connecting people - the beauty of aviation

Solutions versus Framing

Basic Framing

NRC, January 5, 2019

Climate change is real and the aviation contribution is also real. But Flight Shame and the image of aviation as the Big Bad Wolf in climate land is more about framing than about facts.

The negative framing of aviation has a history of at least 25 years. We analyzed the framing for the first time in 1998 and found little merit in the claims.

In the mean time the framing has become much worse, has real political influence, and the potential to shape ineffective or even counterproductive policies.

Even main stream media accept the framing without asking questions. On January 5, 2019 the NRC, a respected Dutch newspaper, ran a twelve-page weekend special dedicated to, in their own words, Flight Shame, in which a lot of framing was taken for granted.

On the back cover of that special a bird, the Bar-tailed Godwit, was pronounced to be the Champion of Sustainable Flight. The reason for that championship is interesting.

Basic Framing

Person of the Week

WHO

Bar-tailed Godwit

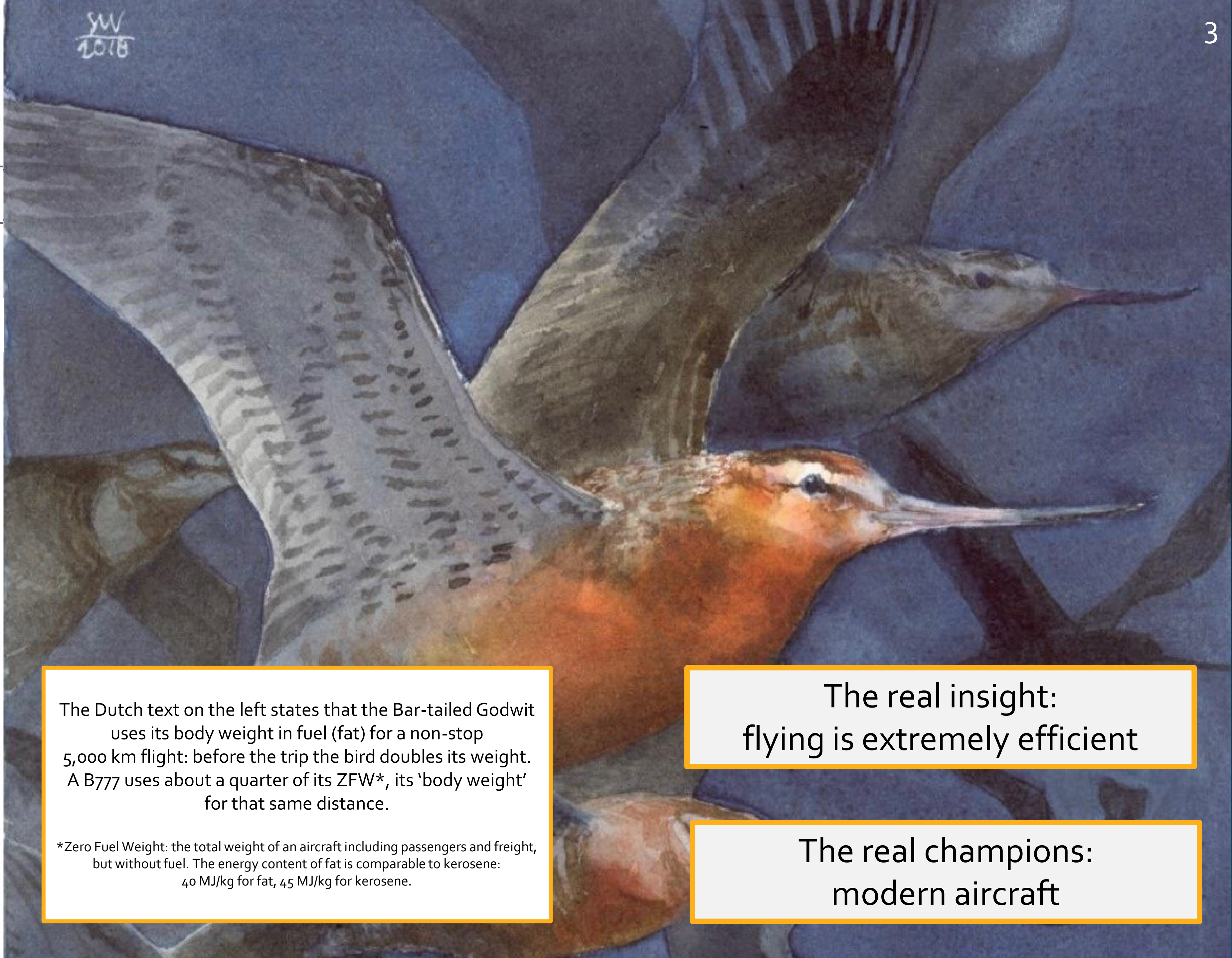
(*Limosa limosa*)

WHY

Champion Sustainable Flight

Energy use:
body weight (ZFW) in fat
per 5000 km

etmaal. Daar verdubbelen ze in een krappe maand hun gewicht, van 200 naar 400 gram. Dat is de brandstof voor de tweede etappe, 5.000 km non-stop naar Taymyr.
De rosse grutto's die in Alaska broeden doen het nog extremer: ze vliegen rechtstreeks naar hun overwinterings-gebieden in Nieuw-Zeeland: 11.700 km, ruim 9 etmalen continu vliegen boven de Stille Oceaan, zonder enige moge-lijkheid om te rusten of te eten!



The Dutch text on the left states that the Bar-tailed Godwit uses its body weight in fuel (fat) for a non-stop 5,000 km flight: before the trip the bird doubles its weight. A B777 uses about a quarter of its ZFW*, its 'body weight' for that same distance.

*Zero Fuel Weight: the total weight of an aircraft including passengers and freight, but without fuel. The energy content of fat is comparable to kerosene: 40 MJ/kg for fat, 45 MJ/kg for kerosene.

The real insight:
flying is extremely efficient

The real champions:
modern aircraft

Basic Framing

Campaign tag, Friends of the Earth Netherlands, October 1998

Picture by: Leonid Andronov / shutterstock.com

In 1998 Friends of the Earth Netherlands claimed that on certain routes aircraft would emit ten times more CO_2 than the train and cause eight times more pollution. See their campaign tag above. They even provided a source for that claim: a report by CE.

However, that report stated that for a typical holiday trip to the Mediterranean, about 1500 km, the direct energy use of the train would be about a third of an aircraft, not 10%, and the pollution of the trip by train would even be higher, by about 15%.

The key words in their message turned out to be 'on certain routes': the claim is valid only for routes on which the train, like the TGV*, uses electricity from nuclear power plants.

The French electricity, which the TGV uses, was in 1997 for 85% provided by nuclear power plants. Then the claim is valid. That is, if you take only the use of direct energy into account and disregard the energy used for building and maintaining the rail infrastructure.

* Train à Grande Vitesse or, in English, HSR: High-Speed Rail.

Basic Framing

Eurostar too claims 90% less CO_2 emissions than aircraft on the same route. It is even a central part of their marketing, providing a great assist to activists. See the screen shot on the left, taken from the Eurostar website.

British Energy

Industry	Electricity generation
Fate	Acquired by Électricité de France, delisted 3 February 2009
Successor	EDF Energy
Founded	1995
Defunct	2009, continued as subsidiary until 30 June 2011
Headquarters	London, UK
Products	electrical power
Revenue	£2,999m (2007)
Operating income	£794m (2007)
Net income	£465m (2007)
Website	www.british-energy.com/

British Energy was the UK's largest electricity generation company by volume, before being taken over by Électricité de France (EDF) in 2009.[1] British Energy operated eight former UK state-owned nuclear power stations and one coal-fired power station.

In a press release Eurostar states the reason for the low emission: they use electricity from a low-carbon source. And they do. Eurostar sources its electricity from British Energy, a company that was acquired by EDF, a French company, in 2009. And BE generates its electricity mainly with nuclear power plants.

Friends of the Earth's real message:

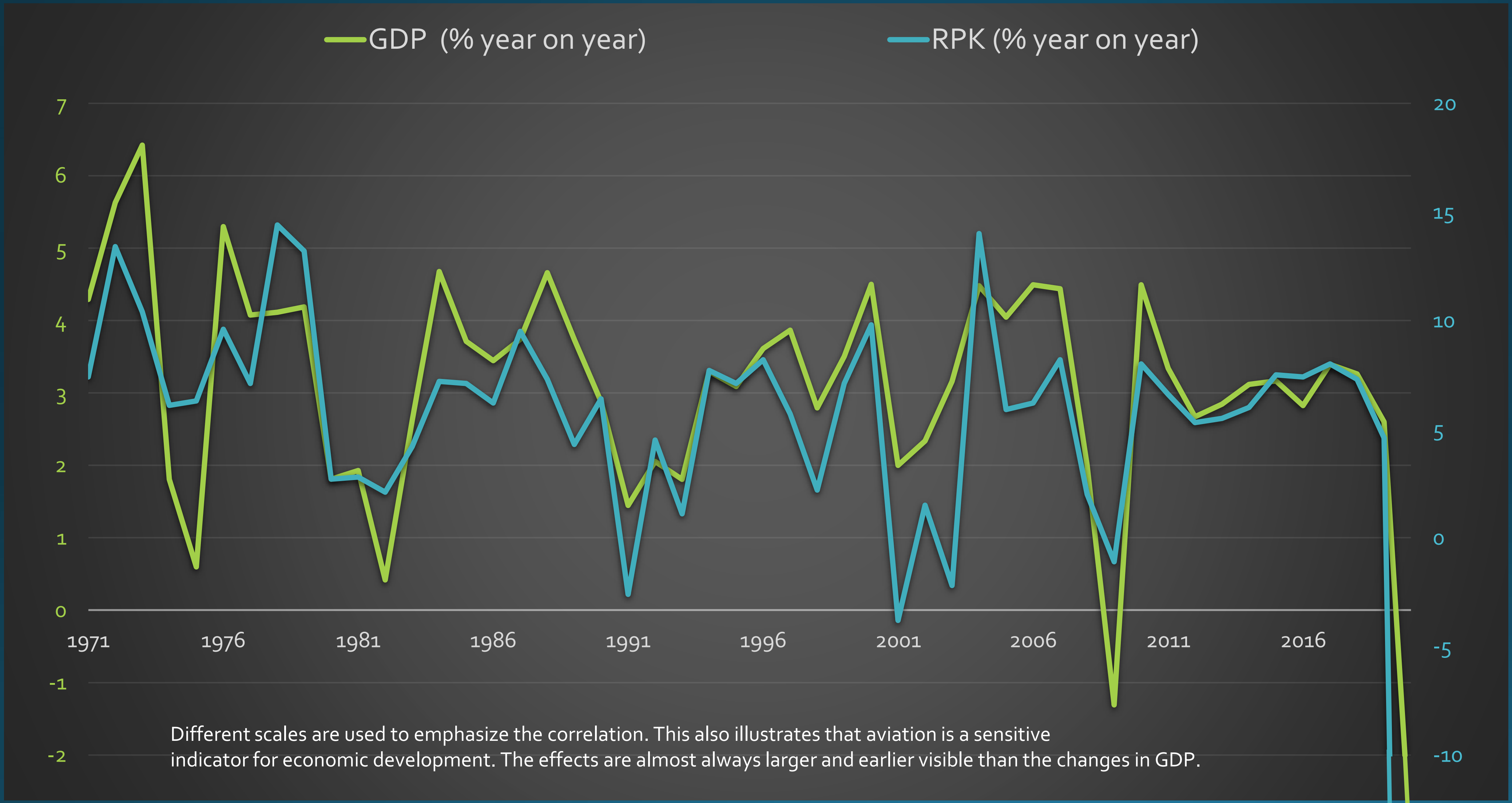
Nuclear Power, the way to go

So although their claim is indeed true, it does have consequences for what the real message of both Eurostar and Friends of the Earth should be.

The Analysis

Topics menu:

Important insight: aviation is infrastructure



Source for GDP: World Bank, National accounts data and OECD National Accounts data files
Source for RPK (Revenue Passenger Kilometers): ICAO, World total revenue traffic

2020: RPK -65.5% GDP -3.4%

An airline is a company, but aviation itself is not. It is infrastructure. And just like other infrastructure, and like for instance capital and human capital, aviation is a need-to-have element for economic development. How much of each element is needed or used depends on the actual economic development. It is not aviation that drives the economy, it is the economy that drives aviation.

It is therefore also not an airport or an airline that causes growth of aviation. The cause is a society that opts for economic growth.

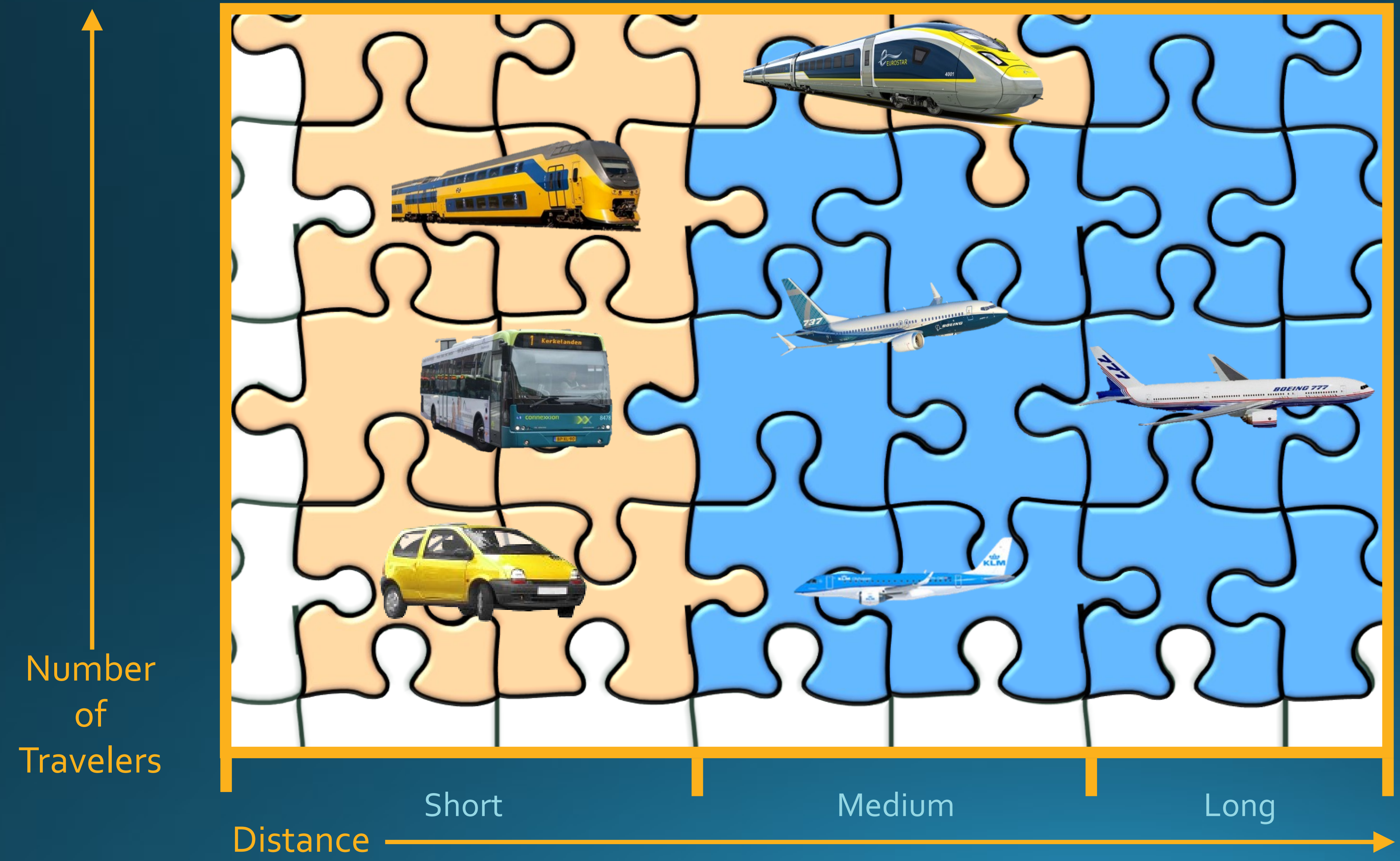
If the choice for economic growth is made it is inconsistent and counterproductive to use resources to limit growth of aviation as a stand-alone issue.

It would be more beneficial to dedicate resources to counter the negative effects of aviation. Like indeed the effects on the climate.

In 2020 the covid-measures caused a disconnect: the reduction in RPK was extreme. The need remained however, so recovery was quick.

MENU

The Economic Puzzle



Every transportation mode has its own place in the puzzle. The average cost of building HSR-track for instance is about 25 million euro per km (or 40 million dollar per mile), so HSR can only be build for busy routes. According to the European Chamber of Auditors you need 25,000 or more passengers per day. That is if the subsidy (in Europe almost all rail infrastructure is subsidized) needs to remain limited.

Connections by aircraft need little infrastructure and are thus possible with 100 or even less passengers per day.

For longer distances there is no alternative for aircraft, as ocean liners became economically obsolete with the arrival of the B747. The capital cost alone of an ocean liner per pkm* is ten times the cost of a 747.

Ocean liners are obsolete for climate reasons as well: despite the low speed a passenger ship uses per pkm seven times the energy an aircraft does.**

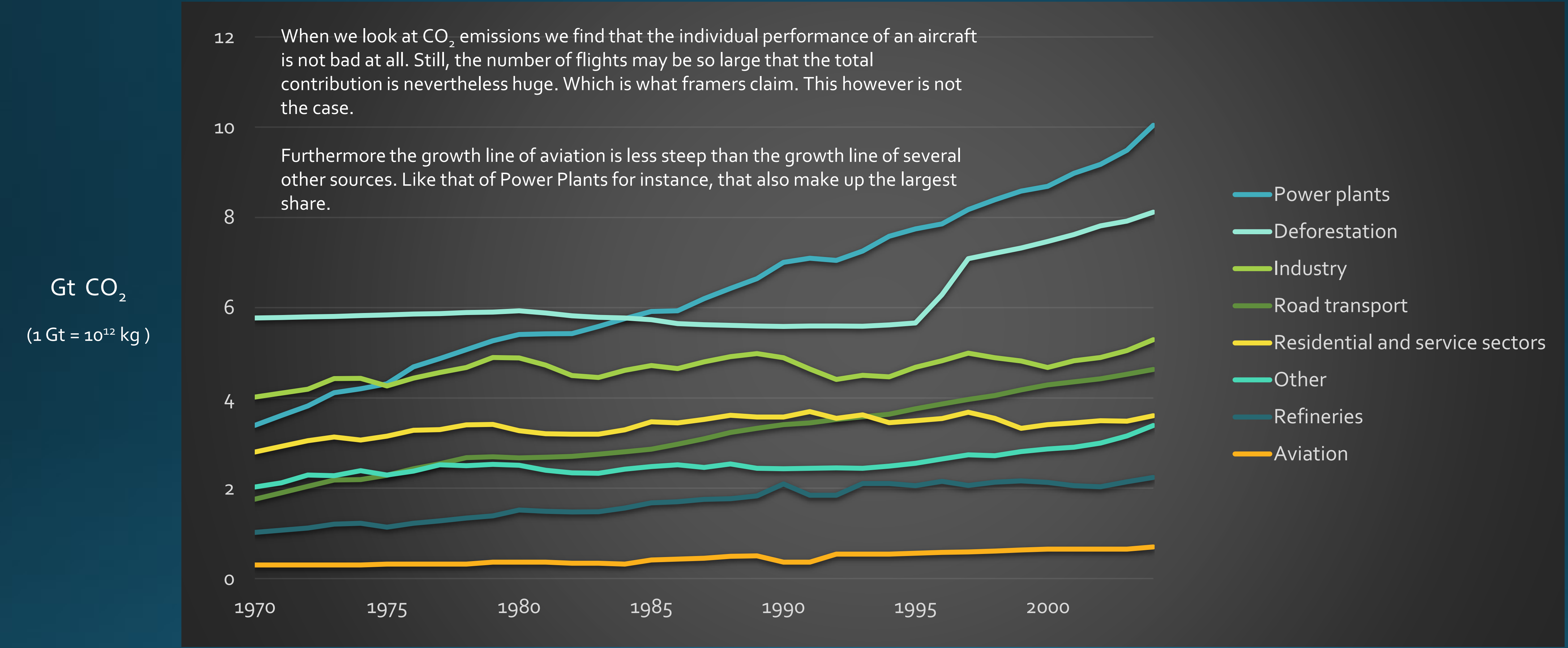
* pkm= passenger kilometer: the transport of one passenger over one kilometer.

** George Marshall of the Climate Outreach Information Network: "Travelling to New York and back on the QEII, in other words, uses almost 7.6 times as much carbon as making the same journey by plane." The Guardian, December 20, 2006.

