EU countries' energy consumption and efficiency indices

By the conceptual team of Global Arena Research Institute

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"Working and conceptual papers" are analytical reviews of existing resources, including academic literature, think tank analyses, and inputs from formal institutions such as the World Bank, European Commission, and OECD. They are not intended to present original research but rather to build a background for developing research concepts used in data-driven analytics. Originally intended as internal working material, these papers are published when they are deemed to be of broader public interest. This paper is part of a series of "conceptual papers" produced as part of a project supported by the International Visegrad Fund and Konrad Adenauer Stiftung in Prague.

Energy consumption and efficiency indices vary among EU countries due to differences in factors such as industrial structure, economic development, climate, and energy policies. However, the European Union has been aiming to improve energy efficiency and reduce energy consumption through various initiatives and policies. The energy consumption of EU countries is typically measured in terms of total energy consumed in various sectors such as transportation, industry, residential, commercial, and agriculture. This data is often reported in units like million tonnes of oil equivalent (Mtoe) or petajoules (PJ). Energy efficiency indices measure the efficiency of energy use in different sectors of the economy. These indices may include indicators such as energy intensity (energy consumed per unit of GDP), energy efficiency improvements in specific sectors or processes, and the implementation of energy efficiency measures and policies.

Based on the literature, there are four key ways of measuring energy. Primary, secondary, final and useful energy. These metrics capture the transformations and losses that occur across the energy chain. The differences between the first stage (primary energy) and the last (useful energy) can be very large.

- Primary energy

Primary energy is the energy that is available as resources such as the fuels that are burnt in power plants before it has been transformed. This relates to the coal before it has been burned; the uranium; or the barrels of oil. Therefore, primary energy is the energy that's harvested directly from natural resources. Sources of primary energy are divided into two basic categories, primary fuels and primary energy flows. Primary energy almost always needs to be converted through an energy conversion technology to make this primary energy source into an energy currency or a secondary fuel before it can be used.

- Secondary energy

When primary energy is converted into a transportable form it becomes secondary energy. For example, when coal is burnt in a power plant to produce electricity, electricity is a form of secondary energy. Secondary energy includes liquid fuels (such as gasoline and diesel which are refined oil), electricity, and heat. Secondary energy sources are also called energy carriers because they move energy in a usable form from one place to another. The well-known energy carriers are:

- Electricity
- Petrol
- Hydrogen

Secondary energy sources are used because their use is easier than using a primary energy source. For example, using electricity for lighting is safer than using petroleum in candles or kerosene lamps. On the other hand, the transformation of primary energy to secondary energy is associated with some inefficiency.

- Final energy

Once secondary energy is transmitted to the consumers it becomes final energy. Final energy is what a consumer buys and receives, such as electricity in their home, heating, or petrol at the fuel pump. Final energy is a term that refers to all energies delivered in a form ready to be used by the end-user, for example, petrol for the user's vehicle, the electricity available through the user's socket and others. Due to the many ways it can be used, final energy comes in many forms such as electricity, thermal energy, and mechanical energy.

- Useful energy

It is the energy that goes towards the desired output of the end-use application. It refers to the energy that is converted into a form that can directly serve a practical purpose or perform work. For example, for a lightbulb, it's the amount of light that is produced. For a car, it's the amount of kinetic (movement) energy that is produced. However, a significant portion of the energy generated is wasted in the process for example heat, which is not useful for moving the car and is instead spread into the environment. To improve efficiency and reduce waste, it is essential to maximise the proportion of useful energy in any energy conversion process.

According to the European Environment Agency (EEA) early estimates, in 2022, the EU's final energy consumption by end users fell by 1.5% compared to 2021 levels. Primary energy consumption, which includes all energy uses, also fell by 4% from 2021 to 2022. Even though since 2005 overall reduction in energy consumption is observed, achieving the 2030 targets will require annual reductions in energy consumption at a much faster rate than has been reached

over the last decade. It is very unlikely that the EU will meet its energy efficiency targets for 2030 without strong and immediate actions to reduce energy consumption in the coming years. Reducing energy consumption typically leads to a reduction in environmental damage associated with the production and consumption of energy. It supports the achievement of the EU renewable energy and greenhouse gas targets, lowers emissions of air pollutants with its associated health benefits and enhances energy security.

In September 2023, the EU adopted the recast Energy Efficiency Directive (EU) 2023/1791, which set a binding target for 2030 of 763 million tonnes of oil equivalent (Mtoe) for final energy consumption (FEC), and an indicative target of 992.5Mtoe for primary energy consumption (PEC). FEC represents the energy used by final consumers. PEC represents the total energy demand within a country, including losses.

Energy efficiency indices

Based on the existing research there is no single indicator for energy efficiency as different analyses utilize different indices. All energy efficiency indicators are used to assess the progress in energy efficiency and to measure energy savings. Among many ways in which energy efficiency can be measured, few indices are more prominent.

Energy efficiency indices in Europe typically refer to various metrics used to assess and monitor the efficiency of energy usage within different sectors of the economy. These indices can vary in their scope and methodology but generally aim to quantify the relationship between energy consumption and output or activity. Some common energy efficiency indices used in Europe include:

- Energy Intensity

  This index measures the amount of energy required to produce a unit of economic output, such as GDP. A decrease in energy intensity indicates improved energy efficiency.

- Primary Energy Consumption

  This index tracks the total energy consumed within a given region or sector before any conversion or transformation. Monitoring changes in primary energy consumption provides insights into overall energy demand trends.

- Final Energy Consumption

Final energy consumption refers to the energy consumed by end-users for various purposes, including transportation, heating, cooling, and electricity use. Tracking changes in final energy consumption helps evaluate efficiency improvements at the point of use.

There are also some other more specific sector-based efficiency indices such as the energy efficiency index for buildings, transport energy efficiency index, industrial energy efficiency index and renewable energy efficiency index.

- Energy Efficiency Index for Buildings

  This index focuses specifically on energy use in the building sector, including residential, commercial, and institutional buildings. It typically considers factors such as insulation, heating and cooling systems, lighting, and appliance efficiency.

- Transport Energy Efficiency Index

  This index assesses the energy efficiency of transportation systems, including road, rail, air, and maritime transport. It may consider factors such as vehicle fuel efficiency, modal shifts, and infrastructure improvements.

- Industrial Energy Efficiency Index

  Industrial energy efficiency indices evaluate the energy efficiency of manufacturing and industrial processes. This can include measures such as energy intensity per unit of production, adoption of energy-saving technologies, and process optimization.

