A Silent Transition: Growth with Less Environmental Weight

Jonas Grafström

Abstract Across Europe, environmental performance has improved alongside economic expansion. Since 1990, most EU countries have seen a steady decline in territorial CO_2 emissions, improved energy-efficiency, and reductions in pollution, enabled by common instruments such as emissions trading, product regulations, and renewable energy targets. While the broad pattern is visible across member states, some cases demonstrate especially sustained and measurable decoupling. Sweden offers one such example. Between 1990 and 2023, the country reduced territorial CO_2 emissions by 38% while GDP more than doubled. Air pollutants fell across nearly all tracked categories, energy intensity declined, and hazardous chemical use decreased despite rising population and output. These outcomes emerged gradually—not through disruption or centralized intervention, but through quiet steps. This essay examines how those long-term shifts unfolded. It draws on empirical indicators of emissions, energy use, and resource flows to illustrate how Sweden reduced its environmental weight while maintaining economic growth.

Keywords Decoupling · Environmental policy · Carbon emissions · Resource efficiency · Technological change · Economic growth · Sweden

***JEL* Classifications** O44 · O52 · Q56 · Q58 · Q01

Introduction

What if a country could grow richer while using fewer resources, emitting less pollution, and consuming less energy per unit of output?

I thank Christian Sandström and Magnus Henrekson for useful comments and suggestion on earlier versions of this essay.

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M. Henrekson et al. (eds.), *A Green Entrepreneurial State?*, International Studies in Entrepreneurship 49, https://doi.org/10.1007/978-3-032-15512-2_14

EU countries' greenhouse gas emissions decreased by 29% between 1990 and 2021. Emissions decreased in 24 out of 27 member states. At the same time, the union's real GDP increased by 62%. In relation to GDP growth, greenhouse gas emissions have decreased in all EU member states since 1990.

This essay examines decoupling between economic growth and environmental pressure by delving deeper into the example of Sweden (based on data from Statistics Sweden and the Swedish Environmental Protection Agency). Over the last three decades, the country has quietly pursued that path (Grafström and Sandström 2021). Between 1990 and 2023, Sweden's population rose by almost 25% and real GDP nearly doubled. Yet, over the same period, total carbon dioxide emissions declined by over 38% while energy use remained unchanged (Swedish Energy Agency 2025). Air and water pollution has declined across most categories. Of the 26 tracked air pollutants, 24 showed reductions.

Sweden tells a story not of grand transformation, but of cumulative shifts—thousands of incremental changes in technology, behavior, policy, and industrial design. Cleaner vehicles, more energy-efficient buildings, electrified infrastructure, and smarter logistics have all played a role. So too have stable institutions and a policy environment that rewarded long-term thinking over short-term gain.

This essay focuses on observed empirical shifts and their implications for the resource intensity of growth. Using national data from 1990 onward, it traces trends in CO_2 emissions, energy and water use, industrial inputs, transport fuels, and air pollutants. It also includes less visible indicators—such as consumption-based emissions and the use of hazardous chemicals—that capture the environmental impact embedded in imports and production. Together, these metrics reveal a society that has managed to produce more output with less environmental strain.

Sweden's experience does not offer a universal blueprint, but it provides a compelling case study. The observed pattern of progress challenges the assumption that economic growth and ecological degradation must always go hand in hand. Decoupling—while incomplete and uneven—is already happening.

None of these shifts were inevitable. Each depended on a combination of policy, innovation, and private response. When viewed together, they form a picture of material change: a society growing wealthier and larger, yet placing less strain on air, water, and material resources (McAfee 2019).

More from Less

What people consume, how they travel, and how buildings are heated have undergone substantial changes since the early 1990s—but not always in ways that are immediately visible. Most of the shifts have occurred quietly: one instance of efficiency improvement at a time, one regulatory change at a time or just responses to relative price changes. The result is not a sudden transformation, but an accumulation of adjustments that show up in national statistics. Across energy systems, vehicle fleets,

Table 1 Changes in key environmental and resource indicators for the European Union

	Period	Change (%)
CO_2 emissions	1990–2021	−28
Methane	1990–2021	−38
Arsenic	1990–2021	−90
Lead	1990–2021	−95
Sulfur Dioxide	1990–2021	−93

Source Eurostat (2024)

industrial processes, and emissions profiles, the numbers suggest a society that has learned to operate with less environmental weight per unit of output.