CO_2-emissions (worldwide, absolute and growth)

When we look at CO_2 emissions we find that the individual performance of an aircraft is not bad at all. Still, the number of flights may be so large that the total contribution is nevertheless huge. Which is what framers claim. This however is not the case.

Furthermore the growth line of aviation is less steep than the growth line of several other sources. Like that of Power Plants for instance, that also make up the largest share.



Sources: IEA; EDGAR 3.2 and FT2000; USGS, FAO, GFED; WL

Original Publication: Olivier, J.G.J., Van Aardenne, J.A., Dentener, F., Pagliari, V., Ganzeveld, L.N. and J.A.H.W. Peters (2005)

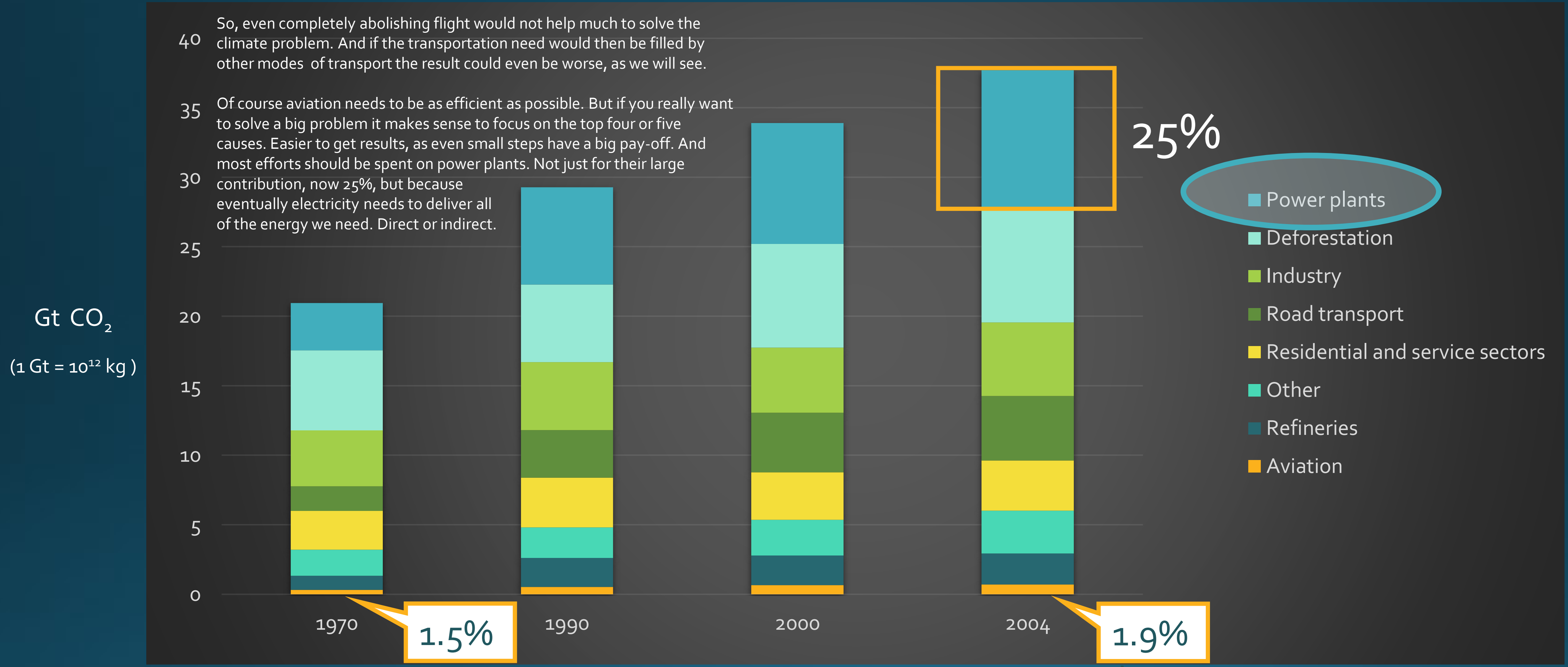
Recent trends in global greenhouse gas emissions: regional trends 1970-2000 and spatial distribution of key sources in 2000 Env. Sc., 2 (2-3), 81-99. DOI: 10.1080/15693430500400345.

MENU

CO_2-emissions (worldwide, total and share)

So, even completely abolishing flight would not help much to solve the climate problem. And if the transportation need would then be filled by other modes of transport the result could even be worse, as we will see.

Of course aviation needs to be as efficient as possible. But if you really want to solve a big problem it makes sense to focus on the top four or five causes. Easier to get results, as even small steps have a big pay-off. And most efforts should be spent on power plants. Not just for their large contribution, now 25%, but because eventually electricity needs to deliver all of the energy we need. Direct or indirect.

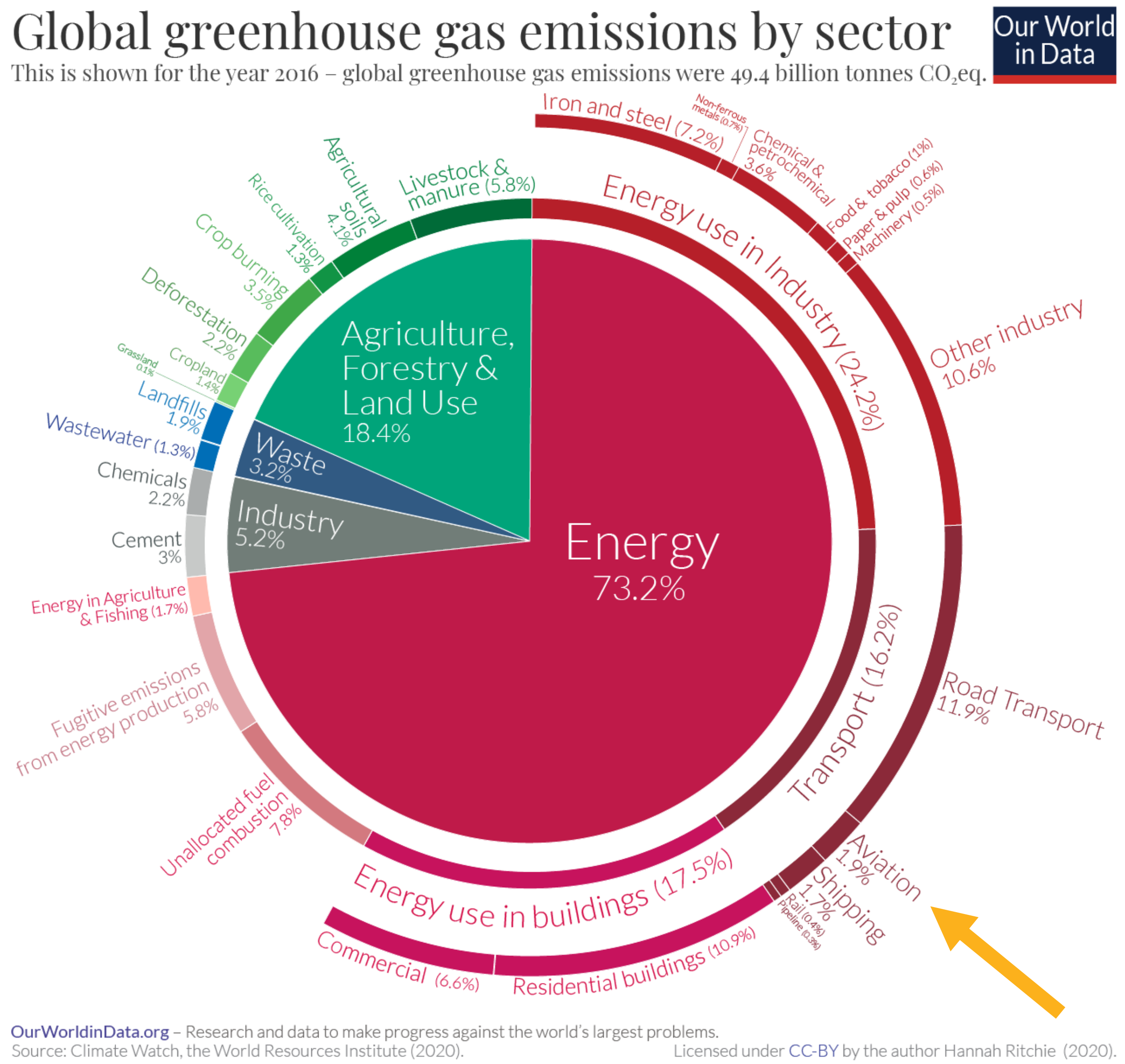


Sources: IEA; EDGAR 3.2 and FT2000; USGS, FAO, GFED; WL

Original Publication: Olivier, J.G.J., Van Aardenne, J.A., Dentener, F., Pagliari, V., Ganzeveld, L.N. and J.A.H.W. Peters (2005)

Recent trends in global greenhouse gas emissions: regional trends 1970-2000 and spatial distribution of key sources in 2000 Env. Sc., 2 (2-3), 81-99. DOI: 10.1080/15693430500400345.

Total GHG emissions worldwide by sector



The most recent numbers in the previous graph were from 2005, but in 2016 too, and considering all emitted Greenhouse Gases, aviation's contribution was less than 2%. So even abolishing aviation completely would not deliver much of a benefit.

Moreover, transport should then not be provided by other means of transport, because that could even have the opposite effect: in addition to passenger ships, other alternatives too often perform worse than an airplane.

This of course not withstanding the fact that aviation too must become emission-free. The problem is that, unlike other modalities, aviation has become increasingly efficient for decades. This makes it difficult to improve even further.

Fortunately, there is time to develop solutions: the contribution of aviation will only be relevant when the major emissions sources, such as electricity production, have become emission-free.

All in all, the focus on aviation is amazing. The focus should be on producing emission-free electricity. That would get rid of 25% of the emissions. The next step should be transitioning all energy use from fossil fuel to electricity, or when that is not possible to hydrogen or e-kerosine made with emission-free electricity. This would get rid of another 50% of the emissions -or over 73% in total- including the 2% emissions by aviation.

Complex Framing

The New York Times

(Sept. 19, 2019)

‘Worse Than Anyone Expected’: Air Travel Emissions Vastly Outpace Predictions

The United Nations aviation body forecasts that airplane emissions of carbon dioxide, a major greenhouse gas, will reach just over 900 million metric tons in 2018, and then triple by 2050.

2.75 Gt

the rapid growth in plane emissions could mean that by 2050, aviation could take up a quarter of the world’s “carbon budget,”

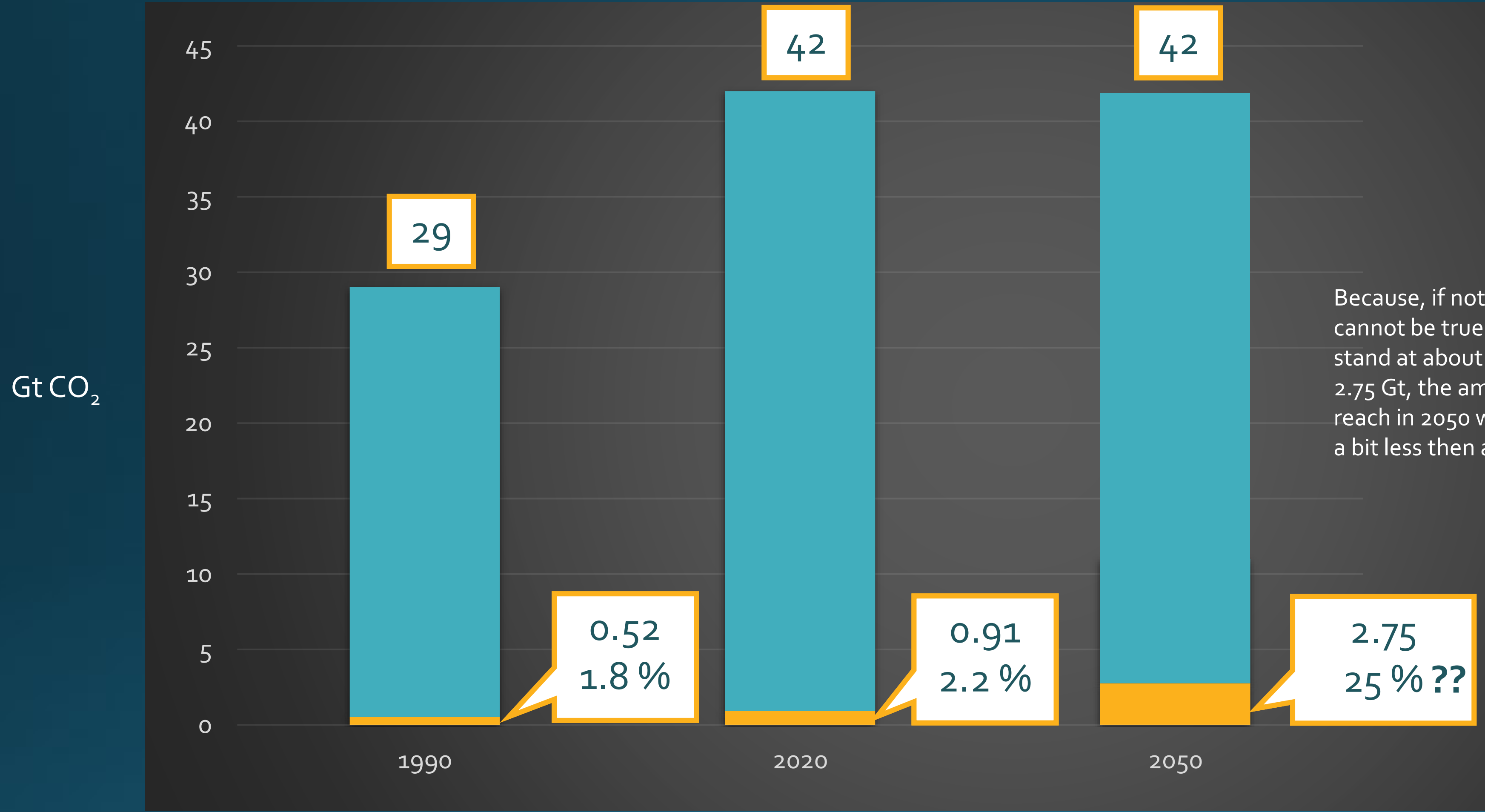
The fact that aviation is at present a small contributor has been grudgingly accepted by framers as something that is hard to deny.

So, the framing has changed, as we already saw in the previous example, from aviation as a huge contributor *now* to aviation as the greatest *future* threat.

See this NYT piece. The headline is alarming and at a first glance the content seems to state that aviation alone will be responsible for a full quarter of the world’s carbon emissions by 2050, as aviation is on track to triple its emissions from 0.9 Gt now to 2.75 Gt in 2050.

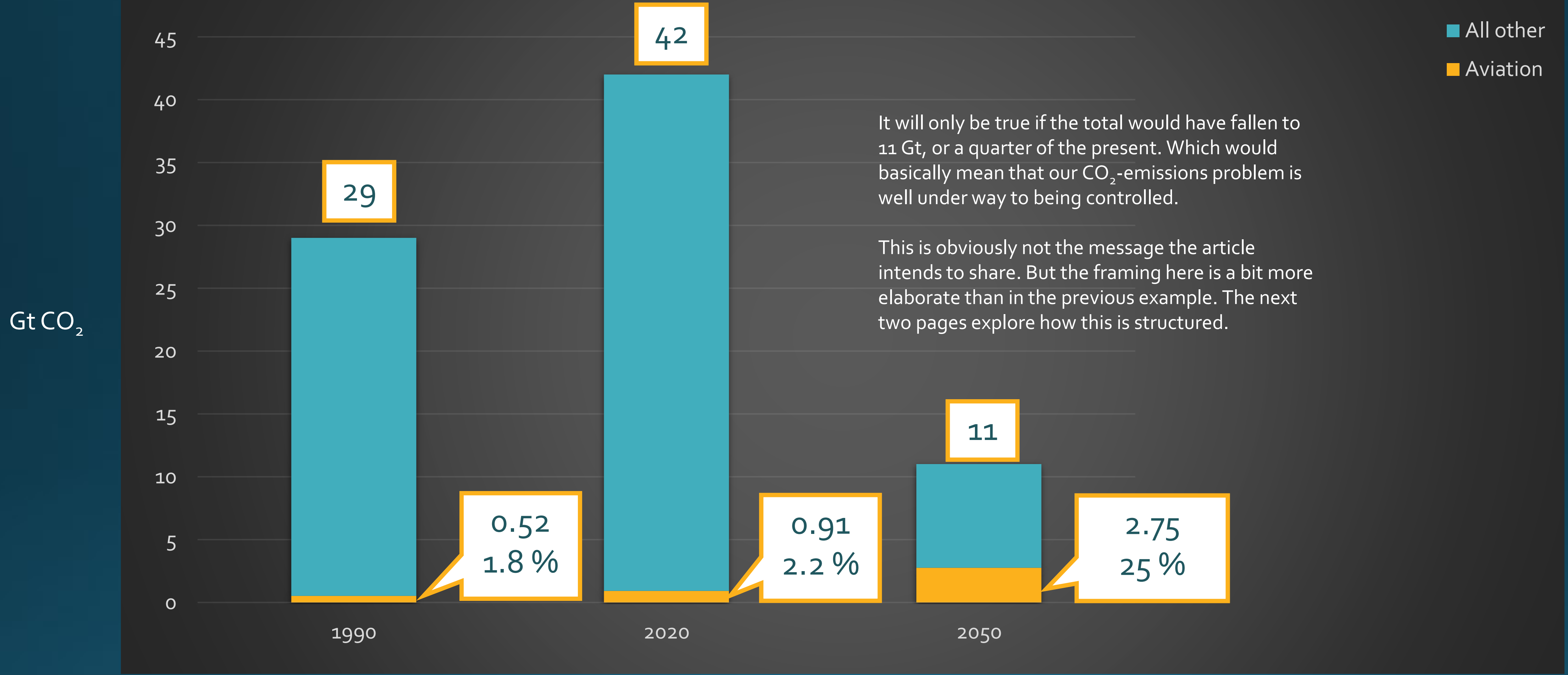
However, a first quick check indicates that something else is going on. See the next two pages.

Complex Framing



Because, if nothing else changes, this cannot be true. Present day CO_2-emissions stand at about 42 Gt total worldwide and 2.75 Gt, the amount aviation is expected to reach in 2050 when nothing is done, is quite a bit less then a quarter of that.

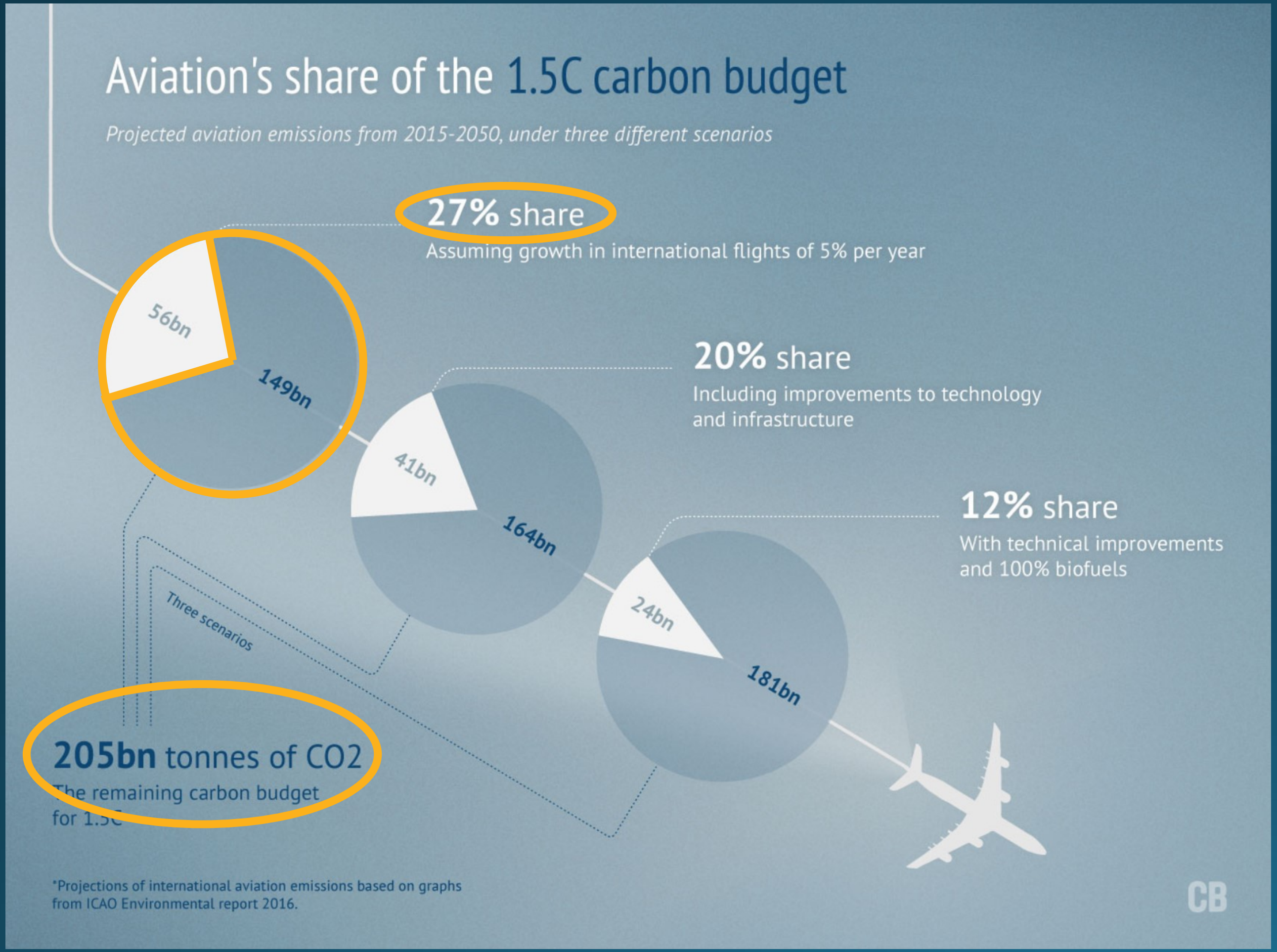
Complex Framing



It will only be true if the total would have fallen to 11 Gt, or a quarter of the present. Which would basically mean that our CO_2-emissions problem is well under way to being controlled.

