CAN EUROPE GREEN ITS GROWTH?

AN ANALYSIS OF CO2-GDP DECOUPLING BETWEEN 1990 AND 2030

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Abstract

The European Union pledged to reduce greenhouse gas emissions by -55% of its 1990 level before 2030. In this study, we analyze the link between GDP and territorial emissions in the European Union between 1990 and 2018. Dividing the period into three shorter phases (1990-2007, 2007-2014, and 2014-2018), we find that the majority of cuts in emissions occurred during the second phase. To better understand what caused these variations, the LMDI decomposition method is applied to the Kaya equation. The main result is that economic growth has slowed down emission reductions because energy intensity of GDP and carbon content of energy parameters have been decreasing too slowly. Simulations until 2030 show that the current rates of decrease in the energy intensity of GDP and carbon content of energy are not fast enough to achieve the "Fit for 55" target. Only scenarios with a yearly GDP contraction between -1% and -2% bring emissions to that level. The only way to achieve this target while growing GDP would be to immediately hike up the speed of decarbonization to unprecedented levels (by a factor of between 2 and 7.5 time), an assumption that should be considered highly unplausible.

Keywords

decoupling, economic growth, Europe, CO2, Fit for 55, sufficiency

1 Introduction

The findings of the IPCC's AR6 report are unambiguous: human activities are the main cause of climate change and their impacts are putting the habitability of many areas of the world at risk. The threat of a breakdown in climate stability calls for significant and immediate action to reduce greenhouse gas (GHG) emissions, which has prompted a number of countries to announce plans to decarbonize their economies.

The European Union pledged to reduce greenhouse gas emissions by 55% of its 1990 level by 2030 (European Commission, 2019). In its current design, this strategy assumes a certain degree of decoupling between Gross Domestic Product (GDP) and emissions. This "green growth" strategy presupposes that eco-efficiency gains will enable to reduce the carbon intensity of the economy, therefore allowing additional production in parallel to a lowering of emissions.

In order for this strategy to achieve the -55% target, the rate of decoupling must be absolute, sufficient in magnitude, and consistent over time. There is now a wealth of literature on the topic of decoupling, showing that historical evidence of absolute decoupling is weak (for meta-studies, see Haberl et al. (2020) and Vadén et al. (2020)) and even a few synthetic paragraphs in the third report of the IPCC AR6 (Parrique, 2022). Yet, this literature falls short on several aspects. First, it either studies short periods of time or bundle longer periods into deceiving averages, assuming that decoupling is a progressive, almost linear phenomenon. Second, only a few studies explore the underlying variables that explain the sources of decoupling. And finally, these studies have almost never taken into account a sufficiency criterion for successful decoupling in relation to a specific climate target.

Le Quéré et al. (2019) is one of the few studies that attempts to explain what exactly caused the reduction in emissions. Looking at territorial CO_2 from 18 OECD countries, they find that emissions decreased by an average of -2.4% per year from 2005 to 2015, alongside a +1% growth in GDP. Out of the four variables considered in their analysis[1], they find that the largest contributors to emission reductions are the reduction in the fossil share of final energy (it explained 47% of the emission cuts) and the reduction in energy use (another 36% of emission cuts). Further exploring the causes of the drop in energy use, they observe that since the fall of the energy intensity of GDP has been steady since the 1970s (around -1% and -2% per year), the lower energy use could be explained, at least in part, by the slowdown of GDP growth.

In another study, Sadorsky (2020) looks at the energy-related CO_2 emissions of the G19 between two seven-year intervals (2000-2007 and 2010-2017), so before and after the financial crisis of 2008. Results show that, for most countries, increases in

[1] Energy use; fossil share in final energy; fossil energy consumed or lost in energy production; and the carbon intensity of fossil energy.

economic activity are the largest contributor to additional CO_2 emissions, which explains why, for G19 as a group (and for 11 out of 19 countries), the increase in CO_2 emissions post-financial crisis was smaller than the increase in CO_2 emissions pre-financial crisis. Overall, the main variable pushing down emissions is the decrease in energy intensity, with only 6 out of 19 countries experiencing absolute decoupling in the post-financial crisis period.

In a more recent study, Bersalli et al. (2023) show that, between 1965 and 2019, 26 out of the 28 countries considered have reached their peak emissions just before or during an economic recession. They did so through the combined effect of lower GDP growth (an average -1.5% per year) and lower energy and carbon intensity during and after the crisis. According to the authors, a reduction in production and consumption brings emissions down in the short term, while structural changes occurring during the crisis further decouple GDP from emissions, allowing economic growth to resume with a smaller quantity of associated emissions.

In order to better understand the relationship between economic growth and carbon emissions, the present study analyzes the link between GDP and territorial greenhouse gas emissions in the European Union over the 1990-2018 period (our analysis stops in 2018 to avoid factoring in the exceptional impact of the COVID crisis). To track the changing dynamics of this decoupling, we examine yearly changes and divide the period into three phases (1990-2007, 2007-2014, and 2014-2018). We then identify the underlying causes of the decoupling and simulate different scenarios to estimate the decoupling requirements for Europe to achieve its -55% target by 2030.

2 Material and Methods

Looking at the evolution of territorial CO_2 emissions and GDP from 1990 to 2018, we study both the 28 EU countries[2] (EU28) as a whole, as well as the 10 largest emitters in that group[3] (LE10), who account for approximately 84% of emissions over the period (see Section 7.1). To better understand what drives emissions, we analyze the four variables of the Kaya equation: *GDP*, *population*, *energy intensity of GDP*, and the *carbon intensity of energy* (see section 7.2 for data sources).

GDP data are obtained from the World Bank[4] and the population and primary energy consumption from Eurostat. *Primary energy consumption* measures the use of energy in its primary form, excluding energy carriers used for non-energy purposes.

[2] Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Greece, Germany, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, United Kingdom.

[3] Belgium, Czech Republic, France, Germany, Italy, Netherlands, Poland, Romania, Spain and the United Kingdom.

[4] Not all GDP data run as far as 1990: the dataset for Hungary only starts in 1991, for Slovakia in 1992, and for Croatia, Latvia, Estonia, and Slovenia in 1995.

It includes energy consumption by end users, such as industry, transport, households, services, and agriculture, plus the energy consumption of the energy sector itself.

We use the EDGAR v7.0 database to track territorial CO2 emissions. This dataset presents emissions from fossil fuel use (combustion and flaring), industrial processes (cement, steel, chemicals, and urea), and the usage of common products such as cars. Because the CO2 emissions considered in this dataset do not include Land Use Land Use Change and Forestry (LULUCF), we add the LULUCF data provided by UNCCF. This provides the best available estimation of the total CO2 emissions for the 28 European countries.

To identify the factors influencing CO2 emissions, we used the Kaya equation in the following form:

$$CO2 = \frac{CO2}{E} \times \frac{E}{GDP} \times \frac{GDP}{POP} \times POP$$

CO2: CO2 emissions.

E: Primary energy consumption.

POP: Population.

CO2/E: carbon content of energy.

E/GDP: energy intensity of GDP.

GDP/POP: GDP per capita.

We combine this equation with the Logarithmic Mean Divisia Index (LMDI) decomposition method[5] to estimate the relative weight of each component in the evolution of CO2 emissions. This basically tells us which of the four variables has been most actively impacting emissions.

3 Results

3.1 Three decoupling phases: slow-fast-slow

The first finding is that there were three clear phases between 1990 and 2018 in the pace of the decarbonization of EU28: slow (1990-2006), fast (2007-2014), and slow (2015-2018). This is true both for the EU28 and for the 10 largest emitting countries (Figure 1 and Figure 2). In a first phase between 1990 and 2006, economic growth was significant (+2.3% per year on average for EU28), while emission reduction was almost null (-0.3% per year on average). It is during the second phase (2007-2014) that emission reduction really began. In a context of near stagnant economies (+0.6%

[5] In this paper, we use the additive LMDI decomposition method because it is more efficient than its multiplicative counterpart for quantity indicators, such as CO2 emissions, as explained by Ang (2015).

of GDP on average per year for EU28), emissions dropped by an average -2.6% each year. After 2015, the starting point of the third phase, the rates of economic growth went back up to pre-2007 levels and so did emissions, which stabilized at +0.2% per year on average.

