

The Uneven Transition
Visualising Emissions, Economic Development, Climate Responsibility and
the global shift away from fossil fuels.

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Composite Visualisation

The five charts below form our composite visualisation.

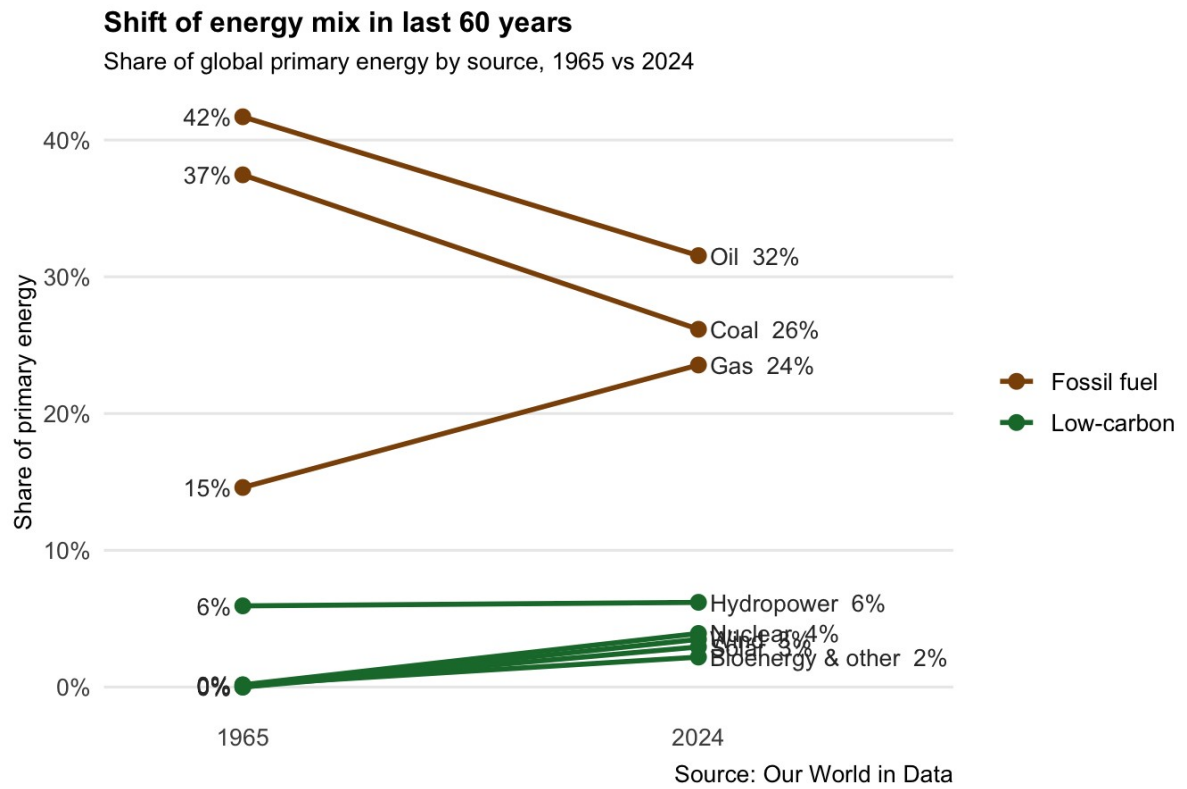
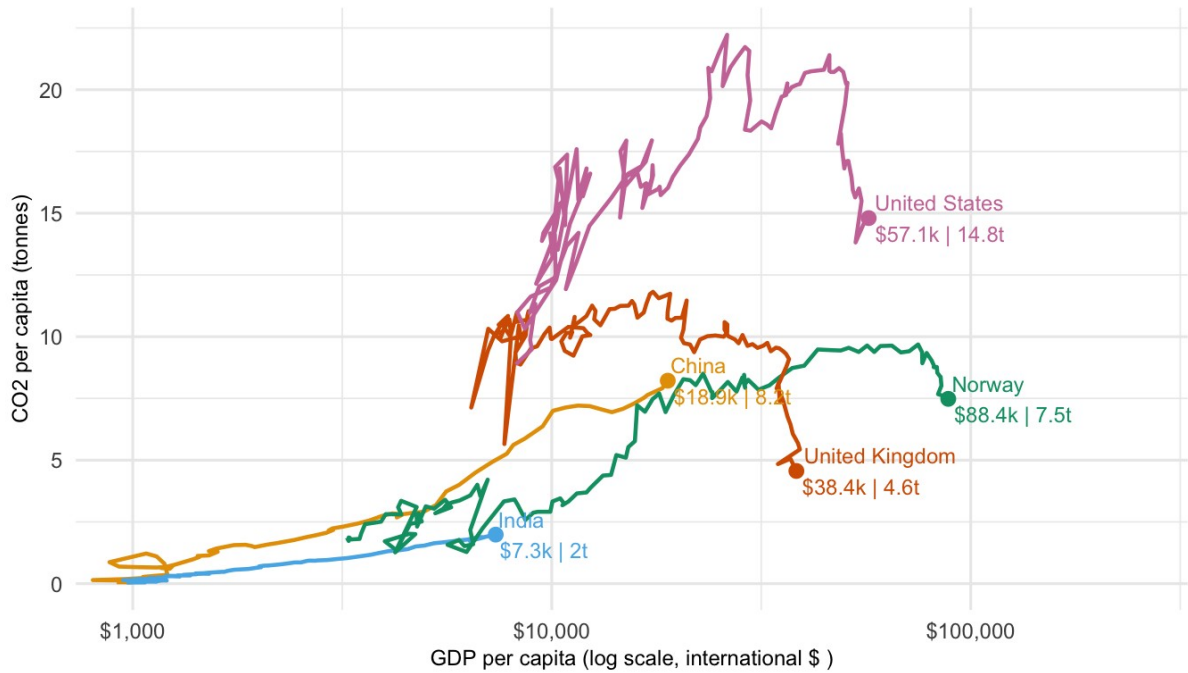


