

Can We Keep Flying? Decarbonising New Zealand's Domestic and International Aviation

Wallace Rae
Paul Callister

Working Paper 19/02

2019



Institute for Governance
and Policy Studies

A research institute of the School of Government

INSTITUTE FOR GOVERNANCE AND
POLICY STUDIES
WORKING PAPER
19/01

MONTH/YEAR

September 2019

AUTHORS

Wallace Rae
Paul Callister

INSTITUTE FOR GOVERNANCE AND
POLICY STUDIES

School of Government
Victoria University of Wellington
PO Box 600
Wellington 6140
New Zealand

For any queries relating to this working paper, please
contact igps@vuw.ac.nz

DISCLAIMER

The views, opinions, findings, and conclusions or
recommendations expressed in this paper are strictly
those of the authors. They do not necessarily reflect the
views of the Institute for Governance and Policy Studies,
the School of Government or Victoria University of
Wellington.

New Zealand should be pushing much harder on finding ways to do aviation more sustainably. Without the ability to fly in and out, New Zealand's got a problem. It's an existentially important thing and I'm not seeing the level of urgency and creativity around solutions. Is it biofuels? Is it synthetic fuels? Is it the electrification of your domestic aviation? Is it electrification of your ferries? Given the geographic location of New Zealand, I expected to see much more concern if you're trying to be net zero by 2050.

Energy expert Michael Liebreich in the Spinoff, 13th July 2019

Introduction

New Zealand is a long way from the world's large continents and most major population centres. Humans only recently reached our shores using winds and currents. Maori were the first to arrive followed by Europeans around 400 years later. Nowadays, almost all visitors to our remote Pacific islands arrive by aircraft.

Two of our largest export industries are dairying and tourism. Together they earn valuable income that supports New Zealand's relatively high standard of living. But both are significant contributors to greenhouse emissions.

There is a recognition in New Zealand of an urgent need to decarbonise our economy.¹ Reflecting this, the Zero Carbon Bill was introduced to Parliament in early May 2019. If passed into legislation, it aims to set a target of zero carbon emissions by 2050. Agriculture, especially the dairy industry, features prominently in climate change discussions in New Zealand. But articles on Stuff², The New Zealand Herald³ and The Otago Daily Times⁴ websites have now begun to highlight the significant impact of air travel on climate change. Eating less meat or giving up dairy products, catching the bus or driving an electric car can all help reduce both our personal and national carbon footprints. However, for New Zealanders a single economy class return trip to Europe elevates one person's carbon footprint by an estimated 6 tonnes⁵ according to one carbon calculator, 8 tonnes⁶ by another and over 11 tonnes⁷ by a third.⁸

¹ In this paper we focus primarily on carbon. But as will be discussed there are other important emissions from aviation.

² <https://www.stuff.co.nz/environment/climate-news/111873871/climate-change-is-an-auckland-professors-nofly-movement-beginning-to-soar>

³ https://www.nzherald.co.nz/travel/news/article.cfm?c_id=7&objectid=12221564

⁴ <https://www.odt.co.nz/lifestyle/resilient/trying-stay-grounded?fbclid=IwAR18kQkVxnsc9siAKkmsgZyZxzilqf7tBnCOBEfQU-tBOykB73qDmXH3opg>

⁵ <https://www.clevel.co.uk/flight-carbon-calculator/>

⁶ <https://calculators.enviro-mark.com/public?calculator=travel>

⁷ <https://www.atmosfair.de/en/offset/flight/>

⁸ If travelling first class, using the last calculator the figure rises to nearly 27 tonnes.

Given our place in the world, it should be no surprise that domestic aviation emissions are swamped by emissions from international flights in and out of New Zealand. These are the flights that bring tourists and business people to New Zealand and allow New Zealanders to explore the world, attend conferences and undertake business overseas. However, increasingly it is tourism which is the largest component of international travel, particularly in relation to New Zealand.

According to Tourism New Zealand, in 2018 total tourism expenditure was \$39.1 billion, an increase of 7.7 percent (\$2.8 billion) from the previous year.⁹ International tourism expenditure increased 9.6 percent (\$1.4 billion) to \$16.2 billion and contributed 20.6 percent to New Zealand's total exports of goods and services. Tourism generated a direct contribution to gross domestic product (GDP) of \$15.9 billion, or 6.1 percent of GDP.

Perhaps reflecting the importance of the industry, the tourism strategy produced by the government, also in May 2019, does not have climate change at its centre. Instead it has words such as 'sustainability' sprinkled through and avoids setting out a realistic plan for decarbonising the industry.¹⁰

In the introduction to the Tourism Strategy summary document it states

International visitor arrivals have grown by 43 percent in the last five years and spending by domestic visitors is also rising.

This increase in tourism growth is only expected to continue. Annual international arrivals are forecast to reach more than five million by 2024.

These projections are based on data put out by MBIE which suggests international tourism arrivals could increase from 3.9 million people in 2018 to 5.1 million by 2024. This is up from 2.8 million in 2005. Almost all will arrive and depart by air. While travel to and from Australia is popular, many are forecast to come from China and other places a long distance from New Zealand.

In a Biodiversity Strategy consultation by the Department of Conservation, beginning in August 2019, climate change is seen as a major threat. But while tourism is seen as placing pressure on our environment, continued growth in international arrivals is also assumed.¹¹

The New Zealand government also has a direct interest in aviation. As a majority shareholder in Air New Zealand, the government has an interest in solving this problem for an airline which

⁹ <https://www.tourismnewzealand.com/about/about-the-tourism-industry/>

¹⁰ <https://www.mbie.govt.nz/immigration-and-tourism/tourism/new-zealand-aotearoa-government-tourism-strategy/>

¹¹ <https://www.doc.govt.nz/globalassets/documents/conservation/protecting-and-restoring/biodiversity-discussion-document.pdf>

presents itself as sustainable.¹² However, due to network expansion in recent years its emissions have until recently been increasing.¹³ In May 2019 the company announced it would buy eight Boeing 787-10 Dreamliner long distance aircraft. These could be flying for the next two decades. In the press release the efficiency gains of the new craft was emphasised.¹⁴

During a subsequent interview Air New Zealand's CEO, Christopher Luxton, claimed a 25% fuel saving (over the 777-200 ER), but this gain in efficiency will depend on the number of seats sacrificed to extend the normal range of 11,900 km to 14,180 km by adding New York as a single flight destination.¹⁵ It is clear from this interview that there will be fewer seats in economy and more in the premium class. A claim was made that the airline would save the emission of 190,000 tons of carbon per year and become more sustainable, yet the airline is still expanding and extending its network to Taipei, New York, and Chicago. Borne out by the overlap of delivery dates, the 787-10 aircraft will be phased in from 2022 whereas the 777-200ER aircraft will not be phased out until 2025.

