The Global Warming Reduction Potential of Night Trains

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Abstract

Night trains have the potential to reduce EU greenhouse gas emissions by 3%.

According to opinion polls, 7 out of 10 Europeans would be willing to take the night train instead of the plane if the offer seemed reasonable to them. Back-on-Track, a European network of night train initiatives, has used this as a basis to examine air passenger numbers in the EU in 2019 to see which air connections could be replaced by night train connections. Distances up to 1500 km as well as distances up to 3000 km were considered with different scenarios. Overall, up to 32% of passengers could switch to night trains if there were an attractive offer. This would reduce emissions from air traffic by 26%. In order to create such an offer, up to 2500 more night trains would be required, as well as a considerable improvement in the framework conditions, in particular a reduction in track access charges.
Why this paper?

The potential of night trains has been recently examined in a couple of studies, but
- the studies either examined a predefined target network
- the potential passenger numbers were examined based on given constraints
- if climate effects were calculated, non-CO₂ effects have been ignored

This paper is a follow-up to our 2021 study* on EU air passenger volumes that could be shifted to night trains and examines possible climate effects in a scenario assuming optimal conditions.

We assumed
- a capable rail infrastructure on TEN-T routes prepared for 160 km/h max. speed
- modern rolling stock with substantial improvements of privacy, security and comfort
- an average occupancy rate of 80% like for other means of transport that require booking
- a level playing field that allows for reasonable ticket prices

*Oui au train de nuit (2021): Half of the air passengers will benefit from night trains, if Europe invests
The current global warming potential of aviation

EU greenhouse gas (GHG) emissions 2019
CO₂e incl. radiative forcing (RF) of non-CO₂ emissions (factor 3.0 using GWP* method)

- Road 19.03%
- Aviation (with RFF 3.0) 11.68%
- Aviation (just CO₂) 5.13%
- Ships 3.62%
- Railways 0.12%
- Other Transport 0.13%
- Other Sectors 65.42%

12% of the EU’s current global warming contribution are from aviation - far more than the 5% when you just look at CO₂ emissions.

Source: EEA | EU-28 data
Only aviation emissions continue to grow

**Development of EU GHG emissions 1990-2019**

incl. projection for aviation (with all existing measures)

Predicted to further **grow 3% per year** aviation has been and remains the main cause of the increase in transport emissions.

Source: EEA, Data 90-19, Forecast 20-40 | EU-28 data | *incl current RF (GWP*) of non-CO₂ emissions of aviation
GHG emissions by means of transport

Planes have **28 times** more greenhouse effect than night trains, ...

... and still **16 times more** with 100% sustainable fuels.

Base Source: [IEA](#) | *incl current RF (GWP*) of non-CO₂ emissions of aviation | **remaining well-to-tank emissions and RF when using Sustainable Aviation Fuel (SAF), source: [Sausen](#)
Night trains go further

High Speed trains compete on distances up to 500 km

As sleep is not perceived as travel time Night Trains compete with a -8 h head start up to 1500 km at 75 to 125 km/h

High Speed Night Trains could beat the plane up to 1900 km with just 150 km/h average speed and still attract passengers beyond that (roughly 10% less per extra h). With this speed they can go up to 3000 km and return in a day.

With 200 km/h HS Night Trains (like the D901 Beijing-Shenzen) could beat the plane at distances up to 2700 km
Which flights can be replaced?

• We analysed Eurocontrol data for flights from EU-28 Airports*.
• We excluded
  • connections to islands and places not connected by rail
  • connections separated by more than 3000 km road distance
  • connections which are served by day trains in less than 4 hours and
  • connections to other continents
  • connections with less than 100,000 passengers per year (as 140 passengers per day and direction might be insufficient to fill a feeder train)

• The reported passenger numbers per connection differ from the total number of passengers in the EU-28 due to under-reporting. Therefore, the total numbers per connection were extrapolated to the total passenger numbers.
Replaceable connections 500-1500 km:

According to our 2021 estimate, out of yearly 1.1 B EU aviation passengers in 2019

- **362 M** passengers travel on replaceable routes from 501 to 1500km distance.