This is obviously not the message the article intends to share. But the framing here is a bit more elaborate than in the previous example. The next two pages explore how this is structured.

Complex Framing



The NYT-article is based on a 2015 report from an activist group about the carbon budget. The thing is that depletion of the carbon budget is cumulative.

The budget tries to predict how much CO_2 can be added to the atmosphere before a certain temperature rise, in this case 1.5°C, becomes unavoidable.

The predictions differ quite a bit between forecasters and over time, but the 2015 prediction used in this report was that 205 Gt could still be added.

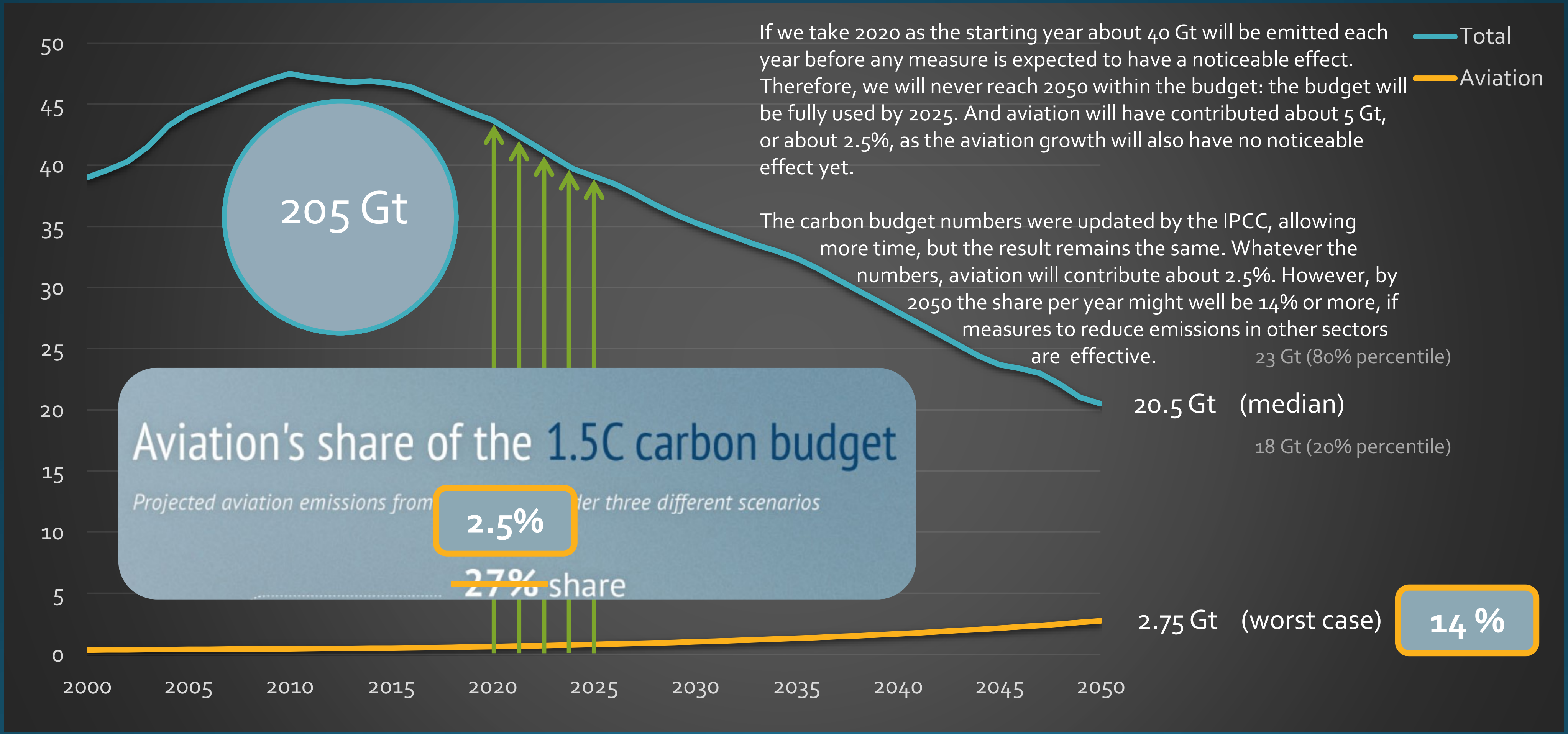
The cumulative amount that aviation was expected to emit, ***from 2015 up to 2050***, was 56 Gt, thus 27% of that budget.

So, as is shown on the next page, the framing is again quite obvious once you understand what the numbers stand for.

Source: www.carbonbrief.org

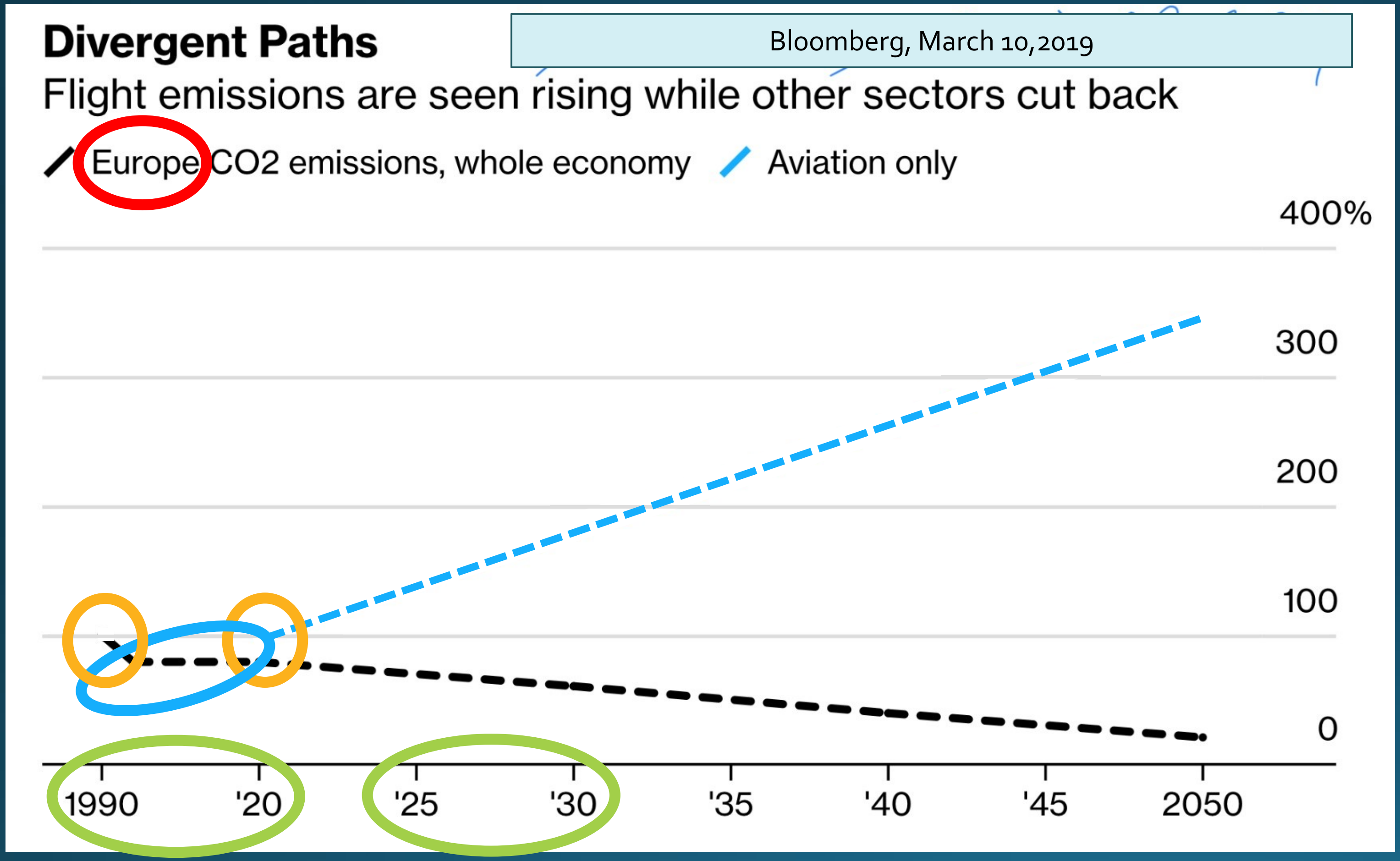
Complex Framing

Gt CO_2



Source emissions prediction: David S. Lee, Ling Lim, Bethan Owen, *Shipping and aviation emissions in the context of a 2°C emission pathway*, Manchester Metropolitan University (2013)

Percentages: Favorite Tool for Framing



So, the aviation share is limited and for the next few decades the growth will have a limited effect too. But that is not what the framing tries to convey, by using the graphic on the left.

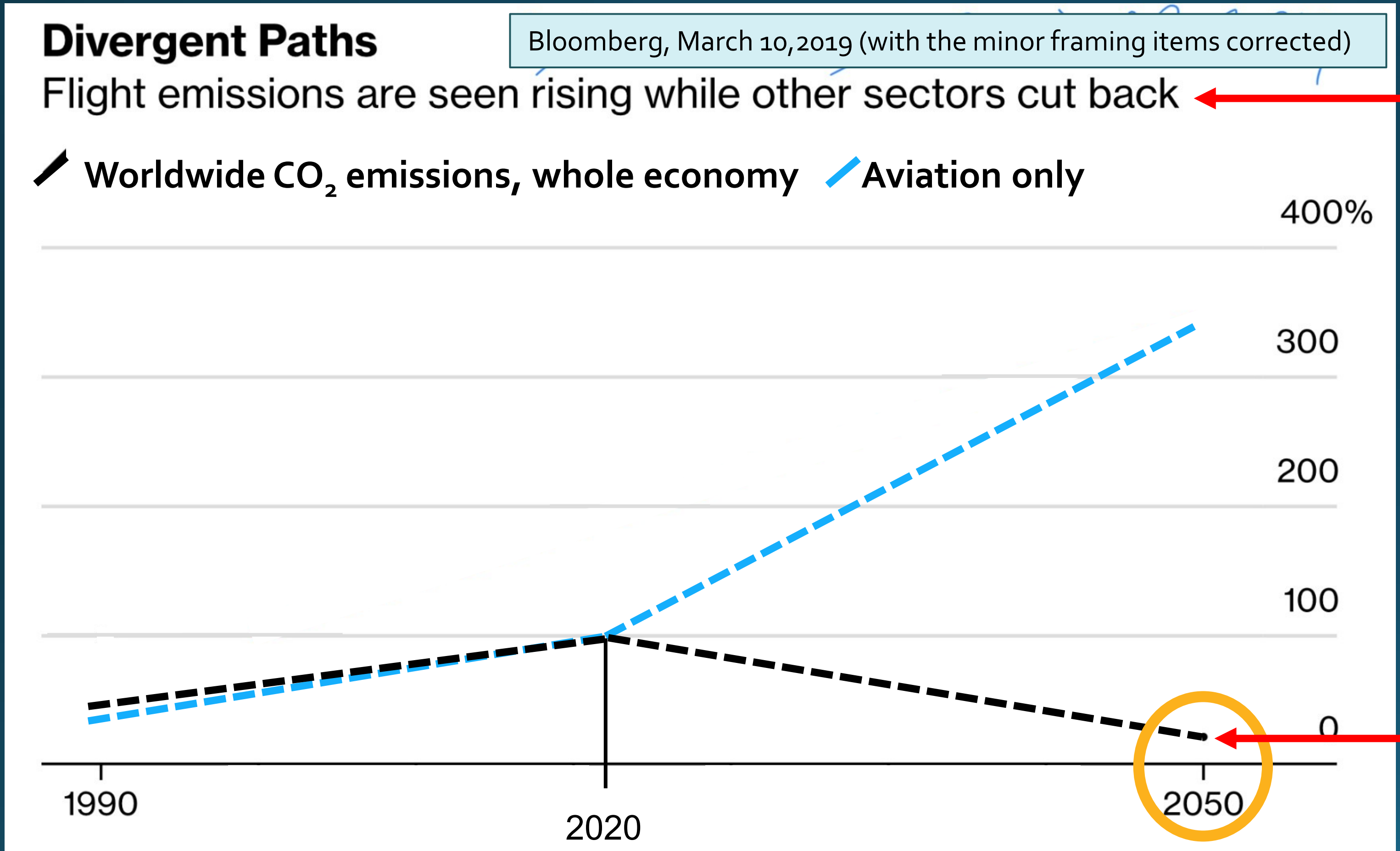
As simple as this graphic is, it contains a lot of framing: four minor issues and two major ones.

The minor ones are:

1. aviation is an international worldwide activity and if you restrict data to a specific area, be it an airport, a country or even a continent, you run into allocation issues and misleading representation.
2. The base line of 100% is set in 2020 for aviation and in 1990 for the whole economy.
3. For aviation the prediction, 2020 - 2050, is displayed, but not the history.
4. The history, the first thirty years, is bunched together in the graph space for five years.

Of the two major issues one is obvious, but the other one, "*Flight emissions are seen rising while other sectors cut back*", only stands out when you correct for the minor ones. Which we will do on the next page.

Percentages: Favorite Tool for Framing



Geneva – The International Air Transport Association (IATA) published information confirming that carbon emissions per passenger have declined by more than 50% since 1990.

The not-so-obvious major issue is the sub-headline that frames aviation as not having addressed emissions issues, while other sectors took their responsibility.

Historically that is obviously not true: the growth of aviation emissions was about the same as that of the economy as a whole: about 2.5% per year.

But the growth of aviation is on average twice that of the economy as a whole: about 5% per year. So for at least the last thirty years aviation was already very active and successful in cutting back emissions. And of course, it is precisely this head-start that makes it very difficult to improve even further, while other sectors are just starting to cut back.

So, the prediction that, if nothing changes, from now on aviation emissions will grow with 5% per year is probably correct. But this brings us to the other major framing issue. The graph expects the total world-wide emissions to drop to about 20% by 2050.

This total includes the aviation emissions. So, this can only be true if the aviation emissions, despite their rise (to 345% in this graph), will remain a minor part of the whole.

For people used to working with numbers and percentages the obvious message from this graph is therefore quite different from the framing: aviation is not the Big Bad Wolf in climate land, aviation has relatively little influence.

So how about the Future

- Contribution small now
  - technical and operational improvements continue, but will lag growth
- Share may become 14% or more
  - if non-aviation reductions are succesful
- **Time available 30 years**
  - aviation makes no difference when others not successful

Although the focus of framers on aviation is a bit strange, as aviation on its own will never be able to solve the worldwide climate issue, aviation as a responsible team player still needs to do whatever is possible to reduce emissions.

The good news is that the time available for aviation to solve its problem is rather large. The difference aviation makes will only become meaningful when measures outside of aviation have had a quite large effect.

As there is no rush, aviation should refrain from technical or operational measures that lead to emission reductions, but that may have a negative impact on safety.

Above all, measures that are not cost-effective should be avoided. These would deflect resources from areas where they would have a much bigger impact, a much bigger bang for the buck. Our biggest problem is not aviation, but the energy-transition.

On top of that, as we will see later, solving the energy-transition problem will also solve the aviation problem.

Suggested Options

1. Fly less and limit mobility
2. Tax fuel to increase efficiency
3. Build more HSR-track
4. Energy transition

We can now have a fact-based instead of a framing-based look at the four options that have been suggested to reduce the aviation climate footprint. Of these, option number 2 can have two purposes.

The first is to increase the cost of flying in general, in the hope that people will stop flying, covered under option 1, or that they will switch to HSR, covered under option 3.

The other motivation of option 2 is, as stated, the belief that an increase of the cost of fuel will lead to more fuel efficiency. This is a misunderstanding based on lack of aviation knowledge.

Unfortunately, aviation knowledge is quite often not applied (and perhaps not even readily available) in the public debate so far. That may lead to policies that have a negative impact on our society and at the same time are ineffective or even counterproductive for the climate.

A lose- lose situation. Precisely the reason why framing can be very harmful. Facts remain important, despite the fact that ultimately most decisions are driven by emotion.

Option 1: Fly less, limit mobility

The New York Times

Opinion

What if All That Flying Is Good for the Planet?

Without tourism, it's easy to imagine the Serengeti turned into cattle ranches.

By Costas Christ

Mr. Christ is the founder of Beyond Green Travel.

Nov. 19, 2019

If we really did all stop flying, would that save the planet?

The counterintuitive answer is that it might actually do the opposite.

April 9, 2016

SUNDAY REVIEW

When the Oil Fields Burned

In 1991, Saddam Hussein's troops set off an inferno in Kuwait, creating an environmental catastrophe.

By SEBASTIÃO SALGADO

Early visionaries of aviation, like Santos Dumont, saw it as a means to unite the word. In the words of KLM-founder Albert Plesman: "The air ocean unites all peoples."

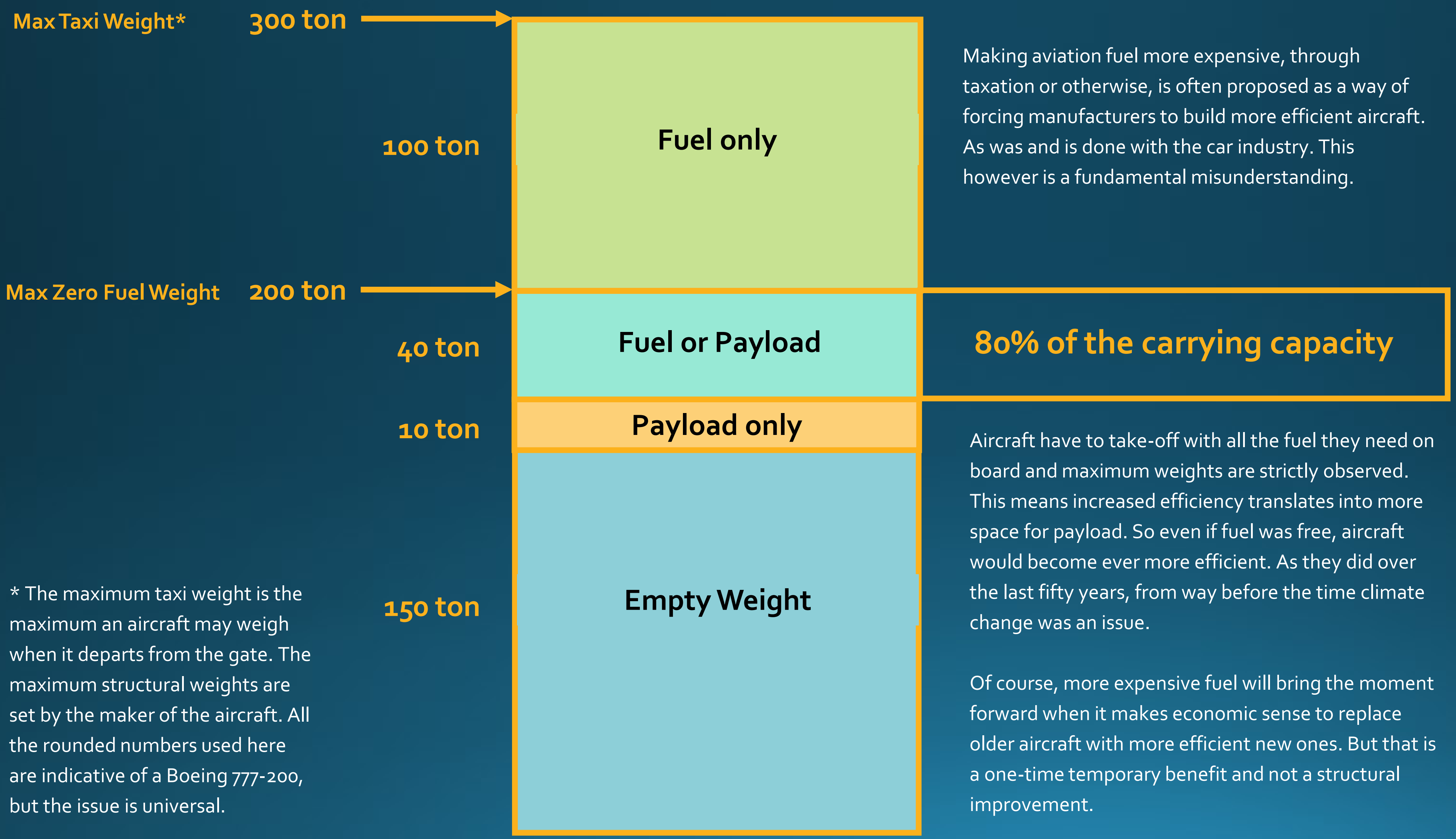
That sentiment was echoed when in 1944 the Chicago convention, see its preamble, decided to stimulate international connections, with tax exemption for international travel as one of the results. Better to trade than to fight and if you know your neighbor a bit better you are more likely to do the first. Armed conflict is bad for people, and not beneficial for the environment or the climate either.