Figure 1. The energy mix in 1965 vs 2024

Growth and Emissions Decoupling

Each line shows countrys trajectory over time (1900–2022)

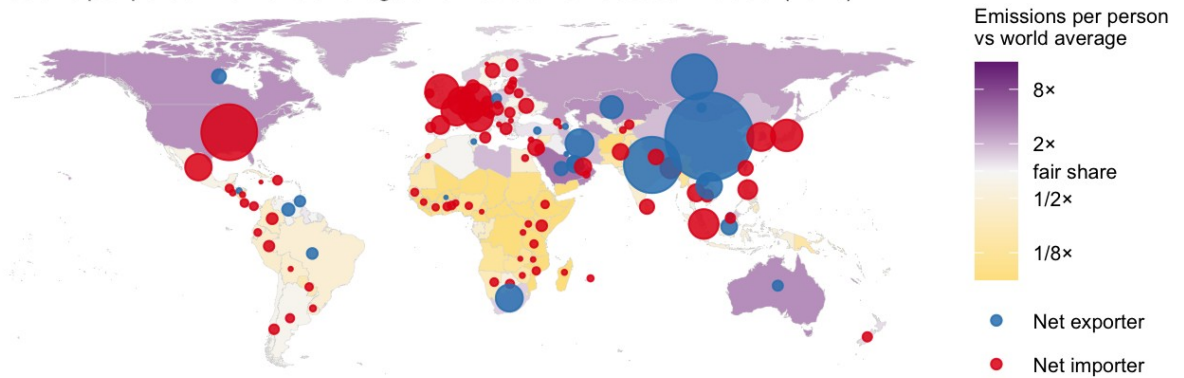


Source: Our World in Data

Figure 2. Per Capita emissions against income

Per Capita Emissions and Trade Embedded CO2

Emissions per person vs world average and net CO2 embedded in trade (2023)



Source: Our World in Data

Figure 3. Consumption-&-production-based emissions per person against their fair share

