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Exploring Energy Sufficiency Benefits, Limitations, Deployment, and Opportunities in Europe

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Abstract
Following the industrial revolution, greenhouse gases continue to grow, and this increase degrades the ozone layer and accelerates the global warming. The climate change has considerably transformed our way of life and the way we produce, buy, transport, and use energy. To reduce the impact of the energy crisis different levers are activated such as energy efficiency, renewables energy and energy sufficiency. The aim of this article is to explore the benefits, limitation, deployment, and opportunities in Europe of energy sufficiency. The research conducted also includes real case studies on energy sufficiency. Furthermore, Covid-19 pandemic and Ukraine war have negatively impacted energy availability and costs.

Keywords: Energy sufficiency, Energy efficiency, Renewable Energy, Covid19, Ukraine war

1. Introduction

The average temperature on earth continues to rise, and this puts its future at risk. **According to Lindsey & Dahlman, (2020)**, the 2022 surface temperature was 1.55 °F (0.86 °Celsius) warmer than the 20th-century average of 57.0 °F (13.9 °C) and 1.90 ˚F (1.06 ˚C) warmer than the pre-industrial period (1880-1900). This global warming is due to the high concentration of greenhouse gases (GHG) in the atmosphere.

Contrary to what many people think, greenhouse gases are not inherently negative. Indeed, they are part of the elements that help to regulate the climate. The average temperature on earth is +14,76°C and without greenhouse gases the temperature would be much lower around -18°C. At this temperature, life on earth and development for human beings, animals, and nature (trees etc.) would be almost impossible.

Following the industrial revolution, greenhouse gases continue to grow, and this increase degrades the ozone layer and accelerates the global warming. The effects are already present: increase of the rate of sea level, extreme weather events such as storms, floods, forest fires and droughts.

The four mains greenhouse gases are:

- Carbon dioxide (CO_2): its accumulation in the atmosphere contributes to 2/3 of the increase in the greenhouse effect generated by human activities (combustion of gas, oil, deforestation, cement works, etc).

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- Methane (CH_4): ruminant farms, flooded rice paddies, garbage dumps and oil and gas operations are the main sources of human-induced methane.
- Nitrous oxide (N_2O): it comes from nitrogenous fertilizers and certain chemical processes.
- Sulphur hexafluoride (SF_6): it comes for example from high voltage electrical distribution cells

Figure 1 represents a generalized classification of activities leading to the emission of greenhouse gases into the atmosphere **(Yoro & Daramola, 2020).**

