RENEWABLE HORIZONS: INVESTIGATING FEASIBILITY IN CONSUMPTION TRENDS

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Abstract The European Union's ambitious target to achieve zero emissions from passenger cars by 2035 has sparked significant strategic overhauls among European car manufacturers, pushing them towards a 100% electric vehicle fleet. Concurrently, a forthcoming heating law, slated to take effect from 2024 initially in Germany, aims to drastically curtail the installation of gas and oil heating systems in favour of heat exchangers. These legislative shifts are already straining the power grid, necessitating a substantial expansion of renewable energy capacity. Projections indicate an ongoing surge in energy demand, underscoring the imperative of a global transition away from fossil fuels. However, this endeavour poses formidable challenges for nations worldwide. This study delves into the current state of renewable energy and its projected evolution, stressing the imperative of significantly boosting renewable energy deployment to achieve sustainable electrification of passenger vehicles globally. It highlights the need to triple the share of renewable energy sources, quadruple efforts across all transportation sectors, and increase the overall transition away from fossil fuels fifteenfold. While conventional renewables such as solar, wind, hydro, and biofuels remain integral, emerging technologies like nuclear fusion offer promising avenues. Nonetheless, attaining complete independence from fossil fuels may prove elusive, considering non-energy applications of crude oil and other fossil resources. The study also assesses potential ecological ramifications and balances the environmental impacts of these energy transitions.
Keywords renewable energy, defossilization, nuclear fusion

Introduction

The discussions about opportunities to stop carbon dioxide emissions have remained as the most complex topic ever since. While environmental associations stress the fact that the ongoing measures targeting the goal of zero emissions had not been sufficient, companies and societies are struggling with political decisions. On the one hand, sustainable measures seem to be too expensive and inefficient, on the other hand specialists claim that talking about a decarbonization is not enough and that we had had to talk about a defossilization instead (Schlögl, 2019, Kramer, 2019). A global defossilization would remain in a stop of using crude oil, natural gas, and coal, especially for energy means. The usage of fossil fuels differs between economic sectors. While coal is mainly used for industrial purposes (about 84 %) and natural gas is mostly used for residential and commercial/public service purposes (about 43 %), and industrial purposes too (about 38 %), crude oil is used for mobility and transport purposes by about 65 %. The amount of energy associated with this is equivalent to about 25 % (around 36.361 TWh) of the total energy produced from fossil fuels worldwide in 2021 (IEA, 2021).

In the mobility sector most, manufacturers track a full electric strategy, which indicates the end of combustion engines and a future of electronic engines. Especially European OEMs

(Original Equipment Manufacturers) are forced to do so since the European Parliament had decided to reach zero emissions in the fleets of OEMs by 2035 (EU, 2019, EU, 2022).
Besides engines, energy carriers play an even higher role. Accumulators are the mainly used energy carriers in mobility and transportation. Accumulators show a much higher energy efficiency of about 77 % (Archer, 2018), but the production causes environmental damage especially for the sourcing of lithium and cobalt (Cheeseman, 2022, Occhipinti, 2021). Projects for new battery techniques are ongoing to improve range and charging times, whereby the electricity infrastructure is still missing. It is also questionable whether existing electricity networks can withstand the demanded performance and whether the supply can be provided entirely by renewable energies.
Another commercially used energy carrier is hydrogen. In combination with fuel cells this energy carrier shows an overall energy efficiency of about 30 % (Archer, 2018). One major (economic) disadvantage is the high volatility of hydrogen. For a safe transportation of hydrogen very high pressure or a very low temperature is needed. The pressure in tanks increases as the temperature rises and must be reduced, resulting in fuel loss. This property and the high flammability also have major disadvantages for safety.
Direct burning of hydrogen in a combustion engine is possible in principle, but several projects of independent companies in different branches showed that a commercial use would be too expensive for the end-user and therefore not realistic.

Research methodology, methods, and data collection

The purpose of this paper is to calculate the need of renewable energies to replace fossil energy carriers. The analysis shall show if a corresponding replacement is possible respecting the resulting environmental consequences. Therefore, the paper follows a realistic philosophy and an inductive approach.
Only secondary data is used in this paper. The value of interest is the amount of (electrical) energy gained from fossil energy carriers and renewable energies.
The level of analysis depends on the individual data transparency and the scope of the data. The consumption per category and the needed amounts of renewable energies to replace fossil energy carriers are calculated. Available prognoses are used to enable the calculation of corresponding forecasts.
Interpretations about the calculated values are done if applicable. Accordingly, the paper corresponds to archival research in a descriptive manner.
The central questions of this work are: how must the efforts according to the installation of renewable energies be accelerated to address the set goals accordingly and which environmental consequences may result from these efforts?
The scope is defined over types of fossil energy carriers, commercially used renewable energies, and the availability of corresponding data.