- Renewable Energy Penetration

  While not strictly an energy efficiency index, monitoring the penetration of renewable energy sources in the energy mix is essential for assessing progress towards a more sustainable and efficient energy system.

The most common indicators relate energy consumption to an indicator of economic activity (or consumption unit) measured in physical values (tons, employees, m2). They are called ODYSSEE-specific or unit energy consumption. These indicators are in principle easier to monitor and more rapidly updated than energy efficiency indicators that depend on the availability of data on end-use consumption. They include:

- Market penetration of efficient technologies: number of efficient lamps sold, % of label A++ in new sales of electrical appliances and others.

- Diffusion of energy efficient practices: % of passenger traffic by public mode; of efficient motors in industry and others.

- Market penetration of end-use renewable: % of dwellings with solar water heaters, % of efficient wood boilers for heating and others.

To enrich the interpretation and better monitor energy efficiency trends, more complex indicators are also used that are called “advanced indicators”. These indicators do not need additional data: they just use the same data as the usual indicators but include additional calculations.

The ODEX index is used in the ODYSSEE-MURE project to measure the progress of energy efficiency by the main sector (industry, transport, households) and for the whole economy (all final consumers). For each sector, the index is calculated as a weighted average of sub-sectoral indices of energy efficiency progress; sub-sectors being industrial or service sector branches or end-uses for households or transport modes.

Stages of the energy chain result in losses

The world produces a lot of energy, and most of it is lost along the way. The four different measures capture the energy that is available at different stages along this chain. The energy losses in each stage can be described as follows.

- Primary to secondary energy

  The conversion of primary to secondary energy can be very inefficient because the energy losses can be quite high. In thermal power plants which convert fossil fuels, biomass or nuclear into electricity, up to two-thirds of the primary energy is wasted as heat. As a result, for every three units of energy that is put into it, only one unit of electricity is produced.

  Because primary energy losses are particularly large for fossil fuels, their contribution to energy demand is much higher in primary energy terms compared to the other three ways of measuring energy. This is an important aspect because it can distort our perception of how much of a contribution low-carbon sources make. For example, in primary energy terms, they can appear smaller because they are diluted by the wasted energy that comes along with fossil fuel burning.

- Secondary to final energy

It is inevitable that some energy losses also occur when secondary energy is transformed into final energy. For example, energy is lost in the process of delivering it to the consumer. This is called a 'transmission and distribution' loss. When energy is transported from a power plant (secondary energy) to homes (final energy), for example, some energy is lost while transmitting it through power lines.

- Final to useful energy

  No appliance is completely efficient in providing only the desired output. For instance, in a lightbulb, the useful energy is the light. Nevertheless, lightbulbs also produce some heat hence a lightbulb is not completely efficient in providing energy. For example, in the case of cars, the useful energy from cars is movement but engines also produce heat and noise. As a result, no appliance that uses energy can be fully efficient. Any energy that is not used specifically for the desired use of an appliance is waste.

According to the European Environment Agency (EEA) early estimates, in 2022, the EU's final energy consumption by end users fell by 1.5% compared to 2021 levels. Primary energy consumption, which includes all energy uses, also fell by 4% from 2021 to 2022. Even though since 2005 overall reduction in energy consumption is observed, achieving the 2030 targets will require annual reductions in energy consumption at a much faster rate than has been reached over the last decade. It is very unlikely that the EU will meet its energy efficiency targets for 2030 without strong and immediate actions to reduce energy consumption in the coming years.

Reducing energy consumption typically leads to a reduction in environmental damage associated with the production and consumption of energy. It supports the achievement of the EU renewable energy and greenhouse gas targets, lowers emissions of air pollutants with its associated health benefits and enhances energy security.

In September 2023, the EU adopted the recast Energy Efficiency Directive (EU) 2023/1791, which set a binding target for 2030 of 763 million tonnes of oil equivalent (Mtoe) for final energy consumption (FEC), and an indicative target of 992.5Mtoe for primary energy consumption (PEC). FEC represents the energy used by final consumers. PEC represents the total energy demand within a country, including losses.

Types of energy consumed

Out of the total energy available in the EU, around two-thirds is consumed by end users for example EU citizens, industry, and transport (final energy consumption). The remaining one-third is mainly lost during electricity generation and distribution, used to support energy production processes or in non-energy uses (like asphalt or bitumen).

In the EU in 2021, petroleum products (such as heating oil, petrol, and diesel fuel) represent 35% of final energy consumption. Electricity and gas (natural and manufactured gas) ranked second with 23% each. Direct use of renewables (not transformed into electricity, for example, wood, solar thermal, geothermal or biogas for space heating or hot water production) follows after with 12%, derived heat (such as district heating) accounts for 5% and solid fossil fuels (mostly coal) is equal to 3% of final energy consumption. The real consumption of renewable energy is higher than 12% because other renewable sources, such as hydropower, wind power or solar photovoltaic, are included in electricity.

Within the EU Member States, the final energy consumption pattern varies considerably. In 2021, petroleum products accounted for more than 55% of final energy consumption in Luxembourg and Cyprus. For example, electricity accounted for over 30% in Malta and Sweden, while gas made up more than 30% in the Netherlands, Hungary, Belgium and Italy. Renewable energies accounted for over 25% of final energy consumption in Finland, Sweden and Latvia. Therefore, there are rather significant differences among EU member states when it comes to final energy consumption.

Energy is consumed by different sectors of the economy such as households (energy consumed in citizen's dwellings), transport (rail, road, domestic aviation or inland shipping), industry, services (including commercial and public services), and agriculture and forestry. When analysing different sectors, the transport sector accounts for the biggest share of final energy consumption with 29% of final energy consumption, followed by households (28%), industry (26%), services (14%), and agriculture and forestry (3%)