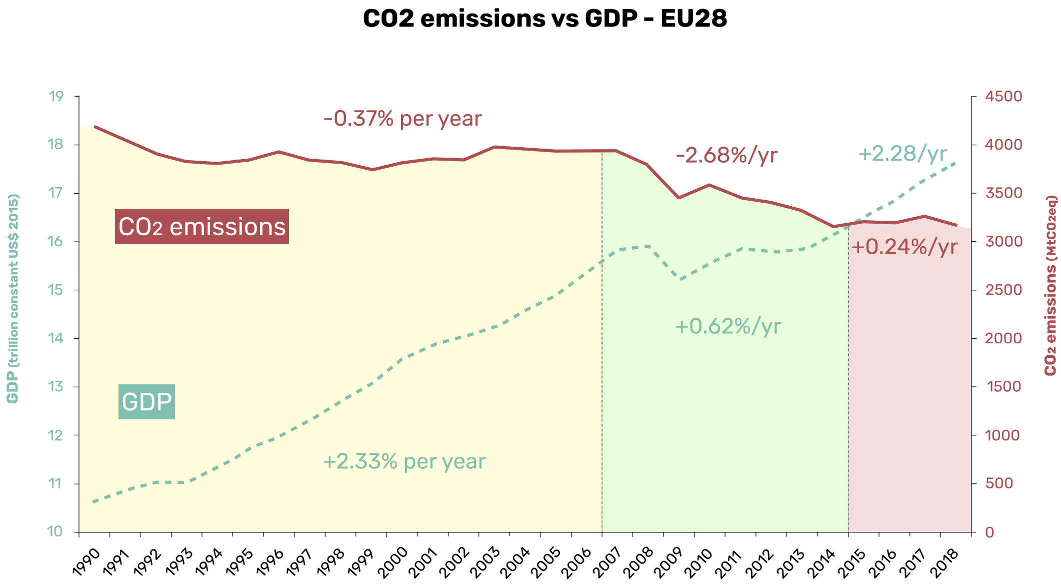

Figure 1: CO2 emissions and GDP between 1990 and 2018 for the European Union (EU28). The figures indicated on the curves correspond to the average yearly evolution of CO2 emissions (in red) and GDP (in green) over each time period (1990-2006 in yellow, 2007-2014 in green, 2015-2018 in red).

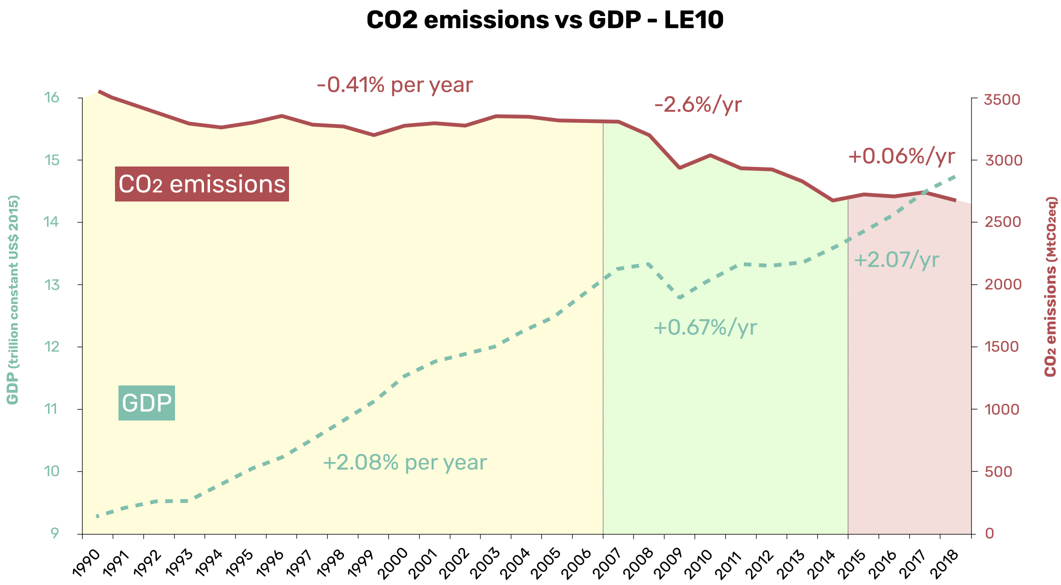

Figure 2: CO2 emissions and GDP between 1990 and 2018 for the 10 most emitting countries (LE10). The figures indicated on the curves correspond to the average yearly evolution of CO2 emissions (in red) and GDP (in green) over each time period (1990-2006 in yellow, 2007-2014 in green, 2015-2018 in red).

Looking at both the average and median yearly values (see Section 7.3), this slow-fast-slow pattern is consistent for 19 countries out of the EU28 (Figure 3) and 8 countries within the group of most emitting nations (LE10). We include three countries in that group of 19 (Czech Republic, Germany, and Romania) that experienced a significant decrease in emissions before 2007. Emissions went down during a short time period following the collapse of the Soviet Union (1990-1992) before going back to a slower pace of reduction. Except for these three countries, GDP is, on average, always above +1% during the first and third phases, and emission reductions always smaller than -1.2%. France is a good case in point: emissions decreased slowly until 2006 (-0.1% on average per year), then decreased faster between 2007 and 2014 (-2.1%), to finally increase after 2015 (+2.1%). Out of the 19 countries, 12 only started lowering emissions after 2007 (average or median values), and 14 saw their emissions increase after 2014 (14 if we look at averages and 13 if we look at medians).

Most nations that are not following the slow-fast-slow pattern are part of the former European Eastern Bloc (Poland, Bulgaria, Estonia, Latvia, Slovakia, and Slovenia). The other three are Greece (2% of EU28 emissions), Malta (0.1% of EU28 emissions), and the United Kingdom (11.8% of EU28 emissions). Eastern European countries have been transitioning from industrial to more service-oriented economies during that time, which might explain why they experienced robust GDP growth throughout the 30–year period with a regular decrease in territorial emissions.

And yet, even in this group of outliers, the rate of CO2 emission reduction slowed down when economic growth got stronger. Emissions in Greece started decreasing in 2007 and continued steadily after that but with near-stagnant levels of GDP growth. Malta's GDP has been growing continuously and strongly since 1990 (always above 3.8%/yr on average), with emissions decreasing slowly (at best -1.3%/yr on average) until 2015, when the growing GDP was combined with an acceleration of emissions decline, mostly explained by a reduction of fossil fuel use in energy production (Erbach and Carvalho Fachada, 2021). The United Kingdom, on the other hand, shows a slightly different pattern: CO2 emissions started decreasing significantly in 2007 but kept going down even after 2014 when economic growth exceeded 2%, thus presenting a slow-fast-fast pattern. This can be explained by the closing of electricity production based on coal which started in 2014 then replaced mainly by gas-based electricity production (Erbach and Szczepanski, 2022).

Going back to the overview for EU28, and only considering individual years with decreasing CO2 emissions (therefore excluding years where emissions increased), the total emission reduction during 2007-2014 was 1.5 larger than the one during 1990-2006 (920 MtCO2 for 2007-2014 and 612 MtCO2 for 1990-2006), even though phase 1 is more than twice longer than phase 2.

Considering only the emissions values of the starting and ending years of each period, with a linear approach, the EU28 lowered emissions by 1008 million tons (MtCO2) over these three decades: -253 MtCO2 during 1990-2007, -783 MtCO2 during 2007 -

2014, and +28 MtCO2 during 2014-2018. The rate of emission cut over the whole period (-0.9% per year) is deceiving because it covers three wildly different speeds: -0.3% between 1990 and 2007, -2.8% from 2007 to 2014, and +0.2% afterward.