Of course, promoting international cooperation is a political choice and we are free to make that choice or not. Although climate issues would also today seem to benefit if international cooperation would trump domination of agendas by international or even national conflicts.

But today we have another rationale too, as presented in the 2019 NYT-piece on the left. Deforestation is the second largest contributor to CO_2-emissions and a lot is caused by people wanting to make a living by growing cash-crops. Like palm-oil. Aviation will bring opportunities for other activities that may be more beneficial for both the people and the planet.

So, in the world we live in today, promoting international connections might still be a good idea. To debate that is legitimate, but that debate should then not be about individual benefits, but about the pros and cons for societies and the planet at large. And the final decision is of course political.

Option 2: increase fuel cost to drive efficiency



Making aviation fuel more expensive, through taxation or otherwise, is often proposed as a way of forcing manufacturers to build more efficient aircraft. As was and is done with the car industry. This however is a fundamental misunderstanding.

Aircraft have to take-off with all the fuel they need on board and maximum weights are strictly observed. This means increased efficiency translates into more space for payload. So even if fuel was free, aircraft would become ever more efficient. As they did over the last fifty years, from way before the time climate change was an issue.

Of course, more expensive fuel will bring the moment forward when it makes economic sense to replace older aircraft with more efficient new ones. But that is a one-time temporary benefit and not a structural improvement.

* The maximum taxi weight is the maximum an aircraft may weigh when it departs from the gate. The maximum structural weights are set by the maker of the aircraft. All the rounded numbers used here are indicative of a Boeing 777-200, but the issue is universal.

Internal Efficiency Driver is Very Effective

- 1960: 8.5 liters per 100 pkm * (DC8)
- 1970: 3.3 liters per 100 pkm (B747)
- 2000: 2.3 liters ** per 100 pkm (B777)
- At speeds of 800 – 900 km/hour ***

* pkm stands for passenger kilometer: the transport of 1 passenger over 1 kilometer. A car using 6 liters per 100 km uses 6 liters per 100 pkm with a driver only, 3 liters per 100 pkm with an additional passenger and 2 liters per 100 pkm when carrying three persons.

This illustrates how important load factors are for the efficiency of a vehicle. The high average load factor is one of the reasons for the efficiency of aircraft.

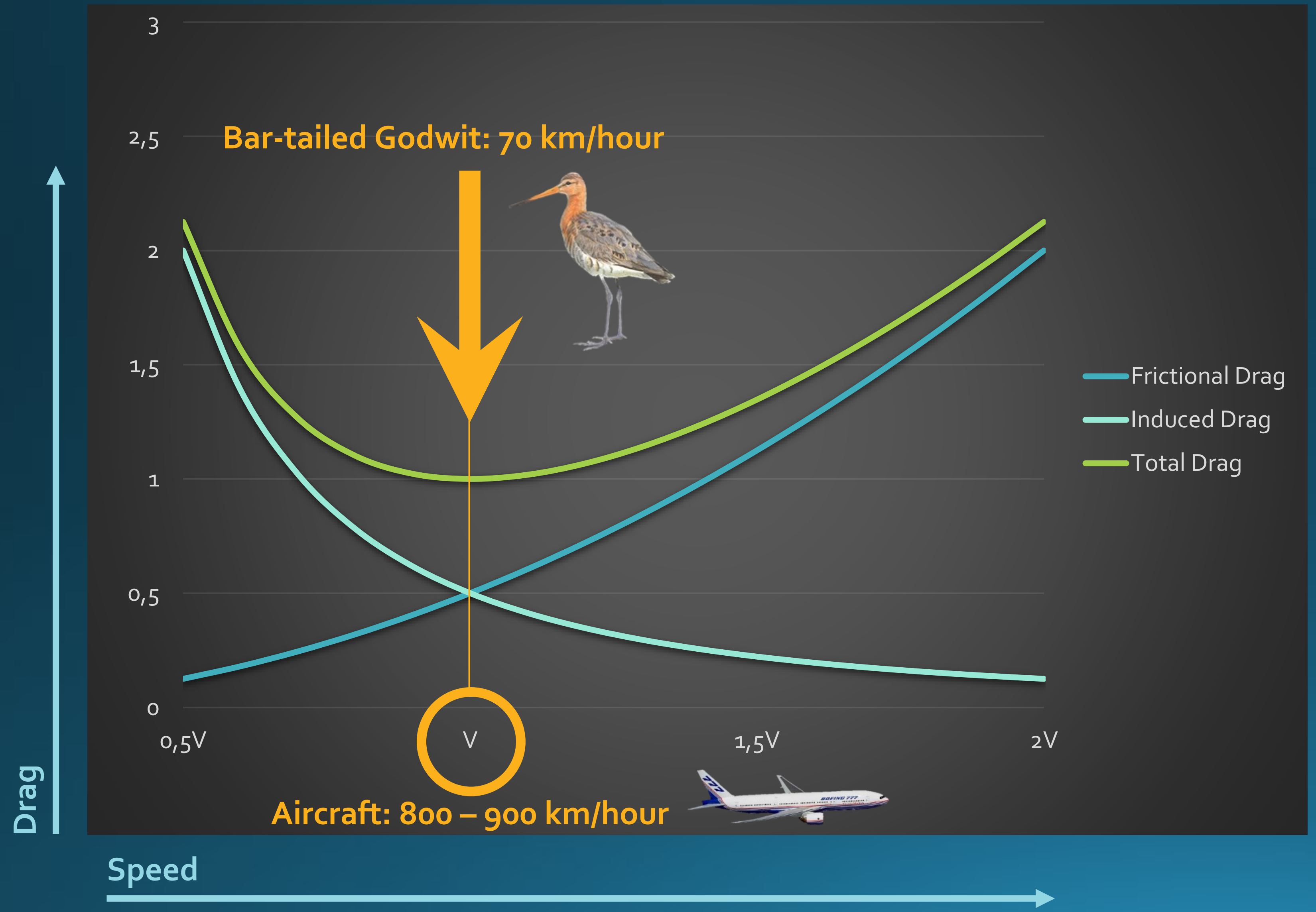
** The 2019 worldwide average for the worldwide fleet is 3 liters per 100 pkm, about the same as a modern car with two persons.

*** This might be the most amazing characteristic of flight: at speeds of eight or nine times the average speed of a car, the energy use is about the same as of a car carrying two or three persons.

This is especially amazing for people who know that the aerodynamic drag of a car, or any other object, goes up with the square of the speed. So the drag at aircraft speeds is 60 to 80 times greater than the drag when travelling at 100 km/hour. Which is the reason why limiting speed is an effective way of cutting back car emissions.

That this does not work for aircraft is hard to grasp for a non-aviation person, but will be explained on the next page.

The Secret of Flight: more Speed is less Drag



For many people it is hard to understand that aircraft fly very fast and that they are nevertheless very efficient. As they know frictional drag increases with the square of the speed. So 8 x the speed means 8^2, so 64 times, the frictional drag. Which is also true for aircraft of course.

However, everything that flies on wings, be it a bird or an aircraft, also has to deal with induced drag: the drag of those wings. At higher speeds sufficient lift to stay airborne can be generated by smaller wings or a lower angle under which the wing moves through the air. Or both. This decreases the induced drag, and this is also a function of the square of the speed. But in the opposite direction.

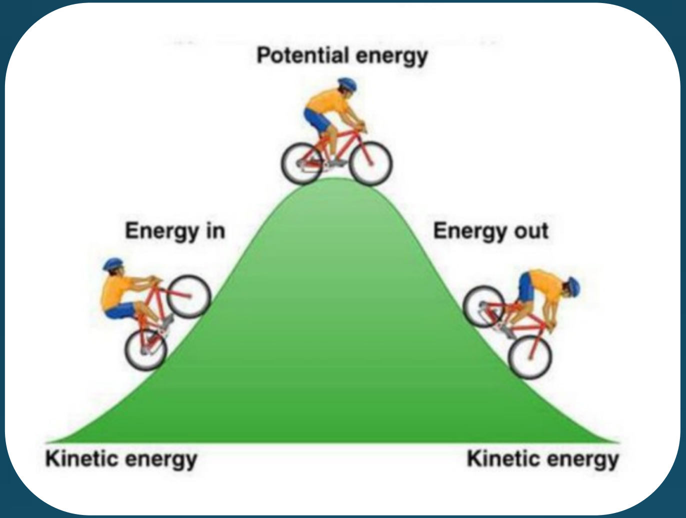
So, there is an optimal speed, which is the speed at which these two types of drag are equal. At which speed this happens depends on the weight of the bird or the aircraft. For a 300-gr/10-ounce bird like the Godwit that speed is about 70 km/hour, for an aircraft like an A320 or a B777 it is about 800 to 900 km/hour. It is no coincidence that these are their respective cruising speeds.

For more details and more interesting facts about flight see:
Henk Tennekens (1997), *The Simple Science of Flight: from insects to jumbo jets*, Cambridge (MA): The MIT press.

Option 3: build more HSR-track

- Old framing
  - 90% less emissions
- Plus new framing
  - climb uses much energy
  - so don't fly within 500 km
- Lack of knowledge is not a problem
  - you can just do the math

The Conservation of Energy Law



Knowledge of the laws of physics and the structure of the atmosphere is helpful in understanding why airplanes are so extremely fuel efficient. But you don't need it to determine which mode of transport produces the least emissions in which situation. Simple calculations will do. How much energy do you use, how many passengers do you transport, and over what distance do you travel. See the following pages for those calculations.

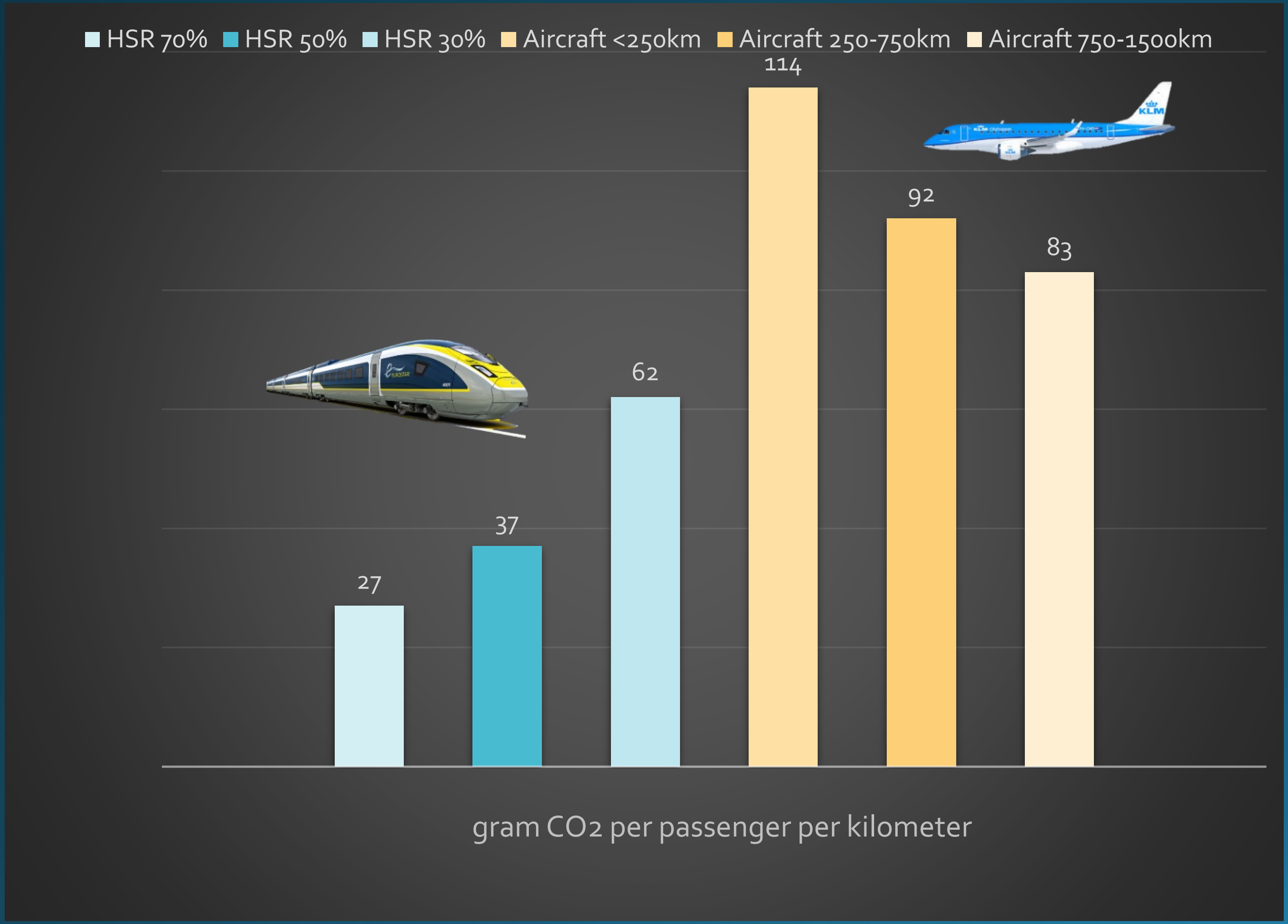
The old framing, trains emit 90% less per pkm than airplanes, is still used. Recently, new framing was added: climbing to the cruise altitude takes a lot of energy and that is why you should stay on the ground for distances of up to 500 km.

Indeed, the energy consumption per passenger per kilometer (pkm) over distances shorter than 500 km is somewhat higher than for flights over longer distances with the same aircraft. However, that has nothing to do with the energy required to climb to the cruise altitude. As a result of the law of the conservation of energy, that energy is almost completely recovered during the descent. An airplane flying at an altitude of ten kilometers uses the potential energy to maintain its speed it the descent when the power is reduced to idle and can cover at least another 200 km while descending. Precisely on short distances, the potential energy built up during the climb is thus almost completely recovered.

On the longer distances, less is recovered, because the weight of the fuel carried up to the cruise altitude also represents potential energy. But the weight of the fuel consumed during the cruise flight disappears from the aircraft. In short, the shorter the flight, the more fully the energy used for the climb is recovered. The fact that an aircraft is on average more economical over longer distances than at short distances is because the air density, and thus the resistance, at normal flight altitude is only about a third of the air density at sea level. You benefit less from this on short distances. See the blog post 'Knowledge Lost' for a more detailed explanation.

MENU

Option 3: build more HSR-track



For trains, the distance makes little difference to the emissions per passenger per kilometer (pkm), but the average load factor is important. This is 50% for HSR. For reference, load factors of 30%, the average of the regular train, and of 70% have been added.

Due to their great flexibility, aircraft have a high and stable load factor of more than 80%, but here the distance makes a difference. Following an often-made distribution, we looked at destinations that are less than 250 km, from 250 to 500 km, from 500 to 750 km and from 750 to 1500 km away from Amsterdam. All distances as the crow flies.

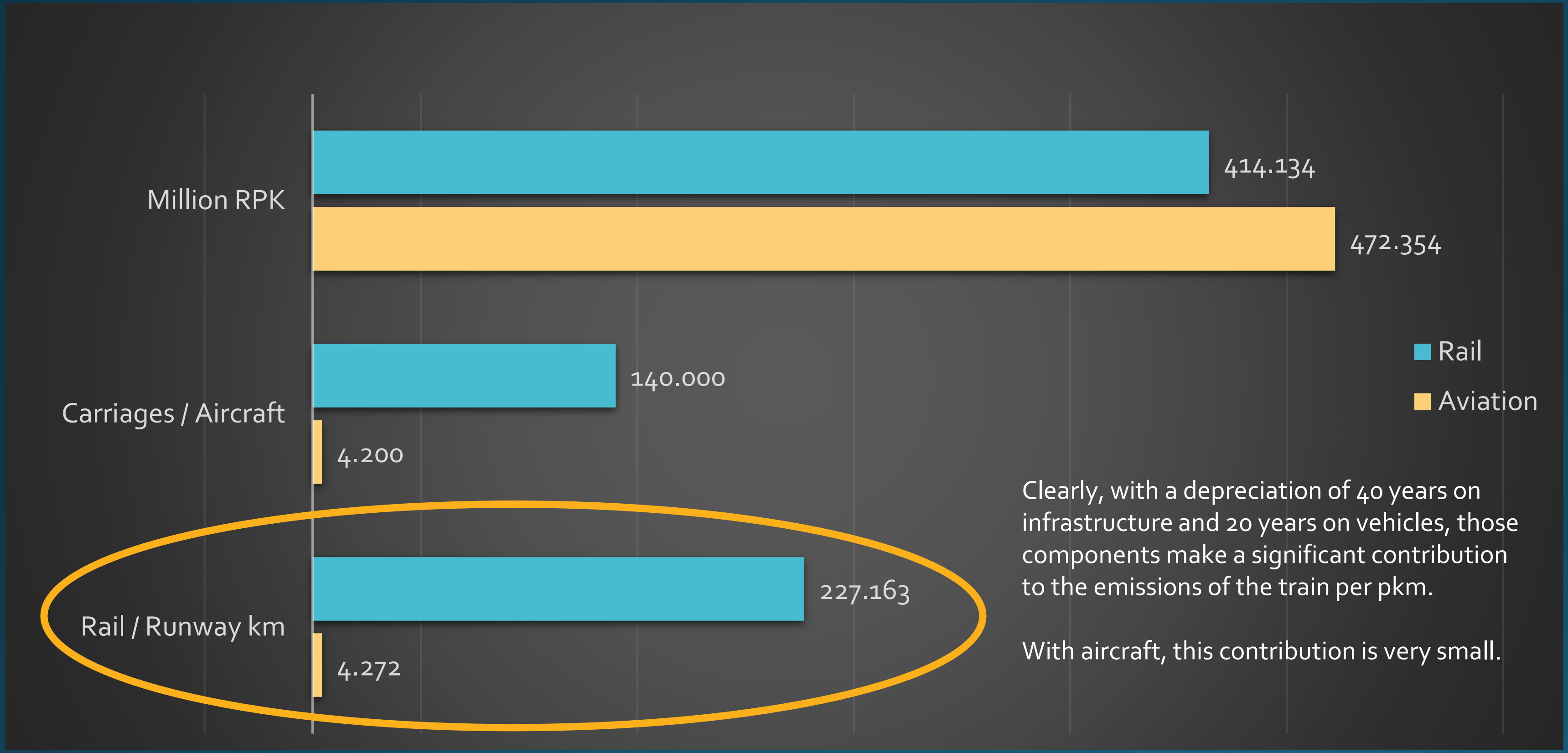
The average emissions from flights between 500 and 750 km (90 grams/pkm) turned out to be almost equal to the average of flights between 250 and 500 km (92 grams/pkm) and they have therefore been combined in the graph.

The consumption of an HSR train is somewhat difficult to find, but Milan Janić of TU Delft arrives at 40 grams/pkm at a load factor of 100%. He calculated with an emission of 546 grams of CO_2/kWh for electricity production.

These emissions vary quite a bit in Europe, from 56 grams in France to 751 grams in Poland. In this and the following graphs, calculations have been made with the current European average of 255 gr/kWh, thus with 19 grams for 100% occupancy and 37 grams for 50%.