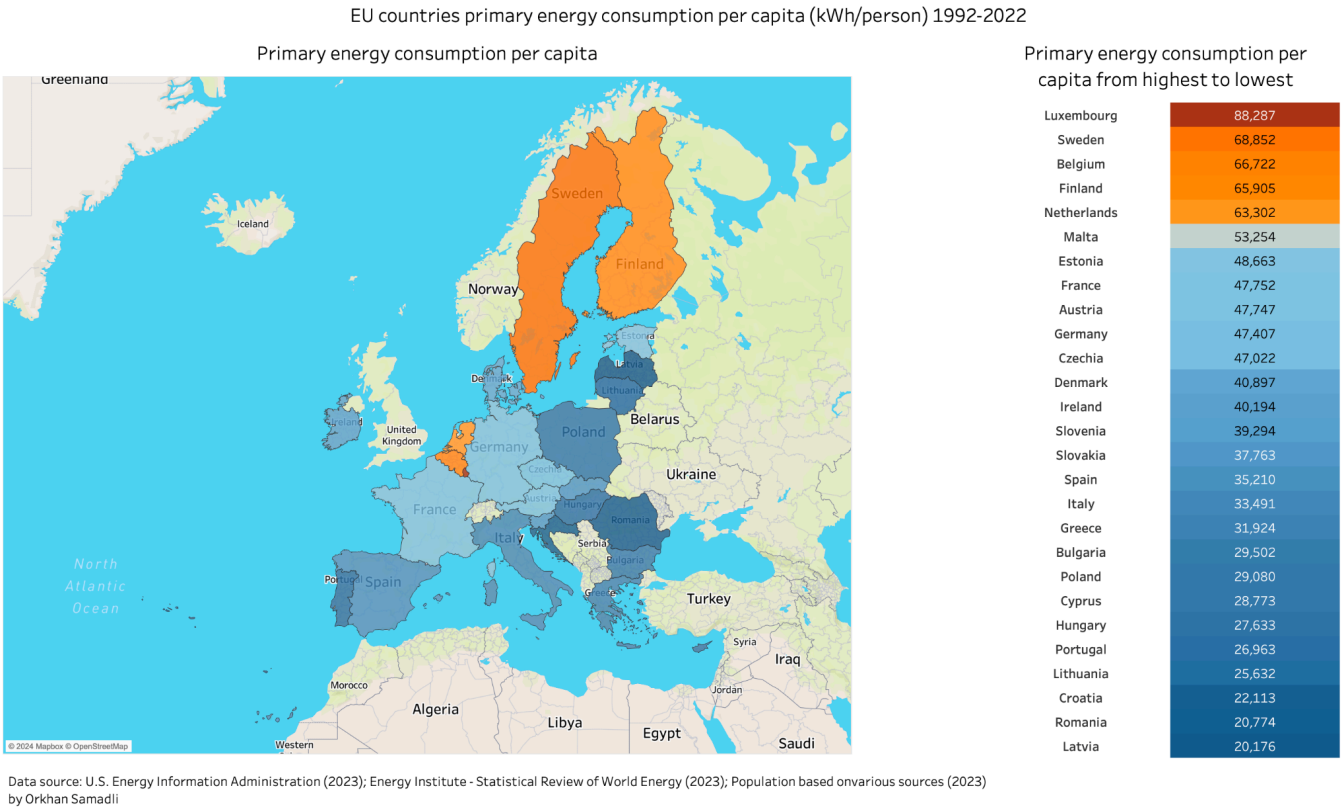

Figure 1. EU countries' primary energy consumption per capita (kWh/person) from highest to lowest 1992-2022

Based on the graph above, Luxembourg is at the top of the list among EU countries when it comes to average primary energy consumption per capita. The following subsections will aim to present Luxembourg's energy profile highlighting key possible reasons behind its high energy consumption.

When analysing the graph below on average EU energy consumption throughout 1992-2022 a clear downward trend can be observed. A sharp decline has been recorded in 2020 which can be associated with the impact of the COVID-19 pandemic. Various restrictions and decreased economic output across the EU countries significantly decreased EU primary energy consumption. Although a slight increase in energy consumption can be observed in 2021, according to the graph in 2022 EU energy consumption returned to the the pandemic level recorded in 2020 and overall presents the lowest level for EU energy consumption since 1992.

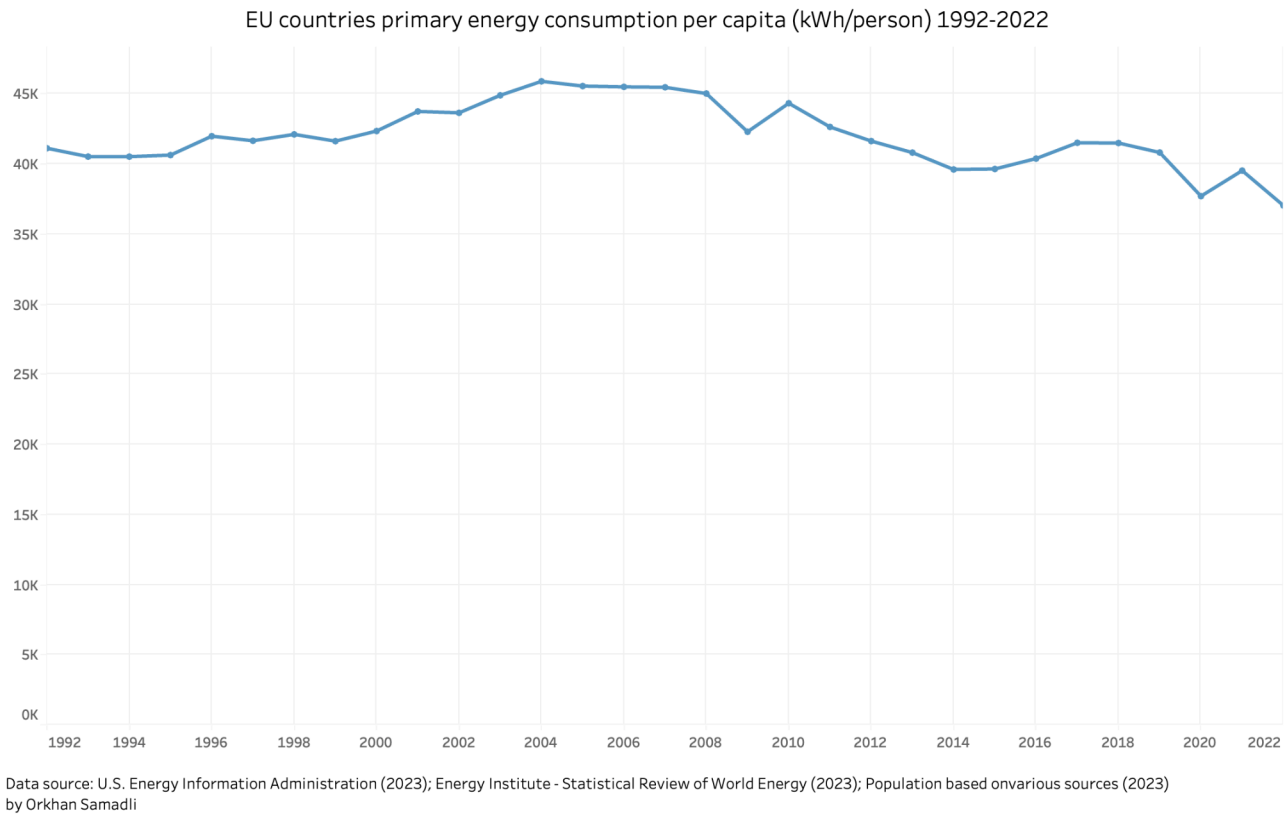

Figure 2. EU countries' primary energy consumption per capita (kWh/person) from 1992-2022