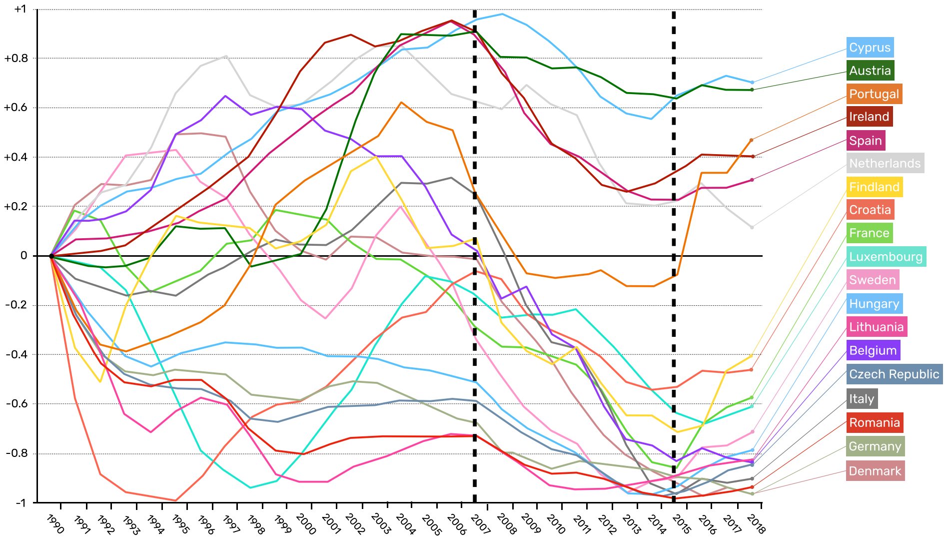

Figure 3: Evolution of normalized CO2 emissions for 19 countries with the strongest rates of emission decrease during 2007-2014. For each country, CO2 emissions original time series are normalized with respect to the maximum or minimum value, whichever is largest in absolute value. The curves are then drawn considering 1990 as the base 0.

3.2 How much decoupling is enough?

Now that we know the scale of past emission reductions, let us evaluate how these fares are compared to the European decarbonization target. In its "Fit for 55" package, the European Commission pledged to reduce its 1990 emissions level by 55% by 2030. In the year 1990, the EU28 emitted 4186 million tons of CO2 (see section 7.4 for emissions per country), which implies a target of 1884 million tons of CO2. In 2018, European emission levels were at 3178 MtCO2, which is 1294 MtCO2 over the target, requiring an average reduction of at least -3.4% each year until 2030.

Figure 4 displays the average yearly evolution of GDP and CO2, showing that a significant CO2 emissions reduction (larger than -1%) occurred almost exclusively when the yearly GDP growth was close to or below +1%. In the past 30 years, only four countries have reached reduction rates faster than -3.4% per year (dashed horizontal line in Figure 4), which is the reduction speed that would achieve the -55% target. Italy (-4.75%/year) and Spain (-4.41%/year) reached that decarbonization speed during a recession period (2007-2014). The United Kingdom has sustained a strong decarbonation rate (-3.3%/year), most likely due to the switch from coal to gas for electricity production (Erbach and Szczepanski, 2022). And Romania reduced territorial emissions by a yearly average of -3.7% during 1990-2006 and -6.2% during 2007-2014 while growing its GDP at an average rate of +1.5% and +2.3%, respectively, most probably because of its transition from an industrial to a service economy (Kirov, 2017).

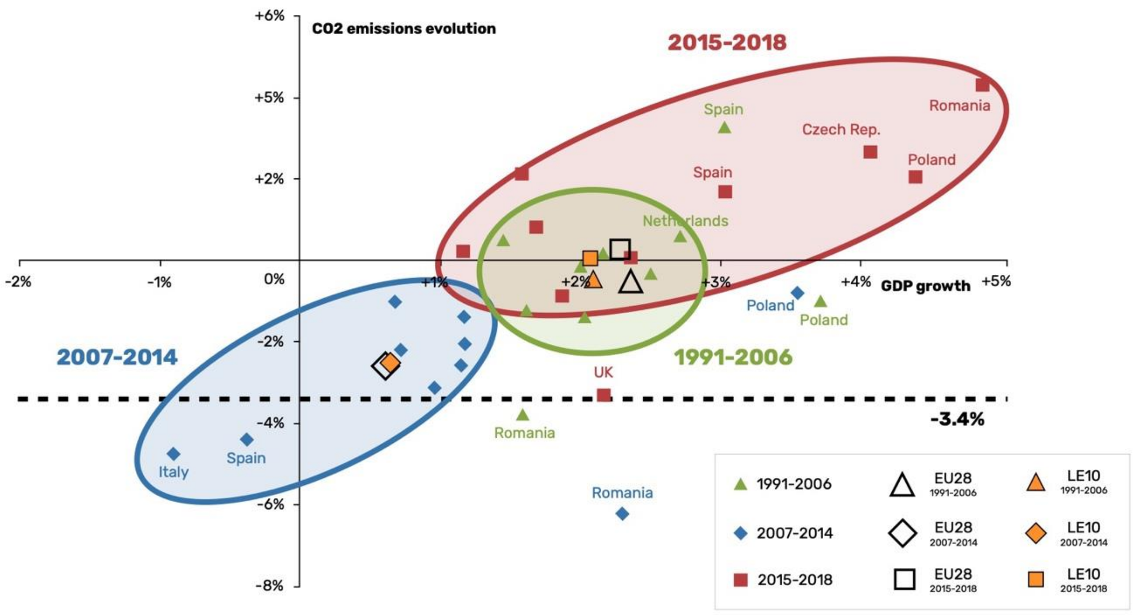

Figure 4: Yearly evolution of CO2 emissions and GDP for EU28, LE10, and each most emitting countries over the three time periods. The dashed line marks the -3.4% yearly CO2 emissions reduction rate necessary to achieve the "Fit for 55" target.

3.3 What explains the reduction in emissions?

While previous findings show that the rate of emission decline fluctuates between periods, it does not explain what might be causing these variations. In order to do that, we need to look more specifically at the evolution of the four variables of the Kaya equation (carbon content of energy, energy intensity of GDP, GDP per capita, and population). We do so using the LMDI methodology (see Section 6) and considering the emissions from the starting and ending years of each of the three time periods (see Section 7.5).

The analysis shows a steady causation pattern over the whole period (Figure 5a, Figure 5b, Figure 5c). *GDP per capita* and *population* tend to push CO2 emissions up, while the *energy intensity of GDP* and the *carbon content of energy* tend to pull them down. It is the relative power of these opposing variables that ultimately determines whether total emissions increase or decrease. For instance, as displayed in Figure 5a for EU28 during 1990-2006, the push up variable (+2% for GDP and +0.2% for population) have almost exactly counterbalanced the pull down variables (-1.6% for energy intensity and -1% for carbon content), which is why emissions remained more or less stable at -0.4% per year.

Since the impact of demography was constant over the 30-year period (+0.2% per year), all the upward variations in emissions can be explained by economic growth. This is what partly explains the slow-fast-slow pattern in the evolution of emissions: the yearly GDP per capita component in EU28 went from +2% during 1990-2006 to 0% during 2007-2014, to finally return to +2% during 2015-2018. The same pattern applies to LE10 and most other countries. For instance, France saw its GDP per capita component grow by a yearly +1.4% during the first period before experiencing a seven-year stagnation after the financial crisis (-0.1% between 2007 and 2014), to finally return to a positive +1.5% yearly growth rate after 2015.

Concerning pull-down variables, the analysis revealed that *energy intensity of GDP* affected emissions reduction more than the *carbon content of energy*. The energy intensity of GDP reduced emissions for the EU28 over the three periods by -1.8%, -1.6%, and -1.8%, while the carbon content of energy only by -1%, -1.3%, and -0.6%. Overall, changes in energy intensity of GDP were respectively 1.8, 1.2 and 3 times more impactful than the carbon content of energy for each of the respective time periods.

