solar, 2000-2022²⁶

2. Electrification leads to a reduction of final energy consumption

Given the fact that utilizing primary energy, for a decarbonised system, as a measure of energy is not insightful, looking at the case of final and useful

energy, and how their evolution is impacted by the radical transformation (which has only just started) of the global energy system appears more relevant.

This transformation will be mainly carried out by heavy electrification across all energy sectors. As a case in point, looking at IEA's NZE scenario (through fig. 11), the share of electricity in the global final energy demand is projected to reach 52% in 2050, as opposed to 20% in 2021. The transport sector, as stated previously, is set to have the biggest jump in electrification, with high penetration of electric vehicles. Despite providing around 50% of final energy, electricity is set to provide two thirds of useful energy by 2050⁹.

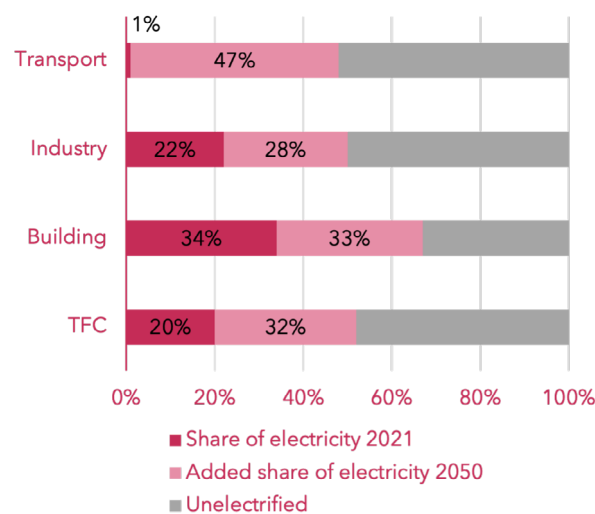


Figure 11. Final electricity consumption and non-electricity demand by sector in the IEA NZE scenario

For some sectors, however, **electrification will either not be possible or cost-effective** in the foreseeable future^{9,27}. As an example, around 50% of energy demand for energy-intensive industries is for high grade process heat (>400°C)²⁸ which is more challenging to electrify. Most of the technologies do exist and are established in the industry, but their implementation is rather **limited by costs**²⁷. Alternative energy vectors would take the lead for long range transportation²⁹, existing district heating networks (which are strategic assets) might also reduce the need for heat pumps. Or simply industry feedstocks can't be electrified, hence increasing the share of unelectrified demand.

Final energy will be impacted by efficiency.

Increasing electrification will thus mechanically lead to **a decrease in final energy consumption** as processes using electricity as a vector are more efficient, as stated previously. Hence, while maintaining constant energy services (assuming no increase in conversion efficiency from useful energy to energy services), electrification provides a reduction in energy consumption. It is thus crucial to **support policy**

choices that push towards electrification of our energy systems. Whether looking at IPCC scenarios, Low Energy Demand scenarios or IEA scenarios, electricity consumption, and hence the share of electricity in final consumption, is set to increase considerably for each sector through technology switching measures that offer better final to useful energy conversion efficiencies. All scenarios illustrate a pathway where electricity reaches at minima 42% of final energy consumption. IEA expects a share of 52%, the LED scenario 55% and the median of IPCC scenarios 46%^{9 15 23}. Differences in final energy consumption levels will mostly be due to different scopes for each scenario:

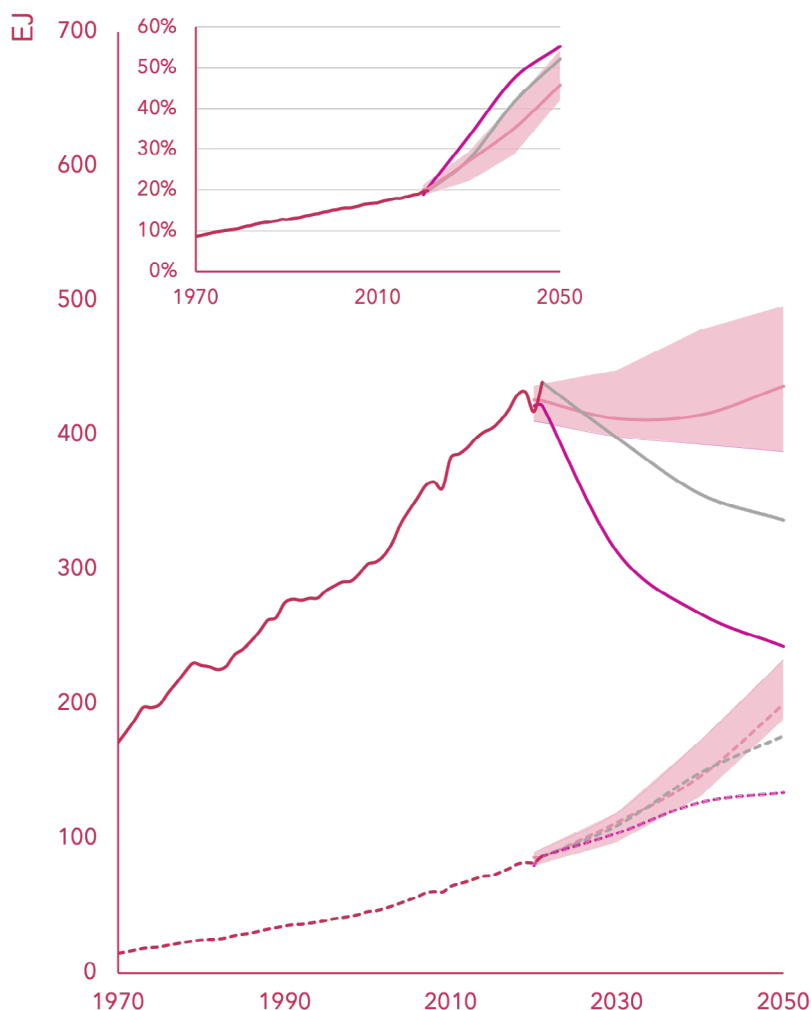
IEA provides a stronger focus on renewables and efficiency measures, as opposed to IPCC scenarios, which rely more on CDR technologies (see our report on this topic³⁰).

LED scenario insists more on useful energy demand reduction, while still maintaining high electrification.

This illustrates the strong benefits of electrification despite transition scenarios offering very different socio-economic pathways. The projections for final energy and electricity consumption for these scenarios are illustrated by Figure 12.

In any case, the will to reduce humanity's energy consumption should not prevent new renewable electricity capacity to be built. In fact, every additional GW of renewable capacity will allow new end-uses to be electrified or low-carbon fuels such as hydrogen to be produced, thus reducing the associated emissions. Hence, efforts to scale-up renewable energy and push electrification should intensify rather than slow down or the quantity of available renewable electricity will be a limiting factor in the race for net zero.

Despite efficiency being the most effective way for reducing our energy consumption and thus decreasing global emissions, scaling up cleaner and more efficient technologies takes time due to the size of the system. Without having to wait for stock turnover and the development of clean energy technology, behavioural



Side notes

The upper left chart represents the share of electricity in final energy demand, for both historical and scenario pathways. The same legend is applied with regards to color.

The IPCC IMP scenarios consist of all 7 scenarios compatible with the 1.5°C pathways, with or without high overshoot. They can be found under the C1 & C2 in the IPCC AR6 report.

- IPCC AR6 IMP scenarios range
- IPCC IMP median scenario final energy
- IEA NZE final energy
- Low Energy Demand final energy
- Final energy consumption - historical
- IPCC IMP median scenario electricity consumption
- IEA NZE electricity consumption
- Low Energy Demand electricity consumption
- Electricity consumption - historical

Figure 12. Evolution of global final energy demand and electricity demand for different energy transition scenarios. Shares of electricity in total final energy demand calculated^{9 23 15}

changes, defined as demand-side mitigation in the IPCC reports, can reduce emissions from the current stock of emissions-intensive assets through two factors: **averted demand** and **user behavioural changes**.

For example, reducing the thermostat temperature is a choice to reduce the quantity of useful energy (e.g. user changes) in the form of heat supplied to the room. This will result in a reduction of the final energy consumed to power heating devices, which are for the moment mainly fossil fuel-based technologies such as gas boilers. The IEA estimates that setting thermostats at no more than 19–20 °C in homes, offices and other commercial buildings in winter reduces cumulative emissions from the existing stock of fossil-fuelled boilers by 10% until 2030, allowing the time needed for clean-heating retrofits to take place³¹.