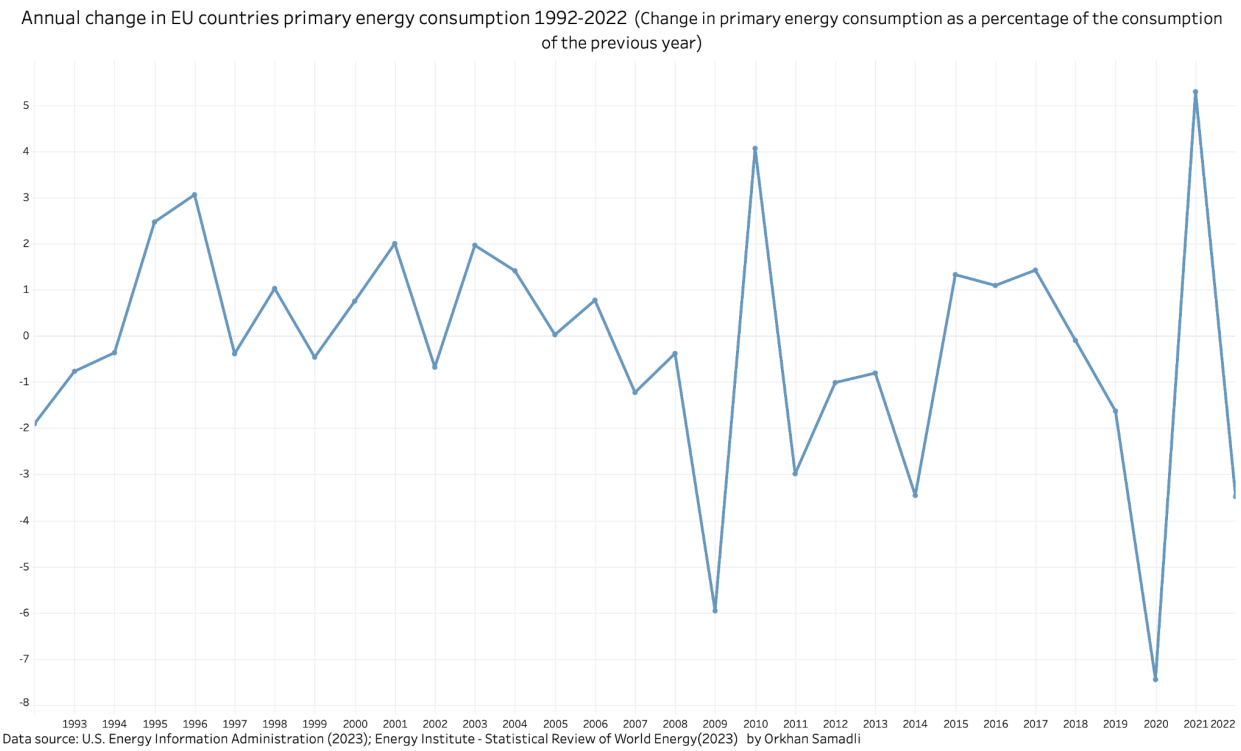

Figure 5. Annual change in EU countries' primary energy consumption 1992-2022

This graph shows how primary energy consumption in EU countries changes from year to year. The change is given as a percentage of consumption in the previous years. In 2019 one year before the COVID-19 pandemic change in primary energy consumption was 1.63%. A sharp decrease in annual change in primary consumption can be observed in 2020 equal to -7.45% due to the impact of the Covid-19 pandemic. In 2021, the change in the primary energy consumption again increased and was equal to 5.29%. When compared to 2021, in 2022 the the energy consumption decreased and the annual change was equal to -3.48% which is most likely linked to the war in Ukraine and the EU energy crisis

The energy system of Luxembourg

Luxembourg has a fossil fuel-intensive energy mix driven by a high demand for transportation fuels, notably from transiting freight trucks and commuters. Luxembourg's energy system is characterised by high import dependence and reliance on fossil fuels. According to Country Report 2023 of Luxembourg, more than 90% of its energy supply (100% of oil, natural gas and biofuels and 86% of electricity) comes from foreign suppliers. The most dominant energy source in Luxembourg is oil, which covers most transportation demand. In 2021, oil accounted for 69% of Luxembourg's energy mix, natural gas 18% and 12% from renewable energy sources. The high share of oil reflects the central role of transportation in Luxembourg's economy. Natural gas

is the second-largest energy source, covering large shares of industrial, residential and commercial demand.