The impact of the energy intensity of GDP on CO2 emissions has been rather stable over the whole period. This reduction in energy consumption can be explained by two phenomena. First, the transition of most European economies from industries to less energy-intensive services. This structural change explains 21% of the decline in the energy intensity of GDP between 2000 and 2019 in Europe (ODYSSEE-MURE, 2021), although there are wide variations between countries. The impact of de-industrialization was negligible in the Netherlands, Portugal, and the UK, whereas it explains a large part of the lower energy intensity in Austria, Hungary, Croatia, Finland, and Sweden, where the share of industrial activities in GDP has significantly decreased.

The second phenomenon that explains lower energy consumption is energy efficiency. With less energy-intensive technologies, the same quantity of GDP can be produced from a constant quantity of energy, thereby lowering the average energy content of a unit of GDP. Energy efficiency improved in the EU at an average rate of 1.2% per year between 2000 and 2019 but has slowed down to less than 1% since 2014 (Lapillonne and Sudries, 2020). According to the same study, the main improvements in energy efficiency are related to housing due to stronger regulations, but even that sector has seen a slowdown after 2014 (2.1% per year overall from 2000 to 2019, but with a decrease to 1.6% per year since 2014). The industry sector has seen a similar pattern: high energy efficiency gains from 2000 until 2007 (1.8% per year) and slower gains since 2008 (0.8% per year).

The second pull-down variable is the carbon content of energy, the portion of fossil fuels within the overall energy consumption. It dropped fast in the 1990s (-1.5%/yr on average), with a rapid decrease in coal consumption (Eurostat, 2022). Over the past two decades, it has been decreasing slowly but steadily, around -0.6% per year since 2000, with the main drivers being the growing share of renewable energy to produce electricity and the switch from coal to gas to produce heat and electricity (EEA, 2020).

With both population and carbon intensity being stable over the period, the balance between GDP growth (upward variable) and the energy intensity of GDP (downward variable) determined most of the variation in emissions. If energy intensity decreases faster than GDP per capita increases, then emissions go down in absolute terms - that is what happened between 2007 and 2014 (Figure 5b). On the other hand, if GDP grows faster than the decline in energy intensity, then emissions go up – this is what happened during 1990-2006 (Figure 5a) and 2015-2018 (Figure 5c).

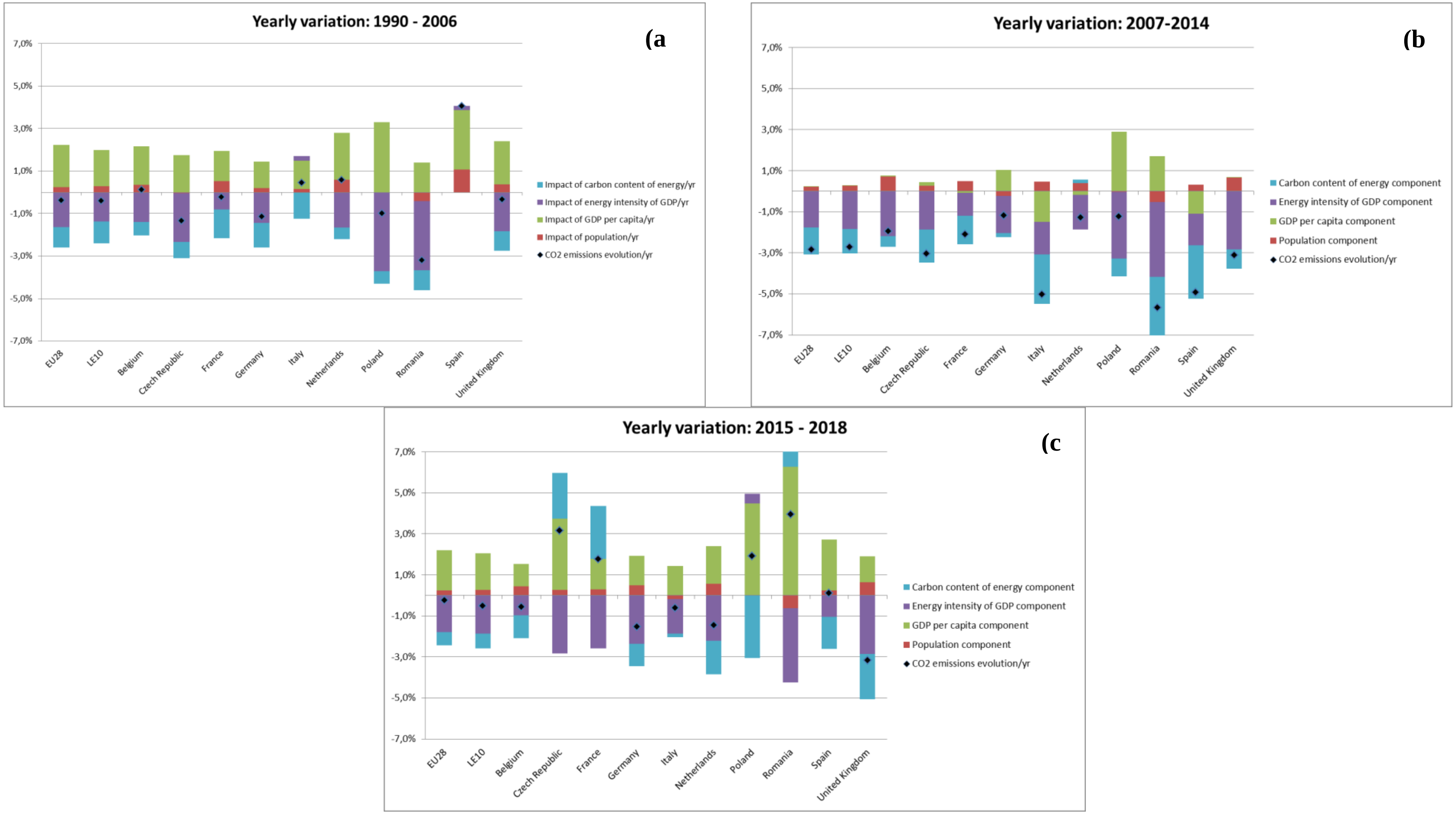

Figure 5: Kaya equation decomposition of yearly variation of CO2 emissions over the three time periods (a) 1990-2006, (b)2007-2014, (c)2015-2018 for EU28, LE10 and each of the 10 most emitting countries of EU28.

3.4 How to reach sufficient decoupling in 2030?

Building on the findings of the previous sections, we can now estimate how fast the energy intensity of GDP must decrease in order to achieve the -55% target for EU28. To do so, we use a slightly different version of the Kaya equation that shows the variables that determine the energy intensity of GDP. Basically, the energy intensity of GDP (EIG) was calculated by dividing total CO2 emissions by the carbon content of energy (CCE), GDP per capita (GPC), and population (POP).

$$EIG = \frac{CO2}{CCE \times GPC \times POP}$$

We then simulate the evolution of these parameters from 2018 to 2030 alongside five different GDP scenarios (-2%, -1%, 0%, +1% and +2% yearly variations) and different values for the yearly evolution of the carbon content of energy (from 0% to -4%). The demographic changes are the same in all scenarios: +0.23% per year, corresponding to the average value of this parameter over the 2010-2018 period.

The objective of this simulation is to show all possible combinations of GDP and carbon intensity variations that would achieve the -55% target by 2030, meaning a decarbonizing speed of at least -3.4% per year from 2018 to 2030. To put these projections in perspective, we compare the different expected speeds to the average rates of decline of the energy intensity of GDP and the carbon content of energy in the past three decades (Table 1).

Average of yearly values	1990-1999	2000-2009	2010-2018
Energy intensity of GDP	-2,0%	-1,6%	-1,9%
Carbon content of energy	-1,5%	-0,7%	-0,6%

Table 1: Average yearly variations of the energy intensity of GDP and carbon content of energy for EU28

The results are clear: the current rate of decrease in the energy intensity of GDP and carbon content of energy are not fast enough to achieve the -55% target while growing GDP. In fact, the only scenarios in which the target is reached are those in which GDP contracts between -1% and -2% (Figure 6).

