

# Cars, Planes, Trains

## Physics and Mathematics of Sustainable Energy

College of the Atlantic. October 23, 2023

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 CO<sub>2</sub>.
- Carbon intensity of electricity in grams of CO<sub>2</sub>e 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 CO<sub>2</sub> 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 CO<sub>2</sub> would be emitted as a result of generating this amount of electricity, assuming the US average carbon intensity.
- (h) How much CO<sub>2</sub> 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?

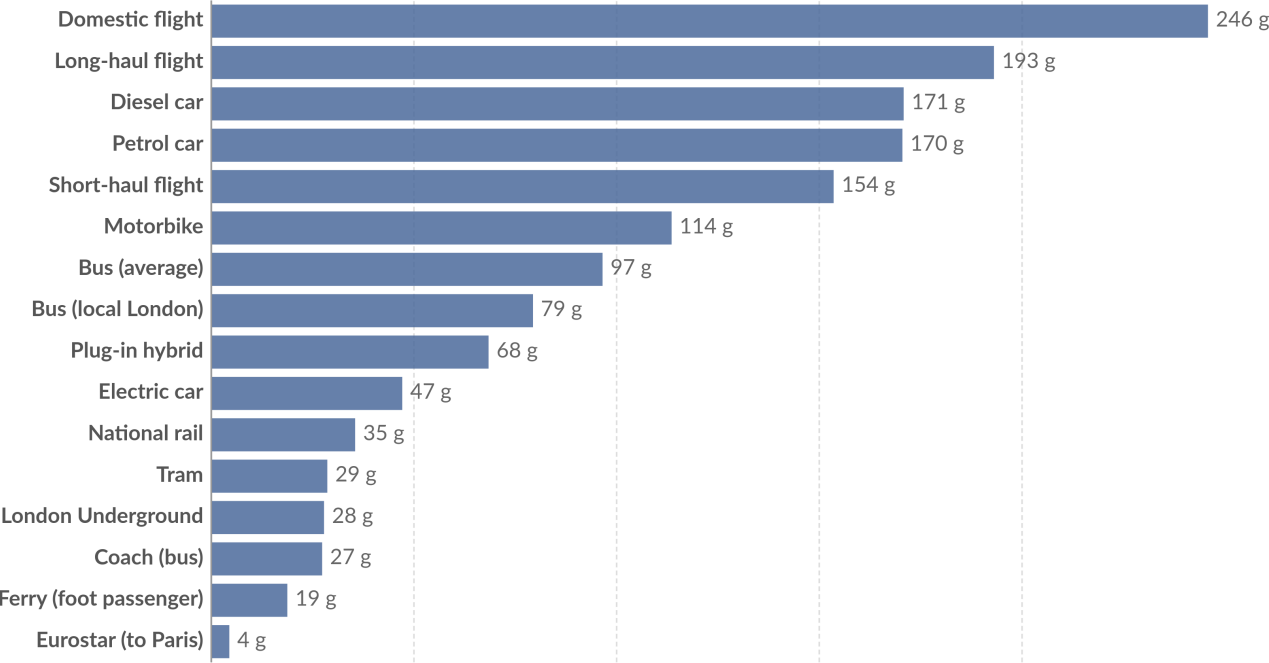
2. Suppose you fly from New York to California twice in a year. What are the emissions associated with these flights. Put this number in perspective.

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-equivalents<sup>1</sup> 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](https://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 (CO<sub>2</sub>eq): 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' (CO<sub>2</sub>eq). This takes all greenhouse gases into account, not just CO<sub>2</sub>. To express all greenhouse gases in carbon dioxide-equivalents (CO<sub>2</sub>eq), each one is weighted by its global warming potential (GWP) value. GWP measures the amount of warming a gas creates compared to CO<sub>2</sub>. CO<sub>2</sub> 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 CO<sub>2</sub>. 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 CO<sub>2</sub>eq over 100 years, we'd multiply each gas by its GWP over a 100-year timescale (GWP100). Total greenhouse gas emissions – measured in CO<sub>2</sub>eq – are then calculated by summing each gas' CO<sub>2</sub>eq 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>.