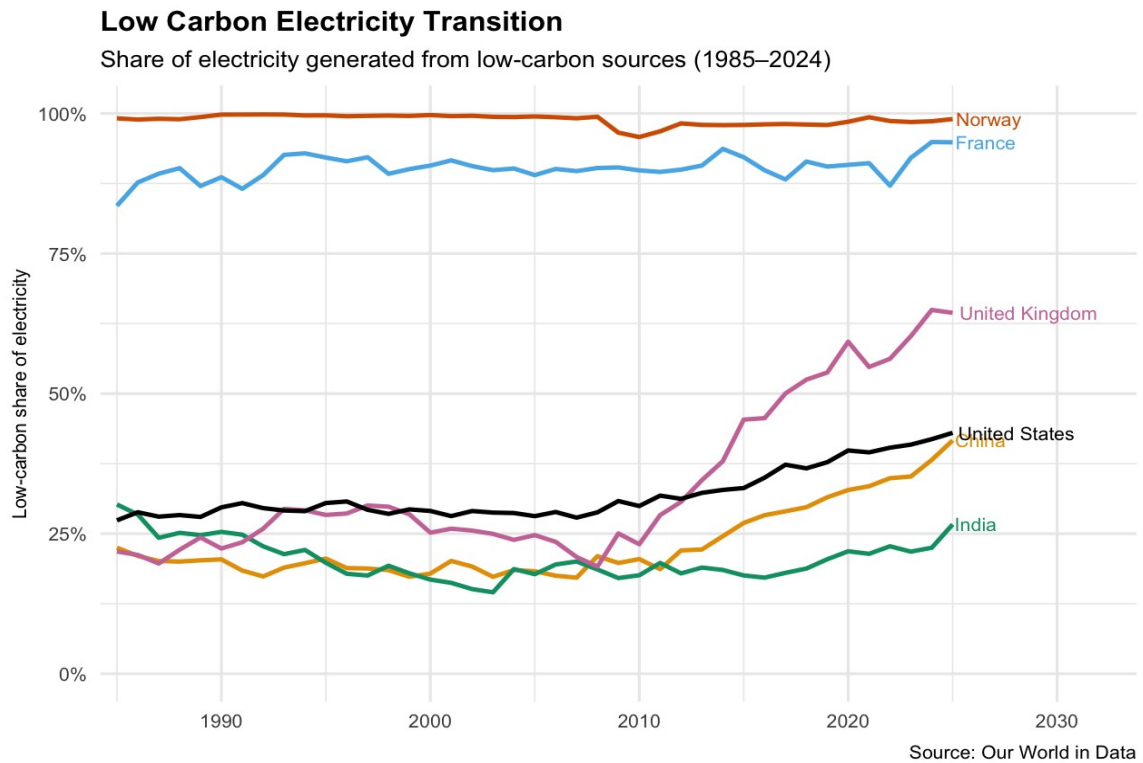


Figure 4. Low carbon share of electricity generation over time

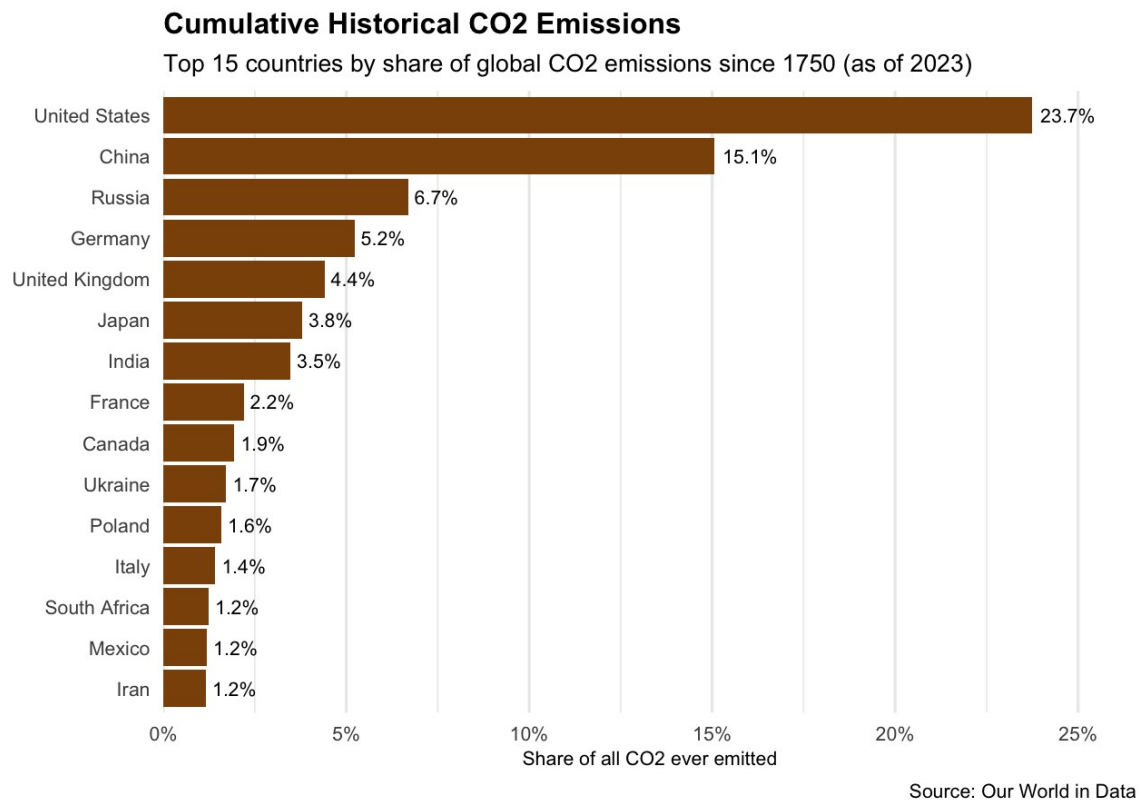


Figure 5. Countries with the highest cumulative CO₂ emissions, historically

1. Knowledge Building

We often frame climate change as one big global problem while completely overlooking the fact that this global problem consists of multiple interconnected challenges. We have built a composite visualisation that puts this data into perspective and **answers the question of whether the world is genuinely moving away from conventional sources of energy and whether or not that shift is fair**. The fairness discussion is important because climate change is not just about reducing emissions, but also about deciding who is responsible for taking actions and the severity of those actions. This idea of common but differentiated responsibilities has been a key part of international climate policy since the first global climate agreement (United Nations, 1992). Questions such as who should reduce emissions first, who contributed the most to the problem, and who should bear the costs cannot be answered using a single metric.

For this analysis, we used two open-source datasets published by ‘Our World in Data’ (OWiD). After reviewing multiple datasets, we selected these because they complement each other by linking national energy production and consumption with CO₂ while maintaining consistent country-level coverage and reporting standards across long time periods. These can be downloaded from either the OWiD portal or their GitHub repository. The first dataset is called the ‘CO₂ and Greenhouse Gas Emissions’ dataset (Ritchie et al., 2023), and the second one is the ‘OWiD Energy’ dataset, which Our World in Data compiles from the Energy Institute's Statistical Review of World Energy (Energy Institute, 2025). The ‘CO₂ and Greenhouse Gas Emissions’ dataset covers national CO₂ emissions from fossil fuels, industry