If Europe wants to maintain a +2% GDP growth until 2030 and still reach the Fit for 55 target, it would need to decarbonize much faster than in the 1990s (the highest decarbonization speed of the period). This would require either to decrease the carbon content of energy 2.9 faster (reaching -4.38% per year, compared to -1.5% in the 1990s) or, alternatively, to decrease the energy intensity of GDP 2.5 faster (-4.9% per year compared to -2% in the 1990s). Considering a mix of these two leverage points, the minimal requirement for achieving the target (shown as the shortest path in Figure 6) would require to almost double the rates of decrease of both the carbon content of energy (1.9 times faster) and the energy intensity of GDP (1.7 times faster).

If decarbonization does not come back to its 1990s speed, this would require an even larger decrease in GDP. Considering the conditions observed in the 2010s as a reference, sustaining a +2% economic growth per capita while still bringing down emissions to -55% would require either reducing the yearly carbon content of energy at least 7.5 times faster (in order to reach a yearly -4.4%) or alternatively reducing the yearly energy intensity of GDP at least three times faster (in order to reach a yearly -5.8%). Acting on both variables at the same time would require a fastening by a factor of 4.2 for carbon content of energy (to reach -2.5%/year) and by a factor of 2 for energy intensity of GDP (to reach -3.8% per year). This is the shortest path from the 2010s data point to the +2% GDP growth line on Figure 6.

Here is the bottom line: achieving the -55% target (-3.4%/year of CO_2 emissions reduction until 2030) is highly unlikely unless general levels of production and consumption go down or if the speed of decarbonization is multiplied by a factor of several times the fastest emission-cutting speed achieved since the 1990s.

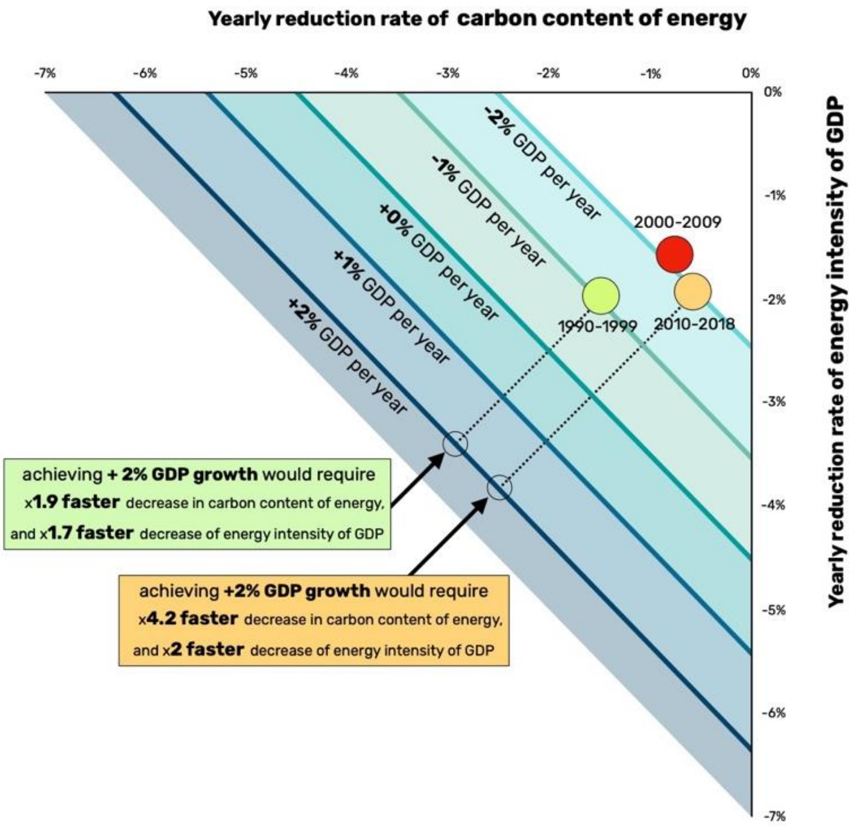

Figure 6: Variations of the yearly energy intensity of GDP for different values of carbon content of energy in five different GDP scenarios (-2%, -1%, 0%, 1%, and 2%). The three coloured points represent the average decarbonisation speed for each of the three decades since 1990.

4 Discussion

These findings give a more nuanced picture of the feasibility of green growth as a decarbonization strategy for Europe. Achieving the -55% target by 2030 while maintaining a rising GDP requires unprecedented structural shifts in recent history. Moreover, this political target is relatively unambitious compared to scientific targets in line with Paris Agreement-compatible 1.5°C mitigation pathways, which range between -61% and -70%, excluding LULUCF[6] (Climate action tracker, 2023b; Wilson et al., 2020). It should be noted that these so-called "cost optimal" targets combine domestic reductions and international support to reduce emissions abroad. If only acting on national emissions, a science-based target for 2030 would require much higher emission cuts.

And these targets only consider territorial emissions, which is problematic for European economies that have gradually outsourced their most polluting production abroad. Adding imported emissions, which represent 1/3 of the EU's footprint (Bourgeois et al., 2022), would make the necessary emissions cut even larger. This matters for transition strategies. Supply-side policies that affect the *energy intensity of GDP* and the *carbon intensity of energy* (the two technical means to decarbonize economic growth) only affect territorial emissions without much impact on imports, at least compared to demand-side policies that directly target overall energy use.

One possible solution to this problem would be to bring back the most emitting production on the continent. But such reindustrialisation would either slow down or even reverse the decrease in the energy intensity of GDP, the key factor which explained most emissions cuts since the 1990s (see Section 3.3). Reindustrialising while keeping emissions down would require to counterbalance the slowing down of energy intensity reduction with a faster removal of fossil fuels in the energy mix. Historically, the carbon intensity of energy in Europe has been quite stable over the last 30 years (-1.5%/yr in the 1990s, -0.7%/yr in the 2000s, and -0.6%/yr between 2010 and 2018), and there is little evidence to suggest that it will suddenly drop in the coming seven years. Climate Action Tracker (2023a) estimates that policies adopted by EU member states by March 2022 would only result in emission reductions of -35% below 1990 levels.

Another weakness of the "Fit for 55" target is that it ignores equity issues. Accounting for historical emissions and differentiated transition capacities would demand larger cuts in emissions for high-income countries as to enable lower mitigation rates for low-income nations (Robiou du Pont et al., 2017; Robiou du Pont & Meinshausen, 2018). Even though the European Union causes only 10% of global CO2 emissions, it is responsible for 25% of all cumulated emissions and 29% of excess emissions over

[6] Taking LULUCF into account would bring the 2030 emission reduction target to 60-61% (Climate action tracker, 2023b).

the global planetary boundary for climate change (Hickel, 2020). Including equity would bring 2030 targets in the range of -95% (Climate action tracker, 2023b) to -145% of 1990 emission levels (Climate Equity Reference Calculator, 2023).

A major drawback of our analysis is that it only examines carbon, one single environmental impact among an array of others. As insufficient as it is, the relative decarbonization of Europe is a success story compared to the evolution of other environmental indicators that have either stagnated or worsened (Bruckner et al., 2023). Material footprint is a good case in point: it has increased in Europe by +9.4% between 1995 and 2019 (Bruckner et al., 2023). This is particularly problematic since the extraction of natural resources is responsible for more than 90% of the global biodiversity loss and 23% of global greenhouse gas emissions (IRP, 2020). Abandoning fossil fuels while sustaining fast economic growth would require considerable quantities of materials to build and maintain renewable energy infrastructure (Capellán-Pérez et al., 2019). Again, however difficult decarbonising economic growth is, it will be significantly more difficult to do so while also mitigating other environmental pressures.

Bottom line: Given the historical trends and projected scenarios explored in the present article, it seems highly implausible that the European Union will manage to achieve its (relatively unambitious) -55% target while maintaining high rates of economic growth. Taking science-based targets, equity, and other environmental pressures into account, the state of high implausibility of green growth becomes a near impossibility. If economic growth is an obstacle to sustainability, a choice must be made between giving Europe a real chance to fall back within safe and just planetary boundaries (Rockström et al., 2023) or growing its economy.