Source: Oui au train de nuit, 2021
According to our 2021 estimate, out of yearly 1.1 B EU aviation passengers in 2019

- Another 213 M passengers travel on replaceable routes from 1500 to 3000km distance.

For 50% of 1.1 B EU aviation passengers night trains could provide an alternative.

Source: Oui au train de nuit, 2021
How many would use the alternative?

69% of Europeans are very or fairly willing to use night trains.

So, if night trains were offered to 50% of all EU aviation and we can assume 69% would use them (as long as prices are reasonable and travel times competitive as in the 500-1500 km segment) …

… and if some would use night trains even if travel times (excl. sleep) exceed those of a plane trip so we may assume 11.4% less potential per 1 extra hour (at 150 km/h avg. speed) so we may still assume 53% average preference in the 1500-3000 km segment …

25% of Europeans are very willing to use night trains.

… then 32% of all EU aviation passengers would shift to night trains.

Source: YouGov
The GHG avoiding potential of night trains

EU CO\textsubscript{2}e* Emissions 2019

*incl. a Radiative Forcing Factor (RFF) of non-CO\textsubscript{2} emissions
(3.0 times the CO\textsubscript{2} value using GWP* method)

Avoidable 3,03%
Aviation (with RFF 3.0) 11,68%
Ships 3,62%
Railways 0,21%
Other Transport 0,13%

Road 19,03%

1,54% by Night Trains with up to 125 km/h on 501-1500 km rail distances
1,49% by HS Night Trains at 150 km/h on 1501-3000 km rail distances

If, as estimated, 32% of EU aviation passengers would shift, this equals 26% of aviation and 8.6% of traffic emissions.

Source: EEA

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How does it pay off?

The EU emitted 4732 Mt CO$_2$e in 2019 (incl. non-CO$_2$ RF/GWP*).

3,03 % of these emissions are **143 Mt CO$_2$e** every year.

12 billion €

@ 85 € EU carbon permit price
What needs to be done?

Making night trains more attractive:

- **Reduce their track access charges** to marginal cost
- Keep long-term timetable slots
- Give them equal priority with other long-distance traffic
- Tax international rail no higher than international aviation
- Tax mobile hotels no higher than stationary ones
- Charge according to environmental cost

Almost cost-neutral when confined to sleeper services, but important to serve higher travel distances and thus increase market share
What needs to be done?

Investing in new rolling stock:

250 M additional passengers per year need **2066 new night trains** with 10 coaches and 414 berths each that may go everywhere with at least 200 km/h  
(approx. 67 B €* order volume)

112 M additional passengers per year need **488 new HS night trains** with 788 berths each in sleeper and couchette coaches that may go almost everywhere with up to 270 km/h  
(approx. 30 B €* order volume)

**2554 new night trains**  
*97 B € order volume*

@ 85 € EU carbon permit price amortised within **8 years**.

* Estimate based on published order volumes: 400 M € for 140 coaches and 75 M for 15 multi-system engines and 335 M € for 12 trainsets
What about road traffic?

As the modal shift from road to rail has a much lower climate saving potential than the shift from air to rail, the GHG reduction potential of road traffic was not yet considered.

We think that night trains are not set to be an alternative for budget-sensitive coach travellers. However, an attractive night train net would inevitably make car travellers shift, which represent 57% of all travellers on 500-1500km distances.

Some studies assume that at least 5% of car traffic can be replaced with a better night train service. Five Percent of the 11.5% share of cars in the EU total greenhouse gas emissions could add another 0.58% reduction potential.
#3percentOverNight

Thank you. And let’s share the good news!
Annexe.
Which radiative forcing factor did we apply?

We apply a so-called radiative forcing factor (a.k.a. RFI, Emission Weighting Factor or Multiplexer) of 3.0 on the CO₂ emission value in order to accommodate all known non-CO₂ effects with the best currently known estimate by Lee et al. (2021).