As shown in Table 1, the European Union provides many examples of this trend.

In what follows, emissions, fuel use, electricity demand, chemical inputs, and water consumption are examined in relation to economic growth. Although the data do not suggest uniform progress, they do reveal a general direction. As output has expanded, the intensity of resource use has fallen. Some indicators declined slowly, others sharply while a few increased. Together, they offer a picture of how environmental pressure has evolved across sectors—and how the material basis of growth has shifted.

The overall pattern of "more from less" in Sweden is illustrated clearly in Table 2, which shows the changes in emissions, energy, water, and hazardous chemical use, adjusted for economic growth. The figures reveal a broad-based decoupling between environmental impact and GDP.

The pattern presented in Table 3 is most evident in the trajectory of CO_2 emissions. In 1990, emissions stood at 71.6 million tonnes. By 2023, emissions had declined to 44.4 million tonnes, even as GDP more than doubled. That shift did not result from an economic slowdown, but from structural and technological changes across multiple sectors. Energy systems became less carbon intensive. Industrial processes grew more efficient. Transport fuels diversified, and heating shifted away from oil.

Consumption-based emissions reflect the greenhouse gases generated in the production of goods and services consumed domestically, regardless of where those emissions occur. This includes imports such as electronics, food, industrial materials, and transport services. This approach is complementary to territorial accounting, which only measures emissions within national borders.

As shown in Fig. 1, Sweden's domestic consumption-based CO_2 emissions declined from 39.6 to 29.6 million tonnes, equivalent to a 25% drop between 2008 and 2022. The reduction suggests changes in the composition of imports, improvements in production efficiency abroad, and shifts in domestic consumption patterns.

Car ownership continued to rise, yet average fuel consumption per kilometer fell. From 1990 to 2024, the number of passenger cars in traffic in Sweden increased from approximately 3.6 million to nearly 5 million while average fuel consumption per vehicle declined substantially (Trafikanalys 2025). New gasoline-powered cars sold in 1990 consumed an average of around 9 L per 100 km. By 2018, consumption had

Table 2 Percentage changes in key environmental and resource indicators relative to GDP in Sweden, 1990–2024

	Period	Change	GDP Growth	Change per unit of GDP
CO_2 emissions	1990–2023	–38	101	–69
Consumption-based CO_2 emissions	2008–2022	–25	28	–42
Greenhouse gases from domestic transport	1993–2022	–27	101	–64
Use of liquefied petroleum gas	1993–2023	–49	101	–75
Greenhouse gases from cars	1993–2024	–33	101	–67
Energy consumption	1993–2024	–5	101	–53
Electricity consumption	1993–2024	–3	101	–52
Use of water	1995–2020	–6	73	–79
CFC emissions (freons)	1993–2024	–92	101	–96
Use of health- and environmentally hazardous chemical products (incl. export)	2008–2020	–5	19	–24

Source Grafström and Sandström (2024), Swedish Environmental Protection Agency (2024a, 2024b, 2024c) and Statistics Sweden (2025)

Table 3 Absolute change in CO_2 emissions and economic growth in Sweden, 1990–2023

Year	CO_2 emissions (million tonnes CO_2-equivalents)	GDP (billion USD, 2023 prices)
1990	71.6	259.9
2023	44.4	584.96

Source Swedish Environmental Protection Agency (2024a) and Statistics Sweden (2025)

dropped below 6 L per 100 km for comparable gasoline models and even further for hybrids. For the fleet as a whole, the Swedish Environmental Protection Agency estimated a reduction in average CO_2 emissions from new cars from over 200 g per kilometer in the early 2000s to 120 g by 2018. In 2024, the average was 63 g.

Figure 2 captures a key contradiction turned into a success: a transportation sector that has grown in volume while shrinking in terms of emissions.