This does not mean that a sustainable Europe is out of reach. After decades of focusing on eco-efficiency, recent literature on sufficiency (Jungell-Michelsson and Heikkurinen, 2022; Spangenberg and Lorek, 2019), degrowth (Hickel et al., 2022; Kallis et al., 2018) and post-growth (Hickel, 2021; Jackson, 2019) has brought up an array of new options to the table. In terms of climate mitigation, Keyßer & Lenzen (2021) demonstrated that a degrowth pathway minimizes several key risks for feasibility and sustainability compared to technology-driven, decoupling scenarios. Creutzig et al. (2022) found that demand-side options can reduce emissions by 40-80%, and that only 3% of these policies have a negative impact on wellbeing (for more, see Chapter 5 of the IPCC, 2022). This literature suggests that sufficiency/degrowth/post-growth policies (for a review, see Fitzpatrick et al., 2022) are not only more ecologically effective in bringing emissions down but could also yield a diversity of positive social outcomes.

This brings us to another essential point to consider. All along, we used GDP as a valid indicator of economic activity, as it is often done in decoupling studies (Wiedenhofer et al., 2020), therefore assuming that economic growth was desirable in and of itself. But instead of solely focusing on GDP, certain recent studies explore the possibility of decoupling wellbeing from environmental pressures. For example, Fanning et al. (2022) looked at the interaction between 11 social indicators and 6 biophysical indicators for more than 140 countries from 1992 to 2015. Their main finding is that countries tend to transgress planetary boundaries faster than they achieve social thresholds, and that certain nations with lower footprints manage to socially outperform others that are ecologically heavier.

Focusing on wellbeing is key to differentiate planned degrowth from recession (Hickel, 2021). Bringing down GDP is neither a valid nor a feasible policy objective. The key to bringing emissions down rather lies in specific policies targeting energy- and/or carbon-intensive forms of production and consumption such as industrial farming and animal products (McGreevy et al., 2022), car-based mobility (Cattaneo et al., 2022), or luxury emissions (Wallace and Welton, 2023). To be socially sustainable, these actions must be complemented by several other policies such as the reinforcement of basic public services (Coote et al., 2019), work time reduction (Kallis et al., 2013), and the redistribution of wealth (Jackson and Victor, 2021). The grand total of these policies may result in a macroeconomic contraction of GDP, but unlike a recession, one that is designed to reduce ecological footprints while improving wellbeing.

5 Conclusion

This study identified three phases in the evolution of CO2 emissions in Europe since 1990: slow reduction between 1990 and 2006, fast between 2007 and 2014, and slow again between 2015 and 2018 (Section 3.1). Overall, the majority of the cuts in emissions occurred during the second period. Even though the 2007-2014 phase was much shorter in duration than the first one (1990-2006), its cumulative emission reductions were 1.5 larger. This first result comes to question the prevailing discourse that assumes Europe has been gradually decarbonizing since the 1990s. The data showed that in the last 30 years, fast cuts in emissions have been the exception rather than the rule.

Another result is that economic growth slows down emissions reductions (Section 3.3). The large majority of European countries have never managed to reduce emissions faster than a yearly -2% when rates of GDP growth were above +1% per year. This may explain why no European country has ever sustained stable rates of decarbonizing in line with the "Fit for 55" target, namely a minimum of -3.4% per year (Section 3.2). The only countries that have escaped this pattern have done so during temporary periods of de-industrialization which only happen once.

Our simulations showed that the current rates of decrease in the energy intensity of GDP and carbon content of energy are not fast enough to achieve the -55% target while growing GDP (Section 3.4). Under the current conditions, the only scenarios where the target is reached involve a -2% yearly reduction of GDP. Even if Europe gets back to the faster decarbonization speeds of the 1990s, achieving the target would still require a -1% yearly contraction of GDP. The only way to achieve this target while maintaining positive rates of economic growth would be to immediately hike up the speed of decarbonization to unprecedented levels (by a factor of between 2 and 7.5), an hypothetical scenario that should be considered highly unplausible.

Put together, these results cast serious doubts on the feasibility of the current European Union's strategy for climate mitigation. If reaching the -55% target is highly implausible with current rates of economic growth, more ambitious science-based targets, including imported emissions, other environmental pressures, and equity issues, are even further out of reach. In times of climate emergency, it might be time for Europe to shift its historical green growth position for a degrowth/post-growth strategy.

6 Appendix 1: LMDI Decomposition Method

The Logarithmic Mean Divisia Index (LMDI) method allows the analysis of the relative weights of the different components in the evolution of a given parameter. In this study, we investigated the evolution of CO_2 emissions and decomposed them using the Kaya equation.

$$CO2 = \frac{CO2}{E} \times \frac{E}{GDP} \times \frac{GDP}{POP} \times POP$$

CO2: CO2 emissions. E: Primary energy consumption. POP: Population.

CO2/E: carbon content of energy. E/GDP: energy intensity of GDP.

GDP/POP: GDP per capita.

To simplify the calculations, we assigned specific variable names to each component.

CCE: carbon content of energy; EIG: energy intensity of GDP; GPC: GDP per capita; POP: population.

We then obtain: CO2 = CCE x EIG x GPC x POP

The LMDI method with an additive approach allows us to transform this equation to define the change in CO2 emissions between two dates, T1 and T2, as follows:

ΔCO2 = ΔCCEef + ΔEIGef + ΔGPCef + ΔPOPef

Where:

$$\Delta \mathrm{CCE_{ef}} = \left(\frac{CO2_{T2} - CO2_{T1}}{lnCO2_{T2} - lnCO2_{T1}}\right) \times \ln\left(\frac{CCE_{T2}}{CCE_{T1}}\right)$$

$$\Delta \mathrm{EIG_{ef}} = \left(\frac{CO2_{T2} - CO2_{T1}}{lnCO2_{T2} - lnCO2_{T1}}\right) \times \ln\left(\frac{EIG_{T2}}{EIG_{T1}}\right)$$

$$\Delta \mathrm{GPC_{ef}} = \left(\frac{CO2_{T2} - CO2_{T1}}{lnCO2_{T2} - lnCO2_{T1}}\right) \times \ln\left(\frac{GPC_{T2}}{GPC_{T1}}\right)$$

$$\Delta \mathrm{POP_{ef}} = \left(\frac{CO2_{T2} - CO2_{T1}}{lnCO2_{T2} - lnCO2_{T1}}\right) \times \ln\left(\frac{POP_{T2}}{POP_{T1}}\right)$$

7 Appendix 2: Additional information

7.1 Share of CO2 emissions for each EU28 country in 2018, with and without LULUCF

2018	Share of CO2 emissions including LULUCF	Share of CO2 emissions without LULUCF
LE10	**84,4%**	**83,1%**
Germany	23,0%	21,9%
United Kingdom	11,8%	11,0%
France	9,8%	9,6%
Italy	9,6%	9,9%
Poland	9,2%	9,6%
Spain	7,4%	8,0%
The Netherlands	5,3%	4,8%
Czech Republic	3,4%	3,1%
Belgium	3,2%	2,9%
Austria	2,0%	2,0%
Greece	2,0%	2,0%
Romania	1,6%	2,4%
Portugal	1,5%	1,5%
Hungary	1,5%	1,5%
Ireland	1,4%	1,1%
Denmark	1,2%	1,0%
Finland	1,2%	1,4%
Bulgaria	1,1%	1,3%
Slovakia	1,0%	1,1%
Estonia	0,6%	0,6%
Slovenia	0,5%	0,5%
Croatia	0,4%	0,5%
Luxemburg	0,3%	0,3%
Lithuania	0,2%	0,4%
Cyprus	0,2%	0,2%
Sweden	0,2%	1,2%
Latvia	0,2%	0,2%
Malta	0,1%	0,05%

7.2 Data source for each parameter of the Kaya equation

Variable	Unit	Time period	Source
CO2 Emissions **without LULUCF**	MtCO2e	1990-2018	EDGAR V7
LULUCF	MtCO2e	1990-2018	UNFCCC
GDP	US$ constant 2015	1990-2018	World Bank
Population	Number of inhabitants	1990-2018	Eurostat
Primary energy consumption	ktoe	1990-2018	Eurostat

7.3 Average and median yearly evolution of GDP growth and CO2 emissions for EU28, LE10, and each individual country over the three time periods.