It is likely the Jevon paradox will be invoked – that is; *the increase in efficiency will encourage the airline to seek an increase in passenger capacity*. The result is very likely to be an increase in carbon emissions not a decrease.¹⁶

More significantly there was no mention of how fossil fuels will be amended or replaced with either biofuel or synthetic fuel. Despite some early experiments with biofuel, Air New Zealand's short term sustainability strategy relies heavily on efficiency gains and on promoting an ineffective voluntary carbon-offset scheme. Based on their own information sent out to Frequent Flyer members in early 2019, under 2% of their frequent flyers offset their flights through the Air New Zealand offset scheme. Long term plans are vague but depend on technological innovations.

Air New Zealand is also replacing some of its turboprop fleet.¹⁷ As of April 2019 it had 22 ATR72-600, with an average age of 3.1 years. Seven new ones are on order. Given the young age of these currently fossil fuel powered aircraft, Air New Zealand is likely to want to keep them flying to well beyond 2030.

If all aviation, both domestic and international, is included in New Zealand's carbon reduction targets we face a very significant challenge.

¹² <https://p-airnz.com/cms/assets/PDFs/2018-sustainability-report-exec-summary-report.pdf>

¹³ <https://www.airnewzealand.co.nz/sustainability-carbon-reduction-management>

¹⁴ <https://www.airnewzealand.co.nz/press-release-2019-airnz-announces-multi-billion-dollar-investment-in-new-fuel-efficient-boeing-787-10-dreamliners>

¹⁵ <https://www.newshub.co.nz/home/travel/2019/05/the-reasons-behind-air-new-zealand-s-decision-to-invest-in-boeing-s-787-10-dreamliner.html>

¹⁶ https://en.wikipedia.org/wiki/Jevons_paradox

¹⁷ <https://www.airnewzealand.com/fleet>

We also have another major challenge: that of dealing with our waste stream, including a considerable amount of difficult to recycle plastic. How is this related to aviation? As we will explore, one of the partial solutions to decarbonising New Zealand's aviation industry may also help us better deal with our waste.

Like Michael Liebreich, we believe that New Zealand urgently needs to develop a credible plan for decarbonising our aviation industry. In order to help further discussion around this issue we have produced this working paper. In this paper we focus primarily on air travel for people. Clearly airfreight is also very important for New Zealand whether it be importing goods or selling our products overseas.¹⁸ Many flights combine freight and passengers, but freight is not an area we have specifically researched. We also do not consider emissions from military-related aviation. We present some of our own 'back of the envelope' calculations but are conscious that more detailed investigation is needed.

We would like to thank Simon Millar of Pure Advantage for allowing us to re-use much of the material published on that website in July 2019.¹⁹ We have also drawn on material posted on New Zealand's Fly Less Kiwi Facebook page.²⁰

While this discussion focuses on New Zealand the issues are relevant to our Pacific Island neighbours, who are vulnerable to the effects of climate change but also depend heavily on aviation.

Finally, neither author is an aviation expert. However, as individuals concerned about climate change we consider it is important to generate debate about flying. We need others to take these discussions forward, refine the arguments, and more importantly determine the solutions.

¹⁸ Increasingly there is discussion in the media about food miles, including isolating out air miles
https://www.independent.co.uk/news/food-miles-carbon-footprints-climate-change-sustainability-a9050406.html?fbclid=IwAR231j35-5to88tyAWYd_8KUDdhjbh84RPyuz2q1r9oS3Rh4pyXWeWdibwA

¹⁹ <https://pureadvantage.org/news/2019/06/18/can-new-zealanders-keep-flying-while-reducing-their-carbon-footprint-1-3/>

²⁰ <https://www.facebook.com/groups/352684145282681/>

Our demographic makeup

We have already mentioned New Zealand's remote location. But our demographic mix also adds to the challenge of decarbonising aviation. Over recent decades the number of people living in New Zealand who were born overseas has continued to increase. In 2013, 1,001,787 people (25.2 percent) were born overseas, an increase of 303,159 people since the 2001 Census (19.5 percent).²¹

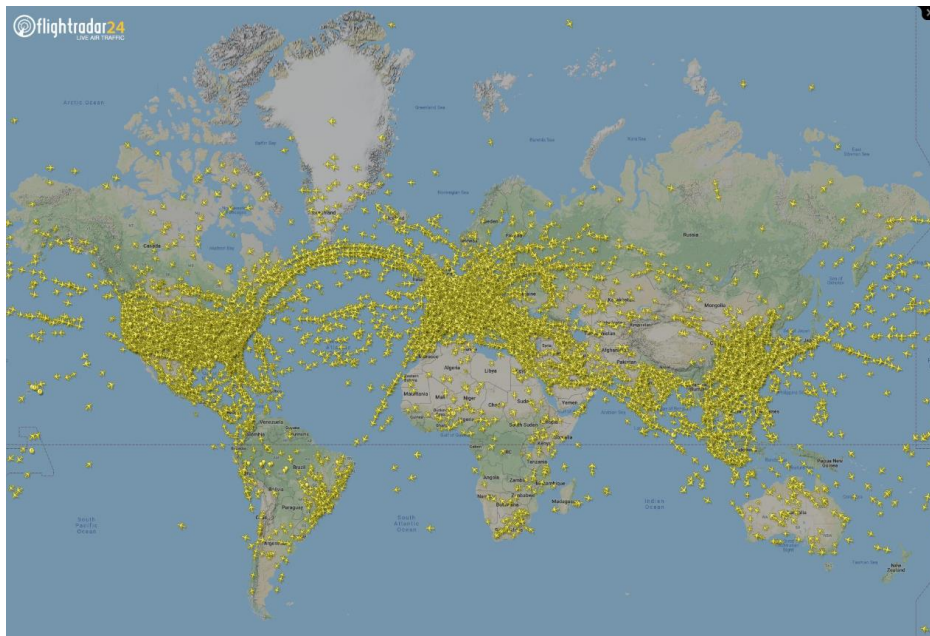
More difficult to estimate is the number of New Zealanders who live overseas. Some estimates put this at over 1 million.²² This includes one in six Maori.²³

This suggest that many individuals have family and friendship links outside New Zealand.