As the graph shows HSR does indeed perform better than an aircraft in terms of direct emissions. But this is only part of the story. Because the construction of an HSR line involves quite a lot of emissions and you really must take these into account.

Vehicles and Infrastructure in Europe



Source: Eurostat, and CE, *External Costs of Traffic in Europe*, Delft, 2011

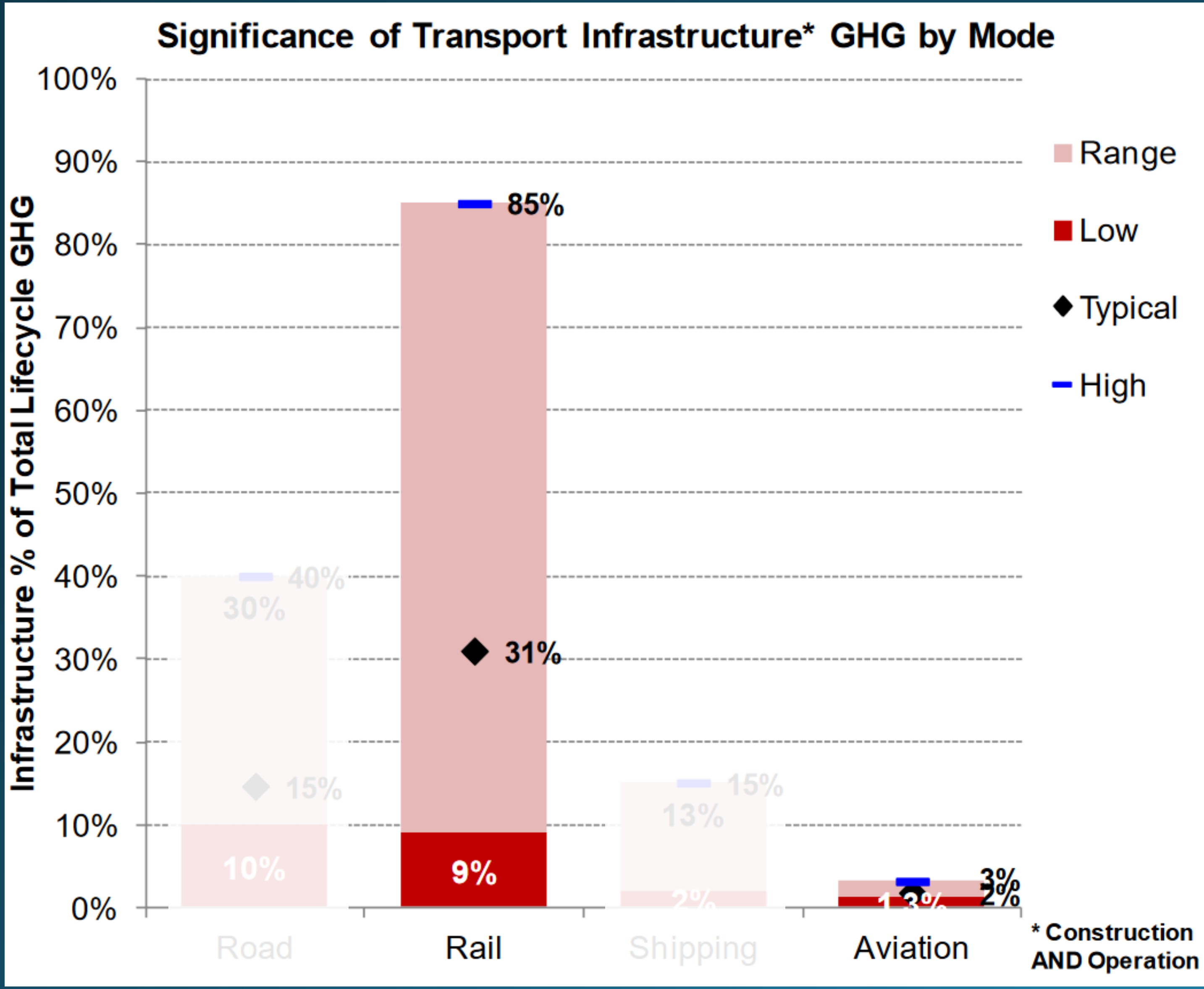
* Runways: 445 airports (Eurostat) with on average 3 runways (assumption) with an average length of 3,2 km (assumption). Aircraft pkm is intra-European traffic only, both domestic and international. Runways and aircraft also produce intercontinental pkms, but as this will only diminish their contribution even further we decided to spare ourselves the effort to split the allocation.

As can be seen the CO_2-emission caused by the rail infrastructure will be significant and we will investigate that in more detail on the next pages.

For rail the contribution of vehicles will also be significant, but the exact data are hard to get and for our purpose, showing that flying is often more efficient than HSR, this turns out to be not important. But a first quick scan yielded the following results. Production of a rail carriage, empty weight about 40 ton, creates about 1,400 ton CO_2. Depreciation over 20 years results in 70 ton per year or 23 gr CO_2 per pkm.

The empty weight of a medium range jet is also about 40 ton, but due to the different mix of materials the production may cost more energy. But even if it would cost four times more energy the emission per pkm would still be less than 3 gr/pkm.

Infrastructure share



Source: Eurotransport GHG 2050, *Final report*, 2011

This graph, in which GHG stands for Green House Gas, also displays how little infrastructure contributes to aviation emissions and how much to rail.

For aviation the contribution of the infrastructure is on average 2% of the total life cycle emissions, with a maximum of 3%.

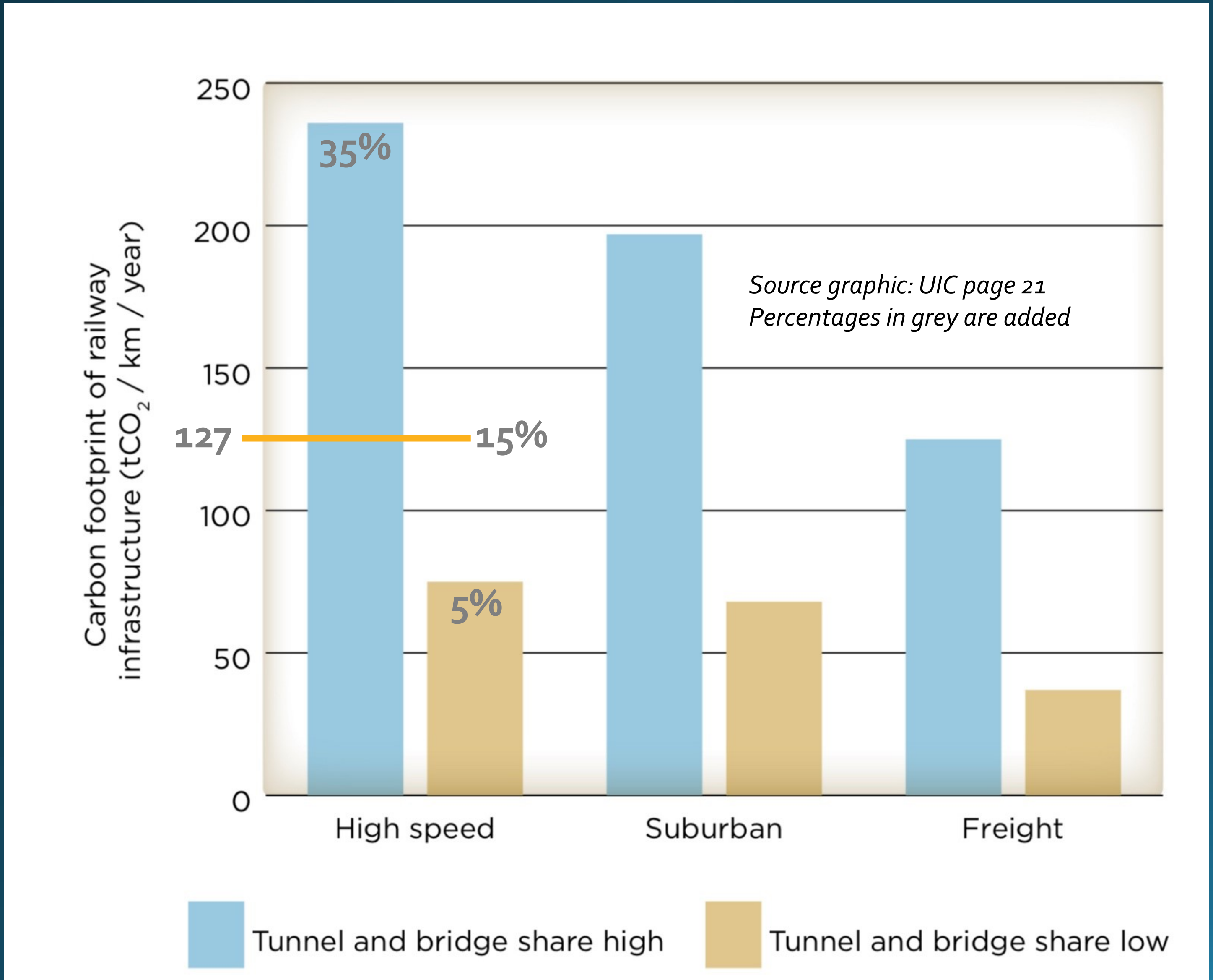
For rail the average is 31%, and for HSR it may run as high as 85%. Which means that for HSR the direct energy use, the energy for the propulsion, may be less than 15% of the total.

85% may seem like a lot, but HSR-track must stay clear of existing infrastructure and differences in height and curves must be smoothed out. Sometimes a vulnerable environment needs to be protected as well by building additional tunnels.

All in all, quite a lot of tunnels and viaducts may be required. The share of tunnels in the total length of a route can therefore vary between, for example, 5% on the Spanish Plateau and the Northwest of France, to 45% for the British HS2 (London-Birmingham).

It is not surprising that this has consequences for the embedded emissions per kilometer of railway.

Infrastructure emissions



The higher the percentage of tunnels, the greater the emissions per year. A study by the International Union of Railways (UIC, 2016) states emissions of 70 tons of CO_2/km/year with 5% tunnels. For 35% tunnels, the UIC gives 240 tons/km/year. See graphic.

For 15% tunnels, interpolation yields 127 tons/km/year. For 1 million travelers per year, that equals 127 grams/pkm. So, even with few tunnels HSR is not a good option for low-volume routes.

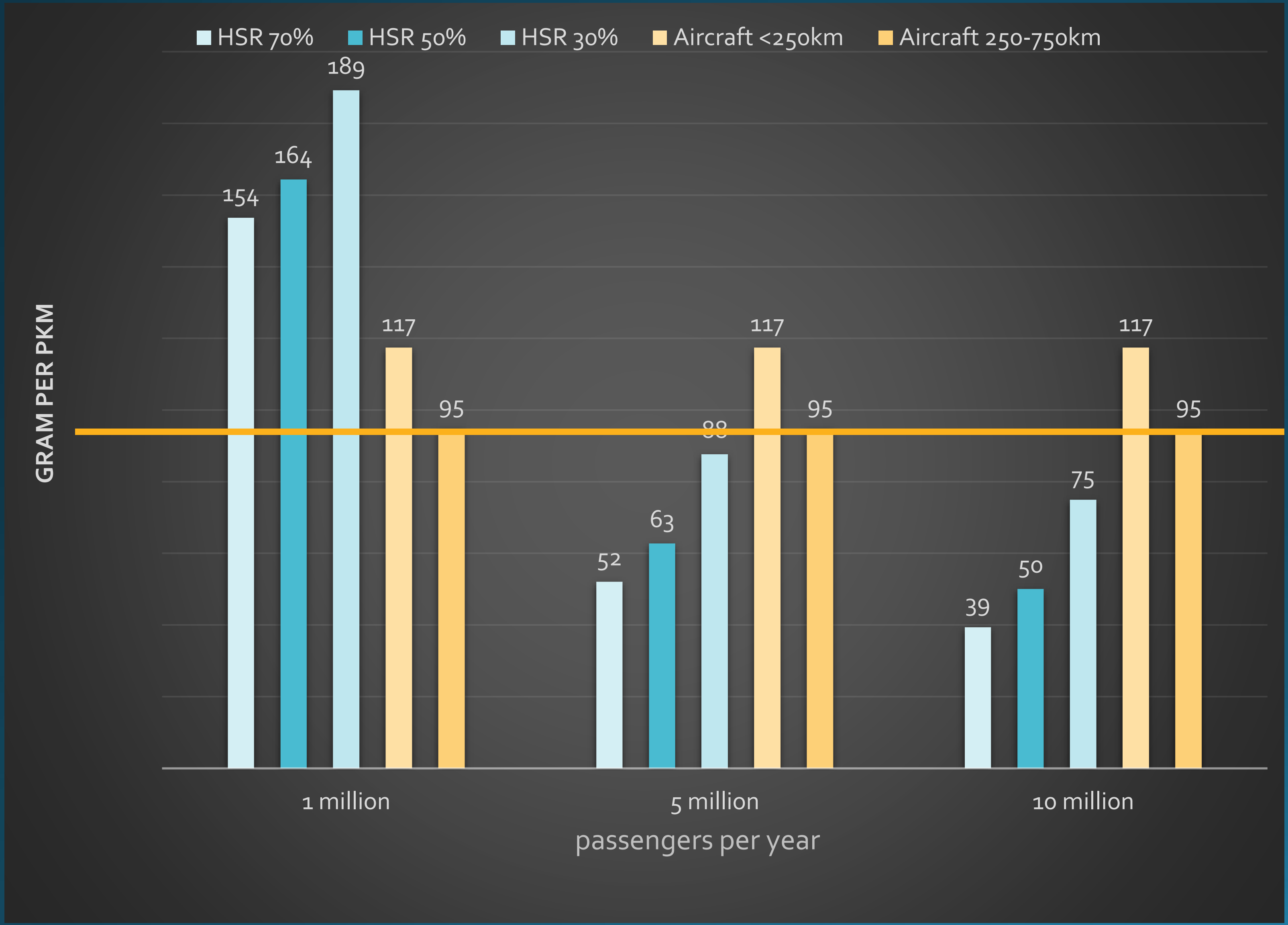
UIC also indicates that the data is somewhat lacking. Not all sources of emissions could be included.

Perhaps that is why this value seems a bit on the low side compared to the HS2, for which extensive data are available in the public domain.

With 10% tunnels in 2011, these state 5333 tons per km, which, if depreciated over 40 years, comes down to 133 tons/km/year. With 15% tunnels that would be 185 tons/km/year, 50% more than the UIC findings.

In the following graphs, however, conservative calculations have been made regarding HSR and the emission used is 127 tons/km/year.

Infrastructure included



The mark-up for infrastructure is of course not dependent on the load factor, but only on the total amount of pkms per year. It doesn't matter whether that amount is reached with a few full trains or with many almost empty ones.

According to a report by the EU Court of Auditors, the limits for a viable HSR connection are distances up to 500 km, with at least 9 million travelers per year. That is why we start at a million travelers/year and look at distances less than 750 km. The graph shows the results for three different traffic volumes.

Do note that distances less than 250 km do not really matter. Up to 250 km the HSR is not the alternative for aircraft, but for cars. Air traffic between Amsterdam and the destinations Brussels and Düsseldorf, for example, is almost exclusively network traffic. This are passengers who start or end a longer journey to or from their final destination via the Amsterdam hub. These routes see virtually no local transport: less than 3%.

The next page shows another influence: the detour factor. The shortest connection between A and B is a straight line, but that route is almost never possible. However, the average detour differs quite a bit between aircraft and HSR and should therefore also considered.

	London - Paris		Amsterdam - Milano		München - Athens		Rome - Madrid	
	Distance	Factor	Distance	Factor	Distance	Factor	Distance	Factor
Direct	345	1.00	828	1.00	1500	1.00	1360	1.00
Aircraft	410	1.19	1047	1.26	1685	1.12	1529	1.12
Train	472	**1.37**	1222	**1.48**	2288	**1.53**	2327	**1.71**

Source: Infras, *External Costs of Corridors*, Zürich 2002

AMS-LHR

As the crow flies: 360 km

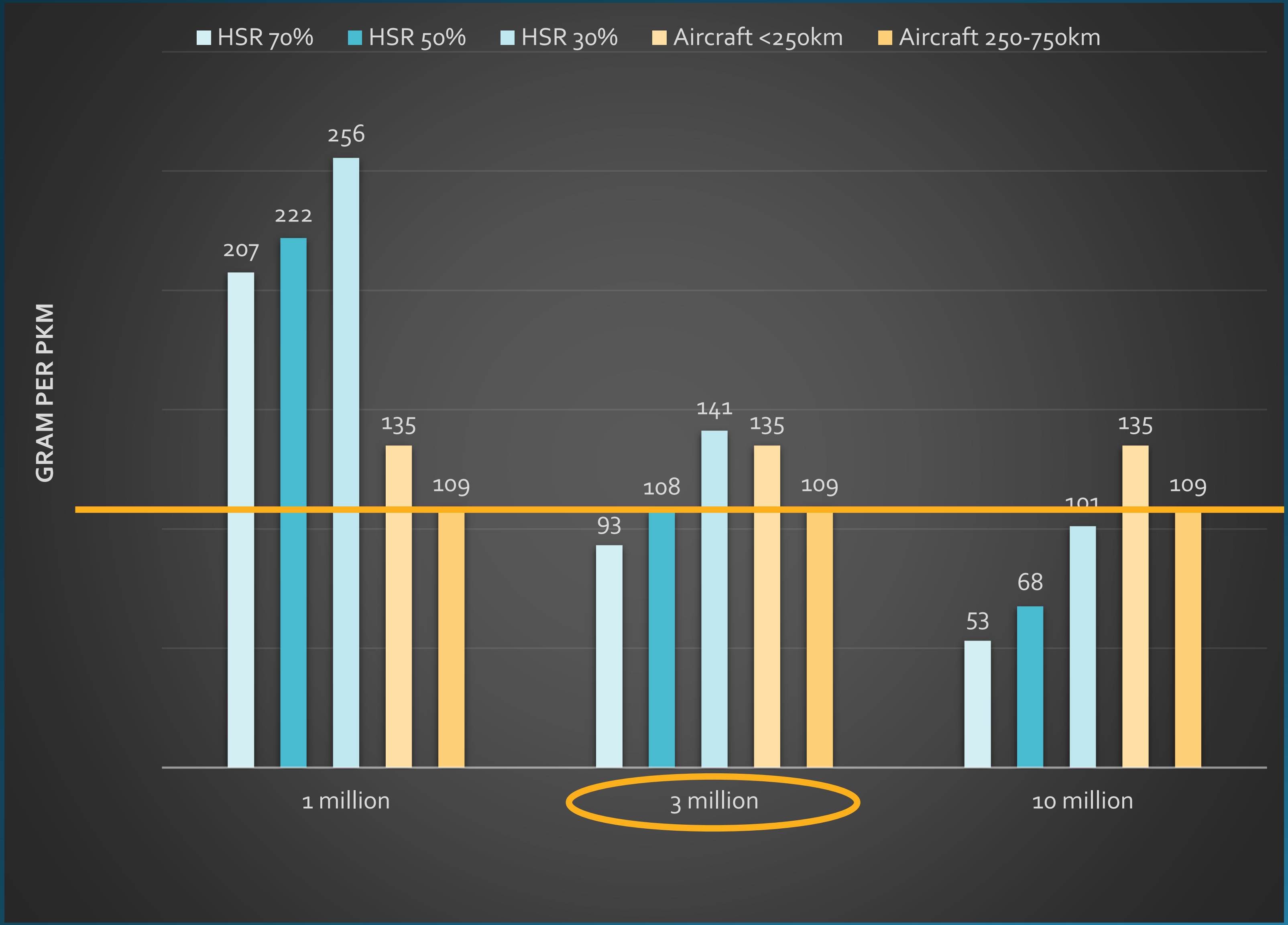
Aircraft: 396 km (+10%)

HSR: 540 km (+50%)

Due to geographical circumstances and/or connections to existing routes, trains often must make significant detours, and this detour factor influences the final performance. For HSR we use an average factor of 1.35 and for aircraft 1.15.

Note: The aircraft detour is usually caused by airspace reserved for military use and can in theory be easily reduced. In practice, this has been not very successful. A second factor is the need to fly around an airport to take off and land into the wind as much as possible. This factor obviously influences very short flights more than longer ones.

Infrastructure and Detour included



As explained on the previous page, in this graphic a mark-up of 15% has been applied for aircraft and a mark-up of 35% for HSR.