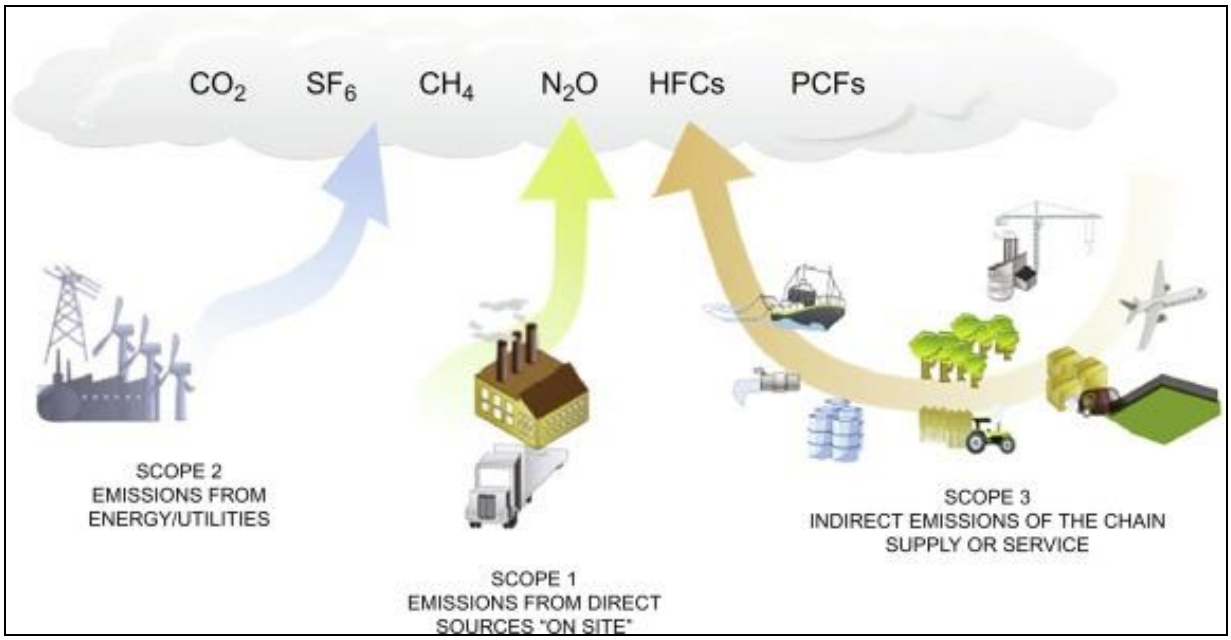

Figure 1. Classified sources of greenhouse gas emission (Yoro & Daramola, 2020)

Because of the current situation, we must mobilize and act. Everyone is concerned: elected officials, economic players, citizens, to reduce our greenhouse gas emissions, but also to adapt to the changes already underway. Energy sufficiency is considered as one of the three energy sustainability strategies, next to energy efficiency and renewable energies **(Zell-Ziegler et al., 2021)**.

Bagheri et al. (2022), state that energy sufficiency mostly aims at curbing the overall demand for energy services while generally improving the well-being of consumers, although that might challenge the relationship to well-being, focusing on the quantity rather than the quality of services accessed and goods accumulated, and require to aim for some redistribution of those services, considering the current inequalities.

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Figure 2represents the change in primary energy consumption in the "business-as-usual" and "négaWatt" scenarios between 2015 and 2050 for France **(négawatt, 2017).**

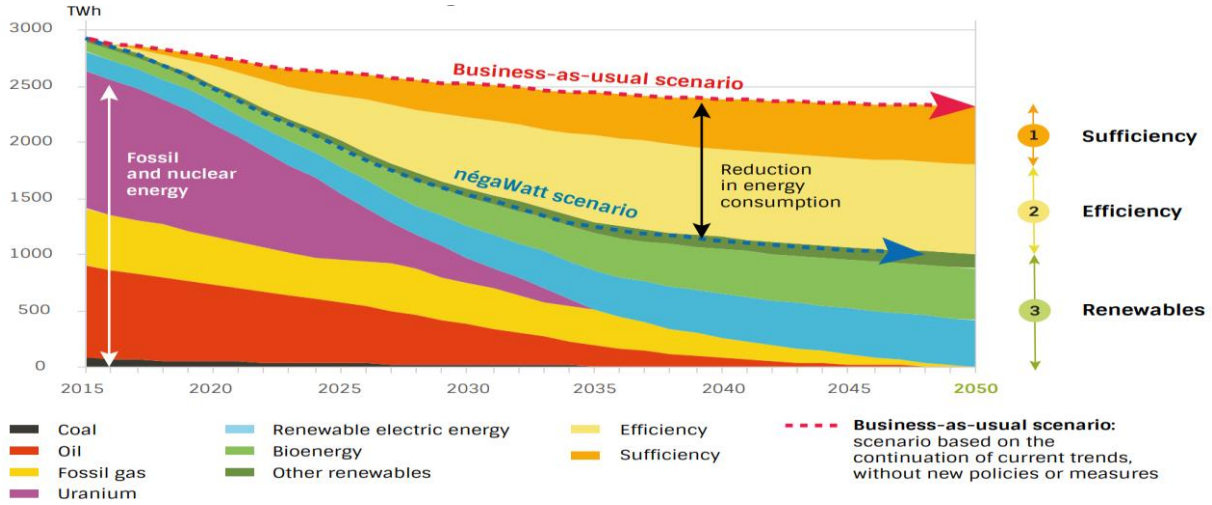

Figure 2.**C**hange in primary energy consumption in the "business-as-usual" and "néga Watt" scenarios **(négawatt, 2017)**

The energy crisis has worsened during these last years due to several factors/events such as covid 19 pandemic, the war in Ukraine and global warming (increase in industrial activities, deforestation etc.).