Country	1990-2006		2007-2014		2015-2018	
	Average	**Median**	**Average**	**Median**	**Average**	**Median**
EU28 - GDP	**2,33%**	**2,35%**	**0,62%**	**1,14%**	**2,28%**	**2,21%**
EU28 - CO2	**-0,37%**	**-0,49%**	**-2,68%**	**-3,12%**	**0,24%**	**0,71%**
LE10 - GDP	**2,08%**	**2,19%**	**0,67%**	**1,16%**	**2,07%**	**1,99%**
LE10 - CO2	**-0,41%**	**-0,48%**	**-2,60%**	**-3,16%**	**0,06%**	**0,33%**
Belgium - GDP	2,16%	2,14%	1,18%	1,16%	1,69%	1,72%
Belgium - CO2	0,16%	0,16%	-2,05%	-2,21%	0,83%	-0,11%
Czech Republic - GDP	2,03%	2,98%	1,15%	2,01%	4,07%	4,18%
Czech Republic - CO2	-1,38%	-1,93%	-2,59%	-3,16%	2,68%	2,56%
France - GDP	2,00%	2,05%	0,72%	0,77%	1,59%	1,49%
France - CO2	-0,17%	-1,04%	-2,18%	-2,07%	2,12%	3,56%
Germany - GDP	1,62%	1,74%	1,18%	1,58%	1,87%	1,86%
Germany - CO2	-1,22%	-0,63%	-1,37%	-2,02%	-0,87%	-0,81%
Italy - GDP	1,45%	1,58%	-0,90%	-0,48%	1,17%	1,11%
Italy - CO2	0,48%	0,47%	-4,75%	-4,67%	0,24%	0,99%
Netherlands - GDP	2,71%	2,70%	0,68%	1,38%	2,36%	2,28%
Netherlands - CO2	0,59%	0,36%	-1,02%	-1,16%	0,08%	-0,61%
Poland - GDP	3,72%	4,60%	3,55%	3,56%	4,39%	4,53%
Poland - CO2	-0,99%	-1,76%	-0,80%	-2,06%	2,05%	1,91%
Romania - GDP	1,59%	3,18%	2,31%	2,82%	4,86%	4,59%
Romania - CO2	-3,78%	-2,51%	-6,21%	-5,53%	4,30%	6,36%
Spain - GDP	3,04%	3,05%	-0,37%	-0,33%	3,03%	3,00%
Spain - CO2	3,27%	4,86%	-4,41%	-3,82%	1,69%	1,77%
United Kingdom - GDP	2,50%	2,56%	0,97%	1,68%	2,17%	2,20%
United Kingdom - CO2	-0,33%	-0,30%	-3,13%	-2,90%	-3,30%	-3,42%

Country	1990-2006		2007-2014		2015-2018	
	Average	**Median**	**Average**	**Median**	**Average**	**Median**
Austria - GDP	2,40%	2,38%	0,94%	1,07%	1,94%	2,12%
Austria - CO2	2,79%	2,54%	-1,60%	-3,18%	0,16%	1,64%
Bulgaria - GDP	0,87%	3,81%	1,78%	1,25%	2,98%	2,90%
Bulgaria - CO2	-2,06%	-5,03%	0,08%	0,20%	-1,30%	-0,89%
Cyprus - GDP	4,43%	4,78%	-0,34%	-0,71%	5,35%	5,77%
Cyprus - CO2	3,95%	2,93%	-1,81%	-3,16%	1,67%	-1,24%
Croatia - GDP	4,00%	4,31%	-0,60%	-0,35%	3,09%	3,16%
Croatia - CO2	0,85%	1,92%	-3,36%	-6,37%	1,61%	3,99%
Denmark - GDP	2,34%	2,50%	0,18%	0,92%	2,60%	2,58%
Denmark - CO2	0,83%	-1,52%	-5,99%	-7,14%	-0,59%	-0,20%
Estonia - GDP	7,13%	6,80%	0,65%	2,73%	3,73%	3,64%
Estonia - CO2	-3,93%	-4,99%	4,36%	-0,98%	0,41%	1,73%
Finland - GDP	2,57%	3,82%	0,13%	0,21%	1,92%	1,98%
Finland - CO2	1,49%	-0,23%	1,94%	-19,75%	11,40%	5,69%
Greece - GDP	3,11%	3,50%	-3,26%	-3,41%	0,52%	0,45%
Greece - CO2	1,70%	1,50%	-3,95%	-5,25%	-2,97%	-2,61%
Hungary - GDP	2,77%	3,90%	0,30%	1,04%	3,88%	3,99%
Hungary - CO2	-1,21%	-1,47%	-4,13%	-3,85%	3,91%	4,54%
Ireland - GDP	6,38%	5,83%	1,06%	1,17%	11,30%	8,99%
Ireland - CO2	2,33%	1,82%	-3,20%	-1,83%	1,39%	1,20%
Latvia - GDP	7,18%	7,09%	0,19%	1,96%	3,39%	3,60%
Latvia - CO2	-26,12%	-18,48%	49,35%	54,82%	4,67%	-22,96%
Lithuania - GDP	6,28%	6,75%	2,19%	3,54%	3,20%	3,26%
Lithuania - CO2	2,69%	6,33%	-6,99%	-5,90%	12,83%	13,74%
Luxembourg - GDP	4,39%	4,01%	2,10%	2,14%	2,64%	2,14%
Luxembourg - CO2	0,17%	1,36%	-2,39%	-3,63%	-0,12%	-0,47%
Malta - GDP	4,84%	4,59%	3,84%	4,45%	6,75%	6,65%
Malta - CO2	1,36%	-1,31%	-1,23%	-0,04%	-8,12%	-7,86%
Portugal - GDP	2,19%	1,87%	-0,56%	-0,30%	2,54%	2,43%
Portugal - CO2	1,80%	4,24%	-3,99%	-3,54%	7,07%	8,96%
Slovakia - GDP	4,66%	5,39%	3,08%	2,68%	3,48%	3,39%
Slovakia - CO2	-2,33%	-1,55%	-1,72%	-1,14%	2,95%	2,12%
Slovenia - GDP	4,01%	3,67%	0,53%	1,10%	3,66%	3,81%
Slovenia - CO2	-0,19%	0,11%	5,19%	-0,05%	2,57%	2,22%
Sweden - GDP	2,46%	2,96%	1,38%	1,92%	2,77%	2,32%
Sweden - CO2	-0,45%	0,54%	-10,54%	-33,72%	32,80%	28,09%