Analysis and results

Collected data and calculation

The distribution of the data is based on an overall consumption of fossil fuels by 11.521 TWh in 2022 in the European Union (Ritchie et al., 2022a):

Natural gas	3.434 TWh
Crude oil	6.148 TWh

Coal 1.939 TWh

The generation of electrical energy from renewable energy sources was distributed in 2022 in the European Union as follows (Ritchie et al., 2022b):

Solar energy 207 TWh (13 %)
Wind energy 420 TWh (22 %)
Hydropower 277 TWh (45 %)
Biofuels 175 TWh (12 %)
Others 182 TWh (8 %)

For categorization and calculation purposes percentual consumption of fossil fuels per sector data in the following table from 2019 is assumed:

Table 1. Percentual fossil fuel consumption per sector in 2019

Fossil fuel	Sector	Percentage
Coal	Iron and steel	34,0 %
Coal	Chemical and petrochemical	7,5 %
Coal	Non-metallic minerals	21,7 %
Coal	Other industry	8,9 %
Coal	Non-specified	12,1 %
Coal	Non-energy use	5,2 %
Coal	Residential	6,4 %
Coal	Services, agriculture and fishing	4,2 %
Gas	Industry	37,6 %
Gas	Non-energy use	11,9 %
Gas	Residential	29,7 %
Gas	Commercial and public services	12,8 %
Gas	Other	0,9 %
Gas	Transport	7,3 %
Oil	Industry	7,3 %
Oil	Non-energy use	16,7 %
Oil	Other	5,4 %
Oil	Residential	5,3 %
Oil	Aviation	8,6 %
Oil	Road	49,2 %
Oil	Rail	0,8 %
Oil	Navigation	6,7 %

(Source: IEA, 2021)

For calculations of necessary installations, following values are assumed:

Solar panels:

Space required per TW: 3.300 km2 (Quaschning, 2018)

Calculated average sun hours per year: 2.296 h (Eglitis, 2022)

Wind turbines:

Average nominal power: 2 MW (onshore and offshore), referenced to ENERCON GmbH which provide over 45% of wind turbines in Germany (IWR, 2022)
Average annual full-load hours: ~ 2.900 h, calculated through different but familiar full-load hours data (Kaltschmitt et al., 2013, Mills et al., 2012, Tafarte, 2014)
Hydropower plants:
An installed cumulative capacity of 1.096 GW results in in an annual production of 4.100 TWh (REN21, 2017)
Biofuels production:
Calculated average equivalent compared to fossil fuels is around 0,79 (FNR, 2023)
Energy contained in 1kg crued oil is around 11,8 kWh (Ritchie et al., 2022a)
Resulting needed space: 27,355 km²/TWh (FNR, 2023)
Please note that needed amounts of water and fertilizers are not respected in this paper.

Categorisation
For analysing purposes, the before presented sectors are categorised as follows:

Table 2. Assigned categories to sectors for analysing purposes

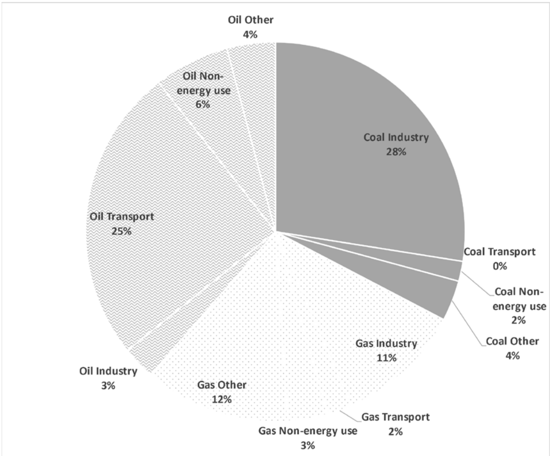
Sector	Assigned category
Aviation	Transport
Chemical and petrochemical	Industry
Commercial and public services	Other
Iron and steel	Industry
Industry	Industry
Navigation	Transport
Non-energy use	Non-energy use
Non-metallic minerals	Industry
Non-specified	Industry
Other	Other
Other industry	Industry
Rail	Transport
Residential	Other
Road	Transport
Services, agriculture, and fishing	Other
Transport	Transport

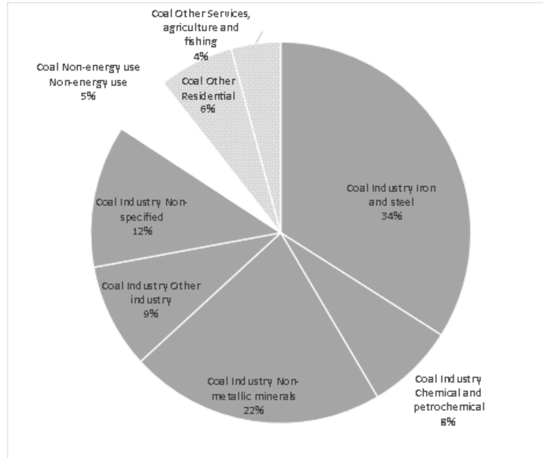
(Source: IEA, 2021)

Results

Fossil fuels consumption by category
The following charts show overviews of the combination of the percentual consumption by sector and the aligned categorisation.