Through this article, the objective is to evaluate if energy sufficiency can concretely be a lever to reduce energy crisis impact.

2. Concept, Advantages, and Application of Energy Sufficiency

The existing literature on energy sufficiency is based on various understandings of the concept and consequently there is no congruent definition of the term energy sufficiency **(Zell-Ziegler et al., 2021)**.

Nevertheless, energy sufficiency is based primarily on the behaviour of each human being. Everyone is free to choose. The energy impact of everyone is not necessarily significant, but the impact of many individuals is very significant. Everyone can (according to his possibilities) and must contribute to the general effort **(Burk, 2020).**

Energy sufficiency can be reached if there is a gradual change in daily individual behaviours. Here are some examples:

- Use of shared means of transport such as carpooling or use of completely carbon neutral means of transport such as bicycles **(Bobinaite et al., 2023)**.
- Implementation of different collective organizations such as exclusive pedestrian zones (where cars are forbidden)

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Energy sufficiency is a constructive and collaborative approach to achieve the implementation of sustainable development of organizations while preserving the resources of our planet. **As stated by M'Baye (2022a)**, the easiest energy to make clean is the energy we don't consume.

In the concept of energy sufficiency, our existing – and often growing – needs for heating, lighting, consumption, travel, are not fundamentally called into question. It is a question of transforming expensive and irrational behaviour (oversizing and multiplication of equipment, no-load operation, etc.).

Sufficiency is fast and cost-effective. Technologies and infrastructure for climate protection require investment, ramping-up, research and development. However, meeting carbon emissions targets implies a steep GHG reduction pathway, which makes the speed and cost of mitigation options crucial. Sufficiency often requires no investment or special infrastructure (or very little), which means it can be implemented rapidly **(Best et al., 2022).**

According to Bagheri et al. (2022), sufficiency is often wrongly understood as being only determined by individual behavioural changes and willingness, and therefore difficult to handle in models, scenarios, and policymaking, when it also relates to policies and infrastructural changes.

Renewable energies are one of the levers to reduce the impact of the facts mentioned above. However, this lever has its limits and cannot be activated alone.On the other hand, we must encourage the use of the most efficient technological advances to optimize the consumption of uses. This signifies to activate the energy efficiency lever **(Hasanbeigi et al., 2015; Hasanbeigi et al., 2013a; M'baye, 2022b)**.

Vadovics& Živčič (2019) indicate that it has become evident that energy efficiency is not delivering on its potential, sufficiency needs to play a more prominent role in sustainable energy policy and action, especially because it offers a way to connect the satisfaction of basic needs with not consuming excessive and unsustainable amounts of resources. While efficiency is about doing things right, sufficiency is about doing the right things**(Erba& Pagliano, 2021).**

Finally, when energy consumption is reduced to its maximum, the renewable energy lever should be activated to limit the use of fossil and nuclear energies. Nuclear presents two major disadvantages: high security risk and problematic treatment of radioactive waste.

3. Rebound Effect

The rebound effect corresponds to the fact that a saving at one point can lead to additional expenditure at another point. The notion of energy sufficiency plays an important role in its combination with energy efficiency and renewable energies. Indeed, it makes it possible to minimize the "rebound effects" that can come with energy efficiency gains.
Rebound literature has defined terms like reverse rebound, prebound or super-conservation to refer to situations where the actual energy demand falls below the expected. Similarly, research

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also refers to "permitting" or "negative" spill over to describe rebound-type effects **(Dütschke et al., 2021).**

One of the typical illustrations of rebound effect is the LED light which consumes less electricity than a conventional lamp. Households are massively equipped with LEDs but turn them off much less. As a result, the energy consumption of this type of equipment has not decreased in some places.

A direct rebound is an increased demand for the same good. Indirect rebounds correspond to all those who save energy and therefore money due to increased efficiency, will spend the money on other things that also consume energy **(DKE, 2018)**.

