Green transport
Technology options

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

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1. Transport a major energy user/CO₂ source

Emissions from different modes of transport

<table>
<thead>
<tr>
<th>Mode</th>
<th>CO₂ emissions</th>
<th>Secondary effects from high altitude, non-CO₂ emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic flight</td>
<td>133g</td>
<td>+121g</td>
</tr>
<tr>
<td>Long haul flight</td>
<td>102g</td>
<td>+93g</td>
</tr>
<tr>
<td>Car (1 passenger)</td>
<td>171g</td>
<td></td>
</tr>
<tr>
<td>Bus</td>
<td>104g</td>
<td></td>
</tr>
<tr>
<td>Car (4 passengers)</td>
<td>43g</td>
<td></td>
</tr>
<tr>
<td>Domestic rail</td>
<td>41g</td>
<td></td>
</tr>
<tr>
<td>Coach</td>
<td>27g</td>
<td></td>
</tr>
<tr>
<td>Eurostar</td>
<td>6g</td>
<td></td>
</tr>
</tbody>
</table>

Note: Car refers to average diesel car.

Source: BEIS/Defra Greenhouse Gas Conversion Factors 2019

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

Energy use - 27%...

Aviation emissions

CO₂: New 38% 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...

Petroleum

Global CO₂ from Transport

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

Emissions – mostly cars

Cars use 45% of it

IRENA

Growth in car sales

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

Global Energy use

Energy consumption in the transportation sector (1960-2016)
### 2. Electric cars & beyond

#### 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?

- **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 vs 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.

#### 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.

#### 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)*

#### 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.

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**EV prospects**

- EVs reduce emissions even taking account of the energy used making their batteries assuming they use green power for charging...if not there’s no real gain - CO2 is just emitted at the power station, not from the tailpipe.

- At present in the UK about 33% of the power on the grid is from renewable sources. That should grow to maybe 60% by 2030, near 100% by 2050. But if EV *uptake* continues to boom as expected, it will strain the grid to supply the power for charging. Maybe 10-20% more power will be needed mostly in the *early evening* when cars are at home. That could unbalance & drain the power system. There may have to be constraints on when you can charge your car after midnight? But this may help: **www.energyvoice.com/otherenergy/210921/new-battery-could-charge-electric-cars-in-ten-minutes-engineers-claim**

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

[More information on the image]


**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 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 (SOx) 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.

Solar & wind powered ships may be a way off for mass use, though with a few exceptions:

- Meantime there are some fixes to cut emissions, but the big issue is why are we shifting all this stuff? And also, do we really need vast cruise liners? And messes like this:


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.

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 chemi-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.

http://sustainableskies.org/solarplanes/ 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 won’t be as cheap as untaxed kerosine!

**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 Solarship 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 Sunseaker, and a 6 seat concept.


But otherwise, maybe not just yet: www.wired.com/2013/04/solar-planes-are-cool-but-theyre-not-the-future-of-flight/


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.

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

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

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

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 others traffic, including pedestrians. Walking, arguably the lowest carbon mobility option, maybe should be given precedent over all else! We need to redesign cities accordingly, with separate cycle ways.


World links: www.worldcyclingalliance.org/who-we-are/about/ + www.worldwidecyclingalliance.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 fight plan optimisation, but that’s still marginal. Using **green/electro fuels** helps. But we may need to change our transport expectation...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 cuckold 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.

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

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