This factor is based on the “GWP**”-method which is used to specify the current global warming (as opposed to the “GWP100” method, which specify global warming within 100 years. Lee et al. also specifies a radiative forcing factor of 1.7 as the best currently known estimate for this method. We examine the current global warming effect as we want to reduce global warming now and not by 2122, so the factor of 3.0 is applicable for our purpose. However, for historical comparisons, GWP100 might be applicable. So our dataset allows to change the underlying factor.

We use normalized radiative forcing factor as we compare means of transport. We acknowledge that for reducing aviation emissions by optimizing fuels, engines and operations per flight calculations of the radiative forcing are to be preferred.

Source:
D. S. Lee et al. (2021): The contribution of global aviation to anthropogenic climate forcing for 2000 to 2018 Atmos. Environ., vol. 244, p. 117834
How did we apply the radiative forcing factor?

The radiative forcing (RF) factor applies only to aviation emissions as they occur in the upper troposphere. It relates to the effect of CO₂ emissions (on the ground). So it must not be applied to CO₂ emissions, not CO₂e values (otherwise the on-the-surface effects included in CO₂e values would be counted twice).

However, when comparing aviation emissions to the emissions of means of surface transport, it must be compared with their CO₂e values so that both accommodate the non-CO₂ induced greenhouse effect. Our calculation can be examined in our dataset. We provided data for all EU-28 member states in 2019, so the basic values can be localised.

Wherever we needed to reduce CO₂e values to CO₂ values in order to apply a RF factor elsewhere, we multiplied the CO₂e value with the proportion of the 2019 EU total CO₂ emission value of the EU total CO₂e emission value (as specified in our dataset).
How did we get aviation emissions?

For the EU total CO₂e emissions we relied on EEA data from Eurostat:

Source: https://ec.europa.eu/eurostat/databrowser/bookmark/e530ee24-474b-4f68-9f03-4c5fc940ca98?lang=en

Aviation emissions were not available in the original source, as according to reporting standards domestic aviation belongs to transport whereas international aviation (like international navigation) must be added to the total emissions. The value for International Aviation was thus derived from the difference between Total (excluding memo items) and Total (excluding memo items, including international aviation). We added Fuel combustion in domestic aviation to get Aviation emissions (and proceeded the same way to obtain navigation emissions).

All emissions were compared to Total (excluding LULUCF and memo items, including international transport), so negative Emissions from land usage (LULUCF) were not taken into account, as it is difficult to compare a share of positive emissions to a net value, particularly in some national breakdowns where huge negative emissions lead to a net total close to the total of positive emissions from transport, like in the case of Sweden.

As we added CO₂e emissions to aviation by applying a RF Factor we always added these additional CO₂e emissions to the total when calculating proportions of the total.
Isn’t radiative forcing dependent on flight distance?

We are aware that radiative forcing depends on flight altitude and is considerably lower for short-haul flights. According to the examples for which the radiative forcing factor (as the CO$_2$ + Non-CO$_2$ value divided by the CO$_2$ value) was calculated, this applies for flight distances that complete with (high-speed) day trains rather than night trains whereas for all examples in the outlined night-train range of 500-3000 km distance the radiative forcing factor is between 3.68 and 4.04. So it is even above the radiative forcing factor of 3.0 that we do apply in line with Lee et. al. (2021).

Source: J.D. Scheelhaase, Journal of Air Transport Management 75 (2019) 68-74
What are the CO$_2$e emissions of night trains?

Our comparison of means of transport is based on IEA data for CO$_2$e per km per person (CO$_2$e/pkm).

**Source:**

We modified this as follows:

- The original chart does not apply a radiative forcing factor on aviation emissions, which we consequently applied elsewhere, so we also applied it here to be consistent, as detailed below.

- We applied a *distance uplift factor* of 8% on the aviation value as the comparison is distance based. This accounts for flight journeys being normally calculated on a point-to-point base, which does not reflect non-direct routing, avoidance of bad weather conditions and queueing to land. The 8% value follows a UK Government recommendation. (*Myclimate* uses instead a detour constant of 95 km independently of the distance flown which equals 8% at a 1,200 km flight distance – right within the night train range.)

