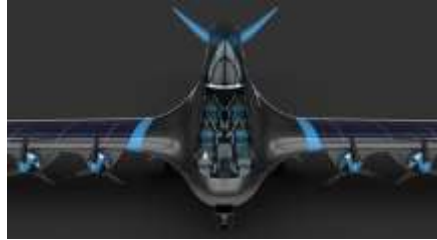


Green transport

Technology options



- 1. Introduction**
- 2. Electric cars**
- 3. Shipping**
- 4. Aviation**
- 5. Trains, buses & Trams**
- 6. Conclusions**



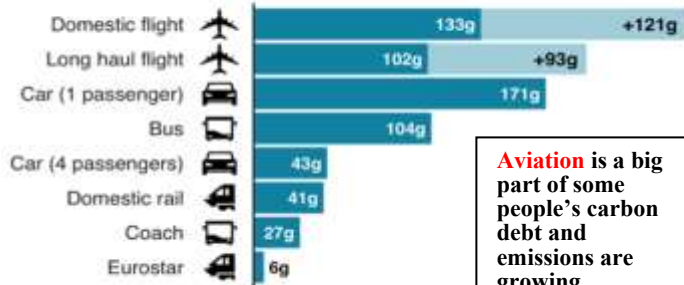
Dave Elliott

1. Transport a major energy user/CO₂ source

Emissions from different modes of transport

Emissions per passenger per km travelled

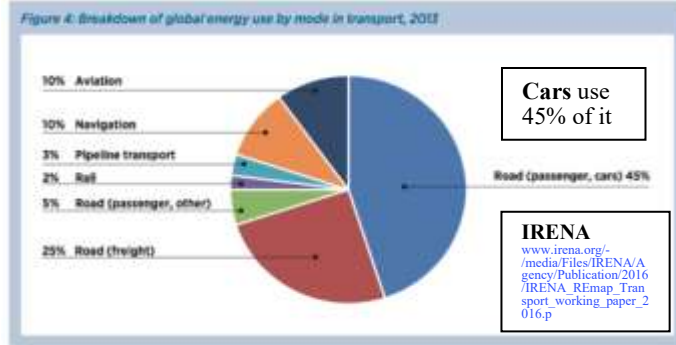
■ CO₂ emissions ■ Secondary effects from high altitude, non-CO₂ emissions



Aviation is a big part of some people's carbon debt and emissions are growing

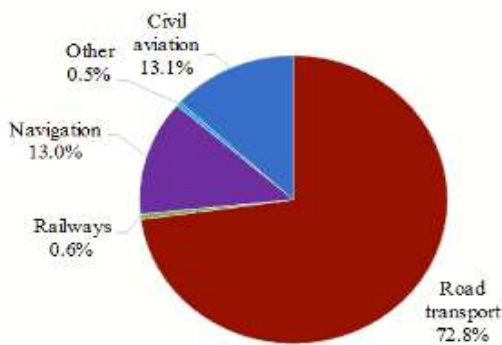
Note: Car refers to average diesel car

Source: BEIS/Defra Greenhouse Gas Conversion Factors 2019



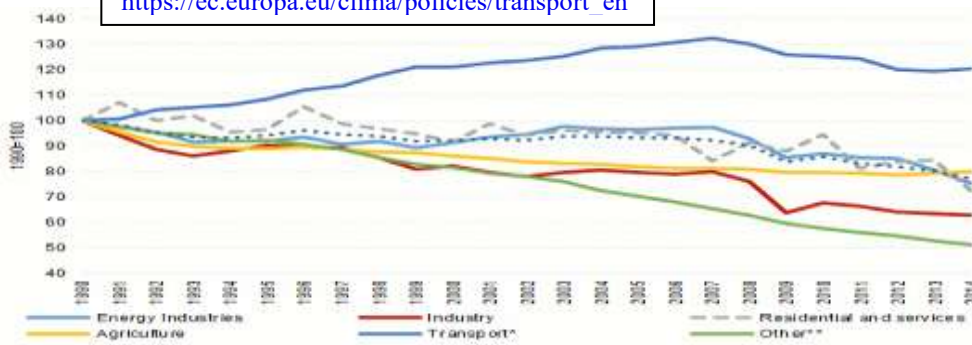
Cars use 45% of it

IRENA
www.irena.org/-/media/Files/IRENA/Agency/Publication/2016/IRENA_REmap_Transport_working_paper_2016.p