In the early 1990s, Stockholm's skyline was not what it was today. Diesel engines rattled through city centers, and few questioned the inevitability of pollution as the price of modernity. Sweden's emissions of nitrogen oxides had fallen by more than half since 1990 (Grafström and Sandström 2021). In transportation, similar developments occurred. Road transport continues to dominate domestic logistics, but

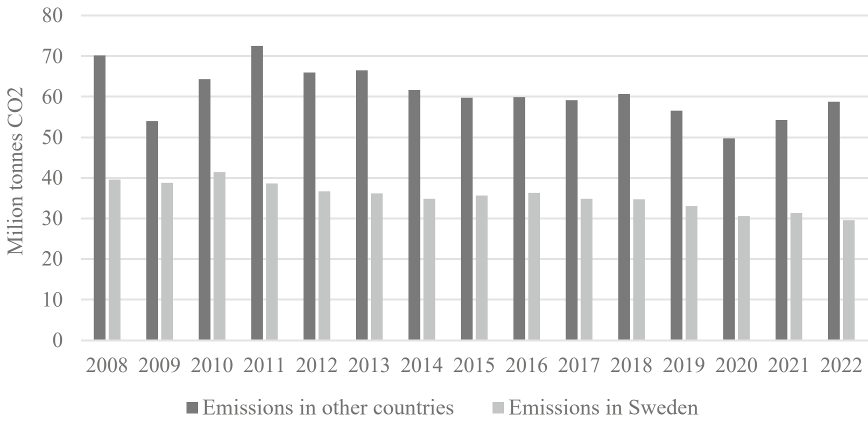

Fig. 1 Sweden's consumption-based CO_2 emissions, 2008–2022 (million tonnes). *Source* Swedish Environmental Protection Agency (2025)

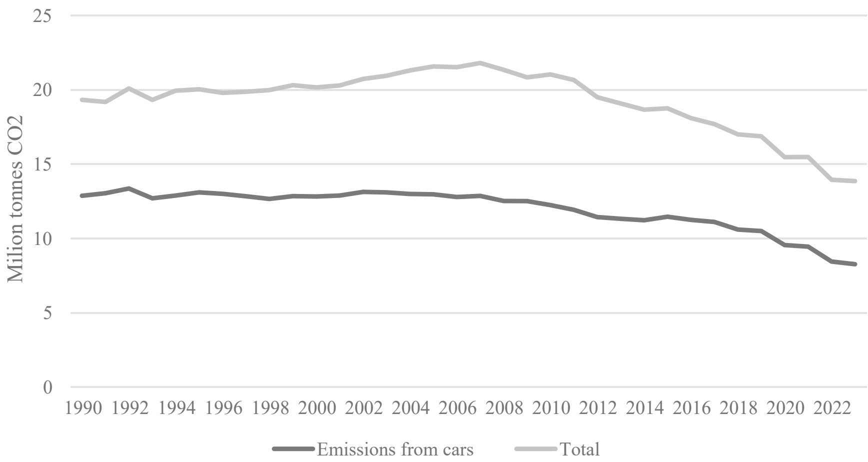

Fig. 2 CO_2 emissions from cars and total emissions from the transportation sector in Sweden, 1990–2023 (million tonnes). *Source* Swedish Environmental Protection Agency (2024b)

improvements in fuel economy, logistics planning, and vehicle design have moderated emissions growth. Railway electrification expanded, and more efficient intermodal hubs were established. Fewer trucks returned empty across the country, and delivery routes were optimized.

Between 1993 and 2018, energy use per unit of industrial output declined by more than 30%. Investments in combined heat and power, automation, and internal energy recovery reshaped the industrial energy profile. The objective was not to scale down production, but to reduce the energy required per unit of value.

Paper production illustrates this transition. Long associated with high environmental impact, the sector adopted closed-loop water systems, waste heat recovery, and steam reuse. Mills that once relied on linear flows now recirculate process water and capture energy that was previously lost (Bajpai 2015). Output has remained high, but with a smaller ecological footprint.

