

Cars, Planes, Trains

Physics and Mathematics of Sustainable Energy

College of the Atlantic. November 8, 2024

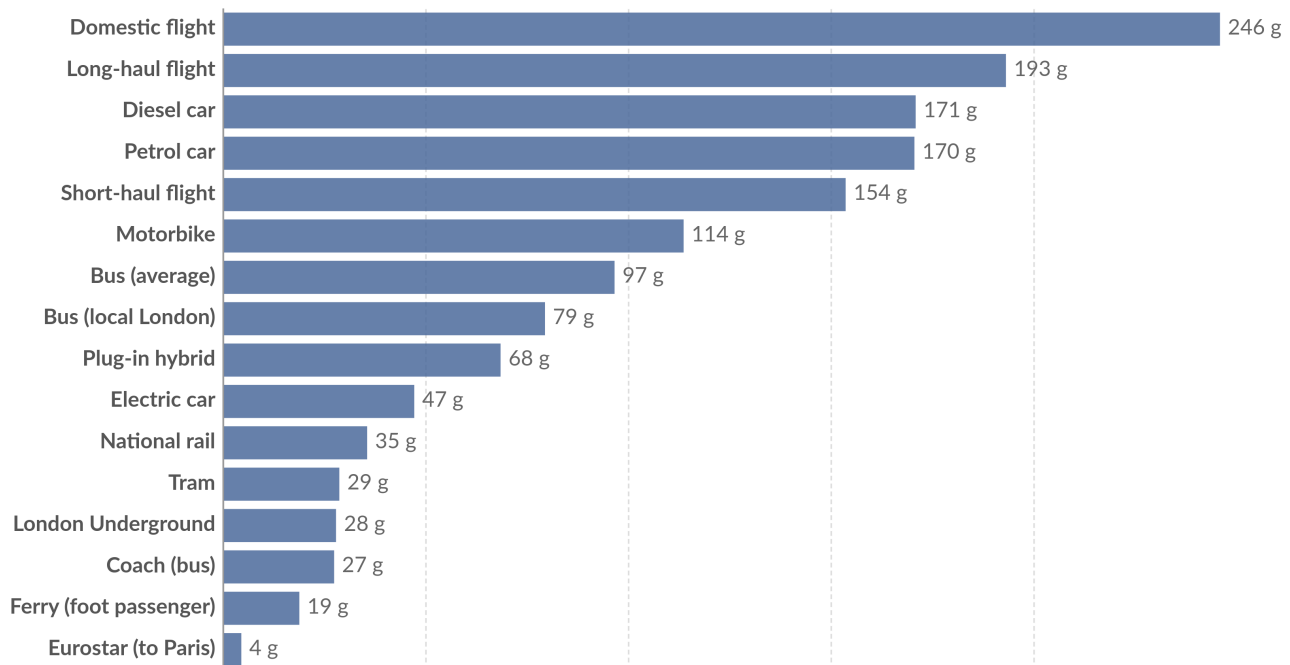
A few facts:

- Gasoline: 10 kWh per liter or 38 kWh per gallon
- Average gas mileage for car in US: 25mpg, but this ranges considerably.
- Carbon intensity of gasoline: 240g per kWh.
- Burning one gallon of gasoline releases around 9 kg of CO₂.
- Carbon intensity of electricity in grams of CO₂e per kWh:
 - US: 376
 - Brazil: 102
 - China: 531

1. Let's compare driving 1000 miles in conventional and electric vehicles.
 - (a) In the conventional car, how much gas does this use?
 - (b) How much does this gas cost?
 - (c) How much CO₂ is emitted by the car?
 - (d) How much of the thermal energy released when burning the gasoline goes into the kinetic energy of the car? Assume that the car's engine has an efficiency of 0.25.
 - (e) How many kWh of electricity would be needed by an electric car to go 1000 miles. Assume that the efficiency of the electric car is 0.85.
 - (f) How much would this electricity cost?
 - (g) How much CO₂ would be emitted as a result of generating this amount of electricity, assuming the US average carbon intensity.
 - (h) How much CO₂ would be emitted as a result of generating this amount of electricity if the electricity was generated in a coal-burning power plant with an intensity of 1 kg/kWh?
2. Suppose you fly from New York to California twice in a year. What are the emissions associated with these flights. Put this number in perspective.
3. Suppose you want to get from London to Paris.
 - (a) What are the emissions if you fly?
 - (b) What are the emissions if you drive in a petrol (gas) car?
 - (c) What are the emissions if you take the Eurostar train?

Carbon footprint of travel per kilometer, 2022

The carbon footprint of travel is measured in grams of carbon dioxide-equivalents¹ per passenger kilometer. This includes the impact of increased warming from aviation emissions at altitude.



Data source: UK Government, Department for Energy Security and Net Zero

OurWorldInData.org/transport | CC BY

Note: Data is based on official conversion factors used in UK reporting. These factors will vary across countries depending on energy mix, transport technologies, and occupancy of public transport.

1. **Carbon dioxide-equivalents (CO₂eq):** Carbon dioxide is the most important greenhouse gas, but not the only one. To capture all greenhouse gas emissions, researchers express them in 'carbon dioxide-equivalents' (CO₂eq). This takes all greenhouse gases into account, not just CO₂. To express all greenhouse gases in carbon dioxide-equivalents (CO₂eq), each one is weighted by its global warming potential (GWP) value. GWP measures the amount of warming a gas creates compared to CO₂. CO₂ is given a GWP value of one. If a gas had a GWP of 10 then one kilogram of that gas would generate ten times the warming effect as one kilogram of CO₂. Carbon dioxide-equivalents are calculated for each gas by multiplying the mass of emissions of a specific greenhouse gas by its GWP factor. This warming can be stated over different timescales. To calculate CO₂eq over 100 years, we'd multiply each gas by its GWP over a 100-year timescale (GWP100). Total greenhouse gas emissions – measured in CO₂eq – are then calculated by summing each gas' CO₂eq value.

Figure 1: Carbon emissions associated with different forms of transportation. Source: Hannah Ritchie (2023) – “Which form of transport has the smallest carbon footprint?” Published online at OurWorldInData.org. Retrieved from: <https://ourworldindata.org/travel-carbon-footprint>.