Emissions – mostly cars

https://ec.europa.eu/clima/policies/transport_en



Global Energy use

Aviation emissions

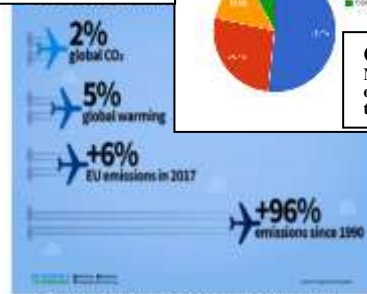
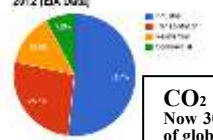


Figure 1: Global and European aviation growth

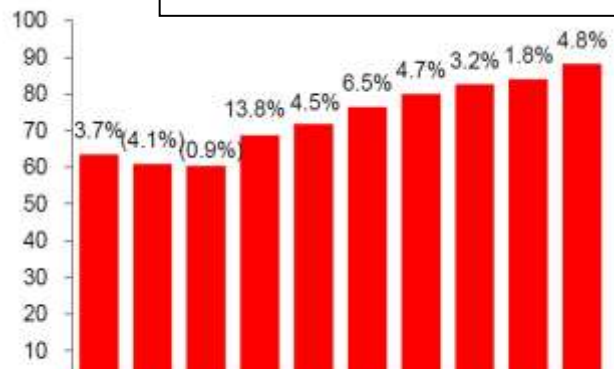
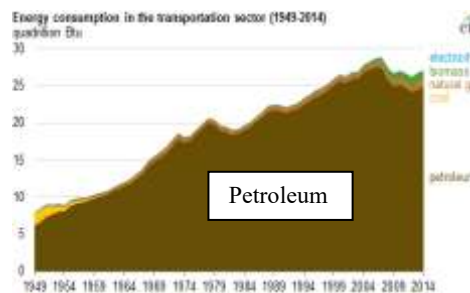
Energy use- 27%.

World Energy Consumption by Sector, 2012 (IEA Data)



CO₂ Now 30% of global total?

Flying is bad news, but cars are worse: most of us do a lot more driving...so that uses more energy in all and creates more CO₂...



Growth in car sales

Global CO₂ from Transport

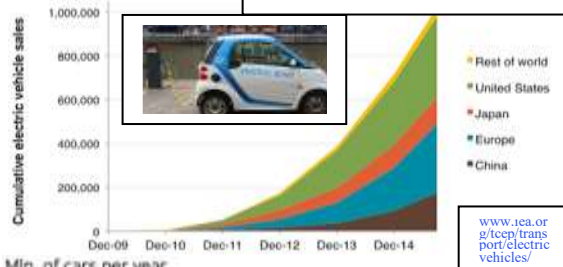
Road users 21%
Ships 3.2%
Planes 2%
Trains 0.3%
Legs 0%

2. Electric cars & beyond

EV History www.driving.co.uk/the-power-to-surprise/history-electric-car/



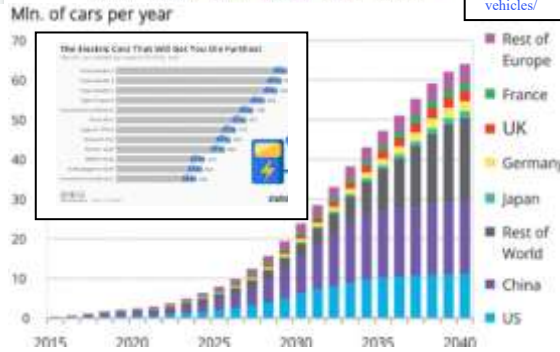
Toyota Prius - The Car Of The Future...Today