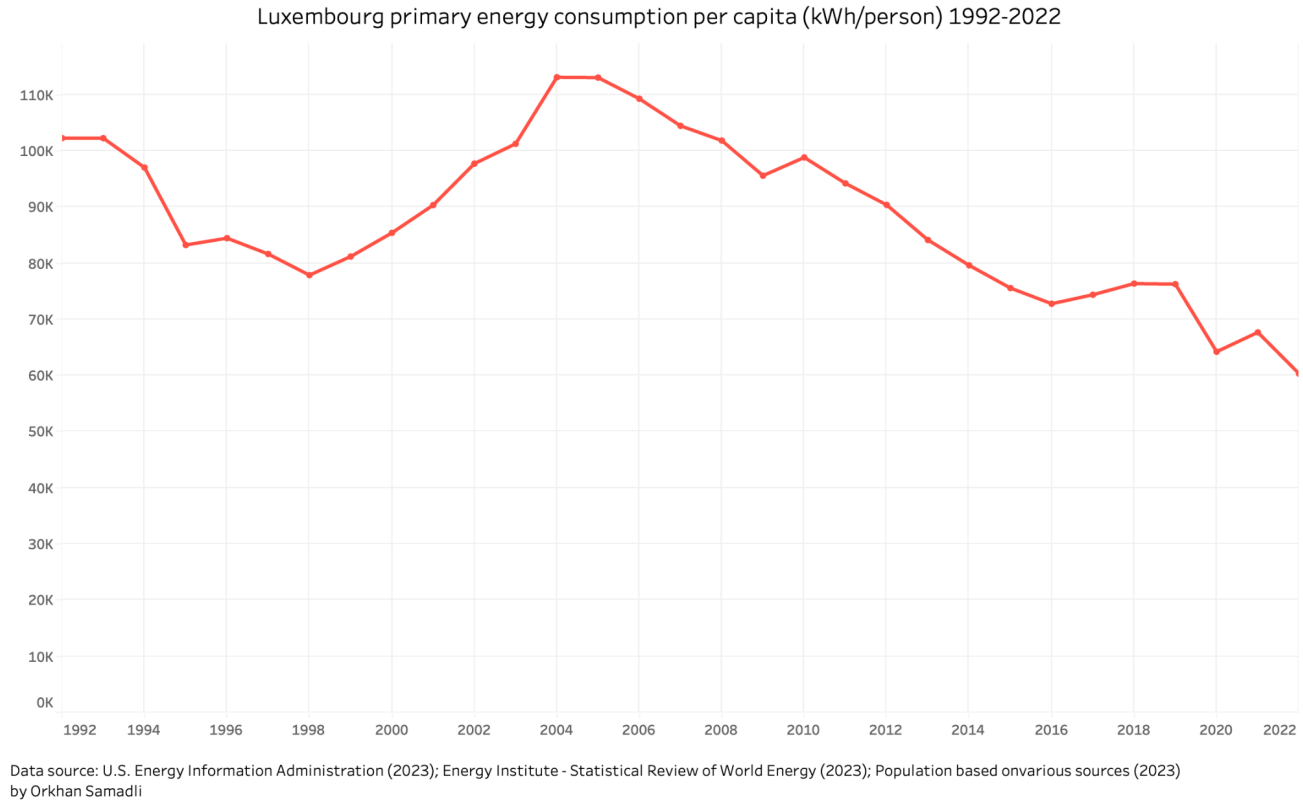

Figure 3. Luxembourg's primary energy consumption per capita (kWh/person) from 1992-2022

The transport sector in Luxembourg

The transport sector is the largest consumer of energy as it accounted for 54% of final consumption in 2017, compared with 34% on average across OECD member countries. Almost all the energy consumed by the transport sector (94%) comes from petroleum products (78% of which is diesel). This makes transport a major source of air pollution. Luxembourg's unique geographical position of being in the centre of the main traffic roads in Western Europe impacts its relatively dense transit of road traffic for goods and people (especially cross-border workers). Moreover, the rate of private car ownership in Luxembourg is the highest in Europe, with 670 cars per 1,000 inhabitants. This rate is influenced by cross-border workers whose company cars are registered in Luxembourg.

Measures aimed at reducing energy consumption in Luxembourg

Despite this demand, the country is committed to reducing emissions. Its climate law sets targets for a 55 % emission reduction by 2030 and a climate neutrality target by 2050. The government has adopted numerous measures to push for energy transition, including a carbon tax which was introduced in 2020 and encouraging renewable generation through subsidies and auctions. Several programmes also support energy efficiency in buildings, industry and transportation, with a target for 49% of all passenger cars to be electric by 2030.

Luxembourg has established a National Energy Efficiency Action Plan (NEEAP) and a National Renewable Energy Action Plan (NREAP) to address its high energy consumption levels and to contribute to the EU's energy and climate targets for 2020 and 2030. Policies have led to a decline in household consumption, despite population growth. Luxembourg's energy intensities have decreased – except during the financial crisis, due to the fall in GDP. However, energy consumption has increased since 2016, particularly in transport. This shows that challenges remain and that efforts must be sustained and even strengthened to meet the 2030 efficiency target.

Final energy consumption by sector in the EU

Based on the graph below, the transport sector accounts for the biggest share of the EU energy consumption with the residential sector taking the second position. Overall, when observing the trends over the years, the share of the transport sector increased from 28% in 2000 to 30% in 2010 and 2021. Whereas, even though the share of the services is relatively low it increased from 12% in 2000 to 14% in 2021. Although the share of industry has decreased from 29% in 2000 to 25% in 2010 and 2021 it takes the third biggest part of total EU energy consumption. The share of households is stable at around 28%, as is the share of agriculture at around 3%.