and land use, all the way back from 1750 for some countries. At the same time, the ‘OWiD Energy’ dataset covers national and global energy consumption broken down by the sources of energy, viz., coal, oil, gas, nuclear, hydro, wind, solar and bioenergy from 1965 onwards. These datasets were chosen because they both report consistently at the country level and maintain population records.

This composite consists of five charts, each presenting a different perspective on the global energy transition. While the overall trend suggests progress, the charts also highlight several important differences and discrepancies depending on which measure is being considered. To understand whether the shift away from fossil fuels is actually taking place, Figure 1 shows that fossil fuels still supplied about 82% of primary energy in 2024, compared to 94% in 1965. However, much of this change has come from oil and coal being replaced by natural gas rather than a shift towards clean energy. Figure 2 shows that some high-income countries have managed to grow their economies while reducing per capita emissions; for example, the UK emits less CO₂ per capita than China while still maintaining a considerably higher income. Whether these reductions represent genuine progress is then questioned by Figure 3, which shows that many developed countries still emit well above the global average on a per capita basis, while the accompanying bubble chart indicates that some of these countries have shifted a substantial share of their emissions abroad through imported goods. Figure 4 shows that although all selected countries have made some progress towards cleaner electricity generation over time, the pace and extent of this transition vary considerably between countries. Finally, to put today's progress into historical context, Figure 5 shows that historical emissions remain heavily concentrated, with the top five countries responsible for nearly 55% of all CO₂ emissions ever.