So what is the contribution of aviation to national and international greenhouse emissions and who flies?

A headline in the July 26th 2019 Australian Business Insider notes 'Wednesday was one of the busiest recorded days in aviation history — and it's going to keep getting busier'. The story went on to say that more than 225,000 flights took to the skies on Wednesday, July 24, more than ever recorded before.²⁴

Figure 1: Flights on 24th July 2019



²¹ <http://archive.stats.govt.nz/Census/2013-census/profile-and-summary-reports/quickstats-culture-identity/birthplace.aspx>

²² http://archive.stats.govt.nz/browse_for_stats/population/mythbusters/1million-kiwis-live-overseas.aspx

²³ https://www.population.org.nz/app/uploads/2010/01/nzpr-vol-33-and-34_paul-hamer.pdf

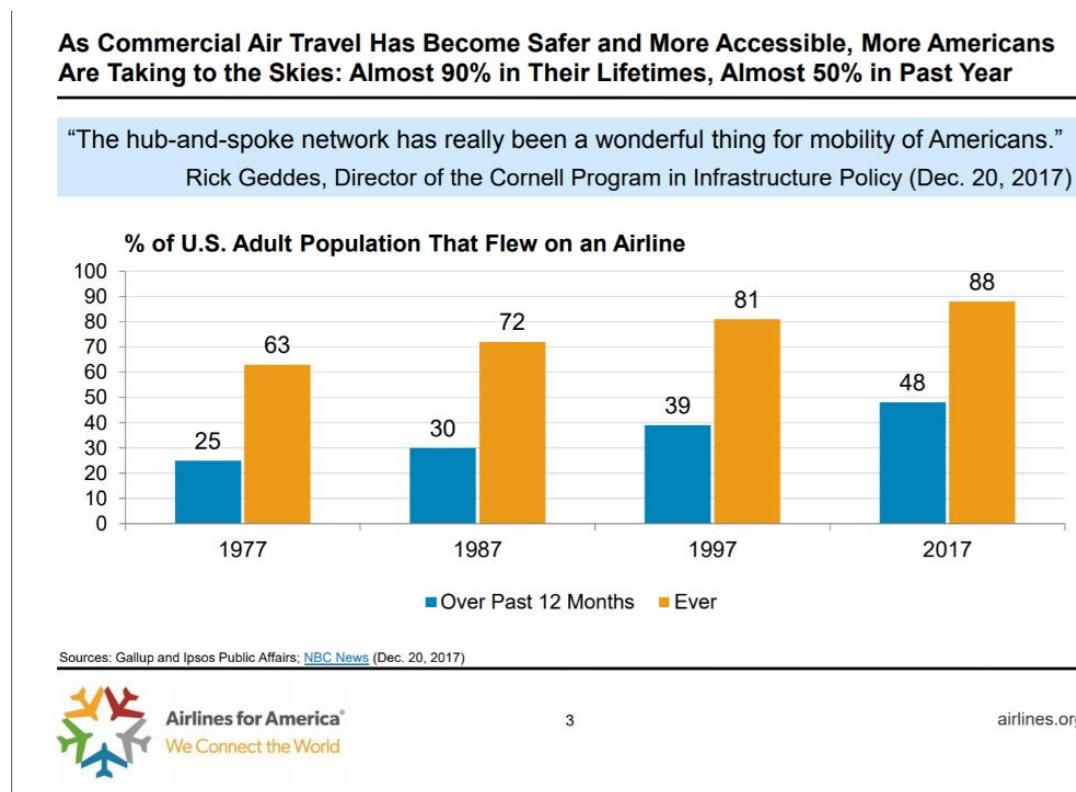
²⁴ <https://www.businessinsider.com.au/most-flights-ever-225000-flightradar24-flight-tracking-2019-7?r=US&IR=T>

Who flies?

Currently, most people in the world do not fly. Writing in 2017, National Geographic estimated that 80% of the world population had never set foot on an aircraft.²⁵

In the UK, an often-quoted figure is that 70% of flights are taken by just 15% of the population.²⁶ In the United States a survey conducted by Ipsos in early 2018 provides some additional information.²⁷ It shows the steady growth of both those who had ‘ever’ flown and those who have flown in the last year. But it does indicate that about half the population are infrequent flyers.

Figure 2:



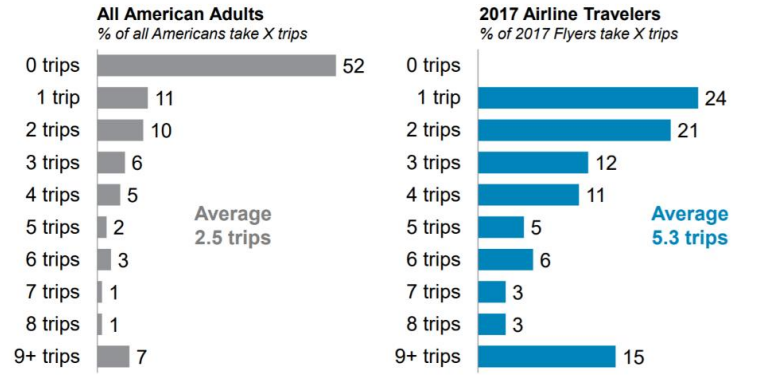
²⁵ <https://www.nationalgeographic.com/environment/urban-expeditions/transportation/air-travel-fuel-emissions-environment/>.