**Sources:**

*Didier Barret: Estimating, monitoring and minimizing the travel footprint associated with the development of the Athena X-ray Integral Field Unit*

- The original chart only refers to trains in general, not to night trains in particular. The 14 gCO$_2$e/pkm average for non-urban-rail encloses regional trains as well as long-distance traffic. As regional trains more frequently operate with Diesel than long-distance trains, we assumed the average for long-distance trains could be within this average and the lowest possible value of 6 gCO$_2$e/pkm, as detailed below.

- The original chart does neither specify CO2e/pkm for planes using sustainable aviation fuels (SAF) nor the emissions of a car with 4 passengers. To discuss options in reducing GHG emissions in the traffic sector, we added these values. Find our calculation for SAF detailed below.
How did we find CO$_2$e values for all these means of transport?

Values for CO$_2$e/pkm for planes highly differ, mainly due to different radiative forcing factors, different scope (well-to-wheel or just tank-to-wheel), relevant set of distances or fleet and assumed occupancy rate.

- The UK Government (2017) average value for short-haul flights (typically UK-Europe connection with less than 3.700 km distance) is 161 gCO$_2$e/pkm applying a 1.9 radiative forcing factor. With a 3.0 RF factor on the tank-to-wheel value would be 254 gCO$_2$/pkm. This value includes a distance uplift factor for delays and indirect flight paths.
- The German Umweltbundesamt (2020) average well-to-wheel value for internationel flights from Germany is roughly 197 gCO$_2$e/pkm applying a 2.08 radiative forcing factor on the tank-to-wheel value (roughly 85 gCO$_2$e/pkm). With a 3.0 RF factor on the tank-to-wheel value the this would be 275 gCO$_2$/pkm.
- The Dutch milieucentraal average well-to-wheel value for aeroplanes in the 700-2500 km range is 172 gCO$_2$e/pkm applying a 1.7 radiative forcing factor on the tank-to-wheel value of 89.4 gCO$_2$e/pkm. With a 3.0 RF factor on the tank-to-wheel value the this would be 288 gCO$_2$/pkm.
- The IEA (2020) average non-urban well-to-wheel GHG intensity of air travel is 144 gCO$_2$/pkm with no non-CO$_2$ radiative forcing (GWP*) applied. We assume 13,5 % or 20 gCO$_2$/pkm for non tank-to-wheel emissions (infrastructure, vehicle production, fuel production and transport) must be withdrawn (in line with the Umweltbundesamt /Milieucentraal values and the IEA Mobility Model presentation from 2016). With a 3.0 RF factor on the remaining tank-to-wheel value of 122 gCO$_2$e/pkm this would be 392 gCO$_2$/pkm.

Sources:
- Department for Business, Energy & Industrial Strategy: Conversion factors 2017 - Condensed set
- MilieuCentraal, 2022. Lijst Emissiefactoren
Why did we choose the IEA values?

<table>
<thead>
<tr>
<th>Distance (km)</th>
<th>Less than 50 seats</th>
<th>51 to 100 seats</th>
<th>101 to 180 seats</th>
<th>181 to 250 seats</th>
<th>More than 250 seats</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 1 000</td>
<td>223</td>
<td>187</td>
<td>141</td>
<td>117</td>
<td>*</td>
</tr>
<tr>
<td>1 000 - 2 000</td>
<td>254</td>
<td>161</td>
<td>117</td>
<td>95</td>
<td>123</td>
</tr>
<tr>
<td>2 000 - 3 000</td>
<td>*</td>
<td>*</td>
<td>109</td>
<td>91</td>
<td>101</td>
</tr>
</tbody>
</table>

After normalizing the radiation forcing factor, the remaining difference in the different calculations comes from the underlying tank-to-wheel emissions value. According to a table provided by the French environment department, which specifies different CO$_2$/pkm values by distance, within the range of 500 - 3000 km distance indicate that the IEA well-to-wheel average of 144 gCO$_2$e, which is 122 gCO$_2$/pkm (w/o RF) is the most realistic assumption within this distance range.

Sources:
Ministère der la Transition écologique et solidaire (2017): Information GES des prestations de transports - Guide méthodologique
How did we calculate emissions for SAF planes?

