1 Plane

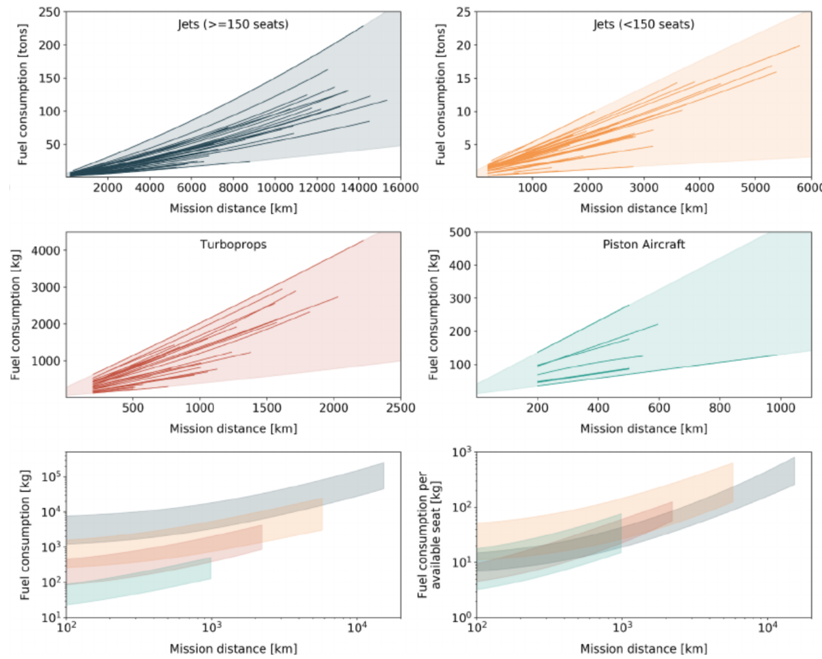

Figure 1: Reduced order regression curves for various aircraft. The bottom left graph is a reproduction of the shaded areas of the ones above it. The bottom right graph shows the efficiencies in fuel consumption on a log-log scale.

From figure 1 [1] we assume a fuel consumption for commercial aircraft of somewhere between 20 and 40 kilograms per 1000 kilometers and passenger. We take a value of 3 kilograms of fuel per 100 kilometers and passengers. Multiplying this by the specific energy of Jet A-1 fuel ($11.97\frac{kWh}{kg}$) results in an energy consumption per kilometer and passenger of $0.359\frac{kWh}{km}$. A holiday trip is assumed to be around 1000 kilometers as an one-way travel, which is approximately the linear distance to Rome, Barcelona, Dublin or Warsaw. This means:

$$E_{EuPlane} = \frac{N}{year} * 2000km * 0.359\frac{kWh}{km} = N * 718\frac{kWh}{year} = N * 1.967\frac{kWh}{day}$$

Most holidays spent outside Europe take place in the USA, China or India. Therefore, we take a distance of 8000 kilometers, which includes the US-east coast and India, but leaves out the US-west coast as well as the coast of China. From repeating the same calculation with the adjusted distance we get:

$$E_{IcPlane} = N * 5744\frac{kWh}{year} = N * 15.737\frac{kWh}{day}$$

2 Cruise ship

A cruise ship alternating between Oslo, Norway and Kiel, Germany requires around 150 kilowatt hours per day and passenger[2]. To account for longer travel distances, we will stick to a slightly higher energy of 200 kilowatt hours per day and passenger:

$$E_{Cruise} = \frac{N days}{year} * 200 \frac{kWh}{day} = 200 * N * \frac{kWh}{year} = N * 0.548 \frac{kWh}{day}$$

3 Car, Bus and Train

For all other types of long distance travel we will assume the same one-way travel distance of 1000 kilometers, as they have to follow non-linear paths to a usually closer destination than in the plane case. Furthermore, we use the same values for energy consumption:

$$E_{CCar} = \frac{N}{year} * 2000km * 1.176 \frac{kWh}{km} / Passengers = 6.292 \frac{kWh}{day} * \frac{N}{Passengers}$$

$$E_{ECar} = \frac{N}{year} * 2000km * 0.167 \frac{kWh}{km} / Passengers = 0.916 \frac{kWh}{day} * \frac{N}{Passengers}$$

We will assume that long-distance buses are usually combustion vehicles, therefore we only consider the combustion energy consumption:

$$E_{Bus} = \frac{N}{year} * 2000km * 0.065 \frac{kWh}{km} = 0.355 \frac{kWh}{day} * N$$

Lastly, the train. Here the TGVs and ICEs will serve as reference for long-distance travel. Using a capacity of 510 seats and occupancy of 67% for TGVs and a capacity of 830 seats and occupancy of 49.1% for ICEs we get a passenger amount of around 342 and 408, respectively. We assume 375 passengers per train on average. By using the same method we did for the train in the transport section, we can conclude that it requires a power of 7.3 megawatts to move a train at 330 kilometers per hours. Therefore, assuming that the train keeps this speed for most of its intercity travel:

$$E_{ICE} = \frac{7300kWh}{330\frac{km}{h} * 375} = 0.059 \frac{kWh}{km} = 59 \frac{Wh}{km}$$

The other most probable high-speed train that would be used is the French TGV, which has a per passenger energy consumption of $48.5 \frac{Wh}{km}$ (The same study confirms our value for the ICE) [3]. We take their average as an approximation:

$$E_{Train} = \frac{N}{year} * 2000km * \frac{0.059 + 0.0485}{2} \frac{kWh}{km} = 0.295 \frac{kWh}{day} * N$$

References

[1] K. Seymour, M. Held, G. Georges, and K. Boulouchos. Fuel estimation in air transportation: Modeling global fuel consumption for commercial aviation. *Transportation Research Part D: Transport and Environment*, 88:102528, 2020.

[2] August Brækken, Cecilia Gabrielii, and Natasa Nord. Energy use and energy efficiency in cruise ship hotel systems in a nordic climate. *Energy Conversion and Management*, 288:117121, 2023.

[3] Eckert Fritz, Larry Blow, Johannes Klühspies, Roland Kircher, and Michael Witt. Energy consumption of track-based high-speed trains: maglev systems in comparison with wheel-rail systems. *Transportation systems and technology*, 4:134–155, 12 2018.