²⁶ https://stay-grounded.org/wp-content/uploads/2019/04/progressive-ticket-tax-frequent-flyer-levy.pdf?fbclid=IwAR16ImpL3965NBkA5CB-WrW3dmsM7sZrN1g8nrdBVogtoEySKtSh-I_C64

²⁷ <http://airlines.org/wp-content/uploads/2018/02/A4A-AirTravelSurvey-20Feb2018-FINAL.pdf>

Figure 3:

On Average, American Adults Took 2.5 Airline Trips in 2017; Flyers Took 5.3 Trips
 7% of Americans and 15% of Flyers Took 9 or More Trips; 24% of Flyers Took Just 1 Trip



Source: Ipsos Public Affairs



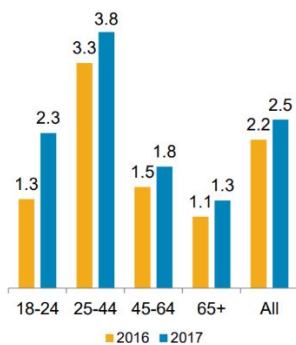
4

airlines.org

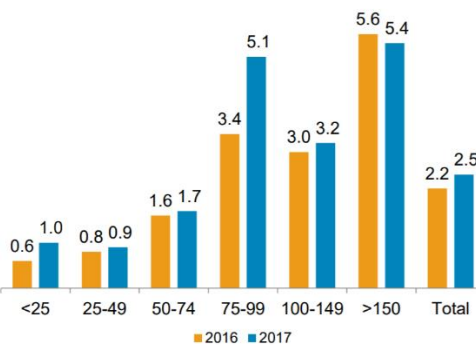
The study provides some important age and income information. It is the younger age groups who are the most frequent flyers. And people from higher income households also fly more. However, there is no information on miles flown.

Americans of All Age Groups and All Household Income Levels – Except the Top Earners – Took More Airline Trips in 2017 Than They Did in 2016

Airline Trips by Age Group



Airline Trips by Annual Household Income (\$000)



Source: Ipsos survey of American adults (January 2018)



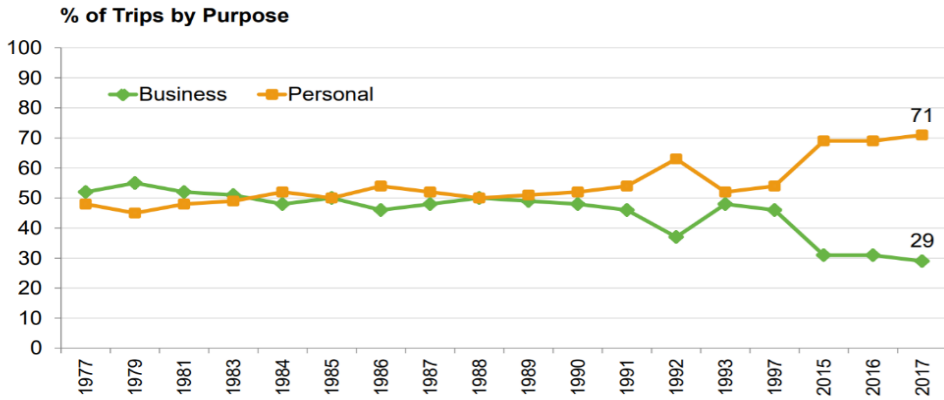
5

airlines.org

Another important piece of data is business versus tourism travel. Increasingly, it is tourism-related flying that dominates.

Figure 5:

More Than Ever Before, Americans Are Traveling by Airline for Personal Reasons



Source: Gallup and Ipsos Public Affairs



6

airlines.org

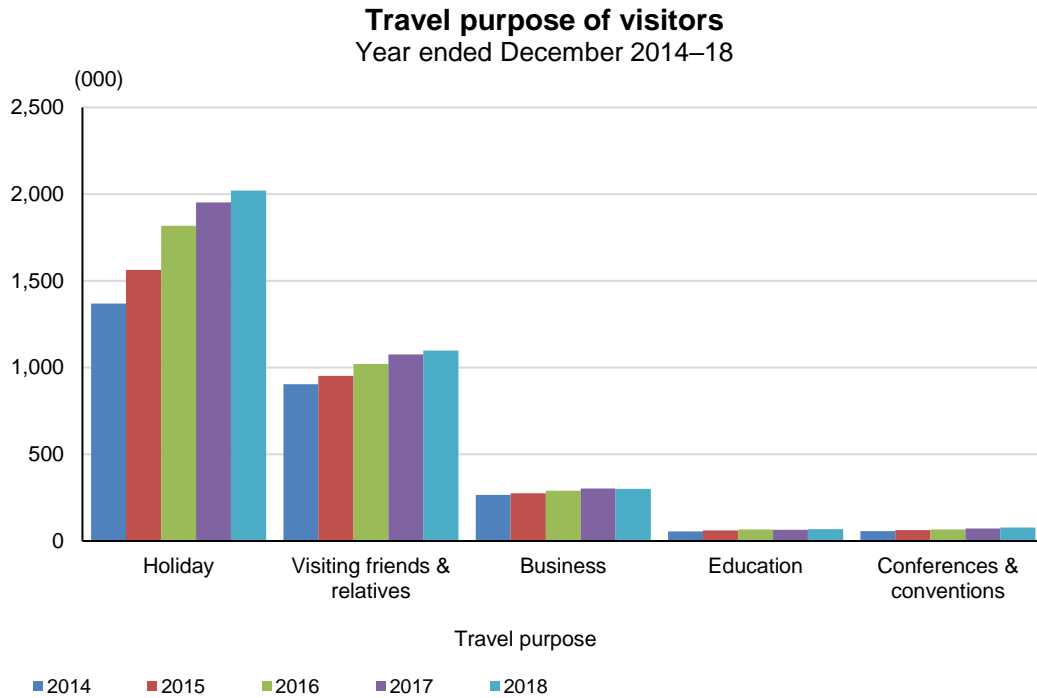
Figure 6:



Statistics New Zealand used to collect reason for travel data for those leaving New Zealand via departure cards. These were discontinued in Oct 2018. However, their most up to date visitor statistics also indicate that business-related overseas travel is much less frequent than travel for

other reasons. A similar pattern exists for arrivals. It is tourism-related travel which has been growing strongly.