Together, these five charts tell one composite story: the global energy transition is real, but it is slow, uneven and unfair. Looking at all five charts together provides a more complete understanding than viewing them individually. Focusing only on the changing energy mix or the reduction in emissions of a single country creates the impression that the transition is progressing more uniformly than it actually is. When interpreted together, the charts show that the overall picture depends on which measure is being considered. For example, while production-based emissions suggest substantial progress in some wealthier countries, the consumption-based perspective indicates that part of this apparent improvement comes from emissions associated with production being outsourced rather than eliminated (Peters et al., 2011). However, this interpretation is not without debate. Jakob and Marschinski (2013) caution that trade-related emission transfers cannot be read directly as wealthier countries outsourcing their pollution, because these transfers also reflect differences in trade volumes and in how carbon-intensive each economy is. This difference between the charts is the new knowledge that the composite provides: whether the global energy transition looks like progress or unfairness depends on which measure is being considered.

2. Theoretical Frameworks

This section explains how our visual follows the ASSERT Framework (Ferster, 2012) and the Grammar of Graphics (Wilkinson, 2005), implemented using ggplot2 (Wickham, 2010). We follow Figure 2 from asking the question to telling a finished story, discussing the Grammar of Graphics within the ‘Represent the Visualisation’ stage.

The ASSERT Framework

Ask a question: While the composite as a whole asks whether the move away from conventional energy is fair, Figure 2 focuses on one specific part of that question, i.e. has economic growth become less dependent on carbon emissions? Defining this question first helped us focus the chart on how economic growth and carbon emissions change together, instead of making it a general comparison of countries. Framing the question this precisely mattered because it told us that the chart would need to show three things at once: income, emissions, and time.

Search for information: After defining the question, we identified the information needed to answer it: measures of economic development, carbon emissions and population for the same countries over a sufficiently long period. We then explored several recognised climate and energy data sources and research based on them, including Our World in Data, the Energy Institute’s Statistical Review of World Energy, and United Nations resources, comparing their variables, geographical coverage and historical depth. Following Kirk (2019), we prioritised data that were open, transparent and well-documented, while Few’s (2009) principles helped us identify datasets that were historically complete, collected using consistent methods and supported by an established source.

Structure the data: We first calculated GDP per capita by dividing GDP by population, since the dataset reports total GDP. We then filtered the data to a small set of high-income and developing economies so the chart could contrast the two, kept only the years where both income and emissions were available, and removed regional totals and grouped categories. Crucially, we arranged each country’s rows in the order of year because Figure 2 draws its lines by connecting the points in the order they appear in the data. By the end of this stage, the table contained continuous variables, viz. income, emissions and year, and one categorical variable, country (Ferster, 2012).

Envision the answer: Before designing the chart, we explored the structured data. First, income values covered a very wide range, from a few hundred dollars to tens of thousands, so that a normal axis would compress the poorer countries into the left corner, so we chose a logarithmic income scale. Second, we realised that the relationship itself was the answer we wanted to show, not the two individual trends. These two findings shaped the design and led us to envision a connected scatter plot, where each country appears as a single line moving through the income-emissions space, so a reader can see whether a line moves downwards while still moving to the right, which is exactly what decoupling looks like.

Represent the Visualisation: The chart was built in ggplot2 using the Grammar of Graphics approach (Wilkinson, 2005), which builds a visualisation by combining different graphical elements. The aesthetic mapping places GDP per capita on the x-axis, CO₂ per capita on the y-axis, and maps each country to a different colour. Following Wickham's (2010) layered grammar, we then added three geometries as layers: a path connecting the yearly values, a point showing each country's latest position, and text labels to identify the countries. The paths are important because our aim is to show each country's progression over time rather than to focus on individual years. Time is therefore represented by the order in which the points are connected, rather than by a separate axis. Finally, we used a logarithmic x-axis, a colour-blind-friendly palette, the standard Cartesian coordinate system, and the identity statistic because the data are plotted without further transformation.