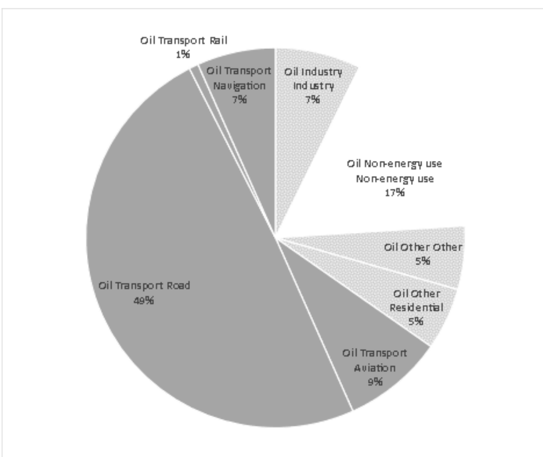
Figure 1. Overview energy consumption by fossil fuel Figure 2. Coal usage for industry purposes: circa 84%

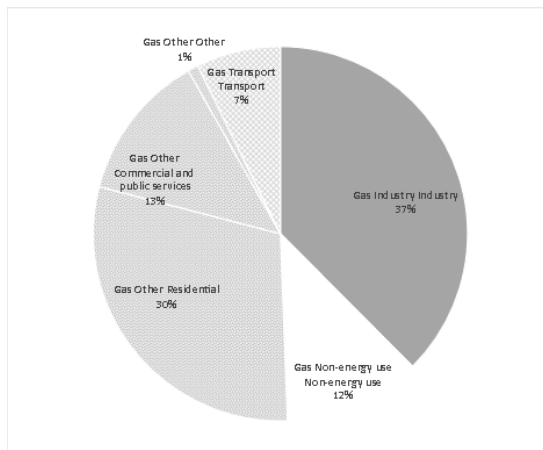




Source: contribution by the author

Figure 3. Oil usage for transport purposes: circa 65% Figure 4. Gas usage for various purposes





(Source: contribution by the author)

In Table 3 the actual consumption is combined with the percentual distribution in the categories.

Table 3. Energy consumption from fossil fuels by assigned categories

Fossil fuel	Category	Percentage	Annual consumption (2022)
Coal	Industry	14,2%	1.632 TWh
	Transport	0,0%	0 TWh
	Non-energy use	0,9%	101 TWh
	Other	1,8%	205 TWh
Natural gas	Industry	11,2%	1.291 TWh
	Transport	2,2%	251 TWh
	Non-energy use	3,5%	409 TWh

	Other	12,9%	1.490 TWh
Crude oil	Industry	3,9%	449 TWh
	Transport	34,8%	4.015 TWh
	Non-energy use	8,9%	1.027 TWh
	Other	5,7%	658 TWh

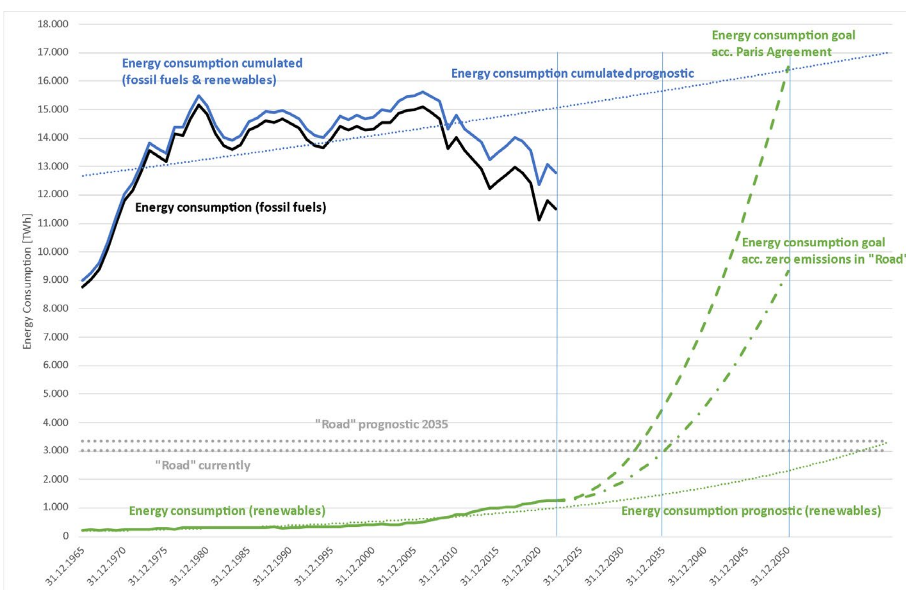
Source: contribution by the authors

The highest consumptions are clearly found in the categories industry and transport. While the "iron and steel" sector plays the most important role in the industry, the "road" sector is the most significant in the transport category.