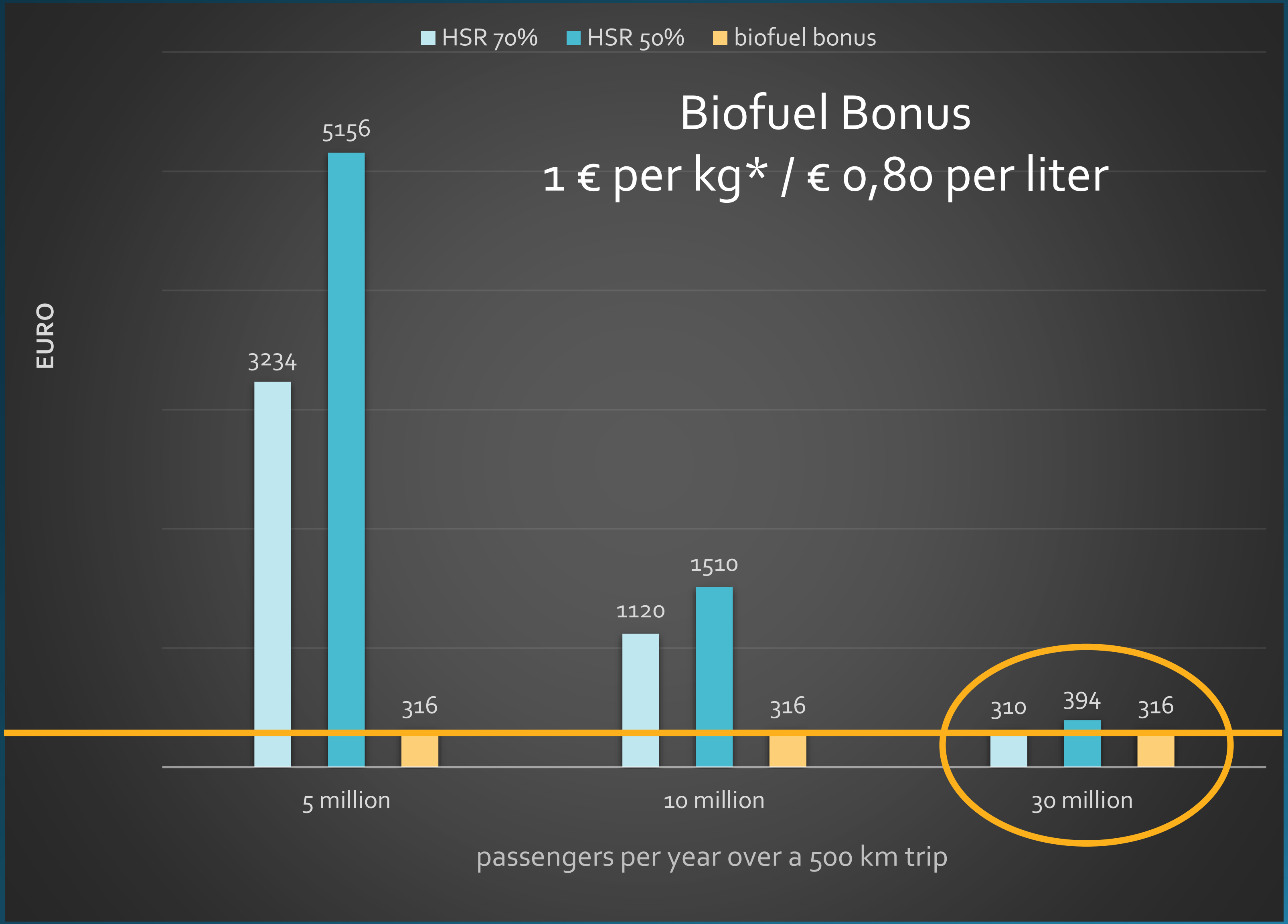
So, with a traffic volume of one million or less passengers per year aircraft always perform better, even by a lot, than HSR.

For an average load factor of 50% and with distances greater than 250 km, the tipping point for emissions per passenger is three million passengers per year*.

However, at that point the cost per ton of emissions avoided is extremely high. So let us have a look at the cost-effectiveness.

* See the post 'HSR-sydrome' for more information about the sources and the calculations used for the train versus plane graphs.

Cost per ton CO_2-avoided per year



At the average load factor of 50%, the cost at the tipping point of three million passengers is of course astronomical. But even with five million passengers it amounts to at least 5000 euro per ton avoided.

Even with ten million passengers per year the cost, at 1510 euro per ton, will still be a multiple of the cost of promoting the production of biofuel. That plan would cost 316 euro per ton avoided.

Only from thirty million travelers onward will the cost per avoided ton be lower than the cost of the biofuel plan. You will find such high-volume routes in Japan and perhaps also in China, but for the time being not in Europe.

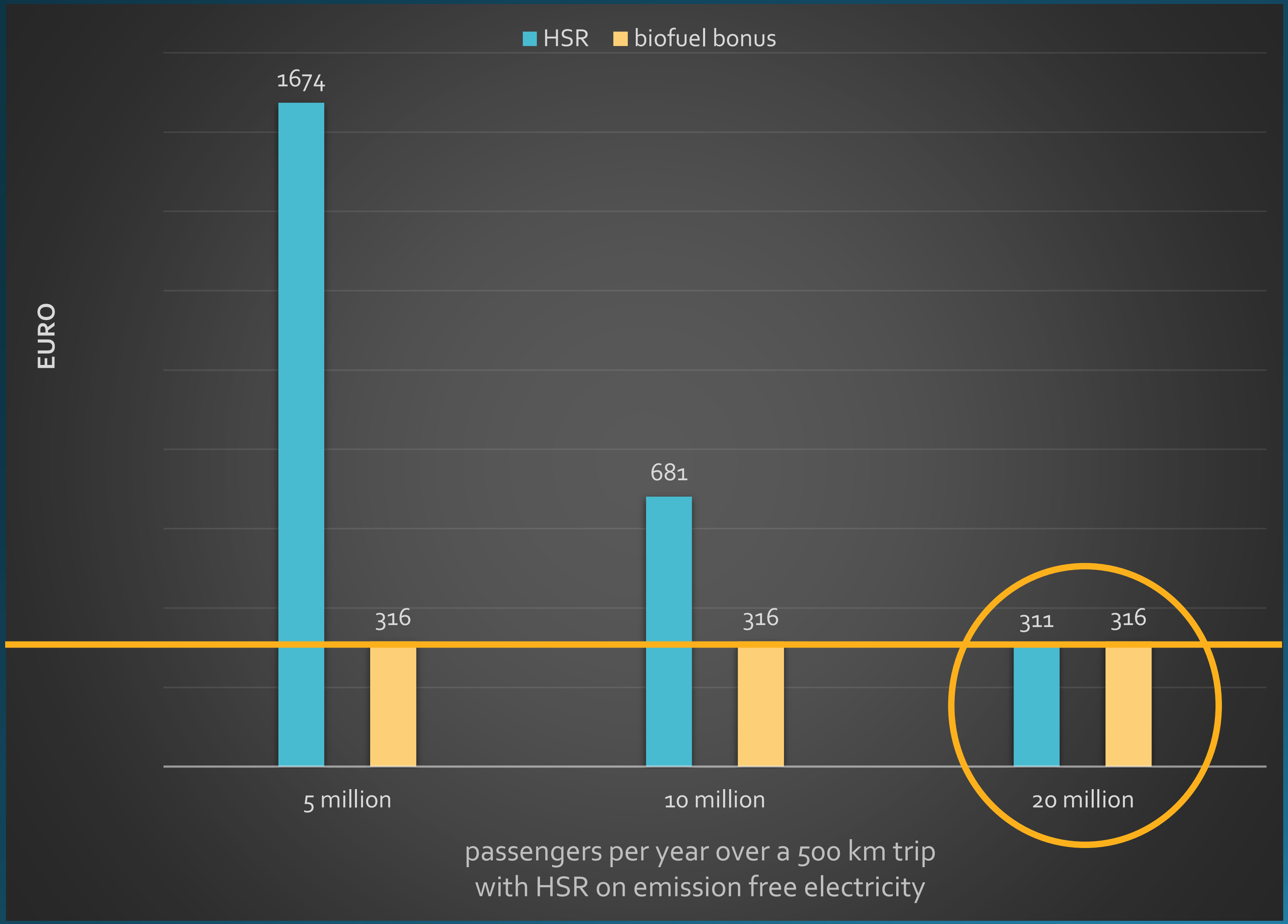
The plan for biofuel has another big advantage. The construction of HSR track can easily take fifteen years. The production of biofuel can start next week and will have an effect immediately.

Moreover, all fuel used for the entire European aviation sector could become biofuel, although that would need an area the size of about 7% of the land now in use for agriculture. While with HSR even the most optimistic potential is less than 4%.

At the moment about 50% of the EU electricity mix is emissions free, but the EU-objective is to make all electricity emission-free. On the next page we will look at the effect this has for trains versus planes, once that goal is reached.

* Aviation does not calculate fuel by volume but by weight because the energy content of a kilo is always the same. While a warm liter contains less energy than a cold one.

Cost per ton CO_2 avoided per year
with emission-free electricity



When in the future all electricity is generated emission-free, only the infrastructure will count. The load factor is then no longer relevant, because the embedded infrastructure emission is only relevant for the total traffic volume. It makes little difference whether the passengers are transported on almost full or almost empty zero-emission trains.

Calculations with this scenario show how dominant the infrastructure emission is. Because even then, flying will remain the better option in a great many cases in terms of cost per ton avoided. The tipping point will decrease from 30 million to 20 million passengers per year.

Using the more realistic cost of 50 million per kilometer shifts the tipping point for zero-emission electricity to 38 million travelers.

In that situation, depreciation over 60 years brings the tipping point to 25 million travelers per year. That volume is expected for the UK HS2, but few, if any, of the other proposed European HSL links even come close.

HSR can replace Aviation in a few cases only

- Climate Considerations:
  - at least **3 million passengers per year**
- Economic Considerations:
  - infrastructure cost
    - at least 25 million euro/km
    - viable from **9 million passengers per year**
  - cost per ton avoided
    - 5000 euro/ton with 5 million passengers per year
    - less than bio fuel from **25 million passengers per year**

Within Europe regular rail is often heavily subsidized. In the Netherlands for instance the train passenger pays only about 40% of the actual cost and on top of that the energy tax on the fuel for the powerplants that generate the electricity is basically zero.

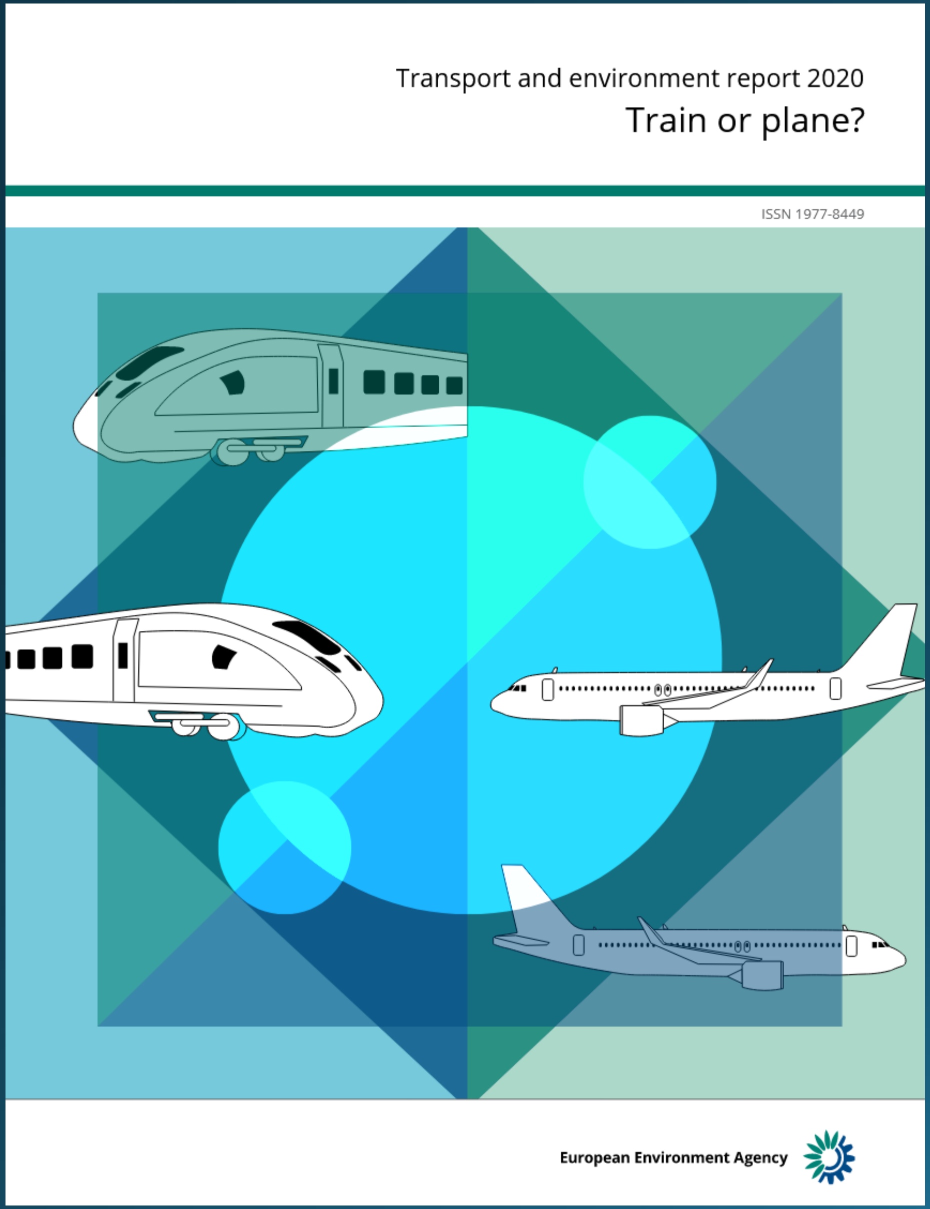
The same is true for HSR, perhaps even more so. The depreciation cost of the infrastructure of the Paris-London Eurostar route would be about 750 million euro per year*. With 10 million travelers per year (Eurostar, 2017) that would be € 75 per trip. Average income per ticket on the Eurostar is € 108.50 (year report 2012), so that would leave less than € 35 for the operational costs.

But that is just the economics of HSR. Climate benefits too will only result when several conditions are met. And they will then come at quite a high cost, given the cost of the infrastructure.

Still, that is a political decision, and we are free to choose that option. Although it would do no harm to look critically at the reports that analyze train versus plane issues. As will be shown on the next pages.

* London-Paris 472 km, of which 50 km Channel tunnel, cost 20 billion, and 422 km other track at 25 million/km, together over 30 billion. Depreciation in 40 years results in 750 million per year.

Most Studies disregard Infrastructure and Traffic Volume



In addition to activists, politicians too often state that substituting HSR for planes is a good idea.

Unfortunately, those politicians also do this on the basis of incomplete reports. See the screenshot on the right, taken from the first page of the Executive Summary of the report shown on the left, produced by the European Environment Agency.

> higher than for rail and air travel. On account of a lack of comparable data, the emission costs related to the manufacturing of trains, planes and cars, their maintenance and scrapping, and the construction and maintenance of the transport infrastructure are not covered in the calculations. Hence, the scope is a well-to-wheel/wake analysis, rather than a life cycle analysis.

It is helpful that the European Environmental Agency already states on the first page of the Executive Summary that emissions from the construction and maintenance of the necessary infrastructure are not included. This saves policy makers the trouble of reading the remaining more than one hundred pages. Because this report is useless if you want to know in what situations it is good policy to build more HSR-track. This report is only useful for framing.

Unfortunately, there is a good chance that a policy maker will not realize the importance of this omission, because it is stated rather casually. In the report itself this comment appears only once, on page 48, and there too in passing, surrounded by a large amount of figures and graphs. Furthermore, the motivation not to include infrastructure -lack of data- comes as a bit of a surprise. The data are obviously available. They are even mentioned in the report, on page 35, albeit somewhat casually here as well:

> of Railways (UIC) by Baron et al. (2011) finds that the carbon footprint of the construction of HSR lines ranges from 96 to 270 t CO_2 per km of track per year. For the HSR project in the Basque Country in Spain, a recent study by Bueno et al. (2017) found a footprint of 251 t CO_2 per km of track per year, which is at the high end of this range. This is due to the high number of tunnels and viaducts that are needed for the line.

The important thing is, this illustrates how important the number of passengers per year really is. Because with one million passengers you are talking about 250 gr CO_2 per pkm for the HSR in the Basque Country, for example. Only for the infrastructure. And with three million that is still more than 80 grams. This second omission, however common it may be among activists, is also quite surprising. Because those passenger numbers are available as well. See the following pages.

Most Studies disregard Infrastructure and Traffic Volume

								air pax (million)	rail pax (million)
Car distance of up to 500 km									
1	Krakow, Poland	Warsaw, Poland	Wieliczka, Poland	Piaseczno, Poland	293	284	High	0.398	
2	Brussels, Belgium	Frankfurt am Main, Germany	Leuven, Belgium	Wiesbaden, Germany	398	366	Medium (transfers/ hour)	0.882	0.09-0.115 (CER)
3	Sofia, Bulgaria	Varna, Bulgaria	Pernik, Bulgaria	Novi Pazar, Bulgaria	441	387	Low	0.288	
4	Bucharest, Romania	Cluj-Napoca, Romania	Ploiești, Romania	Turda, Romania	453	346	Low	0.490	
5	Lyon, France	Paris, France	Saint-Étienne, France	Versailles, France	468	463	High	0.641	3.4 (T&E)
6	Frankfurt am Main, Germany	Hamburg, Germany	Wiesbaden, Germany	Lüneburg, Germany	492	488	High	1.439	1.2 (CER)
7	Athens, Greece	Thessaloniki, Greece	Thebes, Greece	Edessa, Greece	500	368	Medium	1.512	
Car distance of between 500 and 750 km									
8	Amsterdam, Netherlands	Paris, France	Utrecht, Netherlands	Versailles, France	516	467	High	1.403	2 (KiM)
9	Oslo, Norway	Stockholm, Sweden	Drammen, Norway	Ösmo, Sweden	522	426	Medium	1.449	
10	Madrid, Spain	Barcelona, Spain	Guadalajara, Spain	Sabadell, Spain	625	545	High	2.468	3.9 (T&E)
11	Madrid, Spain	Lisbon, Portugal	Guadalajara, Spain	Setúbal, Portugal	629	583	Low	1.518	
12	Copenhagen, Denmark	Stockholm, Sweden	Roskilde, Denmark	Ösmo, Sweden	657	550	Low (transfers/ hour)	1.511	
13	Berlin, Germany	Vienna, Austria	Potsdam, Germany	Sankt Pölten, Austria	685	603	Low	1.051	0.02-0.05 (CER)
14	Vienna, Austria	Zurich, Switzerland	Sankt Pölten, Austria	Zug, Switzerland	722	655	Medium	0.982	0.161 (2019) (CER)

This table is from page 50 of the report.

Even if you add up all air and train passengers for a certain city-pair, you come nowhere close to the nine million travelers per year that the European Court of Auditors considers necessary for a viable HSR connection.

Only three city-pairs top the three million mark and these three already have an HSR connection. Which therefore should not have been built, if saving emissions were the only driving factor. Which it probably wasn't and now that they are built they should of course be used as much as possible, because with over three million passengers they do save on emissions

All other city-pairs in this table stay under three million, so building HSR-track for these would lead to more instead of less emissions.

The question whether there are other city-pairs where it would make sense to connect these pairs with HSR-track to reduce CO_2-emissions is also answered in the report. For those who want to see it that is. As will be shown on the next page.

Most Studies disregard Infrastructure and Traffic Volume

Table 2.1 Top 10 airport pairs for intra-EU air transport, EU-27, 2018

	Passengers carried (× 1 000)
Madrid/Barajas-Barcelona	2 467.8
Frankfurt (Main)-Berlin/Tegel	2 292.6
Toulouse/Blagnac-Paris/Orly	2 282.4
Paris/Orly-Nice/Côte d'Azur	2 144.6
Palma-Barcelona	2 035.7
Berlin/Tegel-Munich	1 985.3
Catania/Fontanarossa-Rome/Fiumicino	1 980.6
Palma-Madrid/Barajas	1 967.3
Munich-Hamburg	1 745.7
Palermo/Punta Raisi-Rome/Fiumicino	1 666.9

Note: Passengers arriving and departing from first named airport.