Tell a Story: Finally, we focused on how the chart would tell its story. The title states the main question directly, so the reader knows what to look for before reading a single data point, and the direct labels at the ends of the lines show where each country stands today. The chart therefore provides the overview first and rewards a closer look with the detail, following Shneiderman's (1996) principle. More importantly, the chart tells a story of two different paths. Some countries continue to grow while keeping their carbon emissions relatively stable, showing early signs of decoupling. Others still see emissions rise alongside economic growth. By placing Figure 2 after the energy mix chart, the story moves from asking whether the transition is happening to asking who is benefiting from it, helping prepare the reader for the fairness discussion that follows.

3. Accessibility

Accessibility focuses on building visuals and charts that as many people as possible can read and understand correctly with minimal to no effort. This includes people with colour-vision deficiency, which is roughly one in twelve men, for whom the red-green contrast can disappear (Wong, 2011). This also includes reducing cognitive effort and making sure the information can be accessed by consumers across various media sources. A chart that fails on these points might become difficult to read and, in some cases, impossible to analyse.

Here, we use Figure 4 to assess the chart's accessibility, as this is the chart where most people would struggle because of 6 lines of one colour each that span long stretches. The design choice here helped in three ways. First, the six-line colours come from a colour-blind-friendly palette, so the lines remain distinguishable under common forms of colour-vision deficiency (Wong, 2011). Second, each country is labelled directly at the end of its line rather than in a separate legend, so the reader never has to hold six colour-country pairs in their memory while reading the chart. Third, colour never works alone in this figure. The country identity is carried by the colour, the position and the text label together, and Bertin (1983) argued that a chart becomes harder to read when a single visual variable is asked to carry all the meaning. The y-axis is also fixed from 0 to 100%, so differences between countries are shown at their true scale rather than being exaggerated by a zoomed-in axis. Beyond using colour, we also tried to make the charts easy to read. Every figure has a clear title that explains its main message, so readers can quickly understand what the chart is about. When readers need to compare values, we use position on a common scale because people judge it more accurately than other visual features (Cleveland & McGill, 1984).

Some design choices have also hampered accessibility. On the left side of the chart, four of the six lines are tangled and intertwined multiple times between roughly 15% and 30% for the first two decades, and there are no labels at the start of the lines. A reader who wants to know where a country began has to trace the line backwards from its label on the right, which can be effortful, especially for low-vision readers. With six lines already shown, adding even one more country could make the chart look cluttered and make it much harder to follow.

The only other real accessibility issue with this chart, and the composite in general, is the relatively small font size of the data and axis labels. However, this is a conscious decision rather than a shortcoming. Increasing the font size causes the labels to overlap, making the charts look cluttered and dense, thereby reducing readability. A subtler issue is that the charts are saved as images, so the text inside them is just pixels. A screen reader gets nothing from inside the chart. Adding a short-written description of each chart's main trend would fix this for blind and low-vision readers (Lundgard & Satyanarayan, 2021). Overall, Figure 4 shows that the composite follows good accessibility practices with a few minor compromises, and the same choices run through the other four charts.

4. Visualisation Choice

Different types of charts are suited to different tasks (Munzner, 2014), so each chart in the composite was chosen for its ability to best answer the question it was intended to address. In this section, we justify the choice behind Figure 3, because it does most of the heavy lifting in our research and required us to make the hardest design decisions. Figure 3 combines two fairness measures by showing how each country's per-capita emissions compare with a fair share, while also showing how much carbon it moves across the globe through trade.

A choropleth was chosen to carry the per-capita comparison because geography is read almost instantly. Readers can recognise continents and locate countries without having to search through a legend. The trade measure was then overlaid as proportional bubbles. The colour channel of the map was already occupied by the fair-share comparison, so the second variable needed a second visual element, and size suits a quantity that runs from small to large; hence, bubbles were chosen. Munzner's (2014) ranking of visual channels tells us the cost of this decision in advance. Position and length are read most accurately, while area is read less accurately, so readers can only estimate the trade values rather than read them precisely (Cleveland & McGill, 1984). We accepted this because the purpose of the bubbles is to show direction and rough magnitude, not exact numbers.