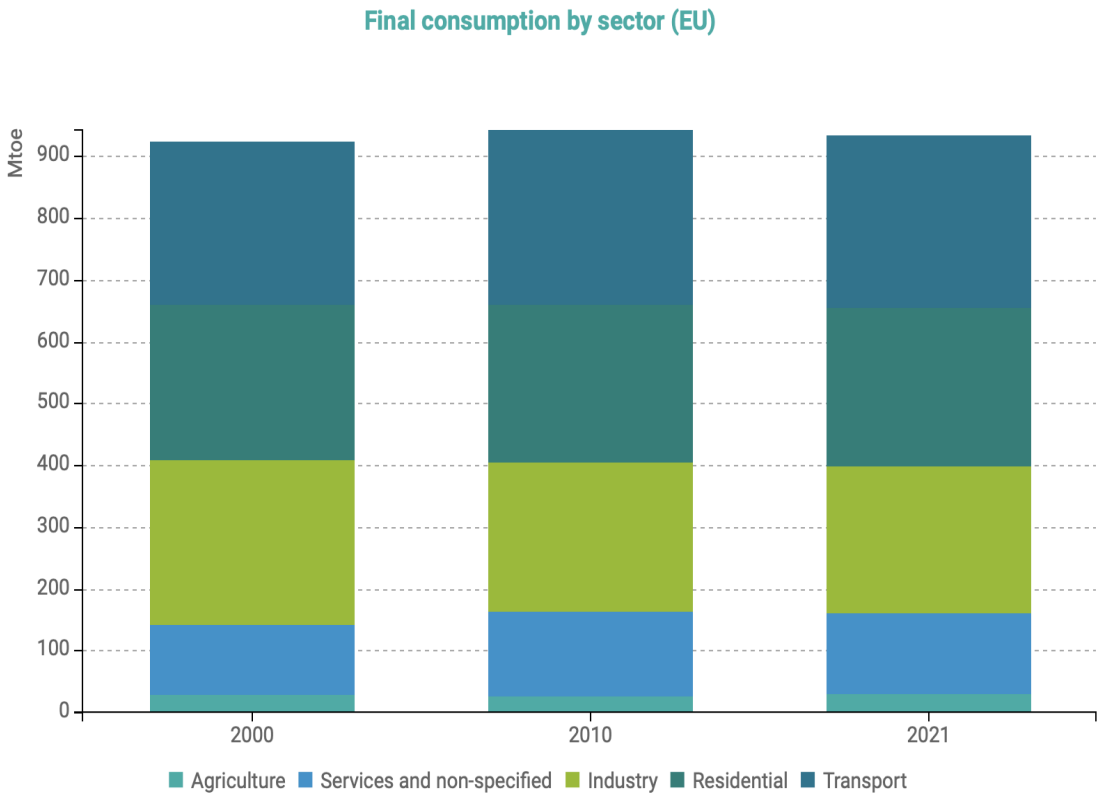

Figure 4. Final energy consumption by sector in the EU 2000 - 2010 - 2021
Source: ODYSSEE-MURE

When analysing each Member state's energy consumption by sector, as based on the graph below it is evident that in half of EU Member States (14), transport is the largest energy consumer sector. Among these countries, Luxembourg is the only country where the transport sector accounts for more than 50% of total energy consumption. When it comes to residential sectors, in eight member states namely Germany, Croatia, Denmark, Estonia, Hungary, Latvia, Czechia, and Romania, the residential sector is the largest consumer. For the five remaining member states (Sweden, Finland, Belgium, Netherlands, and Slovakia), the industry is the largest consumer. Although the agriculture sector in most member states accounts for less than 5% of total energy consumption, in the Netherlands, the agricultural sector accounts for almost 10% of its total energy consumption. Therefore, energy consumption within different sections across member states varies quite significantly.

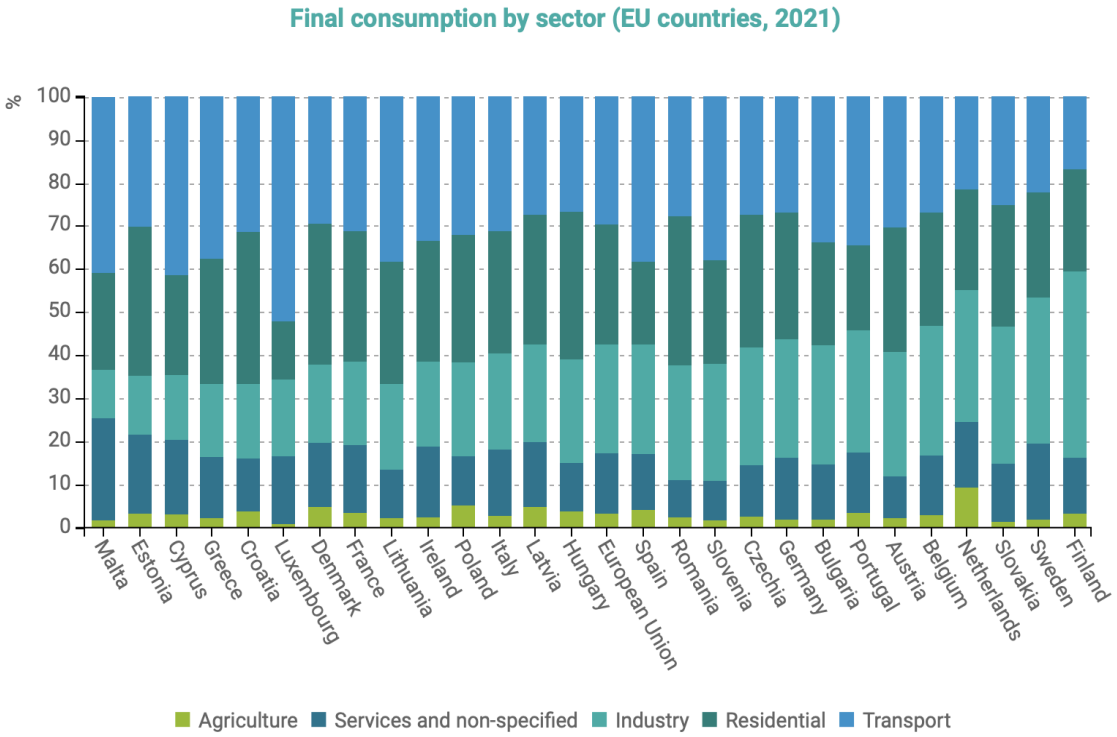

Figure 5. Final energy consumption by sector in the EU countries in 2021
Source: ODYSSEE-MURE

Final energy consumption in the transport sector

The global transport sector consumes about a quarter of the world's energy. Among EU member states, the transport sector is the most energy-consuming, being responsible for 34% of final energy consumption. With 70% of the EU's oil final energy consumption driven by the transport sector, fossil fuels remain the main energy supply for the EU's transportation. This leads the transport sector to account for about a quarter of the EU's greenhouse gas emissions.

Unlike the residential and services sectors, EU legislation is not the major driver for the implementation of energy savings policies in the transport sector. In 2012, it was estimated that EU transport measures represented only 20% of all ongoing transport policies, highlighting the predominance of national measures in the transport sector. However, the examination of the National Energy Efficiency Action Plans (NEEAPs) that EU member states are required to submit every 3 years under the Energy Efficiency Directive (EED) shows that transport is not the most prioritized sector for national energy efficiency strategies and not all EU member stated anticipate energy savings in transport.

Clean and energy-efficient vehicles have an important role to play in achieving EU policy objectives of reducing energy consumption, CO2 emissions, and pollutant emissions. The Directive on the Promotion of Clean and Energy Efficient Road Transport Vehicles aims at a broad market introduction of environmentally-friendly vehicles. It also addresses purchases of vehicles for public transport services. Moreover, alternative low-carbon fuels should gradually substitute fossil fuels for transport propulsion in the long term.

Final energy consumption in the residential sector

The residential sector accounted for more than one-quarter of the EU-27 total final energy consumption in 2020 and it is the second most energy-consuming sector after transport.

Per capita residential energy consumption is highly influenced by the economic situation. Countries with high per capita consumption, such as Luxembourg and Finland, also registered high GDP per capita values. This suggests that higher wealth may indeed lead to more equipped houses and more energy consumption. On the other hand, Bulgaria and Romania, which were the Member States with the lowest GDP per capita, were countries with low residential energy consumption per capita. Thus, lower GDP levels may lead to energy poverty due to their inability to ensure the required levels of energy at home.