Moreover, even if most end-uses will be electrified by 2050, some sectors will still lack some low-carbon technologies to cut their emissions by then. For example, it is unlikely that long-haul plane travel will become low carbon by 2050 so reducing the number of flights, particularly in advanced economies, will be crucial for the sector to reach net zero²⁹.

The IEA estimates that it could save around 170 Mt CO₂, or 40% of the remaining emissions from this sector in 2050³¹.

However, efficiency gains can also lead to **rebound effects**, thus reducing the impact these improvements would have on energy consumption. In their paper, Brockway et al. (2021) studied economy-wide rebound effects by reviewing 21 studies that used the same model on energy-efficiency improvements in different countries and sectors, which gave a mean estimate of 58% rebound, with a median estimate of 55%, implying that more than half of the potential energy savings from the modelled efficiency improvements were not achieved³².

They also surveyed 12 studies that used a variety of other methods to estimate economy-wide rebound effects and found a mean estimate of 71% rebound. Hence, taken as a whole, they provide a consistent message of **economy-wide rebound effects eroding more than half of the potential energy savings from improved energy efficiency**— highlighting that those effects need to be accounted for when designing policies aiming to improve efficiencies.

However, rebound effects generally appear when the cost of the service decreases thanks to efficiency gains, which will not be necessarily the case with the energy transition because the investment may potentially be bigger than the resulting economies, at least in the short term³³ (e.g. for the moment the total cost of ownership of an electric car is higher than a gasoline car even though the cost per km is lower³⁴).

BOX 4 | The impact of behavioural changes on final energy

Although sufficiency measures are necessary for triggering a rapid cut in emissions, its impact on energy consumption is relatively lower compared to efficiency gains thanks in part to electrification.

Indeed, in its updated roadmap for Net Zero by 2050, where a strong focus is made on efficiency measures, the IEA estimates that efficiency gains would save as much as 15% (85 EJ) of final energy by 2050 in the industry sector, 35% (85 EJ) in buildings and 37% (97 EJ) in the transport sector while behavioural changes would only save 11%, 12% and 11% of final energy in these sectors respectively.

In the end, efficiency is expected to participate in 27% reduction in total final energy consumption whereas behavioural changes only 11%⁹.

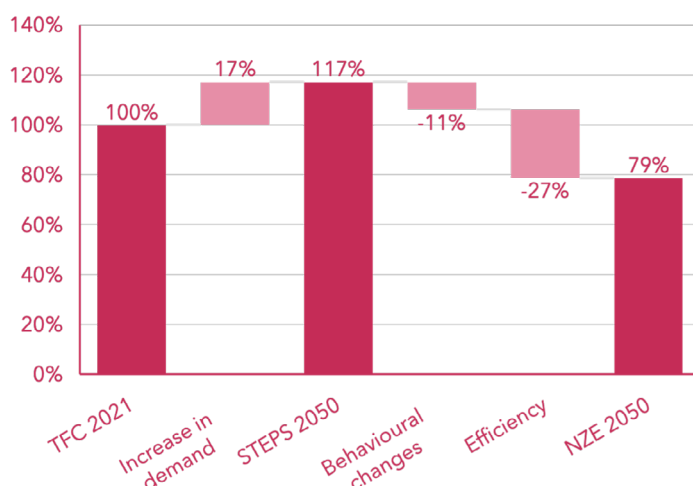


Figure 13. Impact of efficiency and behavioural changes on final energy demand by 2050⁹

Note: Behavioural changes include user changes and avoided demand. Efficiency includes energy efficiency and fuel switching.

CONCLUSION

The energy transition is fundamentally the transformation of an energy system based largely on the combustion of fossil-fuels to a system more dependent on electricity produced by non-combustion methods. The concept of primary energy was suited for a fossil-fuel based system but is not representing accurately the emerging new system. The use of final energy, or even better useful energy, gives a much more accurate view of the energy transition. Given that 2/3 of the current primary energy is lost at waste, the use of this indicator gives the false impression that the current system needs to be matched 1 to 1, which is incorrect.

The growing role of electricity in the energy mix (about 50% or more in most scenarios) will also bring strong efficiency gains which will reduce the final energy consumption- the transition is therefore a paradox: more electricity but less energy. Efficiency should be considered both at a given conversion level but also at the system level- and significant gains are possible. To complement these gains, many measures can be taken on the demand side to further reduce consumption.

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