From 1990 to 2023, Sweden's total energy use remained relatively flat, but the sectoral distribution changed. Industry consumed approximately 140 TWh in 1990, rising to a peak of 159 TWh in 2007 before falling back to 135 TWh by 2023. The post-crisis decline reflects both improved energy-efficiency and structural shifts. Transport followed a different trajectory. Energy use rose through the early 2000s, reaching a peak in 2004, then declining gradually to around 78 TWh—close to the 1990 level. Electrification remains limited in total energy terms but is increasingly visible in new vehicle registrations and fleet performance.

In 1990, housing and services consumed nearly 150 TWh—more than any other sector. Despite rapid population growth and an expanding building stock, energy use declined to 139 TWh in 2023. The decline reflects more efficient heating, widespread district heating systems, and improvements in insulation and appliances. Changes in household energy use predate the period. In the 1970s, oil dominated residential heating (Di Lucia and Ericsson 2014). By the 2010s, heat pumps and thermal networks had displaced fossil fuels. The result is a sector where energy demand has decoupled from both floor area and income. Figure 3 shows how this shift in sectoral composition unfolded over time.

Air quality also improved across several dimensions. Emissions of nitrogen oxides dropped by more than half since the early 1990s (Grafström and Sandström

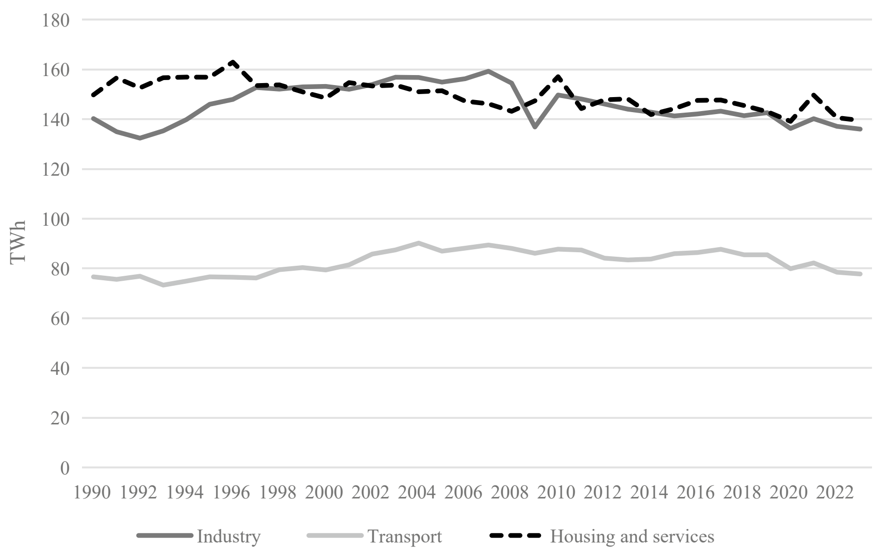

Fig. 3 Sectoral energy use in Sweden, 1990–2023 (TWh). *Source* Swedish Energy Agency (2025)

2021). The shift occurred not through singular policy action, but through a series of embedded changes: catalytic converters, cleaner fuels, and vehicle standards. In the industrial sector, similar improvements took shape. In Luleå, for example, steel output was maintained while cutting emissions per ton of steel, through fuel substitution and process redesign (Pei et al. 2020). Table 4 summarizes these developments, showing that most tracked air pollutants fell by over 50% in absolute terms, and even further when adjusted for economic growth.

Between 1993 and 2022, emissions of air pollutants in Sweden declined across nearly all major categories. The steepest reductions occurred in substances linked to fossil fuel combustion and industrial processes. Sulfur dioxide emissions fell by

Table 4 Percentage changes in air pollutant emissions and intensity Sweden, 1993–2022

Air pollutants 1993–2022	Change emissions	Emissions per GDP unit
Nitrogen oxides	–38	–69
Volatile organic compounds, excl. methane	–53	–77
Sulfur dioxide	–79	–90
Ammonia	–18	–60
PM2.5	–59	–80
PM10	–39	–70
Total suspended particulates—TSP	–29	–65
Soot/Black carbon	–62	–81
Carbon monoxide	70	–86
Lead	–94	–97
Cadmium	–53	–77
Mercury	–61	–81
Arsenic	–61	–81
Chromium	–58	–79
Copper	–30	–66
Nickel	–46	–73
Selenium	–0.6	–51
Zinc	–48	–74
Dioxins	–62	–81
Benzo(a)pyrene	–68	–84
Benzo(b)fluoranthene	–64	–82
Benzo(k)fluoranthene	–71	–86
Indeno (1,2,3-cd) pyrene	–67	–84
PAH 1–4	–65	–83
HCB	–84	–91
PCB	3	–49

Source Swedish Environmental Protection Agency (2024c)

79%, and emissions per unit of GDP declined by 90%. Lead emissions dropped by 94%.