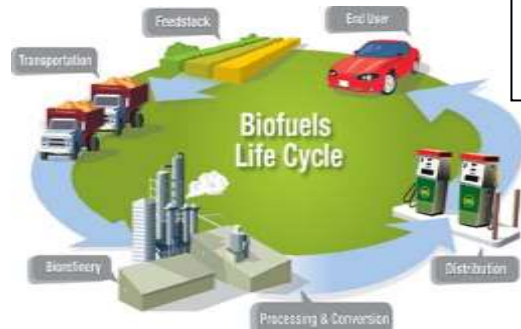
www.ica.org/cept/transport/electric-vehicles/

Problems with EVs

EVs do not reduce **road congestion** or the need for **parking space** or **more roads**. They are also *heavier* than conventional cars, so rubber-wheel-on-road **particulate pollution** can be higher. EV batteries need **lithium** which is not that abundant. Mining it can have major social & environmental implications. Other materials are also scarce.



Biofuels - a better idea?



Some EV **daytime charging** can be done at work or in retail outlet and train station car parks e.g. with solar canopies.

Safety

Lithium Ion batteries can catch fire. But so can **petrol**. **Hydrogen** is also inflammable, but lighter – the gas escape upwards. **Biofuels** may be safer



Energy is used in this cycle and the calorific value of some bio-crops is low
Bio-fuel eco-limits

Some countries have gone for biofuels in a big way. But biodiesel and bioethanol have eco-limits: vast areas of biomass plantation are needed. *A big fuel v food issue*
Biogas and biofuels from **bio-wastes** may be good for some uses (no new land used) e.g. SNG for trucks and vans, like CNG

Hydrogen cars



With **fuel cells** or **direct burn** There are conversion losses in fuel cells, but ranges may be higher.

What about solar cars?

Problem: there's not enough room on board to get sufficient power from **PV cells**.

At best they can be used to add some extra charge to EV batteries, increasing the cars range by maybe 20%. It's maybe easier to charge them when parked from *stationary* PV arrays e.g. solar canopies. But some car companies are having a go.

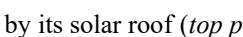
Toyota solar hybrid

It's claimed that if it is only driven four days a week for a maximum of 50km a day, it does not need to be plugged in anywhere..

Hyundai solar hybrid

The solar roof can charge 10% to 60% of the battery per day and with 6 hours of charging. It is claimed it will to increase the travel distance by an extra 1,300km *annually*.

Lightyear claim 12km/hr is added by its solar roof (*top pic*)



www.wired.co.uk/article/solar-cars-prius-toyota-lightyear-one

Self Driving Cars Would they reduce congestion e.g. with electronic e-cab hailing? They should reduce accidents and plot the most efficient routes, but not everyone trusts them yet... With **parking** now often costing more than fuel, there may be an incentive for autonomous cars just to cruise around waiting to be hailed.

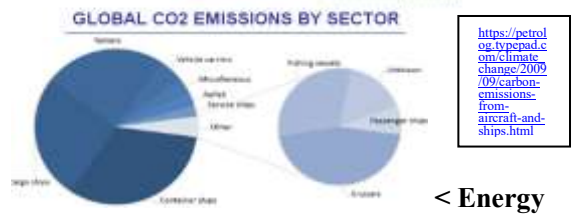
Some mixed messages then- on EVs and others: or just go for more SUVs!

www.newscientist.com/article/2197211-electric-cars-wont-shrink-emissions-enough-we-must-cut-travel-too/ v www.idtechex.com/emails/10878

3. Shipping



Of the total emissions globally, **road vehicles** generate about 21% (see left), but **shipping** is the next highest, at 3.3%, more than **aviation**. That's despite generating less than CO₂/tonne-km: see below. Although ships move on a near frictionless surface, and so are quite energy efficient, we shift a lot more stuff in them.



Passenger ships only represent a small share. **Acid gas (SO_x)** emissions are a key issue with marine diesel- it has a high sulphur content.