According to a presentation of DLR Robert Sausen in Christiansborg, Copenhagen on 01.12.2021, the non-CO₂ effects generally also occur if alternative fuels are used (p. 8). Alternative fuels with fewer aromatics (like the HEFA blend) help to reduce soot particles though, which decrease radiative forcing in a non-linear manner so that 50% less particles reduce the normalized radiative forcing by 20% to 80% (p.13).

How did we calculate emissions for night trains?

We were looking for a better value for night trains than the 14 gCO₂e/pkm for non-urban rail specified by IEA.

11 - 13 gCO₂e/pkm was estimated by UIC in 2013 for a future London-Madrid night train (average 12 gCO₂e/pkm). They used 10 gCO₂e/pkm as base value for long-distance trains, multiplied by a factor of 1.1945 (meaning roughly +20%) for night trains in line with the average factor which is applied in the DB Umwelt Check application when night train connections are compared to day train connections. The factor of 1.1945 is the average of 1.1960 for Paris-Toulouse and 1.1930 for Berlin-Munich in their route comparison.

Source: Union Internationale des Chemins de Fer / DB Mobility Networks Logistics (2013): UIC-Study Night Trains 2.0 New opportunities by HSR?

According to Eurostar their high-speed long-distance trains need between 8.15 gCO₂e/pkm for London-Paris (490.9 km rail distance, 4.000 gCO₂e/trip) and 11.55 gCO₂e/pkm for London-Bruxelles (372.2 km rail distance, 4.300 gCO₂e/trip). This confirms the UIC base value.


However a calculation of 10 randomly chosen night train connections (end-to-end) in the Ecopassenger tool produced a range of 0.2 - 27 gCO₂e/pkm, in average 15 gCO₂e/pkm. Connections in Eastern Europe are overrepresented, without these the average would be far lower. The data for the chosen night train connections is available in our dataset.


Although we are confident, that the average value will be below 14 gCO₂e in the future, we stick to the well-to-wheel value for long-distance trains of 14 gCO₂e as specified by IEA.
Why are emissions 20% higher in the night?

Day trains have 74 seats /coach (ICE3 standard car 2nd class. TGV is not comparable due to shorter coaches) while a conventional couchette car has only 60 berths, so a reduced capacity of 0.8 must be taken into account.

On the other hand for day trains running according to schedule with varying demand a lower occupancy rate must be assumed. The average occupancy rate for long-distance traffic on day trains is 56% for DB ICE trains in 2018 (https://dserver.bundestag.de/btd/19/152/1915246.pdf) without yield management and 67% for SNCF TGV trains in 2016 (taux d’occupation moyen France (https://www.autorite-transports.fr/wp-content/uploads/2017/11/ARAFER_Bilan-annuel-marche-ferroviaire-voyageurs-2015-2016.pdf p.5) with yield management. For night trains here are no occupancy rates available. But frequently reported lack of available space on ÖBB Nightjet trains indicate higher occupancy rates may be realistic. For night trains due to booking requirements yield management can be applied and no regular schedule has to be served. This makes the night trains offer structurally more comparable to flights or coaches that typically reach average occupancy rates of 75% (https://www.eea.europa.eu/data-and-maps/indicators/occupancy-rates-of-passenger-vehicles/occupancy-rates-of-passenger-vehicles).

Passenger aviation had an average load factor of 81,9% in 2021 (https://coronacircus.com/wp-content/uploads/2020/05/wats-2019-medikit.pdf) So a higher occupancy factor of 1.25 can be applied – which outweighs the lower capacity factor of 0.8.

As compared to day trains a higher cleaning effort for bed linen and a lower running time of the rolling stock should be taken into account. Due to a lack of data we leave the 1.2 night train factor unchanged.
Is a 3000 km distance possible?