7.4 Total CO2 emissions (including LULUCF) for EU28.

Unit: MtCO2	1990	2006	2007	2014	2015	2018
EU28	**4186,5**	**3934,3**	**3933,1**	**3149,9**	**3200,4**	**3178,3**
LEC10	**3551,0**	**3320,6**	**3308,6**	**2676,8**	**2723,4**	**2681,5**
Austria	50,5	73,9	70,8	64,5	66,0	64,8
Belgium	113,7	115,8	112,3	97,0	101,8	100,1
Bulgaria	60,9	39,3	42,0	37,0	40,0	34,6
Croatia	18,1	16,1	18,8	11,9	12,7	12,5
Cyprus	4,2	7,6	8,1	6,5	6,5	6,9
Czech Republic	153,9	121,0	124,2	97,7	99,1	108,6
Denmark	60,1	64,3	59,8	38,9	35,7	37,7
Estonia	34,0	15,5	19,0	19,8	17,4	19,8
Finland	40,2	40,7	47,8	25,7	24,5	37,6
France	357,2	344,2	336,9	287,6	296,4	312,2
Germany	1043,7	851,9	824,7	756,5	764,9	730,1
Greece	76,9	100,2	105,3	72,1	66,8	63,8
Hungary	69,0	56,0	54,3	39,7	41,7	46,3
Ireland	38,4	55,1	53,5	42,2	44,6	44,6
Italy	424,7	455,8	469,7	304,6	312,1	306,5
Latvia	7,0	1,0	1,9	8,1	6,8	6,3
Lithuania	29,7	10,2	9,7	4,5	5,4	7,2
Luxemburg	11,9	11,6	11,1	9,5	9,0	9,4
Malta	2,3	2,7	2,8	2,4	1,7	1,6
Poland	342,5	288,4	294,7	269,2	276,0	291,9
Portugal	49,3	60,4	57,4	43,0	47,6	47,7
Romania	159,0	77,6	74,1	44,7	46,8	52,4
Slovakia	51,0	33,6	33,5	28,7	28,7	32,2
Slovenia	12,2	11,4	11,0	15,5	15,7	17,1
Spain	195,4	322,2	338,1	221,7	235,2	236,0
Sweden	19,8	13,9	17,7	3,0	6,1	6,7
The Netherlands	167,1	182,5	183,7	167,2	175,1	167,5
United Kingdom	593,9	561,0	550,3	430,5	415,9	376,4

7.5 Variables of the Kaya equation during 1990-2006; 2007-2014 and 2015-2018 for EU28, LE10 and each of the 10 most emitting countries.

1990-2006	CO2 emissions		Population		GDP per capita		Energy intensity of GDP		Carbon content of energy	
	Total	Per yr	Total	Per yr	Total	Per yr	Total	Per yr	Total	Per yr
EU28	**-6,0%**	**-0,4%**	**4,0%**	**0,2%**	**31,7%**	**2,0%**	**-26,1%**	**-1,6%**	**-15,6%**	**-1,0%**
LE10	**-6,5%**	**-0,4%**	**4,6%**	**0,3%**	**27,2%**	**1,7%**	**-21,9%**	**-1,4%**	**-16,4%**	**-1,0%**
Belgium	1,9%	0,1%	5,7%	0,4%	28,8%	1,8%	-22,3%	-1,4%	-10,3%	-0,6%
Czech Republic	-21,4%	-1,3%	-0,8%	-0,1%	28,1%	1,8%	-36,4%	-2,3%	-12,2%	-0,8%
France	-3,6%	-0,2%	8,5%	0,5%	22,6%	1,4%	-12,9%	-0,8%	-21,8%	-1,4%
Germany	-18,4%	-1,1%	3,3%	0,2%	19,8%	1,2%	-23,1%	-1,4%	-18,4%	-1,2%
Italy	7,3%	0,5%	2,6%	0,2%	21,3%	1,3%	3,3%	0,2%	-19,8%	-1,2%
Netherlands	9,2%	0,6%	9,3%	0,6%	35,3%	2,2%	-26,6%	-1,7%	-8,8%	-0,6%
Poland	-15,8%	-1,0%	0,1%	0,0%	52,9%	3,3%	-59,4%	-3,7%	-9,3%	-0,6%
Romania	-51,2%	-3,2%	-6,5%	-0,4%	22,5%	1,4%	-52,3%	-3,3%	-14,9%	-0,9%
Spain	64,9%	4,1%	17,3%	1,1%	44,7%	2,8%	3,3%	0,2%	-0,3%	0,0%
United Kingdom	-5,5%	-0,3%	5,9%	0,4%	32,4%	2,0%	-29,5%	-1,8%	-14,4%	-0,9%

2007-2014	CO2 emissions		Population		GDP per capita		Energy intensity of GDP		Carbon content of energy	
	Total	Per yr	Total	Per yr	Total	Per yr	Total	Per yr	Total	Per yr
EU28	**-19,9%**	**-2,8%**	**1,5%**	**0,2%**	**0,1%**	**0,0%**	**-12,4%**	**-1,8%**	**-9,1%**	**-1,3%**
LE10	**-19,1%**	**-2,7%**	**1,8%**	**0,3%**	**0,3%**	**0,0%**	**-12,9%**	**-1,8%**	**-8,3%**	**-1,2%**
Belgium	-13,6%	-1,9%	5,0%	0,7%	0,3%	0,0%	-15,3%	-2,2%	-3,6%	-0,5%
Czech Republic	-21,3%	-3,0%	1,9%	0,3%	1,1%	0,2%	-13,1%	-1,9%	-11,3%	-1,6%
France	-14,6%	-2,1%	3,5%	0,5%	-0,5%	-0,1%	-7,9%	-1,1%	-9,8%	-1,4%
Germany	-8,3%	-1,2%	-1,5%	-0,2%	7,3%	1,0%	-12,8%	-1,8%	-1,3%	-0,2%
Italy	-35,2%	-5,0%	3,2%	0,5%	-10,4%	-1,5%	-11,1%	-1,6%	-16,9%	-2,4%
Netherlands	-9,0%	-1,3%	2,8%	0,4%	-1,3%	-0,2%	-11,7%	-1,7%	1,3%	0,2%
Poland	-8,6%	-1,2%	-0,3%	0,0%	20,3%	2,9%	-22,6%	-3,2%	-6,1%	-0,9%
Romania	-39,6%	-5,7%	-3,8%	-0,5%	11,9%	1,7%	-25,4%	-3,6%	-22,4%	-3,2%
Spain	-34,4%	-4,9%	2,2%	0,3%	-7,7%	-1,1%	-10,8%	-1,5%	-18,2%	-2,6%
United Kingdom	-21,8%	-3,1%	4,6%	0,7%	0,0%	0,0%	-19,9%	-2,8%	-6,6%	-0,9%

2015-2018	**CO2 emissions**		**Population**		**GDP per capita**		**Energy intensity of GDP**		**Carbon content of energy**	
	Total	**Per yr**	**Total**	**Per yr**	**Total**	**Per yr**	**Total**	**Per yr**	**Total**	**Per yr**
EU28	**-0,7%**	**-0,2%**	**0,7%**	**0,2%**	**5,9%**	**2,0%**	**-5,4%**	**-1,8%**	**-1,9%**	**-0,6%**
LE10	**-1,5%**	**-0,5%**	**0,8%**	**0,3%**	**5,4%**	**1,8%**	**-5,6%**	**-1,9%**	**-2,1%**	**-0,7%**
Belgium	-1,7%	-0,6%	1,3%	0,4%	3,3%	1,1%	-2,9%	-1,0%	-3,4%	-1,1%
Czech Republic	9,5%	3,2%	0,8%	0,3%	10,4%	3,5%	-8,5%	-2,8%	6,8%	2,3%
France	5,3%	1,8%	0,9%	0,3%	4,5%	1,5%	-7,8%	-2,6%	7,8%	2,6%
Germany	-4,6%	-1,5%	1,4%	0,5%	4,3%	1,4%	-7,1%	-2,4%	-3,2%	-1,1%
Italy	-1,8%	-0,6%	-0,5%	-0,2%	4,3%	1,4%	-5,1%	-1,7%	-0,5%	-0,2%
Netherlands	-4,4%	-1,5%	1,7%	0,6%	5,5%	1,8%	-6,6%	-2,2%	-5,0%	-1,7%
Poland	5,8%	1,9%	0,0%	0,0%	13,4%	4,5%	1,5%	0,5%	-9,1%	-3,0%
Romania	11,9%	4,0%	-1,8%	-0,6%	18,8%	6,3%	-10,9%	-3,6%	5,8%	1,9%
Spain	0,3%	0,1%	0,8%	0,3%	7,4%	2,5%	-3,1%	-1,0%	-4,7%	-1,6%
United Kingdom	-9,5%	-3,2%	1,9%	0,6%	3,8%	1,3%	-8,5%	-2,8%	-6,7%	-2,2%

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