European Union households significantly ramped up their energy consumption in 2021, contributing to 27% of the final energy consumption in the European Union, according to recent data. This reflects an increase of 5.5% compared to the previous year, equating to an almost 11.0 million Terajoules total consumption value.

Final energy consumption in the industry sector

The industry sector accounted for more than one-quarter of the EU-27 total final energy consumption in the year 2020. It was the third energy-consuming sector after transport and households.

In 2018, the Member State with the highest consumption in the industry sector was Germany followed by France and Italy. These three States together with Spain accounted for more than 53% of the total European final energy consumption in the industry sector. More than half of the EU-27 Member States (14 countries) consumed less than 10% of the EU-27 industry's final energy consumption in the same year.

Over the past three decades, final energy consumption in the industry sector in the European Union has been following a slight downward trend. One of the main reasons behind this trend is energy efficiency gains as well as structural changes in the EU's economy. Nevertheless, the

industry is still one of the biggest final energy consumers in most of the member states. As a result, when considering any decarbonisation objectives as well as initiatives related to the security of energy supply it is essential to take into account the energy needs of the industry. Having recognised the need for a higher level of disaggregation of the statistics on final energy consumption in industry, in 2019 the Commission amended Regulation 1099/2008 of the European Parliament and of the Council on energy statistics to introduce obligatory reporting of the data on the energy use of more disaggregated industrial sectors.

In May 2022, prompted by global energy market disruptions that were caused mainly by the war in Ukraine, the Commission presented several measures in its REPowerEU plan, intended to diversify energy supply, boost energy savings and accelerate the transition to green energy. REPowerEU specifically aims for a transformation of industrial processes to replace gas, oil and coal with renewable electricity and fossil-free hydrogen which is closely interlinked with its plan to end the EU's dependence on Russian fossil fuels and, at the same time, to tackle the climate crisis,

In July 2022, the European Commission issued its Winter Preparedness Package, including several measures aimed at securing the supply of natural gas for the EU. As a result, the Council Regulation 1369/2022 on coordinated demand-reduction measures for gas was adopted shortly afterwards, to achieve a 15 % reduction in gas demand for a limited period and to help identify the industrial sectors most suitable to make the savings.

The EU's ambitious climate-related goals together with the current instability of energy supply and price volatility highlight the need for detailed data on final energy consumption in industry. In the current circumstances this concerns, in particular, the volumes of natural gas used in specific sectors, as well as, more generally, the degree of industry's dependence on fossil fuels and the potential to switch to more climate-friendly alternatives in each sector.

Global energy consumption

Concerning global energy consumption, it is important to note that global energy consumption refers to the combined energy use of all households and industry sectors. Differences between countries typically reflect varying income levels, differing attitudes and implementation of efficiency measures, the types of fuels consumed, and the climate zones inhabited. The Asia and Pacific region has the highest primary energy consumption of any region. Within this region, China is the largest consumer of primary energy. The fact that China is currently the largest primary energy consumer in the world is closely related to its population of over one billion people and its still fast-growing economy.

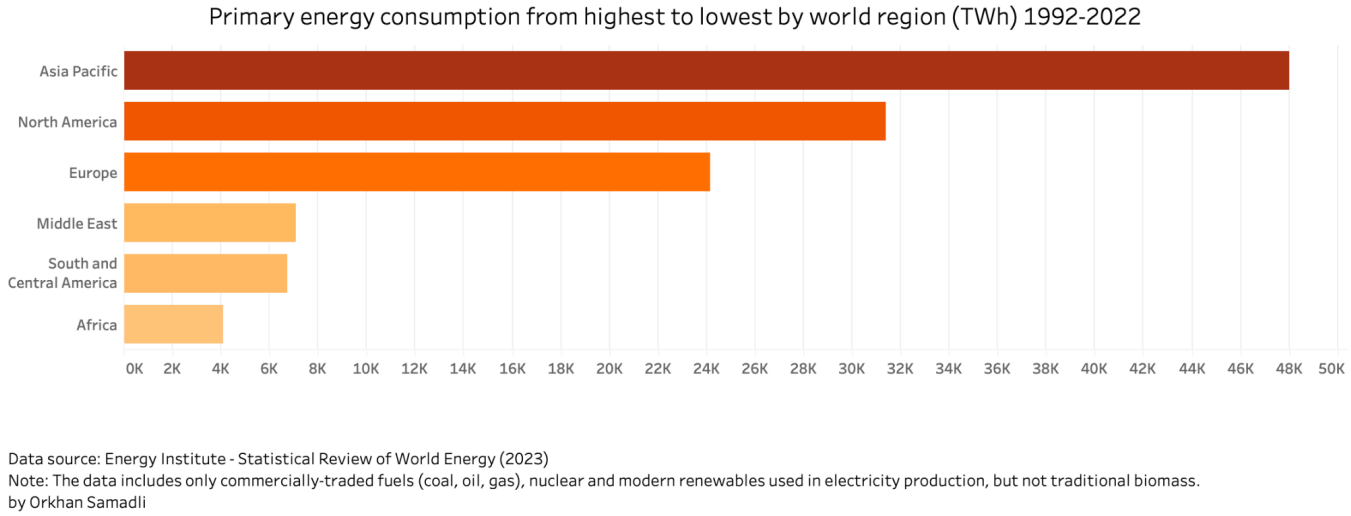

Figure 6. Primary energy consumption from highest to lowest by world region (TWh) from 1992-2022

When analysing energy consumption across various world regions from 1992 to 2022, it is evident that the Asia Pacific region has the highest increase in energy consumption during this period where in 2022 energy consumption is four times higher than it was in 1992. Both Europe and North America exhibit a slight downward trend, whereas all other remaining regions show a slight upward trend in energy consumption. Across all regions, it is possible to observe a decrease in energy consumption in 2020 which is related to the COVID-19 pandemic and the impact it had on the transport and industry sectors. The decrease in energy consumption in 2020 is the sharpest in Europe and North America, whereas the increase in energy consumption in the post-pandemic period is the highest in the Asia Pacific region.