To reach a target in 3000km distance by train within 16 hours, an average speed of 187 km/h must be reached. This is not possible with the currently used rolling stock and engines and without being able to use available high-speed (HS) tracks. The Chinese D901 night train shows that this is achievable though. It travels the 2182 km road distance between Beijing and Shenzhen within 10:56 h which means its average speed (including stops) is 199 km/h. Of course, this is a maximum even in China, other connections are slower. And the Chinese HS network is more dense and seamless than the European one. Nevertheless three ways allow to cover 3000km distances within the next 10 years even in Europe:

Using Ultra-HS trains like the Avelia Euroduplex (Horizon) would allow maximum operation speeds of 300 km/h that compensate the less dense HS network with higher maximum speed (the Chinese night train has a maximum speed of 250 km/h). On suitable distances with a high share of (French) HS tracks this would allow to cover 3000 km distances like Madrid-Warszawa even today.

Speeding up the EU programme to prepare all Core TEN-T tracks for regular speeds of at least 160 km/h (ideally 200 km/h) by 2040 would allow even RIC-compatible rolling stock like Viaggio Comfort moved by an all-current engine (like Vectron HS) to reach average speeds near to 187 km/h - if night trains may also use high-speed tracks where available (at 230 km/h with suitable, pressure-resistant rolling stock) running non-stop between 00:00 and 05:00.

As outlined in our 2021 study (by Oui au train de nuit), you could also extend the trip duration. While two-night connections might not be attractive enough for large passenger numbers (at least in competition with planes), trip lengths of up to 20 h might still be a viable compromise to cover large distances up to 300 km with no more than an average speed of 150 km/h.

Source:
Oui au train de nuit: One every 2 air passengers will benefit from night trains, if Europe invests (2021)
Are night trains expensive?

The estimated investment cost is based on published order volumes for two examples (detailed in our dataset).

RIC-compatible Viaggio Comfort carriages hauled by a 4-current Vectron engine allowing a max. speed of 230 km/h with 10 carriages for 500 passengers (between the ÖBB standard of 7 carriages and the max. length of 14 carriages, allowing bi-directional operation to cut stopover times in cul-de-sac stations). We estimate a current price between 30 and 35 M per train.

Double-deck high-speed Avelia Euroduplex (or Horizon) for 800 passengers with fixed 4-current engines allowing a max. speed of 300 (320) km/h, composed as two sets (allowing channel tunnel operation) with a total 17 carriages as outlined in a non-public feasibility study by Vieregger-Rössler GmbH (2014). We estimate a current price between 58 and 66 M per train.

A comparable airplane (Airbus A380) did cost 210 M € after discounts, 6,5 times more. With an airport turnaround time of 100 min it could do a night train distance 4 to 10 times a day which would compensate the higher price. However, the average passenger plane retirement age is 22 years, which is roughly half the life expectancy of a train.

Sources:
https://simpleflying.com/airbus-a380-cost/
https://en.wikipedia.org/wiki/Airbus_A380

Photos: Screenshots from promotional / trainspotting videos
Is it possible to produce all these trains?

Yes. The global market volume for rolling stock is currently at approximately 56 B € per year. The European market share is 35-38%, roughly 20 B. So, an order volume of 97 B € within 12 years would add **40%** to the current European order volume, but just **14 %** to the current global order volume.

**Source:**
https://www.grandviewresearch.com/industry-analysis/rolling-stock-market

There are plenty of possible manufacturers for RIC-compatible night train rolling stock (for speeds up to 200 km/h). The availability of manufacturers for high-speed rolling stock is more limited, but at least Alstom should have surplus capacities.

**Source:**
https://trainsforeurope.eu/detail/who-could-manufacture-the-night-train-carriages-needed/
Does the network have the capacity?

Shifting the calculated amount of passengers to rail would add 196 B passenger-km at distances from 501-1500 km and 189 B passenger-km at distances from 1501-3000 km, which would almost double the EU total.

**Source:**
[http://appsso.eurostat.ec.europa.eu/nui/submitViewTableAction.do](http://appsso.eurostat.ec.europa.eu/nui/submitViewTableAction.do)

However, this does not proportionally increase track usage.

- There are roughly 6 north-south routes and 6 east-west routes in the TEN-T core network. If only HS trains with 788 berths were used and an 80% occupancy rate was reached, 1573 trains of which 97% are operational (1526) operational per day would be sufficient for this passenger volume, 64 per route and direction.

- Roughly 1/3 can be deducted for non-overlapping routes like Madrid-Brussels and Brussels-Stockholm, leaving 43 trains per route and direction.