According to Sorrell et al. (2020), rebound effects and negative spill overs can erode the environmental benefits of energy sufficiency actions. The magnitude of rebound effects and negative spill overs will depend upon the type of energy sufficiency action and the motivations, circumstances, and choices of individual households.

In addition to the income rebound effect – savings in one area led to spending in others – the idea of a frugality rebound effect has been suggested – ecologically virtuous behaviour in one area can lead to a relaxation of consciousness in another.

The existence of many potential rebound effects justifies the use of the concept of energy sufficiency as a complement to energy efficiency approach.

Figure 3 contains an example of rebound effects.

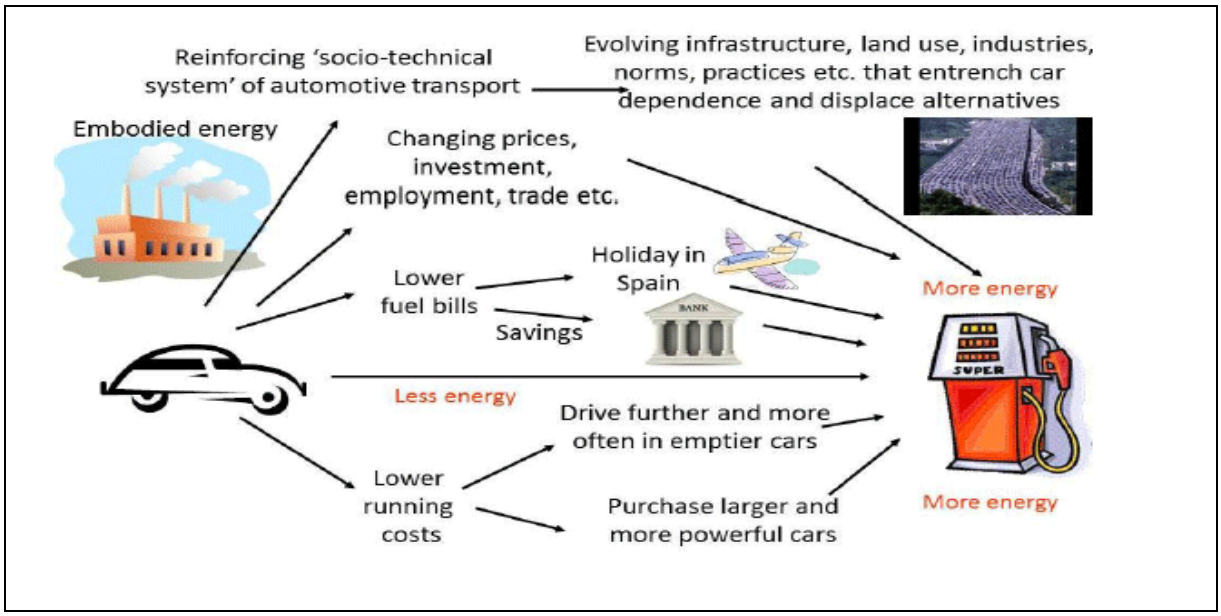

Figure 3. Rebound effects from more fuel-efficient vehicles (Sorrell et al., 2020)

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4. Behaviour and Regulations

If we refer to the energy sufficiency approach, we can see that this approach is global and consequently implies a change in collective and individual behaviour at the very heart of organization such as industrial companies, commercial buildings, cities etc. **(Santos et al., 2018; Hasanbeigi et al., 2013b)**.

As demonstrated by Mbaye (2022c), energy audit permits to identify and improve collective and individual behaviour.

Traditional tools of constraint such as regulations and taxes have limits to involve and engage collaborating organizations and individuals to reduce their environmental impact.

The establishment and implementation of new legislation is a long and complex process that involves a certain inertia due, among other things, to lobbies and the various economic interests that may be involved. The creation of economic incentives to bring out innovative and relevant solutions takes a long time and is an expensive process, despite the urgency of the situation.