Particulate matter also decreased. Emissions of PM2.5 and black carbon fell by 59 and 62%, respectively, contributing to improved urban air quality. Volatile organic compounds, excluding methane, declined by over 50%. Emissions of heavy metals—including cadmium, mercury, arsenic, and chromium—decreased by 50 to 60% as a result of tighter discharge standards and cleaner production technologies.

Several complex organic compounds, such as dioxins and polycyclic aromatic hydrocarbons, declined by 60 to 85%. These pollutants are commonly associated with combustion, waste incineration, and industrial by-products. Carbon monoxide was the only major pollutant to increase in absolute terms, rising by 70%. In relative terms, though, emissions per unit of GDP declined by 86%, indicating that the rise in total emissions was outweighed by economic growth.

Discussion

The reductions in emissions, pollutant discharge, and resource intensity observed in Sweden since 1990 are not the result of any single reform. They reflect a set of overlapping shifts in both economic structure and technological capability. Taken together, these adjustments have altered the environmental profile of production and consumption.

One major factor is the changing composition of the Swedish economy. Over the past three decades, the share of output generated by knowledge- and service-based sectors increased, while the relative importance of heavy industry declined (Segerfeldt 2025). This shift aligns with broader trends in advanced economies and was not primarily driven by environmental goals (Felipe and Mehta 2016). The result has been a gradual movement toward sectors with lower energy and material intensity per unit of value added.

Within industry, process redesign and technological substitution contributed to lower resource intensity. Energy use per unit of output declined, supported by automation, digital control, and equipment upgrades (Lundgren et al. 2016). The energy system itself changed in parallel. A stable supply of low-carbon electricity, dominated by hydro and nuclear power, enabled both industrial and household transitions without triggering an increase in fossil energy demand. Combined heat and power systems, district heating, and improved building insulation all helped moderate total energy use despite population growth and rising floor space (Åberg and Henning 2011).

Incremental technological improvements have had cumulative effects (Grafström 2018). Gains in motor efficiency, building standards, and industrial equipment design contributed to a measurable decline in emissions and energy intensity. These improvements occurred without reducing output. The volume of goods and services produced continued to grow, but each unit required fewer physical inputs. Although decoupling is not complete, the Swedish case illustrates that rising GDP does not inherently require proportional increases in environmental pressure (McAfee 2019).

Policy shaped many of the conditions under which Sweden's environmental performance improved. Although structural change and technological development account for much of the observed decoupling, institutional stability and policy design helped steer both the timing and direction of those shifts.

One of the most influential instruments was carbon pricing. Introduced in the early 1990s, the carbon tax raised the cost of fossil energy and encouraged substitution toward electricity, district heating, and biofuels (Knaggård and Hildingsson 2025). The effect was particularly visible in heating systems, where oil use declined sharply. The tax was introduced alongside reductions in labor and capital taxation, creating a revenue-neutral structure that redistributed the tax burden without raising overall fiscal pressure (Köppl and Schratzenstaller 2023).

Other pricing and regulatory instruments reinforced the shift. Landfill taxes, producer responsibility rules, and deposit-refund systems reshaped behavior across waste systems (Hage 2007). Industrial emissions faced direct limits, but firms retained flexibility in how to comply. The approach focused on outcomes, not uniform methods. Informational tools also played a role. Appliance labeling, public reporting on energy use, and green procurement criteria shaped reputational and normative expectations (Emmelin and Lerman 2008).