Figure 7:



Source: Stats NZ

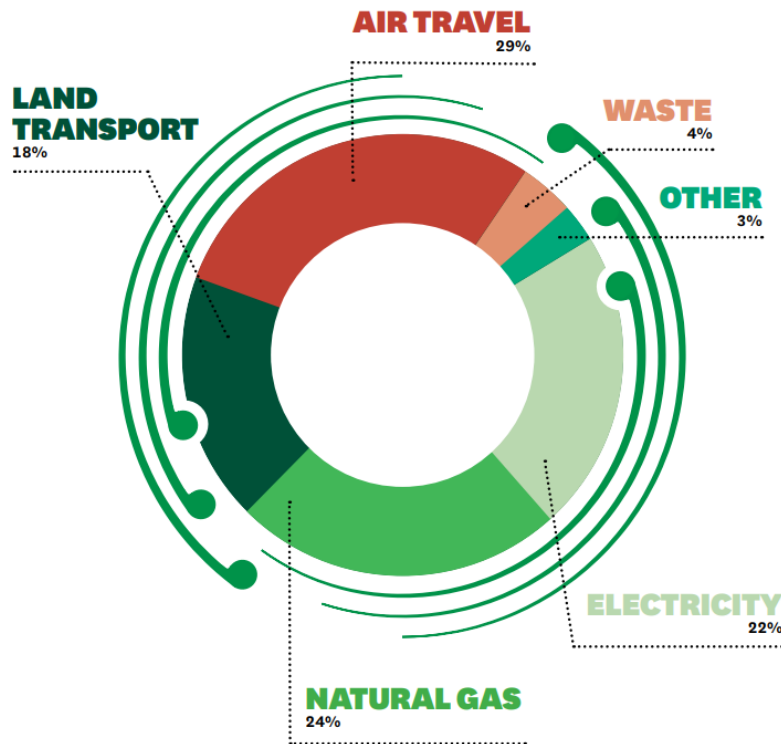
Finally, there are some industries and sectors that are more aviation-intensive than others. Obviously, tourism is very dependent on flying. But another one is academia.

Figure 8 shows a breakdown of Victoria University of Wellington’s emissions in 2018. Aviation emissions make up just under a third of total emissions.²⁸ As they note ‘[a]ir travel remains a very challenging source of emissions for us to manage.’

²⁸ https://www.victoria.ac.nz/_data/assets/pdf_file/0008/1770785/Zero-carbon-plan.pdf?fbclid=IwAR1OI9HUuGSlpOiZmfng8TqOHRiv5Zc6krNB-TvPlcACYIHJOzia2ij7do

Figure 8

FIGURE 2: 2017 GREENHOUSE GAS EMISSIONS, BY SOURCE



Emissions from aviation

Some forms of environmentally damaging activities are easy to highlight and measure. Pictures of the burning Amazon forest, cows defecating while standing in a stream, or a diesel truck belching out black smoke help win over public sympathy for curtailing such activities. But the effects of aviation are more hidden. The industry claims an overall contribution of 2% of the total CO₂ emissions globally from this one fifth of the world's population who currently fly. However, a more nuanced assessment suggests the total contribution to global warming is far greater. More importantly, there is potential for massive growth in emissions just as other sectors are beginning to reduce their global impacts.

According to the Intergovernmental Panel on Climate Change IPCC and the World Meteorological Organisation (WMO), air transport contributes to 4.9% of human-caused climate change.²⁹ Another challenging metric is the IATA forecast that the number of people travelling by air is likely to double to 8.2 billion a year by 2037, with Asia and the Pacific leading

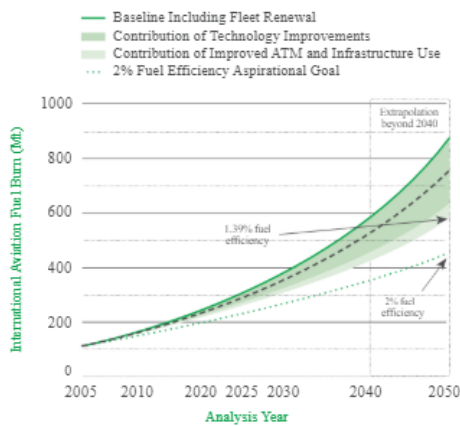
²⁹ <https://phys.org/news/2018-08-effect-global-aviation-environment.html>

the way.³⁰ The forecast for jet fuel is a staggering 9 million barrels a day by 2040.³¹ If the 80% of those in the world who do not currently fly begin to travel at the rate many New Zealanders do and the world begins to dramatically reduce emissions in areas such as ground based transport, then aviation would quickly become one of the world’s most significant sources of damaging greenhouse emissions.

The following graphs give projections produced by the aviation industry. They show an expected upward trend in emissions under various scenarios.³²

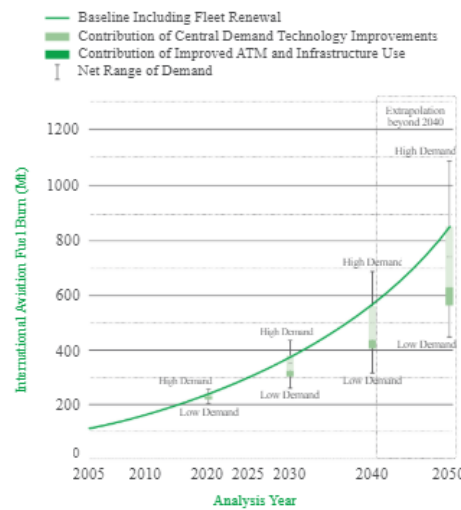
Figure 9

Table 1: Full-flight fuel burn and CO₂ scenarios for the assessment of aircraft GHG trends.



Dashed line in technology contribution range represents the "Low Aircraft Technology Scenario".
 Note: Results were modelled for 2005, 2006, 2010, 2020, 2025, 2030, and 2040 then extrapolated to 2050.

Figure 1: ICAO/CAEP Fuel Burn Trends from International Aviation, 2005 to 2050.



Note: Fuel burn was only modelled for the central demand forecast. The effects of the high and low demand sensitivities shown are based on the ratio of forecasted revenue passenger kilometres for high/low demand relative to central demand.

Figure 2: Range of Uncertainties Associated with Demand Forecast, 2005 to 2050.

Source: ICAO Environmental Report, 2013, Aviation and Climate Change

Already many of the busiest air routes are in our region, including in Australia.