The behavioural economics approach makes it possible to activate decision-making levers, thus becoming a complementary tool with significant results on environmental issues and at low cost.

It is thus possible to employ nudges through different levers such as default choice architectures, social norms, salience, feedback, engagement, micro-incentives and rewards, reciprocity and recognition, framing, decision points as well as ease.

Educating, raising awareness and informing is an essential prerequisite for mobilizing individuals around the preservation of the environment. For actions of the so-called "sufficiency" in favour environment to be perpetuated and become a lasting part of mores, it is above all necessary to bring meaning to the actions. Without this preliminary step and this appropriation of meaning, the durability of the acts will not be integrated by the individual.

Note that this requires effort, time, and support if behaviour is to be changed daily.

5. Case studies

Case study on rebound effect ***(Ouanes, 2022):***

To decarbonize the energy system and achieve climate protection goals, significant increases in renewable energy production are needed. Solar photovoltaics (PV) are an essential part of this transition and the contribution of PV prosumers – households that produce their own electricity – is becoming increasingly relevant. PV prosuming not only influences the electrical energy mix in the household, but it can also lead to behavioural changes influencing energy consumption patterns

On the one hand, these changes can occur in the form of rebound effects, which we define in this context as increases in energy consumption subsequent to an increase in renewable energy use **(Galvin et al. 2021).** On the other hand, PV prosuming may result in reductions in energy consumption, which we understand as sufficiency-oriented behaviour. Depending on the methodology and socio-technical variables used, studies focusing on rebound effects from PV

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prosuming find evidence for both trends, with a varying scope that can range from a reduction or no significant increase in consumption **(Li et al. 2020; Oberst et al. 2019)** to substantial rebound effects, potentially equivalent to the rate of self-consumption **(Frondel et al. 2020).**

The findings of the German research project EE-Rebound indicate increasing electricity consumption, especially for households that installed their PV-systems after 2011. This may be attributed to self-consumption becoming economically more profitable than grid feed-in after this date. Based on a survey among prosumer and non-prosumer households with a subsequent matching of their socio-technical characteristics, the post-2011 PV prosumer group was shown to exhibit an approximately 18 % higher electricity consumption than comparable non-prosumer households **(Galvin et al. 2022).**

Case study on energy sufficiency in transport sector ***(Bobinaite et al., 2023)***
This case study investigated the role energy sufficiency in passenger transport could play in resolving the most pressing energy, climate, and sustainable development issues in Lithuania until 2050, including an increasing demand for energy, a lack of energy reliability and security and an unsustainable use of resources.

Findings revealed a variety of changes due to transition towards energy sufficiency:

- Quantifying the impact on energy consumption revealed that wider use of public transportation and bicycles, as well as slowing the growth rate of passenger car travel will have an impact on better management of passenger-kilometres in the passenger transport sector. This could result in final energy savings and thus slow the growth of energy consumption in the sector, which is the country's largest energy consumer. As a result, in 2050, it is possible to save 550 ktoe of energy, equivalent to an 8.2% reduction in final energy consumption.

- Evaluating the impact on GHG emissions demonstrated annually increasing (by 3.8% to 20.8%) reductions in GHG emissions, resulting in 20 MtCO2eq. savings over the period. For this objective, policy measures are indispensable. They could be directed toward demand control and the transition to non-motorised and less polluting modes of transportation. This should be done in conjunction with education and awareness campaigns. This analysis aimed to draw policymakers' attention to the energy savings potential inherent to energy sufficiency, which can achieve energy, climate, and sustainable development goals.

Case study on energy sufficiency policy ***(Batiactu, 2023):***
The French government has launched an energy sufficiency plan to answer to the current crisis (see section 6). The goal is to reduce by 10% the France's energy consumption.
Like Paris or Lyon, several cities in France have implemented plans to reduce their energy consumption in 2022 fall and winter.