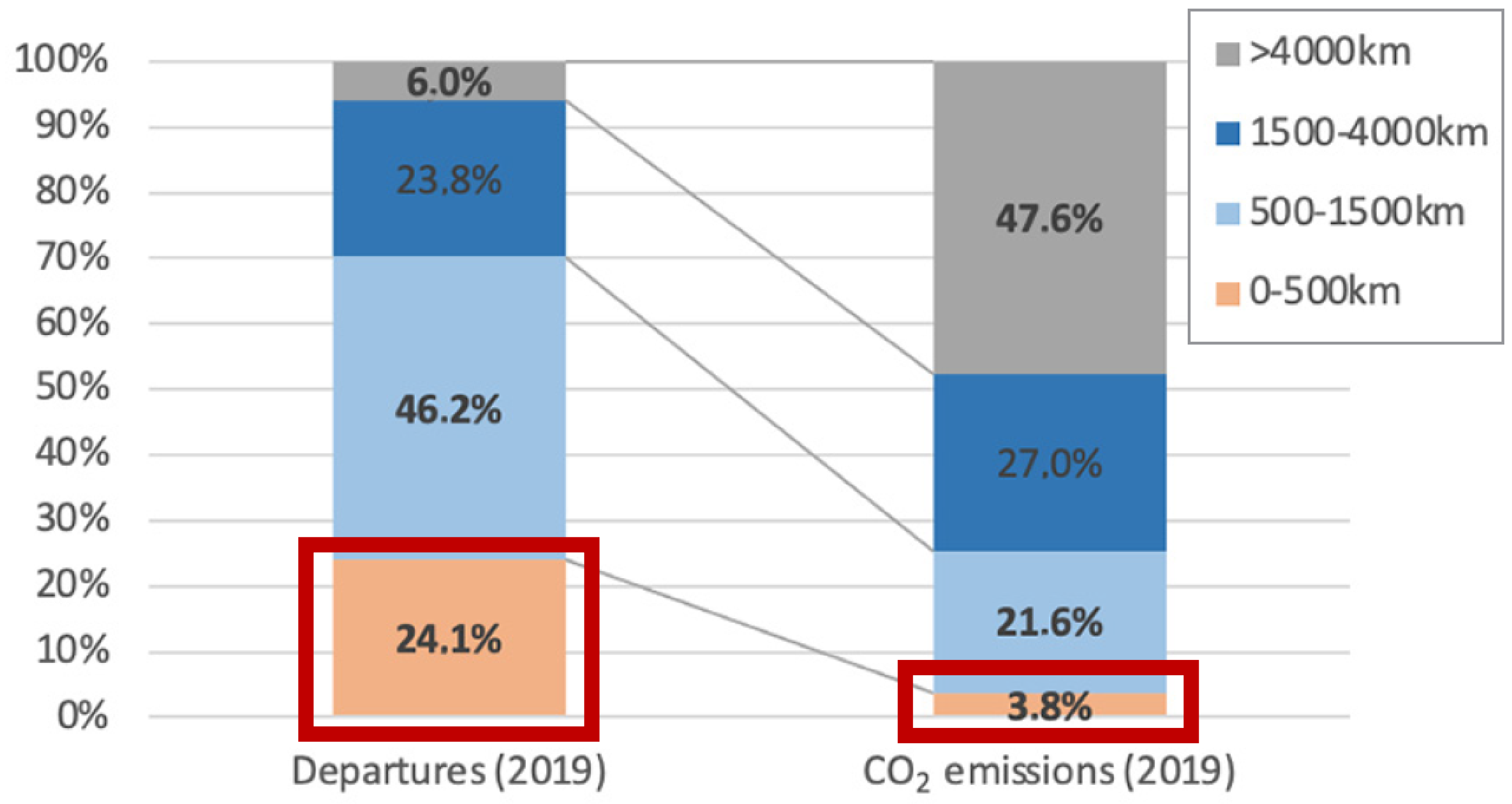
The top ten city-pairs , ranked by the number of air passengers, contains no pairs that top the three million passengers mark. See the table opposite, which, although printed slightly smaller, can be found on page 16 of the report. And of course all European city-pairs below the top ten do not even reach 1.7 million.

This means that, from a climate point of view, there is no justification for the proposed EU policy to replace all flights shorter than 500 km with HSR.

On top of that, the impact of such a policy on aviation emissions, even if it were effective, would be very limited. See the next page. Which illustrates once again how strange the focus on swapping trains for planes is when looking for effective climate action. The effort and funding involved could be put to much greater use.

Problem with Option 3: Scope Extremely Limited

FIGURE 2: % OF FLIGHT VERSUS CO_2 EMISSIONS IN 2019



Source: EUROCONTROL

Even if -disregarding the cost- all flights shorter than 500 km would be replaced by high-speed rail the effect would still be very limited.

Although this would get rid of almost 25% of the intra-European flights, it would prevent less than 4% of the total European aviation emissions, or less than 0.2% of the total European emissions.

So for the majority of flights only option 4 remains: energy transition, so alternative fuel.

Once this is accomplished it would be easy as well as cost effective to use alternative fuel for short-haul flights too. Certainly more effective than building high-speed rail no matter what.

Warning for Option 3

"In the most favorable case for HSR, when it manages to attract a large volume of traffic away from the airplane, it turns out to be an extremely expensive way of achieving only modest reductions of emissions. (…) The concerns raised by these results (…) are multiplied if we take into account the fact that the enormous use of public resources to finance high-speed rail projects comes with a very high opportunity cost."

Source: Daniel Albalate and Germa Bel, *The Economics and Politics of High-Speed Rail: Lessons from Experiences Abroad*, Lexington Books, 2012, p. 110-111

Of course, once the infrastructure is constructed, it is no longer relevant if that was a good idea or not. In both cases it makes sense to use it as much as possible to spread both the embedded emissions and the capital cost of the construction over as many passengers as possible.

Option 4: Energy Transition

- Electricity: storage too heavy
- Hydrogen: volume too large
- Biofuel / E-fuel: cost too high

Biofuel: possible right now

E-fuel: once all electricity is emission-free – 2040?

Aviation has to overcome more obstacles than other domains to become sustainable. For the same amount of energy, batteries weigh forty times as much as jet fuel and for long flights fuel already accounts for a quarter and sometimes even a third of the maximum take-off weight. You cannot increase that maximum weight either because that would kill the high efficiency of flying.

In terms of weight, hydrogen is possible. Its weight is one third of the weight of jet fuel for the same amount of energy. But with hydrogen the volume is a problem: jet fuel provides 36,000 kJ per liter, hydrogen only 10 kJ. Pressurizing helps, but even at 700 bar it's still not more than 5,000 kJ per liter. Liquefaction is also possible, but then you have to cool it to 253 °C below zero and even then, you only get 8,500 kJ per liter. For smaller planes and short distances, say up to 500 km, it is an option. A lot still needs to be developed for this to happen, and suitable aircraft will not be available on any scale much earlier than 2040.

The only real alternatives to jet fuel are synthetic kerosene, to be made, for the time being, when electricity from sun, wind, water or nuclear power plants cannot be used due to a lack of demand, and bio-kerosene from algae or Miscanthus (elephant grass).

Of the latter, both are technically possible and, unlike palm oil or Jatropha, they do not compete with food or forests, because salt or brackish water basins can also be used in the case of algae and poor soil in the case of Miscanthus. An area of a size less than Ireland would cover the needs of all of European aviation.

The problem for both biofuel and e-fuel is the cost. Biofuel for instance is currently two to three times as expensive as fossil fuel. Also, for e-fuel is time a big problem, because you do need emission-free electricity to make it. But in the mean time biofuel would work, if that cost problem can be solved.

European problem with emission-free electricity

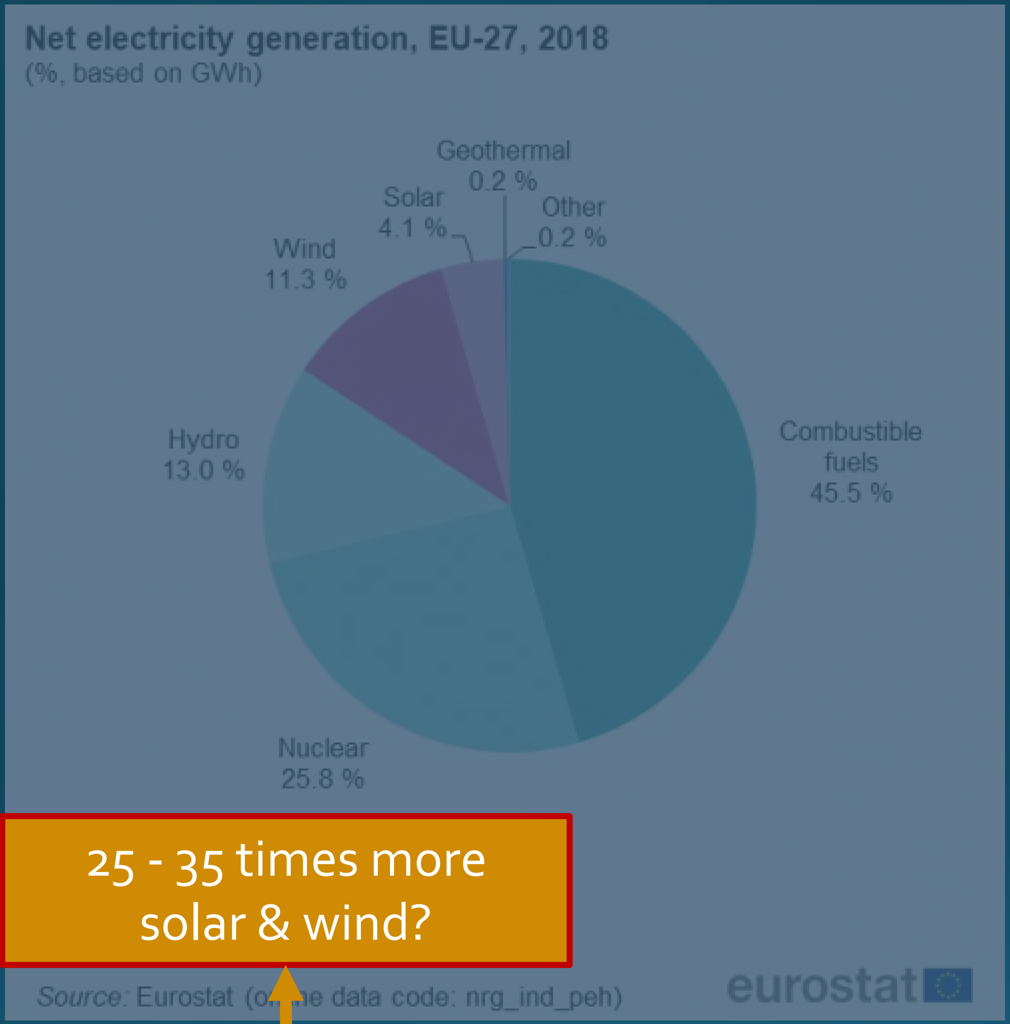
The EU uses 41,000 PJ of energy per year, 10,000 PJ of which is supplied by electricity.

55% of that electricity is now emission-free, of which 26% is provided by nuclear power plants and 13% by hydropower plants.

If we assume that the options for hydropower have all been used by now and that Germany's policy to stop nuclear energy becomes European policy, that means the installed capacity for solar and wind generation must increase sixfold to make all electricity emission-free.

And then at least five-fold again to be able to supply all energy via electricity, because for several applications electricity will first have to be converted into hydrogen and 20 to 30% of the energy will be lost in that process.

Twenty-five times more solar and wind energy seems difficult to achieve, not to mention the reliability of the supply. So, nuclear power plants seem inevitable.



electricity: emission-free: 55%

hydro: 13%
nuclear: 26%
solar & wind: 16%

5 - 6 times more solar & wind

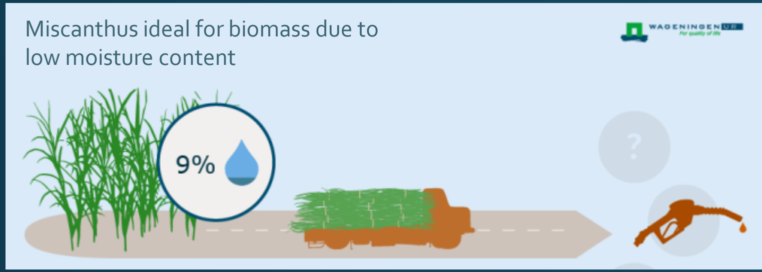
10,000 PJ
electricity

5 - 6 times

41,000 PJ
energy use

25 - 35 times more solar & wind?

Till at least 2040: Biofuel



All said, it will take quite some time before all electricity is generated emission-free and even longer before there are surpluses beyond direct use. Only then should electricity be used to structurally make hydrogen, because 20 to 30% of the energy is lost in the process.

If the need for hydrogen is covered, surplus hydrogen could then be used to make e-kerosene, a conversion in which again 20 to 30% of the energy is lost. Logically, aviation should therefore be the last in line when it comes to large-scale energy transition to e-fuel. But we do have to start now with small-scale development to validate and optimize the processes and to develop suitable aircraft.

Thus, for the time being, biofuel is really the only option. It is also feasible. With Miscanthus*, elephant grass, an area of 63,000 km^2 would cover the need of all of European aviation, 63 million tons of jet fuel per year. That is less than 7 % of the area currently in use for agriculture in the EU.

That may seem like a lot, but it's not impossible either. It will also not be necessary, because emission-free electricity will become available in the end. So, it makes sense to start with small projects.

For example, start with producing biofuel for all EU flights shorter than 500 km. The amount needed then is less than 4% of the total, so about 2.4 million tons, requiring an area of about 2400 to about 4500 km^2. Which is less than 0.4% of the European agriculture area. Even one large country like Spain might be able to accommodate that area. But smaller countries more northerly in Europe, like Belgium and the Netherlands, will also be able to produce all the biofuel needed for their own short distance flights. See the next page.

Of course, hydrogen would work too for distances of up to about 500 km, but most probably only after about 2040. Not just for the emission-free electricity to become available, but also because much development is still needed. But biofuel no longer needed for these flights can then be allocated to longer flights or other purposes.

*Miscanthus will grow on poor soil and needs little water. The yield is 18 (Netherlands and Belgium) tot 30 (Spain) dry tons per hectare per year and as the conversion rate is about 35% the kerosine yield is about 500 tons (NL, B) to 1000 tons (Spain) per km^2 per year.

Source: https://ciba-biojetfuel.com/application-examples-of-miscanthus-giganteus/

Only 300 km² needed for all Dutch flights < 500 km

- Province Groningen: area 2960 km²
    - agriculture now: 1880 km²
    - 100 km² for bio-fuel
    - 16 lots of 625 hectare
    - or 100 lots of 100 hectare

According to CBS, the Dutch Bureau for Statistics, 3,820,000 tons of kerosene were tanked in the Netherlands in 2019. If we assume the European average of 3.8% for flights shorter than 500 km, we arrive at 145,000 tons. With a low yield of 500 ton/ km² approximately 300 km² of Miscanthus is needed.

The Netherlands should be able accommodate those 300 km² easily and that would be a great energy-transition project. Divided between three agricultural provinces, for example Groningen, Noord-Brabant and Zeeland, this would amount to 100 km² per province, i.e. 10,000 hectares.

To give an impression of what this would mean, the map shows that contribution for Groningen, divided into sixteen plots of 625 hectares. But much more and therefore much smaller plots are also possible. Because of the bio-refinery that is under construction in Delfzijl, Groningen may be the most suitable province to start the project.

Focus would help and for this the first goal might be to produce enough biofuel for all flights of the government aircraft. A second goal could be to provide additional biofuel for all flights of the special Amsterdam-Strasbourg scheduled service. Perhaps even more interesting, as this service is for the almost exclusive benefit of MEPs and civil servants and is possible only because of EU-subsidies.

Problem with Biofuel

- Research and Development still necessary
- Oil & Gas companies will not pay
- Airlines can not pay
- Incentive via tax benefit not possible

It is clear what is not possible and also what will not deliver what is needed. The more interesting question is what options do we have that will work.

The solution lies in the fact that the EU wants to triple the present HSR network, which implies building 20,000 km of additional HSR-track, by 2030. That is not possible of course, as construction of track takes on average 18 years. Even if it would be possible to execute all plans it will probably be 2040 before all of them would be completed.

More interestingly however is the fact that there is apparently a lot of money available for this plan. Even using the low cost of 25 million per kilometer, the investment needed will exceed 500 billion euro. With depreciation over 40 years this amounts to 12.5 billion per year. If all flights within 500 km were to be replaced by HSR as a result, this would save less than 4% of the emissions from European aviation, which amounts to 7.5 Mt CO_2.

If we calculate for rail with emissions of 125 tons/km/year, also on the low side, we arrive at 2.5 Mt per year embedded emissions in the new HSR lines, so on balance a saving of 5 Mt. This brings the costs per ton of CO_2 avoided to more than 2500 euro. Compared with other climate initiatives this is steep. Heat pumps amount to 400 euro per ton avoided, offshore wind to 100 euro per ton avoided and nuclear power plants weigh in at 20 euro per ton avoided.

The fact that politicians in Europe are willing to pay so much for a ton of aviation CO_2 avoided is great news though. Because that means there is more than enough money available for an effective policy. As will become apparent on the next pages, such a policy would cost 316 euro per ton of emissions avoided. Less then heat pumps. Furthermore, of the available 12.5 billion per year 10 billion will remain available, for instance for improving rail connections.

Cost of new HSR-track

- Build **20,000 km** HSR-track by 2030
- Cost at 25 million per km: **500 billion** euro
- Depreciation over 40 years: **12.5 billion per year**
- Emissions of all flights < 500 km: 7.5 Mt per year
- Emissions of new track: at least 2.5 Mt per year
- **Maximum avoided 5 Mt**, cost **at least 2500 euro per ton**

This is the calculation of the minimum costs per saved ton of the intended policy, assuming that this policy would be effective. Which, to repeat, it definitely is not, as the conservative calculation on previous pages showed.

Furthermore, the construction of 20,000 km of HSL track will be far from sufficient to replace all flight connections shorter than 500 km, so the resulting saving will even be much less than 5 Mt.

Cost of Bio-bonus (1 euro per kg, 316 euro per ton of CO_2 avoided)

- All flights < 500 km: 7.5 Mt emissions avoided
- Bio-kerosine needed: 2.5 billion kg per year
- Bonus cost: 2.5 billion euro per year
- Available: 12.5 billion per year
- Remains 10 billion for upgrading present rail and/or building nuclear power plants

Perhaps most important, of the apparently available 12.5 billion per year, only 2.5 billion is needed to stimulate the development of bio-kerosene.

This means that 10 billion is still available for improving existing rail connections, something that the European Court of Auditors also advocates.

In addition, that money could also be spent very effectively on the construction of new nuclear power plants, the cost of which is 20 euros per ton of CO_2 saved.

Possible Six-Step Solution

1. Put a sustainability surcharge of 20 euros on all intra-European airline tickets.

2. Divide the proceeds among the network companies mentioned, with the condition that a maximum of half of that money may be used for research and development. The rest must be used for the purchase of biofuel that does not displace food production or nature.

3. This biofuel can be burned in any aircraft but is allocated to the shortest route without an HSR connection. For KLM that would be Amsterdam-Düsseldorf.

4. Give a bonus of 1 euro per kg from EU funds on the total annual consumption on that route as soon as that route runs entirely on the allocated biofuel. This bonus is initially awarded every year and may only be used for the purchase of biofuel.

5. The surplus of biofuel is allocated to the second shortest route and the process repeats.

6. When all flights in Europe shorter than 500 km run on biofuel, whether allocated or not, evaluate if the policy has a sufficiently stimulating effect or if it should be expanded to flights up to 750 km. Or if it can be ended.

Explanation

When it comes to sustainability, stimulating the development of the production of biofuel is much more promising, much cheaper, and very much faster than building more HSR-track.

The focus might be on the European network companies that are part of the three major world-wide alliances. So British Airways for Oneworld, Lufthansa for Star Alliance and KLM/Air France for Skyteam.

After all, flights to destinations outside Europe cause by far the most emissions and are mainly served by these networks. It therefore makes sense to make them responsible for the development of biofuel, including building the stable long-term relationship that offers producers of biomass and biorefineries the necessary security.

This six-step plan would significantly promote the development of biofuel due to the emerging market which can grow rapidly. In the Netherlands, for example, a collaboration could arise between Wageningen University for the development and improvement of feedstock and production methods, farmers for the actual growth, and biorefineries.

And that at relatively low cost. Achieving the savings of 7.5 Mt CO_2 takes a bit less then 2.5 billion kg biofuel. The cost for the EU would be about 2.5 billion euros per year, 316 euros per ton of emissions avoided. This should be acceptable, as it is less than the cost per ton avoided of the much-praised heat pumps.

The Options Evaluated

1. Fly less: **Climate effect small** economic and societal effect huge, climate effect might even be negative: deforestation, conflicts

2. Tax fuel: **No efficiency benefit** might decrease demand, but demand might move to modes worse for climate

3. More HSR-track: **Little effect, huge cost** only on busy and rather short routes, cost / benefit balance even then rather poor

4. Energy transition: **Way to go** biofuel/e-fuel: possible and feasible

Long-distance flights, however efficient aircraft are, may still constitute a sizable part of an individual's CO_2 footprint. But, as is shown, the argument to stop flying cannot be that aircraft are wasteful. On the contrary: they are almost magically efficient.