Alternative fuels
Some ships are using (and also transporting) **liquid natural gas (LNG)**, which is a bit cleaner than marine diesel - less soot. **Biofuel** mixes could be used instead- but that means more biomass plantations. **Green hydrogen** may be better. There are **nuclear** powered warships and ice-breakers. But let's not go there... **Wind power** may be an option- using kites for towing, flettner (Magnus effect) rotors, or modern wind sails, as below.



www.skysails.info/en/ and www.dnvgl.com/expert-story/maritime-impact/ECO-FLETTNER-rotor-sail-stands-the-test.html



The **Energy Observer** at one point tried using helical vertical axis rotors but then shifted to wind sails



It uses wind and solar PV to generate hydrogen that is then stored and used to power its propellers

Solar & wind powered ships may be a way off for mass use, though with a few exceptions: https://en.wikipedia.org/wiki/MS_Viking_Grace Meantime there are some fixes to cut emissions, but the big issue is why are we shifting all this stuff? Also, do we really need vast cruise liners? And messes like this: **A dirty fiddle?** <https://eandt.theiet.org/content/articles/2019/09/shipping-companies-install-cheat-devices-to-hide-sulphur-emissions/> and www.independent.co.uk/environment/shipping-pollution-sea-open-loop-scrubber-carbon-dioxide-environment-a9123181.htm **A better shipping future:** <https://grist.org/article/oslo-wants-to-build-the-worlds-first-zero-emissions-port>

4. Aviation - is green flying possible?

Aircraft emissions are a real problem and finding alternative fuels is not easy. The problem is *weight*. No alternative fuel has a high enough energy density. But **biofuels** are being developed. **Hydrogen** may be an option. Or even **batteries**. Or **PV solar!** Everyone is having a go at **biofuels**, including mustard seeds and algae, usually as additives to standard fuel. But if this lifts off in a big way it will mean *vast areas* of biofuel plantations. The use of biowastes might be a better idea –no new land taken.

Operational & technical fixes
www.iea.org/tecip/transport/aviation/



It is more expensive so far: www.iea.org/newsroom/news/2019/march/are-aviation-biofuels-ready-for-take-off.html

Electro fuels may be viable for short haul flights, with batteries charged when on the ground using green power. So far there are only small prototypes, like DLRs *HY4* four seater and Eviations *Alice*, able to fly with 9 passengers up to 650 miles at a cruise speed of 240 knots. But Airbus are developing a hybrid.



www.wbur.org/earthwhile/2019/08/08/cape-air-eviation-alice-electric-plane At least it ‘flying EVs’ should be a quieter option..

Hydrogen may be a better bet than batteries, using fuel cells, if it can be stored cryogenically or in metal hydride chemic-absorbed form. Otherwise it’s bulky. It might be easier to go for **dirigibles**, using hydrogen for lift as well as power. Then again, if you have large dirigible balloons, why not put **PV** on the top. China has done that. They can fly above the clouds- but *slowly*. There are also hybrid options with wing lift.



Niche market?

Large solar powered dirigibles for slow cruise ship-type holidays

The Chinese project was for very high altitudes: www.fastcompany.com/3052446/china-just-flew-this-gigantic-airship-to-the-edge-of-space
 The Solar ship hybrid is also for specialist use: rescue/remote access <http://sustainableskies.org/solar-ship-sells-four-inflatable-solar-airships/>

What about **solar powered aircraft?** That’s a way off at any scale. *Solar Impulse* did fly round the world, with night time stops. And there are some larger prototypes- a 2 seat *Sunseeker*, and a 6 seat concept.



<https://aroundtheworld.solarimpulse.com/adventure> Fine for fun and short hops: www.solar-flight.com/

Specialists high altitude telecom platform role www.cnbc.com/2018/08/09/airbus-solar-powered-aircraft-just-flew-for-26-days-straight.html
 But otherwise, maybe not just yet: www.wired.com/2013/04/solar-planes-are-cool-but-theyre-not-the-future-of-flight/

Why fly Not much of this look looks very promising in the short term, except perhaps for short-haul flights, though there may yet be break-throughs. See right for Singapore-based HES aviation’s *Element One* concept, using hydrogen fuel cells. Well maybe. But perhaps we should ask- why do we want to fly so much? For short to medium haul, high-speed train journeys can take no longer, in door-to-door time terms, than flying, and it’s more relaxing, with lower emissions.