Renewable needs and forecast

In Figure 5 it seems like that the overall consumption of energy in the European Union is decreasing while the linear prognostic graph shows the opposite which is considered more realistic.
The "Road" prognosis was calculated through a forecast of the amount of passenger car vehicles in 2030 and upscaled until 2035 (Statista, 2023). In 2022, the energy consumption in the "Road" sector laid by 3.025 TWh. In 2035, the prognosis shows an energy consumption by 3.358 TWh, respectively.
Therefore, the increase of installations of renewable energies should be set by around 2,7 times, respectively.
To reach the goals of the Paris Agreement, the efforts should be increased by 13 times, respectively, addressing the added forecast according to future energy consumptions in total.

Figure 5. Historical consumption and forecast



Source: contribution by the authors

Addressing the set goals by the European parliament of zero emissions in the fleet by 2035 and the Paris Agreement, the following Table 4 shows the status of the share of renewable energies, the indicators according to resulting amounts (e.g., areas and number of pieces), and future needs, as introduced in chapter 3.1. For calculation the current share of the different renewable energy types is used.

Table 4. Status of renewable energies and future needs

Renewable energy type	Status	Overall (13 times)	„Road“ (2,7 times)
Solar	298 km²	3.874 km²	805 km²
Wind	72.497 pcs.	942.461 pcs.	195.742 pcs.
Hydropower	74 GW	962 GW	200 GW
Biofuels	4.798 km²	62.374 km²	12.955 km²
Others	182 TWh	2.366 TWh	491 TWh

Source: contribution by the authors

For comparison purposes, the needed space of solar panels and agricultural areas for biofuels for the "Road" goal roughly correspond to 0,33 % of the size of the European Union (compared to 0,12 % today, respectively).

Environmental consequences

Respecting the potentially needed areas to reach a corresponding portion of renewables in the energy mix, possible environmental consequences must be considered. Each type of renewable energies includes certain consequences for local circumstances or whole ecosystems. Solar energy plants might have significant influence in local soil ratios and therefore humidity and temperature. The long-term consequences are hard to derive and need to be evaluated (Matthew et al., 2018, Hernandez et al., 2014). Also wind power engines help to reduce emissions but warm surface temperatures and might have impact on natural streams which are crucial for the global climate (Miller and Keith, 2018). Biofuels have negative effects on food security, water supply, and biodiversity (Tirado et al., 2010, Brinkman et al., 2020, Gasparatos et al., 2011, German et al., 2011). The most significant disruptive effect might have tidal power plants. Overuse of this technique could cause the moon to move away from Earth little by little until it eventually leaves the orbit. According to calculations, this could be the case in as early as 1.000 years. One can expect that the consequences will be experienced much earlier. For the current scope it must be mentioned that these calculations have had a global approach (Liu, 2019).

Conclusion

Besides the enormous efforts according to the electrification of the fleets of European OEMs, even higher efforts in renewable energies and a corresponding infrastructure are still necessary to reach zero emissions. The European Investment Bank provided 19 BEUR for energy-related projects and explicitly 7,2 BEUR for renewable energies in 2022 (EIB, 2023). The investments result in an increase of 1% in renewable energies in the corresponding year. According to the provided calculations, an annual increase of 9,4% would be necessary to reach introduced targets and therefore investments should be set by 67 to 68 BEUR for the acceleration of renewable energies.

Facing the mentioned environmental consequences, new technologies and inventions must be part of the investments. As the most future-oriented and sustainable solution, nuclear core fusion projects like ITER should be supported financially as strong as possible. Running since 2005, 4,4 BEUR have been invested, resulting in nearly 8 BEUR of assets until 2022, respectively. It is planned to finish assembling until the end of 2025. Testing until readiness for commercial use as a blueprint is not planned yet. Therefore, at least the same amount, about 5 BEUR, should be provided to ensure success and prevent wastefulness (ITER, 2023a, ITER, 2023b).

Nuclear core fusion is just one example of many opportunities to make new kinds of renewable energies commercially useable. Besides technical innovations, research especially according to environmental consequences of each of these solutions need also be considered. The so called “energy mix” must not contain fossil energy carriers but each kind of renewables. Environmental as well as social consequences over the whole lifecycles need to be analysed to derive bearable dimensions on a global scale, not EU scale only. In general, from a current point of view, it is possible to reach the goals for 2035 and even 2050, from a European perspective. But it will only be possible in combination with necessary investments. It is a whole different discussion on a global perspective.

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