- The trains run spread over a 8-20 h timeframe. This would add an average **3 trains per hour** per route and direction. This equals roughly **15% of the capacity** of a high speed line.

**Source:**
Does the network have the capacity?

• If night trains can use high-speed tracks they would not get in the way of other traffic (except in Germany). Most of them are exclusive for passenger services, some of them are currently closed at night.

• Night trains get in the way of commuter trains in main stations. This can be solved by using minor stations.

• Also night trains compete during the night with cargo trains on regular tracks (in Germany also on some high-speed tracks). To optimize capacity utilization slower cargo traffic must be separated from faster passenger traffic. Where this is not possible night trains should get priority as the substituting aviation emissions has a higher GHG reduction potential compared to lorry traffic emissions.
Outlook

Our calculation represents an approximation that is intended to serve as an order of magnitude estimate, but requires further specification. We would therefore also like to encourage further scientific deepening of our question.

- Our data material could be supplemented with distances for relations of less than 100,000 passengers. Where such relations are on the route of relations that already have over 100,000 passengers, they would contribute passengers. This would further increase the overall potential. To this end, the resulting night train routes would first have to be identified.

- The aircraft emissions could be refined by calculating the radiative forcing of non-CO2 emissions using a distance-dependent function. This could further increase the savings potential of night train distances between 1501-3000 km compared to distances between 501-1500 km.

- Once possible night train distances are defined, their passenger potential could be specified on the basis of the route-specific average speed. A study by Oui au train de nuit (2020) offers tested calculation methods for this.

- Once possible night train connections and passenger potentials have been defined in this way, their economic viability can be examined. Methods for this can be found in a UIC study (2013) as well as in a study by Vieregg-Rösler (2014); depending on this, implementation priorities can be defined, on the basis of which it can be determined to what extent the volumes could be implemented on the given routes.
About

Back-on-Track.eu
European network to promote cross-border night trains

Back-on-Track is a European network of local initiatives in support of cross-border passenger train services and night trains in particular.

With its more than 300 members, Back-on-Track organises actions, conferences, publishes studies and advises policy makers and the public on night train issues.

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Transport share of EU Greenhouse gas emissions 2019
CO₂e incl. non-CO₂ Radiative Forcing (GWP*), incl. UK

- Road: 19.03%
- Aviation: 11.68%
- Aviation (CO₂ only): 5.13%
- Ships: 3.62%
- Railways: 0.12%
- Other Transport: 0.13%
- Other Sectors: 65.42%

Source: Back-on-Track.eu | 9/2022 | Based on EEA, Lee et al.
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Development of EU Greenhouse gas emissions 1990-2019 in ktCO$_2$e incl. non-CO$_2$ Radiative Forcing (GWP*), incl. UK

Source: Back-on-Track.eu | 9/2022 | Based on EEA, Lee et al.
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Greenhouse gas emissions per km by mode of transport
gCO$_2$e per passenger, well-to-wheel, incl. non-CO$_2$ radiative forcing (GWP*)

<table>
<thead>
<tr>
<th>Mode of Transport</th>
<th>Greenhouse Gas Emissions (gCO$_2$e)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plane</td>
<td>389</td>
</tr>
<tr>
<td>Plane (SAF)</td>
<td>217</td>
</tr>
<tr>
<td>Car</td>
<td>132</td>
</tr>
<tr>
<td>Car (4 pers.)</td>
<td>50</td>
</tr>
<tr>
<td>Coach</td>
<td>22</td>
</tr>
<tr>
<td>Night Train</td>
<td>14</td>
</tr>
</tbody>
</table>

**Source:** Back-on-Track.eu | 8/2022 | SAF = Sustainable Aviation Fuel | Based on IEA (2019), Sausen (SAF)

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As sleep is not perceived as travel time, night trains compete with a **head start of 8 hours**.
Greenhouse gas saving potential of night trains

3% of EU total GHG emissions could be reduced by shifting to night trains.

Source: Back-on-Track.eu | 9/2022 | Based on Eurocontrol, EEA, IEA, Lee et al.
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