In Clermont-Ferrand, the plan has shown a real impact on consumption. First, public lighting decreased by 18% from November 2022 to March 2023 compared to the previous year, thanks to the extinction of public lighting from midnight to 6:00 a.m. (60% of the lights). This represents a

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saving of 570,000 kWh, depending on the city and metropolis. In the 10 municipalities of the metropolis, the regulation of public lighting made it possible to reduce consumption by 26% between November 2022 to March 2023 compared to the previous year, or 1.9 million kWh saved.

In Clermont-Ferrand, the efforts made in public buildings (gymnasiums, offices, or schools, etc.) have also reduced heating consumption by 17.5% between October 2022 and January 2023: -19% for electricity, -17.5% for gas, -7.5% for district heating and -1.5% for fuel oil.

However, this performance did not reduce the energy bill due to soaring energy costs.

6. Other impacts

Covid 19 Pandemic

Global activity decreased significantly during the Covid-19 epidemic. This has led to a significant drop in energy consumption. Many countries around the world have introduced lockdown with the direct impact, for example, of the closure of industrial companies and the reduction of travel of different means of transport (cars, etc.).

In 2020, the global CO_2 emissions decreased by about 5%. In 2021, global anthropogenic fossil CO_2 emissions rebounded and by 5.3% in comparison of 2020, totalling 37.9 Gt CO_2, just 0.36% below 2019 levels **(European Union, 2022)**.

Greenhouse gas emissions have continued to rise following the global economic recovery. However, there are some differences between the different fossil fuels that are most harmful to the environment.

In fact, emissions from natural gas decreased by 1.6% or 118 Mt in 2022, as an already tight gas supply was exacerbated by Russia's invasion of Ukraine and the widespread trade disruptions that followed. Reductions in emissions from natural gas were more than replaced by emissions from coal **(International Energy Agency, 2022)**.

Coal emissions grew 243 Mt to a new all-time high of almost 15.5 Gt. This 1.6% increase was faster than the 0.4% annual average growth over the past decade **(International Energy Agency, 2022)**.

For example, Germany, which was very dependent on imports of Russian hydrocarbons, decided to reopen and extend coal-fired power stations to secure its electricity supply in the coming years, even if it meant polluting more.

Figure 4 represents well the pre and post pandemic period with year 2019 as pivot year.

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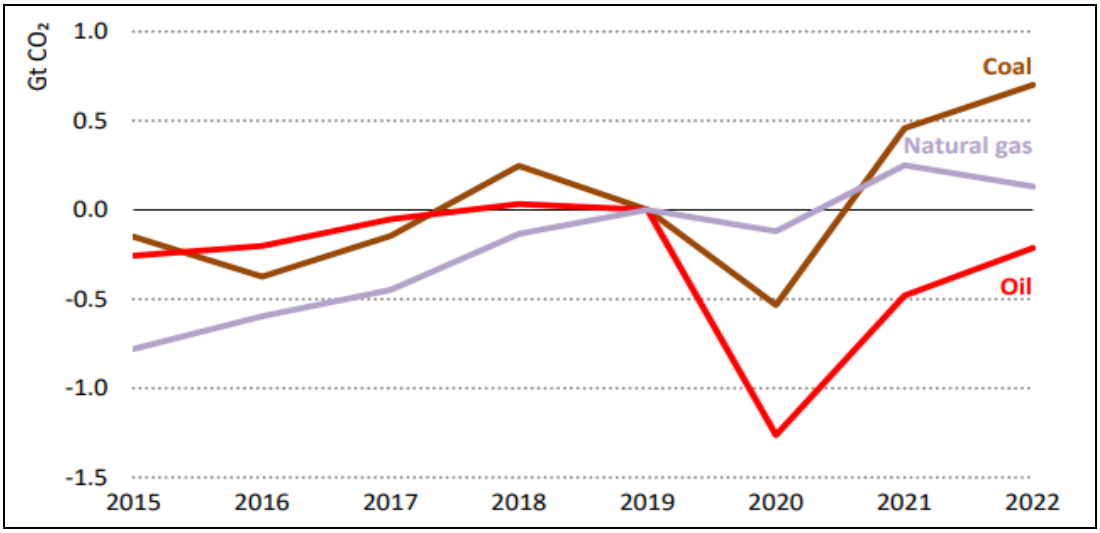

Figure 4. Change in global CO_2emissions by fuel, relative to 2019 levels, 2015-2022(International Energy Agency, 2022)

Ukraine War

The Russian invasion of Ukraine that began in February 2019 has a major impact on energy availability and costs **(Leuser & Pellerin-Carlin, 2022).** This war by the energy crisis which it would have amplified and accelerated has, at first sight, favoured the reduction of consumption. However, looking closer, the decrease is more related to the very high prices than to the discount incentives from governments to their populations.