Rather than choosing between centralized control and market liberalism, Swedish policy relied on structured signals and gradual adjustment. Instruments were designed to align long-term incentives without prescribing specific technologies or pathways. Over time, environmental pricing became an integrated part of economic governance, shaping decisions without dominating them.

Technological and economic shifts are shaped by the institutional context in which decisions occur (Berggren and Bjørnskov 2017). In Sweden, institutional stability and relatively high levels of social trust have supported environmental improvements over time (Marbuah 2019). Political consensus on long-term goals has helped maintain continuity in environmental governance, even as political coalitions changed.

The policymaking process has often emphasized procedural credibility over administrative discretion. Agencies responsible for environmental regulation operate within broadly accepted mandates. This has enabled regulatory frameworks to persist even when there have been government changes. Although policy details are contested, the direction of change has remained consistent (Bergh and Erlingsson 2025).

Coordination among public and private actors has further reduced the friction of environmental adjustment. Employers' organizations, labor unions, and industry associations have long participated in structured dialogue on energy systems, industrial development, and workforce transitions. These arrangements lower the transaction costs of compliance and adaptation.

Urban infrastructure developed gradually but measurably. New buildings were required to meet increasingly strict efficiency codes, and retrofitting accelerated across both public and private building stocks (Niskanen and Rohracher 2020).

Public lighting systems transitioned from sodium vapor to LED. Traffic signals and ventilation systems became sensor-regulated.

Sweden's material consumption, measured by domestic extraction, remained broadly stable over time (Grafström and Sandström 2020). Packaging materials became thinner, buildings increasingly used recycled inputs, and energy was recovered from waste-connected material for use in local heat production. The result was a gradual move toward more circular flows of resources across the board.

Conclusions

There are examples of how countries have been able to combine economic growth with environmental concern. This essay outlined the case of Sweden as well as some statistics for the European Union as a whole.

Sweden's environmental record since 1990 does not follow a dramatic trajectory, nor does it hinge on a singular breakthrough. Instead, it reads more like a slow reengineering of everyday systems—how homes are heated, how steel is made, how waste becomes heat, and how power reaches sockets without concomitant emissions. The numbers tell part of the story: a 38% drop in territorial CO_2 emissions, a 25% reduction in consumption-based emissions, air pollutants falling across the board during a period when real GDP doubled. But behind those figures lies something quieter and harder to replicate: a society that changed course without making a show of it.

There was no moratorium on growth, no sweeping ban on consumption. The economy expanded and living standards rose rapidly. Yet, energy use flattened, emissions per unit of output dropped, and toxic releases shrank. This happened not because anyone flipped a switch, but because multiple parts of the system evolved in a loosely coordinated rhythm. Industrial engineers found ways to reuse heat; households phased out oil tanks; appliance standards nudged manufacturers to trim energy demand; policy kept the direction steady.

Much of this, at its best, rested on trust—not just in institutions, but in the idea that gradual change would be rewarded. When a carbon tax was introduced, it was coupled with reductions in other taxes. When standards were tightened, this was done predictably and gradually over many years. Environmental reform in Sweden was rarely urgent or dramatic, but it was hard to reverse.

Coordination helped, too. Industry groups, labor unions, regulators—none had to agree on everything, but most shared a sense that predictability mattered. It made compliance less adversarial and change less risky. A city could retrofit lighting across its public housing stock without waiting for a subsidy. A steel plant could plan a ten-year upgrade knowing that energy prices would nudge it in the same direction.

This model is not easily exported. Sweden had advantages—a low-carbon electricity grid, high institutional trust, and a policymaking culture that rewards consensus. But it offers a counterpoint to two extremes: that environmental progress requires heroic disruption or that it emerges naturally from growth and innovation.

In the Swedish case, neither story fits. What mattered was a sustained alignment of incentives, expectations, and capacity to adapt.

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His research explores the intersection of technological change, energy systems, and environmental performance, with a particular focus on how institutions and policy shape the transition toward lower resource and emissions intensity. He has published academic articles on innovation diffusion in the energy sector, economic decoupling, and circularity in industrial systems. In addition to his academic work, he is an experienced public commentator on energy and climate policy and has contributed regularly to Swedish policy debates through reports, op-eds, and media appearances.