³⁰ <https://phys.org/news/2018-10-air-traffic-iata.html>

³¹ <https://www.mordorintelligence.com/industry-reports/jet-fuel-market>

³² <https://cfapp.icao.int/Environmental-Report-2013/files/assets/basic-html/index.html#25>

Figure 10: Passenger numbers

The top ten busiest scheduled air routes in the world

	Route	Passengers (2017)
1	Jeju - Seoul Gimpo (CJU-GMP)	13460306
2	Melbourne - Sydney Kingsford Smith (MEL-SYD)	9090941
3	Sapporo - Tokyo Haneda (CTS-HND)	8726502
4	Fukuoka - Tokyo Haneda (FUK-HND)	7864000
5	Mumbai - Delhi (BOM-DEL)	7129943
6	Beijing Capital - Shanghai Hongqiao (PEK-SHA)	6833684
7	Hanoi - Ho Chi Minh City (HAN-SGN)	6769823
8	Hong Kong - Taiwan Taoyuan (HKG-TPE)	6719030
9	Jakarta - Juanda Surabaya (CGK-SUB)	5271304
10	Tokyo Haneda - Okinawa (HND-OKA)	5269481

The top ten busiest scheduled international air routes in the world

	Route	Passengers (2017)
1	Hong Kong - Taiwan Taoyuan (HKG-TPE)	6719030
2	Jakarta - Singapore Changi (CGK-SIN)	4810602
3	Hong Kong - Shanghai Pudong (HKG-PVG)	4162347
4	Kuala Lumpur - Singapore Changi (KUL-SIN)	4108824
5	Bangkok Suvarnabhumi - Hong Kong (BKK-HKG)	3438628
6	Dubai - London Heathrow (DXB-LHR)	3210121
7	Hong Kong - Seoul Incheon (HKG-ICN)	3198132
8	Hong Kong - Singapore Changi (HKG-SIN)	3147384
9	New York JFK - London Heathrow (JFK-LHR)	2972817
10	Hong Kong - Beijing Capital (HKG-PEK)	2962707

New technologies, such as supersonic³³ and urban mobility aircraft³⁴, risk increasing emissions even further.

In New Zealand, domestic aviation, although important, is not the key contributor to the growth in aviation emissions. According to the New Zealand Productivity Commission’s Low-

³³ <https://theicct.org/publications/noise-climate-impacts-unconstrained-supersonics>

³⁴ <https://www.youtube.com/watch?v=HV3bKw2gizc>

Emissions Economy report,³⁵ domestic aviation contributes about 6% of all national transport emissions, but remained relatively unchanged between 1990 and 2016 as the shift to larger and more fuel-efficient aircraft offset the increase in domestic air travel. The Air Transport Action Group estimates that 80% of world emissions come from long flights, that is over 1,500km.³⁶

It is international aviation that accounts for the massive growth in aviation emissions. Yet when countries, including New Zealand, consider their emissions' reduction targets, emissions from international aviation have generally not been counted. The New Zealand Productivity Commission notes (pg 341): 'International aviation and shipping emissions are not covered under the Paris Agreement. The main reason for this is that attributing these emissions to a specific country is more difficult than for other emissions sources. For instance, if a plane flies from Auckland to London with a stopover in Singapore for refuelling, it is not obvious how the emissions liability from these trips should be allocated'.³⁷

The Commission further notes that countries are required to report separately their international transport emissions based on fuel supplied. The data relevant to New Zealand are collated by the Ministry for the Environment.³⁸ These show that emissions rose 362,000 tonnes or 11% in just one year between 2016 and 2017, with MfE calculating these emission levels have increased by 178% since 1990.³⁹ In the last two decades the number of flights out of New Zealand has more than doubled.

³⁵ <https://www.productivity.govt.nz/inquiry-content/3254?stage=4>

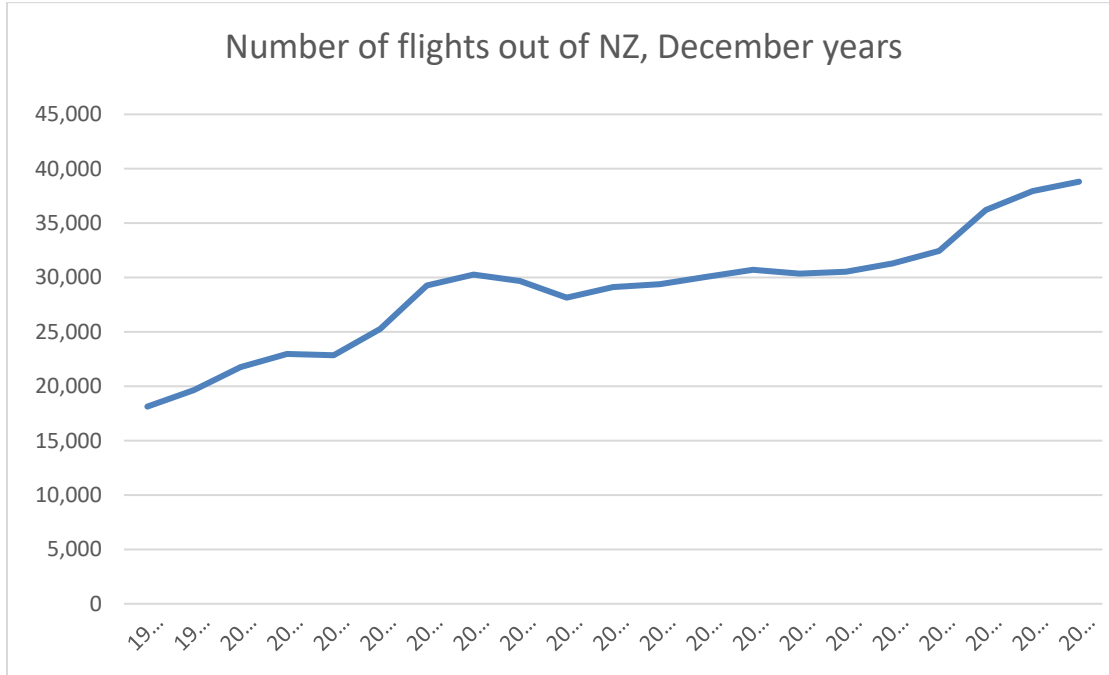
³⁶ <https://www.atag.org/facts-figures.html?fbclid=IwAR3qNkKObBkiDxK0mfmGuU1-UM4zaHYkWy9j199M1uwzSliiDkNKYAqMNFg>

³⁷ For New Zealand this is a somewhat disingenuous argument since New Zealand is essentially a final visitor destination with Antarctica the only destination further south.