The political argument should be that, because of the individual footprint, mobility as such might need to be discouraged or limited. The debate should then be about the negative societal and possibly negative climate effects.

On medium-distance routes too the argument may not be the framing that aircraft are wasteful, because in many situations they outperform cars and HSR. The argument must be a careful cost/benefit analysis, not a gut reaction.

But hands down the best way to go, for climate, society, and the economy, is to develop sustainable fuel. That would really solve the problem of the aviation footprint. Although relatively small now in absolute terms, the footprint might indeed become relatively important in the future if and when emission cutbacks in other domains are successful.

Of the two options for an aviation energy transition, e-fuel is the long-term choice, because it must be made with electricity and therefore only becomes a solution when sufficient electricity is produced emission-free. That will certainly not be the case before 2040. So, develop the process now, but keep the scale limited. So, until at least 2040, biofuel is the option that should not only be developed, but also be implemented as quickly as possible. For example, by applying the six-step plan of the previous page.

A quick look at subsidies

- Aircraft:
  - passenger pays at lest 100% of the cost
- Regular train (Netherlands):
  - passenger pays 45% of the cost
- HSR:
  - no data available
  - educated guess is possible

The costs of flying are low and are paid in full by the passenger. Otherwise, the airline will soon go bankrupt.

In the Netherlands the regular train is subsidized for more than 50%, and there are good reasons for this.

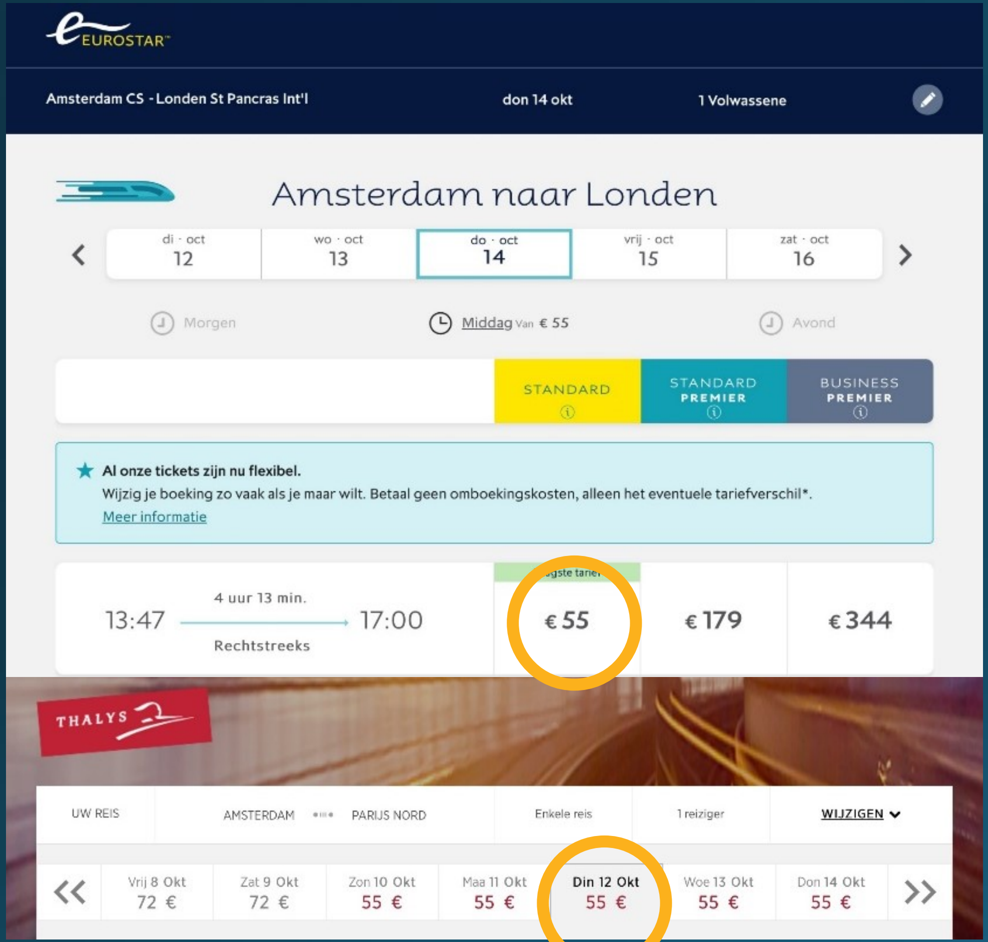
Little is known about the subsidies for the HSR. The EU Court of Auditors did indicate in their report that the prices for HSR were on average lower than the prices for flying on the routes examined.

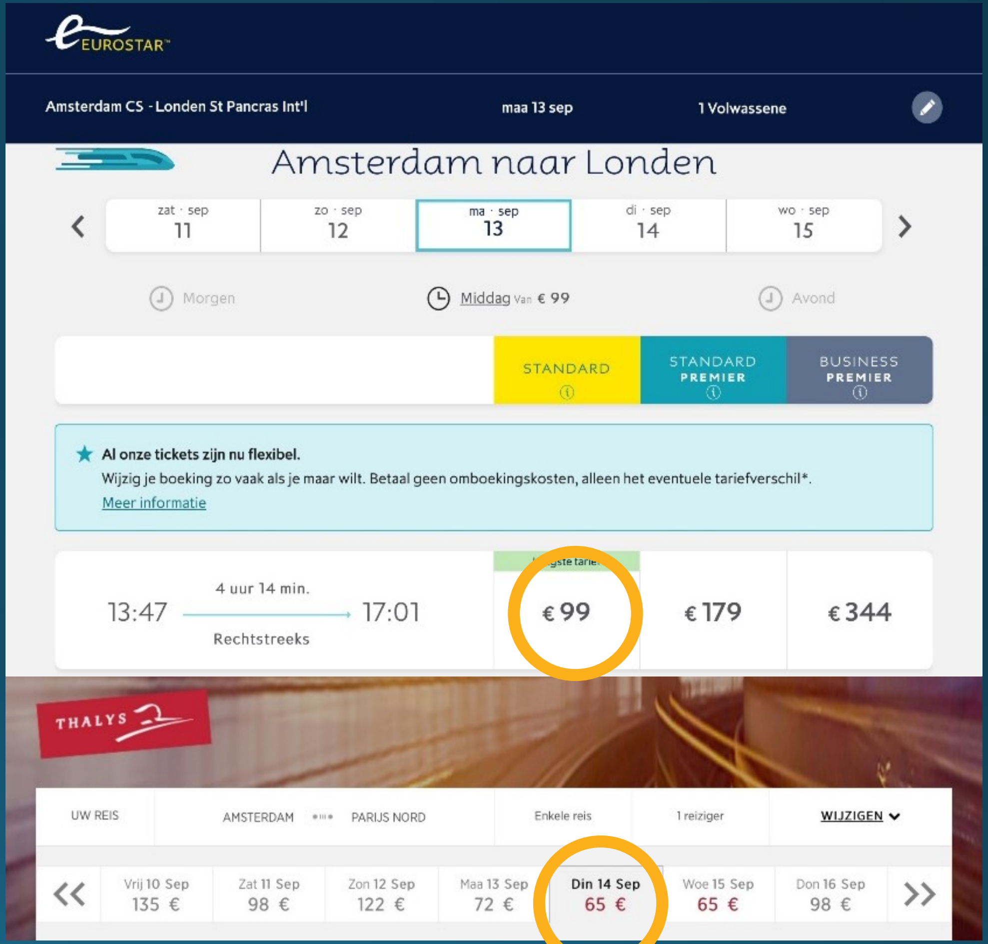
At least for those routes, this undermines the argument that the HSR cannot compete because aircraft tickets are cheap due to subsidies.

On the Munich-Stuttgart route, an HSR ticket was even cheaper than a ticket for the regular train, which confirms the impression that the HSR is heavily subsidized. Again, no problem, it's a political choice, but don't turn it around.

The amount of the subsidy for the HSR is of course greatly influenced by the number of travelers per year. The following pages show a quick exploration of at least the order of magnitude.

A quick look at subsidies





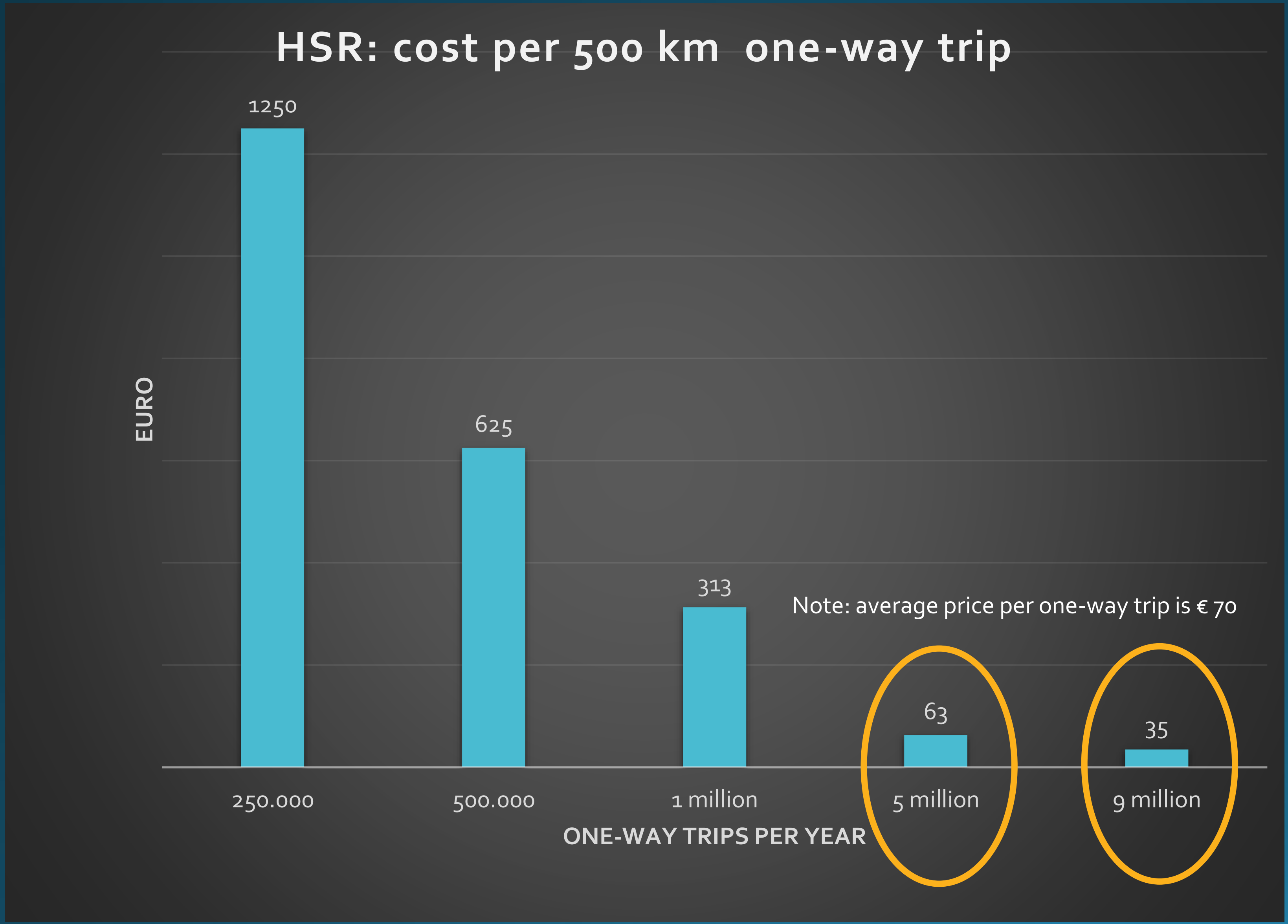
Early booking

Average for a one way ticket € 70

Late booking

This is of course only a very limited sample, but these are the prices found on September 10, 2021, for one-way tickets Amsterdam-London and Amsterdam-Paris with an early booking, one month in advance, and with a late booking, a few days before the travel date.

A quick look at subsidies



Up to at least one million one-way trips per year, the subsidy must be excessive when the average price of a single trip is around 70 euros. With 5 million trips per year the costs of the infrastructure are almost covered, but virtually nothing is left for the operational costs.

THE EU Court of Auditors arrives at 9 million travelers per year as the minimum for a viable HSR connection. In that case, 35 euros per trip would be available for the operational costs.

On the next pages we look at the other, and often mentioned, climate effects of flying.

Other climate effects (1)

In addition to CO_2-emissions, other factors can also have a climate effect. In aviation, contrails, the condensation trails, are often referred to in this context, as well as the height at which the emission takes place. For CO_2, with an average residence time in the atmosphere of about 200 years, the altitude does not matter. For the other factors, the influence is less clear-cut than the effect of CO_2-emissions, which only depend on the easy to calculate energy consumption. The scientific basis for the quantification of the other effects is therefore qualified by the EU as moderate to weak and the margins of uncertainty are large.

Contrails

Contrails, for example, only form when the air is already quite humid, so when a frontal system is approaching. With contrails, clouds are formed somewhat earlier than would otherwise be the case. In drier air, contrails disappear within minutes or do not format all. In addition, clouds have two effects: during the day they reflect solar radiation and so have a cooling effect on the lower atmosphere. At night they reflect radiated heat from the earth and cause warming. Warming appears to be predominant with contrails, but the overall effect is uncertain. The statement that you have to double or even triple the effect of CO_2-emissions from aviation to get the entire climate effect is therefore a bit fast.

Contrail live-span

In addition, contrails only have a short-term effect. If you stop flying today, the effect will be gone tomorrow. The effect is therefore of a completely different order than the effect of CO_2-emissions. Experiments are already underway to avoid the formation of contrails by choosing a lower flight altitude or a different route. That's fine, but you should not introduce this on a large scale yet. Because avoidance costs more fuel. Avoidance becomes an option only once the fuel is produced emission-free.

Other climate effects (2)

NO_x

NO_x-emissions are also complex. At low altitudes this is pollution, for example through deposition in nature reserves, but in the case of aviation this deposition is extremely small. Almost all NO_x is emitted at a higher altitude and it then has a climate effect. It reacts with other gases in the atmosphere. NO_x breaks down methane, which is beneficial because that is a very strong greenhouse gas. But in the process, ozone is formed. This is unfavorable for the climate, because ozone is also a greenhouse gas. Although that might help to keep the ozone hole (remember, from the aerosols?) small. The world is complicated. Moreover, it is not yet clear whether these processes on balance lead to warming or perhaps to cooling.

Relevance of other effects

Incidentally, the other effects are not particularly relevant for the issues we are looking at. The purpose of this document is to illustrate that, other than the framing suggests, aviation is very efficient and it is often truly the best choice from a climate point of view when people are flying now already. The extra effects mentioned mainly affect long distance flights, such as intercontinental traffic. And there the only alternative is passenger ships, which cause seven times higher emissions per passenger. So even if you double the climate effect per pkm of aircraft, it still makes no difference for the trade-off between aircraft and ships.

For continental routes, HSR is only an alternative for relatively short distances, up to 500 km according to the EU Court of Auditors. Aircraft then fly at a somewhat lower altitude and they stay at that altitude relatively short. The altitude effect, if that can be calculated at all, is then limited. Moreover, most flights at those distances take place in daytime, when the effect of contrails is cooling. In addition, if you include effects other than CO_2-emissions in aviation, you must of course also do the same for other sources of emissions.

Summary: Aviation is not the Big Bad Wolf

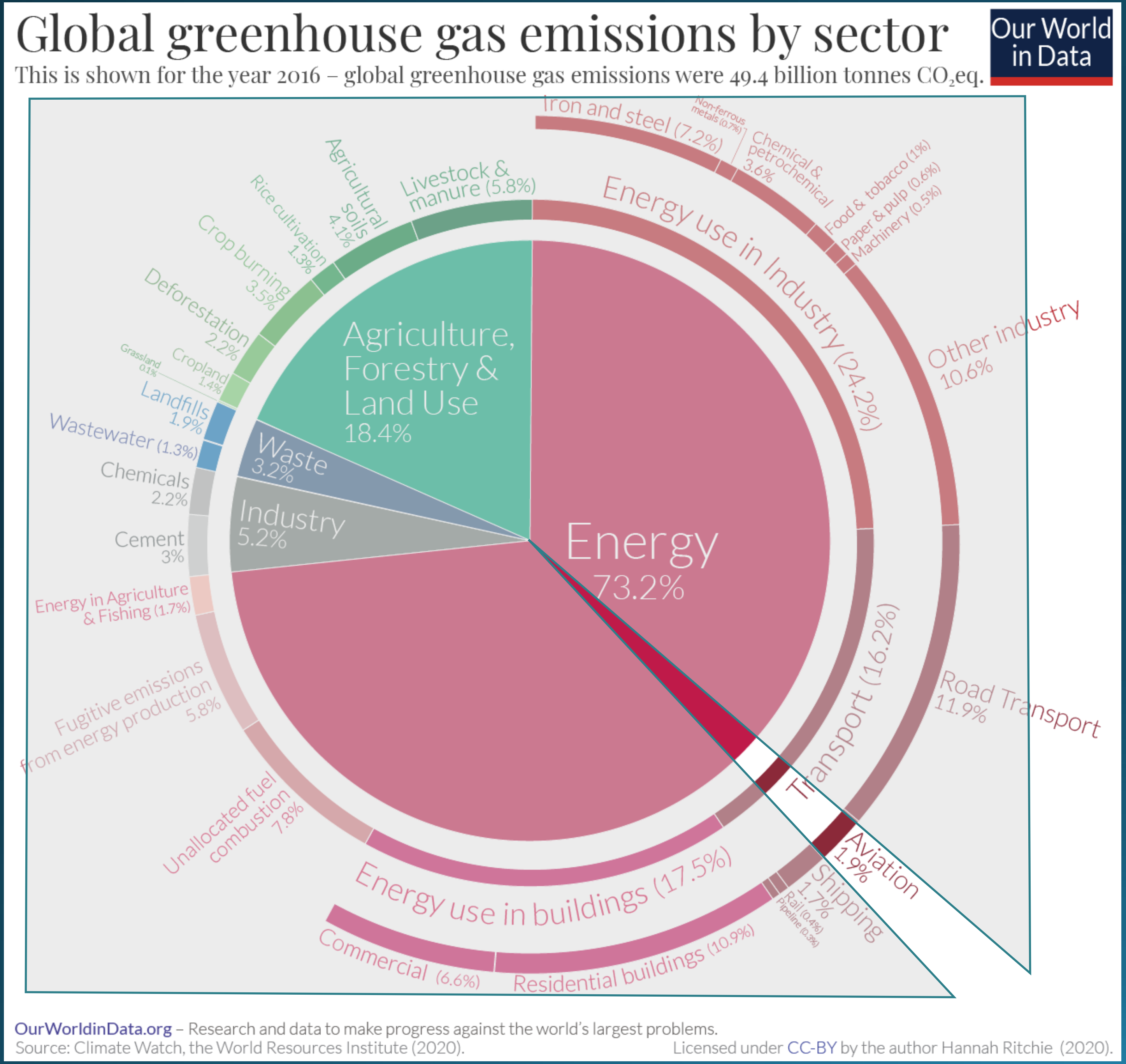
- Flying is extremely efficient
- Contribution is real but small
- Contribution will remain small
- Carbon neutral by 2055 is possible

Contrary to what the framing would have you believe, flying is an extremely efficient form of transport. Of course the contribution of aviation is real, and a long flight adds a considerable amount to a personal CO_2-emissions footprint.

But the total contribution is limited and will remain limited. Of course you can stop flying, but then the advantages and disadvantages must be analyzed. Not those for an individual, but the pros and cons for societies in general and for the planet as a whole. The statement that flying has to stop because aviation is the Big Bad Wolf in the world of climate change is in no sense true.

The incomprehensible focus on aviation also distracts from our real problem: how to generate sufficient amounts of emission-free electricity. When that problem is solved, the problem of aviation emissions is solved as well.

- **If we focus on emission-free electrical power generation**



Let's go back to this picture as a final illustration of the overriding importance of emission-free energy and the small role that aviation has in all of this.

Of course we have to solve the energy problem. The good news is that, if we succeed, the aviation problem will also be solved.

There is every indication that an energy transition is possible and with a successful transition to zero-emission energy, a new era will begin for humanity. This also applies to aviation.

In summary, we certainly don't have to be ashamed to fly. On the contrary. We can be extremely proud of the role that aviation has in society and the way in which this role is fulfilled.

The conquest of the skies is one of mankind's great achievements and aviation really does connect humanity. As the visionary pioneers of aviation hoped it would.


Flight Pride!
The Dawn of a New Age
Thank you
www.notthebigbadwolf.org