For long haul, bio-synfuels/hydrogen may eventually prove viable, but wont be as cheap as untaxed kerosine!

Next? www.forbes.com/sites/jamesellsmoor/2019/03/07/innovation-takes-to-the-skies-electric-planes-are-about-to-revolutionize-the-airline-industry
 Not quite so optimistic: www.transportenvironment.org/sites/te/files/publications/2018_10_Aviation_decarbonisation_paper_final.pdf

5. Trains, buses and trams - and feet

Trains can be fast and have lower emission than aircraft, and are viable for short to medium distances. For shorter journeys there's hydrogen powered **buses** and local **trams**. Much better than cars in emission terms.



High speed trains and Maglev systems already exist and soon we may hyper-train systems – all of them are able to use green power picked up from the track, or syngas/hydrogen carried on board.

<https://theconversation.com/hydrogen-trains-are-coming-can-they-get-rid-of-diesel-for-good-110450>

For shorter journeys the humble **bus** is still very efficient and can be run on biogas or hydrogen with fuel cells



www.theguardian.com/uk-news/2019/may/10/london-to-have-world-first-hydrogen-powered-doubledecker-buses

Trams & light rail make more sense in urban areas- running on rails avoids tire/road surface particulate release



www.newpower.info/2019/03/tram-contract-win-for-robin-hood-energy Powered from rail or overhead contact, they can use green power



But another idea – flywheel trams

The flywheel is spun up to speed at each Tram stop – PV solar could be used on the top of tram stops to charge local batteries/capacitors for this power. See:

www.parrypeoplemovers.com

Back to the street car

Most cities in the EU, the Americas and Asia once had trams. Some still do. And there are campaigns for them to be reintroduced e.g.: <https://bathtrams.uk> and <https://bettertransport.org.uk/bettertrams>

Trolley buses have their merits - no need for rails. But they run on rubber wheels, so they are less efficient than trams



Monorail

It's all about infrastructure and that can be invasive and expensive. But then so are motorways.



Some worry about safety: www.bbc.co.uk/newsbeat/article/37949207/how-safe-are-trams-how-they-compare-to-buses-and-trains

Feet That's more of an issue with the most obvious alternative to trams or buses - **cycling**.

However, that's mostly to do with sharing roads and pavements with other traffic, including **pedestrians**. **Walking**, arguably the lowest carbon mobility option, maybe, should be given precedence over all else! We need to redesign cities accordingly, with separate cycle ways.

UK Links: www.bicycleassociation.org.uk/news-press/moving-the-nation/ and www.sustrans.org.uk/about-us/

Lots of issues: <https://researchbriefings.parliament.uk/ResearchBriefing/Summary/CDP-2019-0159> + www.peoplepoweredmovement.org

World links: www.worldcyclingalliance.org/who-we-are/about/ + www.worldwidecyclingatlas.com/initiatives/the-alliance-for-biking-and-walking



6. Conclusions

We can improve the efficiency of energy use in all transport sectors and switch to renewables in many of them, even for some flights, but we may need to curb transport demand in most sectors.

Efficiency gains can be valuable-better car design, better flight plan optimization, but that's still marginal. Using **green/electro fuels** helps. But we may need to change our transport expectations...and travel less, especially by plane.

Some worry that the bulk of our transport related energy may end up going to **flying** (orange) - as we squeeze oil out of car use.

Or that aviation will absorb all the green energy and biofuels denying its use in other sectors! A cuckoo in the nest. It doesn't have to be that way. But even IRENA could not say what will happen to aviation by 2030. Though it was optimistic about the other sectors.