³⁸ <https://www.mfe.govt.nz/climate-change/state-of-our-atmosphere-and-climate/new-zealands-greenhouse-gas-inventory>

³⁹ https://blog.planetaryecology.org/2019/04/12/new-zealands-greenhouse-gas-update-2017/?fbclid=IwAR0D1-1xjGAHUK3wwKVhFYOKGAKjSostJbYJnNThBvVSeI5BXkFQ_93RYKw

Figure 11:



Source: Statistics New Zealand

Is it possible to get a better estimate of New Zealand’s contribution to global aviation emissions? For the year ending July 2018 estimated jet fuel consumption for international aviation in and out of New Zealand by visitors to the country was 1.65 million tonnes; equivalent to 5.2 million tonnes of CO₂. Another 2,830,000 trips are typically taken by New Zealanders, mainly to Australia, Europe and the Americas, which accounts for another 3.42 million tonnes to make a total of 8.62 million tonne of CO₂ emissions.^{40 41}

⁴⁰ <https://www.stats.govt.nz/news/record-short-term-travel-in-2017>

⁴¹ <https://figure.nz/table/z1upaWRbmYk2UtfV?types=g%2Cm>

Alternatively we could take the Air New Zealand report (2018) on its GHG emissions for international jet fuel; 2.982 million tonne of CO₂.⁴² In a 2018 presentation to shareholders, Air New Zealand claim approximately 40% of the international long haul business, implying total CO₂ emissions of 7.45 million tonnes.⁴³

Significantly, these calculations do not take into account the radiative forcing – the impact on the overall energy balance of the planet – caused by non-CO₂ warming pollutants, such as water vapour, aerosols and nitrogen oxides and contrails increasing high cirrus cloud. Following the publication of a special report by the International Panel on Climate Change (IPCC) on aviation in 1999, the total historic impact of aviation on the climate is estimated to have been two to four times higher than for CO₂ emissions alone. In view of the uncertainty of the science we have chosen the lower estimate of 1.9 times (Measuring Emissions: A Guide for Organizations – 2019).⁴⁴

Allowing for this additional radiative forcing, the estimate due to aviation emissions becomes approximately 16.4 million tonnes of CO₂e. With tourist numbers doubling approximately every 10 years, emissions from international flights to and from New Zealand are projected to continue growing.

For comparison, the total carbon dioxide emissions from all liquid fuelled land transport in 2016 was 14.34 million tonnes of CO₂. If initiatives such as supporting EVs are successful in creating a shift in our light vehicle fleet, a modest saving may be made in the emissions from land transport, once allowances are made for population growth.⁴⁵

Using airport companies as a source of information, it is not surprising that flight numbers are forecast to expand. Auckland Airport company is currently planning for 40 million passengers per year to pass through their facility by 2040.⁴⁶ Wellington Airport have plans for ongoing expansion.⁴⁷ Various estimates have been put forward for the Queenstown region, including Wanaka, such as over 7 million air passengers per year expected by 2045.⁴⁸

A range of calculators allow individuals to estimate their own emissions from flying. There are of course many variables to consider. These include age and type of plane, how full it is, whether trips are direct, whether you travel economy or first class, and as already mentioned,

⁴² <https://p-airnz.com › cms › PDFs › Air NZ GHG Inventory -Report 2018>

⁴³ <https://www.nzx.com/announcements/319297>

⁴⁴ <https://www.mfe.govt.nz/sites/default/files/media/Climate%20Change/corrections-to-2019-measuring-emissions-guide-for-organisations.pdf>

⁴⁵ <https://www.stats.govt.nz/indicators/new-zealands-greenhouse-gas-emissions>

⁴⁶ <https://corporate.aucklandairport.co.nz/airport-of-the-future>

⁴⁷ <https://www.wellingtonairport.co.nz/business/investor-services/2030-masterplan/>

⁴⁸ <https://www.odt.co.nz/regions/wanaka/wanakas-airport-set-eclipse-queenstowns>

of special importance, whether ‘radiative forcing’ is considered. The Flygreen website discusses these various assumptions in detail.⁴⁹ Atmosfair also describes their assumptions.

Carbon dioxide, nitrogen oxide, soot and sulphur particles as well as water vapour from aircraft engines affect the climate with different durations and intensities. But because all of these together add to the layers of greenhouse gases in the atmosphere, atmosfair calculates them approximately in terms of carbon dioxide.

In sum, the different emissions in high flight altitudes of more than nine kilometres have an effect that is about three times as strong as the carbon dioxide of a flight.

In order to appropriately represent the climate impact of all flight emissions, the atmosfair emissions calculator multiplies the CO₂ emissions emitted at altitudes over 9 km with the global average multiplier of 3. This multiplier results when the global warming potential of all non-CO₂ effects is integrated and discounted over 100 years (UNFCCC) and (David Lee et al., “Transport impacts on atmosphere and climate: Aviation”, in *atmospheric environment* (44), 2010).⁵⁰

Figure 12 shows a calculation for someone flying from Auckland to Europe.

Figure 12: Atmosfair calculator

Emission Calculation Results

1 round-trip flight for 1 person

from	to	Flight class	Flight type	Aircraft type
Auckland (AKL)	- Abu Dhabi (AUH)	Economy		
Abu Dhabi (AUH)	- London - Heathrow (LHR)	Economy		

[Edit](#)

Your flight – climate impact of the most CO₂-efficient airlines in comparison*

On stop-over flights a CO₂ comparison for various airlines is not possible. If you are interested in an airline CO₂ comparison, [please enter your flight segments separately](#).

Your CO₂-emissions

Climate impact 11,514 kg CO₂
 Compensation amount € 266

[Show detailed emission data](#) ▼

Your CO₂-Emissions in comparison

Your flight (per person)

kg 11,514

Emissions per capita per year (in India)

kg 1,600

Emissions for one car per year (12,000 km; middle class model)

kg 2,000

Climate compatible annual emissions budget for one person

kg 2,300

⁴⁹ <https://flygrn.com/blog/carbon-emission-factors-used-by-flygrn>

⁵⁰ https://www.atmosfair.de/en/faqs/on_co2_calculation/

As the Atmosfair calculator indicates, a return economy flight to Europe has much higher emissions than driving a fossil fuel car for a year.

These data suggest that individually and as a nation, there is a need to quickly figure out ways to reduce the greenhouse effects of aviation.

Options for decarbonising New Zealand aviation

Courageous new strategies are needed for all of New Zealand's aviation industry. Currently the EU and some Scandinavian countries are taking the lead in aviation fuel transformation.^{51 52} New Zealand needs to reclaim our *clean and green* credibility through joined-up R&D to help innovate and decarbonise the aviation industry.