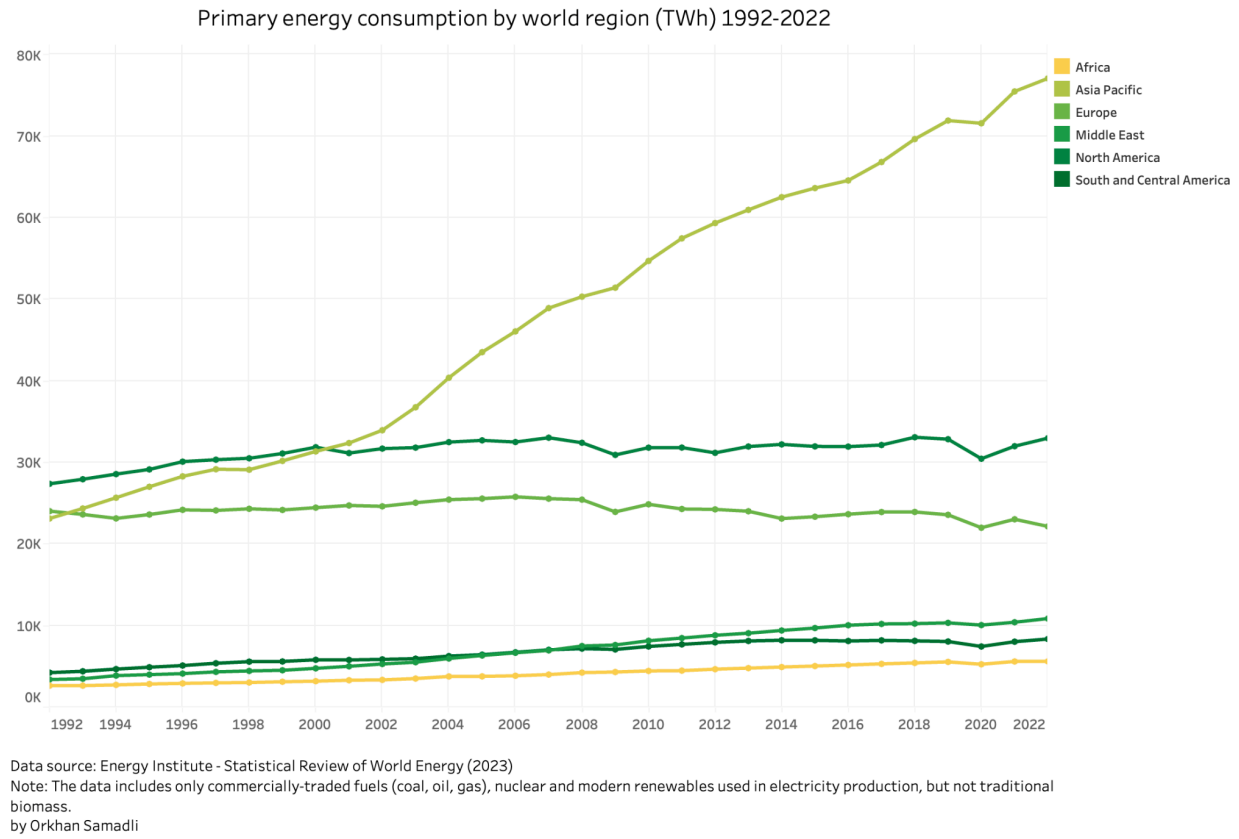

Figure 7. Primary energy consumption (TWh) by world region from 1992-2022

China's energy consumption

China is the largest consumer of primary energy in the world, using some 159.39 exajoules in 2022. This is far more than was consumed by the United States, which ranks second. The majority of primary energy fuels are still derived from fossil fuels such as oil and coal.

China's primary energy mix has shifted from a dominant use of coal to an increase in the usage of natural gas and renewable sources. Since 2009, the share of renewable energy sources in total energy consumption has increased by around 16 per cent. Overall, global primary energy consumption has increased over the last decade not only in China, but it is also expected to increase in other emerging economies like Brazil and India.

China's energy needs significantly expanded due to decades of rapid economic growth. As a result, China is now the world's largest consumer of energy, the largest producer and consumer of coal, and the largest emitter of carbon dioxide. Among all sectors, the industrial sector accounts for two-thirds of China's total energy consumption. Within the industry sector in particular, manufacturing contributes to the largest proportion of China's energy demand, with

much of the energy coming from burning coal. In 2019, manufacturing accounted for about 55 per cent of China's total energy consumption, and 59.6 per cent of the manufacturing sector's energy came from coal.

China is increasingly looking to secure its future energy needs with sustainable alternatives. By the 2016 Paris Agreement, China committed to make non-fossil fuel energy 20 per cent of its energy supply by 2030 and to peak CO2 emissions by 2030.

Most consumed fuel types

Although many governments have set up targets for phasing out coal, fossil fuel remains the second most important source of worldwide final energy consumption after oil. On the contrary, clean energy sources such as biomass and electricity account for around 20 per cent of final energy use. Following the Fukushima disaster, nuclear energy consumption experienced a decrease between 2011 and 2012. Nevertheless, over the following years, it has been increasing again as some governments such as China have been extensively using nuclear energy alongside renewables to address climate change challenges. Renewable energy consumption has grown three times in the past decade as countries are more committed to reducing their carbon footprint. At the same time, over the past decade, most renewable energy sources have become more affordable as the deployment of solar and wind tech has become more accessible and cheaper.

In the EU in 2021, petroleum products were the most consumed (such as heating oil, petrol, and diesel fuel) as those represent 35% of final energy consumption. Electricity and gas (natural and manufactured gas) ranked second with 23% each, followed by renewable energy which accounts for more than 12%. Within the EU Member States, the final energy consumption pattern varies considerably. In 2021, petroleum products made up more than 55% of the final energy consumption in Luxembourg and Cyprus. Electricity accounted for over 30% in Malta and Sweden, while gas made up more than 30% in the Netherlands, Hungary, Belgium and Italy. Renewable energies accounted for over 25% of final energy consumption in Finland, Sweden and Latvia.

This paper was produced by the conceptual research team of the Global Arena Research Institute (GARI) as part of the preparatory work for utilizing GARI's signature digital twin of the globalized environment. Supported by the International Visegrad Fund and the Konrad Adenauer Stiftung, GARI is at the forefront of integrating leading-edge computing technologies with socio-economic and political analysis. These internal conceptual working papers lay the foundation for our digital twin's application, offering critical insights and frameworks that enhance our understanding and foresight into global and local processes across various domains, including economy, trade, politics, defense, society, energy, and the environment.