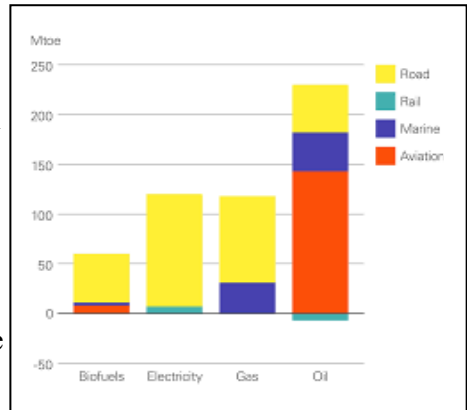
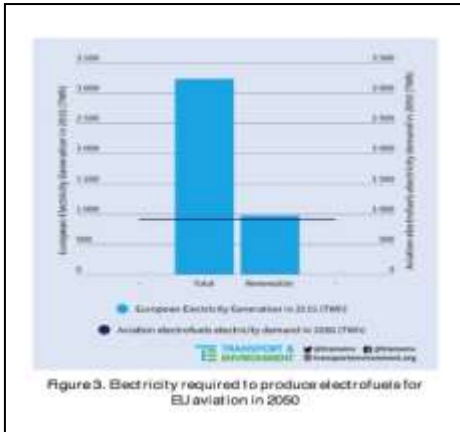
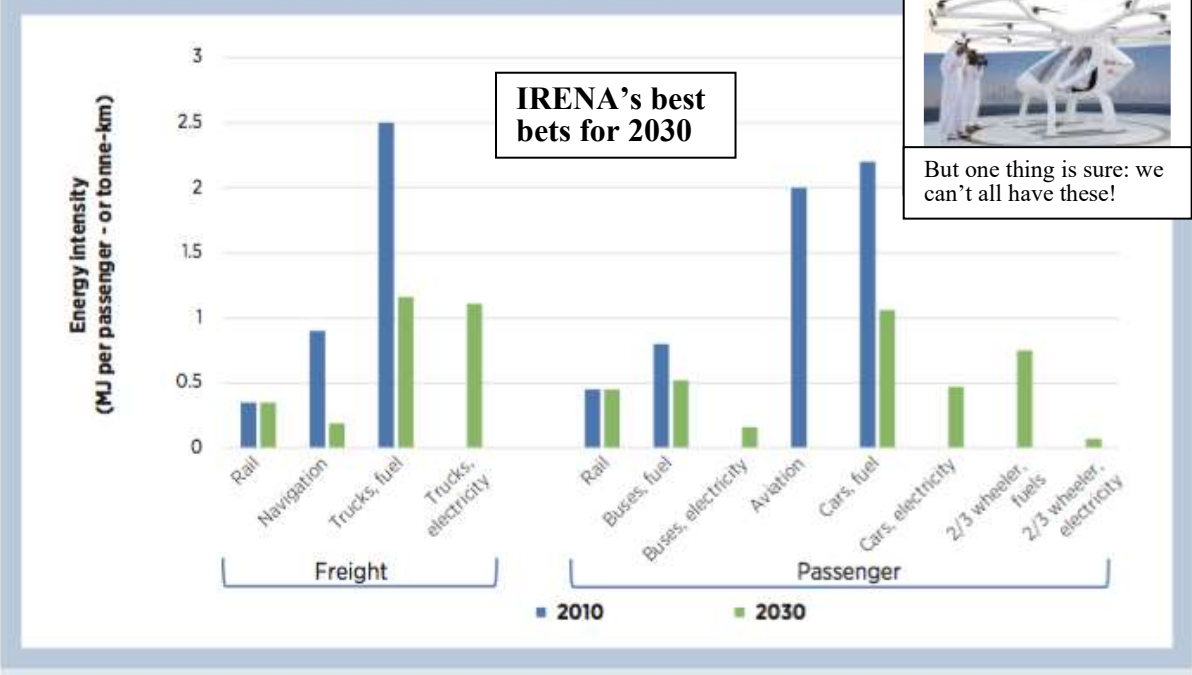


Figure 5: Energy intensity by transport mode, 2010 and 2030



International Renewable Energy Agency

www.irena.org//media/Files/IRENA/Agency/Publication/2016/IRENA_REmap_Transport_working_paper_2016.p

NATTA Network for Alternative Technology and Technology Assessment

Renewable energy technology and policy information service

<https://renewnatta.wordpress.com>

Jan 2020