We did consider three alternatives before settling on this design. A ranked bar chart would have made the values far easier to compare, since bars sit on a common baseline, but it would have removed the geographical context. A cartogram, in which each country is resized based on its population rather than its land area, would have fixed the biggest weakness of our map, but it distorts country shapes so much that readers struggle to recognise them (Monmonier, 2018). Two separate maps, one for the fair-share comparison and one for trade, would have made each map cleaner, but it would have broken the link between the two measures, and that link is the entire point of the chart.

The chosen design also has honest negatives. It is the most information-dense chart in our composite, combining a yellow-to-purple gradient with red and blue bubbles of varying sizes, and some bubbles overlap where countries sit close together. While the colour scheme makes the chart more accessible to people with colour vision deficiency, the bubble size might hinder accessibility. Large countries also naturally command more of the eye than small ones, so the extreme per-person emitters that happen to be small states are easy to miss on the map. In Grammar of Graphics terms, Figure 3 is the only chart that does not use the standard x- and y-axes. Instead, it uses a map and adds points on top of it. This allows the chart to answer two questions at once by showing each country's location and its emissions. Across the whole composite, we matched each visual to its purpose: we used position and length when readers needed to compare values accurately, and colour, area and geography when the overall pattern was more important than exact numbers (Munzner, 2014). Even with these costs, the combined map was the right tool for this goal: a single view where the reader can see who emits beyond their share and who moves their emissions through trade, in the same frame. When the goal is precise comparison, bars are the better chart, as we used in Figure 5. But when the goal is a spatial pattern, map is the better choice.

5. Implications and Improvements

We focus on Figure 1 here because it is the chart most likely to mislead a casual reader. Figure 1 shows the percentage share of each energy source instead of the total amount of energy being used. Because of this, it can make it seem like fossil fuel use has been reduced much more than it actually has. In reality, their share has fallen only slightly, while total global energy use has continued to grow (Energy Institute, 2025), which means the actual amount of fossil fuel being burned has gone up while its share has gone down. A casual reader could simply look at the downward slope of the oil and coal line and get the exact opposite of the truth.

The chart also hides two more things. Since the slopegraph only compares the start and end years, it conveniently hides everything that happened in between, including the oil shocks of the 1970s and the coal expansion of the 2000s (Energy Institute, 2025). And as discussed in the knowledge-building section, a large part of the apparent decline in coal and oil is explained by natural gas replacing them, which is a swap between fossil fuels rather than a move away from them. So even the modest progress the chart shows is less clean than it looks. These are not the flaws in the data or representation but rather the consequences of choosing shares over absolute values and endpoints over the full timeline, both of which are deliberate choices to emphasise structural change and highlight net change between then and now.

Misleading climate charts of this kind are well documented. Cairo (2019) looks at charts used by climate change sceptics, including one that used a very large vertical scale for global temperatures, making a century of warming look almost like a straight line. The chart was not wrong in its numbers; it was wrong in its framing, and it was used to argue that climate change was not happening. Our Figure 1 carries the same type of risk in the opposite direction. Someone arguing that the energy transition is going well could present the falling fossil-fuel shares without mentioning that total fossil consumption has grown, and the chart would appear to support that argument.

There are several ways this visual could be improved. First, it could be shown alongside a chart of total energy consumption so readers can see both the changes in the energy mix and the growth in overall energy use. Second, adding one or two years between 1965 and 2024 would show some of the important changes that happened over time, while still keeping the chart simple. An alternative approach would be to create small multiple charts that illustrate the overall trends for each energy source individually. These charts could also incorporate uncertainty information to emphasise that the figures are estimates rather than precise values. Additionally, using larger text and providing a brief explanation beneath the chart would enhance comprehension for a broader audience. The first improvement does not require a new dataset, as the OWiD Energy dataset already contains both total energy consumption and percentage shares. Another improvement would be to include per-person energy use, making it easier to distinguish population growth from real increases in energy demand. Implementing these modifications would strengthen both the clarity and accessibility of the visualisation, aligning with the idea that effective visuals should aid understanding of the data and minimise the risk of misinterpretation (Tufte, 2001).

6. References

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