European countries are dependent on Russia for the supply of gas up to 45%. To overcome this dependence on Russia, European countries have urgently approached other gas-producing countries. This led to a panic in gas prices as many industrialists feared having to stop their activities and also as a large number of households feared being deprived of heating.

Electricity prices were also strongly impacted in Europe. This is due to the construction of the European energy price system, which connects gas prices to electricity prices. Electricity prices went from a hundred euros per megawatt/hour when the war broke out, to almost 750 euros in summer 2022.

The price of gas will have increased by 200% with leaps to 340 euros per megawatt/hour on the markets, against 80 euros per megawatt/hour in February 2022.

In an emergency, the Europeans have also turned to liquefied natural gas, which arrives by boat, and it comes mainly from the United States. This liquefied gas has 2 major disadvantages. First, it is more expensive than Russian gas. Secondly, it is more polluting because it comes from hydraulic fracturing (shale gas), and it requires more energy for its treatment.

In the wake of the current geopolitical crisis, the IEA has proposed many fast sufficiency options in its '10-Point Plans' to reduce the EU's reliance on Russian gas and oil (**Best et al., 2022)**.

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This crisis is not yet over and the impact on availability, energy costs and carbon emissions will be present for several years.

7. Conclusions

This study has highlighted that energy sufficiency is one of the levers to reduce current energy crisis aggravated and accelerated by the covid 19 crisis, the war in Ukraine and the growing human activities at the origin of global warming. This solution is efficient fall components explained in this article are considered such as the rebound effect. Moreover, energy sufficiency must be associated with the other levers which are energy efficiency and renewable energies.

The goal of energy sufficiency is to reduce the amount of energy needed for the same service while maintaining quality of life. **Sahakian et al. (2019)** state that households, as consumers and citizens, have a role to play in tackling the need to limit energy usage and related carbon emissions, yet approaches which rely solely on individual behaviour change or technological change have proven to be far from sufficient thus far.

Sufficiency policies entail various advantages as a strategy to tackle the current energy crisis as well as the climate emergency, such as:

1. immediate reductions in energy demand,
2. low costs of implementation,
3. keeping energy prices in check,
4. reducing the costs for the transition to climate neutrality,
5. and co-benefits such as improved health**(Leuser & Pellerin-Carlin, 2022).**

There may also be a positive consequence to this energy showdown with Russia: the acceleration of the development of renewable energies and the energy transition. European states want to reduce their dependence on imported energy. The European REPowerEU plan provides additional funding and facilitates the installation of solar and wind farms.

Currently, numerous research on water savings can be found in the literature **(Hasanbeigi & Price, 2015; Gao et al., 2022; M'Baye, 2022d)**. The concept of sufficiency can be applied to water and should be studied. The concept of energy sufficiency can also be pushed even further in the years to come with an even more ambitious goal of getting rid of superfluous behaviours and needs to achieve a simpler and more satisfying life and zero carbon emissions per individual.

List of abbreviations

COVID-19: Coronavirus disease 2019
CO_2: Carbon dioxide

CH_4: Methane

N_2O: Nitrous oxide

SF_6: Sulfur hexafluoride

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LED: Light-emitting diode

GHG: Greenhouse gases

PV: Solar photovoltaics

Ktoe: Kilotonnes of oil equivalent

MtCO2eq: Million Tonnes of carbon dioxide equivalent

Declarations

Availability of data and material

Data sharing is not applicable to this article as no datasets were generated or analysed during the current study.

Competing interests

The author declares that h has no competing interests.

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Authors' contributions

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