But is it actually realistic to think that in the short-term humans can keep flying at current and potentially expanding levels and concurrently decarbonise the industry? In the short term, the answer has to be no. A *reduction in actual flying*, particularly internationally, is the only practical option to meet near-term emission reduction targets. However, this would have significant implications for the tourism industry, for New Zealanders wishing to travel overseas and for trade. There are currently no practical ways to reach overseas destinations except by air.

Most notably in Sweden there is a Fly-less movement.⁵³ It has been credited with increasing interest in train travel. There is also a Fly-less Kiwi Facebook page in New Zealand which discusses ways of reducing flying. And there have been NZ stories about well-known individuals who have cut back flying. For example, scientist Shaun Hendy had a year without flying in New Zealand.⁵⁴ Overseas, there are high profile individuals who have dramatically cut back flying or do not fly at all. Greta Thunberg is probably the most famous.⁵⁵

Those promoting flying less suggest better use could be made of video conferencing, and there are opportunities for organising of meetings so gatherings in distant places can be clustered. Many academics, including some of those most concerned about climate change, are reluctant to give up the opportunities to network offered by attendance at international conferences. But research suggests it is the well-established senior academics, not early career researchers, who fly the most.⁵⁶ A small Canadian study whether those who flew the most were also the most successful. They found that beyond a small threshold there was no relationship between

⁵¹ https://ec.europa.eu/clima/policies/transport/aviation_en

⁵² <https://www.weforum.org/agenda/2017/11/norway-airports-biofuels-avinor/>

⁵³ <https://phys.org/news/2019-04-flight-shame-swedes-rethinking-air.html>.

⁵⁴ <https://www.stuff.co.nz/environment/climate-news/109508954/scientist-shaun-hendys-year-of-no-flying-for-climate-change>

⁵⁵ <https://www.theguardian.com/environment/2019/apr/26/greta-thunberg-train-journey-through-europe-flygskam-no-fly>

⁵⁶ <https://www.mdpi.com/2071-1050/11/9/2694/htm>

scholarly output and how much individual academics fly. Men were more likely to fly than women.⁵⁷

While voluntary reductions in flying help bring the issue attention, they are unlikely to have much direct impact on international tourism.

Disincentives for flying?

Price is a very important factor in determining demand for a product or service. But a study undertaken in Australia shows the cost of air travel had fallen dramatically over the last 25 years. Economy air fares in Australia in 2018 were 55% of the average cost in 1992 (after adjusting for inflation).⁵⁸ Taking a longer timeframe, in 1945, it took 130 weeks for a person earning the average Australian wage to earn enough for the lowest Sydney to London return airfare. In 2009, it took just 1.7 weeks.⁵⁹ This has spurred increased demand.

If voluntary action does not result in a reduction in air travel, disincentives to flying could be implemented. The number of international tourist arrivals could be capped, for example, or the new entry fee of \$35 to New Zealand could be increased.⁶⁰ Or, as in Scotland, a departure tax could be charged, as used to be the case in some airports in New Zealand.⁶¹ Another option is to make it more difficult to build or expand airports. A further idea would be to put a cap on the number of flights that could take place from airports within a particular country and make these allocations tradeable.

The only suggestion relating to aviation emissions proposed by the Productivity Commission in its report is to increase the cost of flying, primarily through a substantial increase in the price of carbon. Quoting Concept Consulting (2017), the Commission estimates that an emissions price of \$100 per tonne of CO₂e could reduce domestic air travel demand by up to 12 percent (pg. 345). Compare this to the August 2019 New Zealand price of around \$24 per tonne of CO₂e. An across the board increase in the price of carbon lifts the cost of all fossil fuels and will affect both the poor and the well off.

It seems that currently there is not the political will to dramatically lift the price of carbon in New Zealand. But aviation fuel could be targeted with a tax. Based on the data already shown

⁵⁷ <https://blogs.lse.ac.uk/impactofsocialsciences/2019/06/21/do-the-best-academics-fly-more/?fbclid=IwAR1sLbhDbk1GMZlbHFH7EO5OWfrUe-iW2LUwLN56t8DkR8m7OeVI7RGFwMU>

⁵⁸ https://theconversation.com/why-our-carbon-emission-policies-dont-work-on-air-travel-99019?utm_medium=email&utm_campaign=Imagine%20&utm_content=Imagine%20+CID_5b51cafb3e97034b36c563fbcc1259ed&utm_source=campaign_monitor_uk&utm_term=Why%20Australias%20carbon%20emission%20policies%20dont%20work%20on%20air%20travel

⁵⁹ <https://www.atag.org/facts-figures.html?fbclid=IwAR3qNkKOBkDxDxK0mfGuU1-UM4zaHYkWy9j199M1uwzSliiDkNKYAqMNFg>

⁶⁰ https://www.nzherald.co.nz/nz/news/article.cfm?c_id=1&objectid=12132687

⁶¹ <https://www.bbc.com/news/uk-scotland-scotland-politics-48191110?fbclid=IwAR0bg4mY8QBtvs6URo6zubf6UpXhXSzG1piSNYDHV4XpKEP1Xt3oM-RhTg>

this would affect higher income households more than lower income ones. Aviation fuel for domestic flying can be taxed, but a 1944 international agreement prevents taxes being placed on fuel used for international travel.⁶²

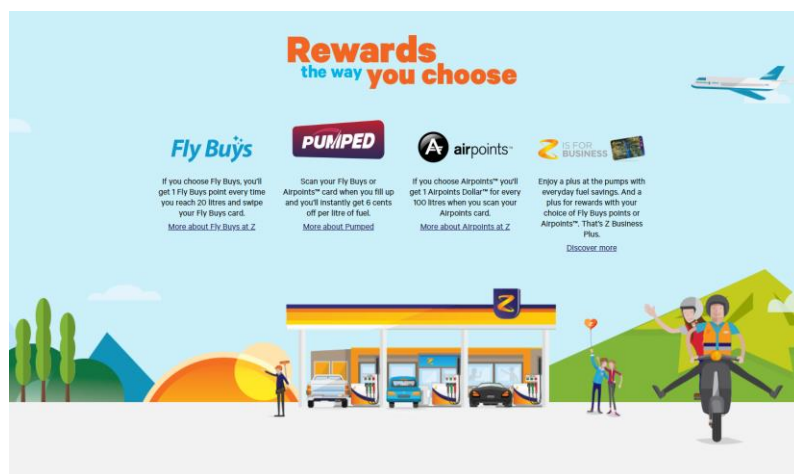
Finally, there are not the same personal incentives for reducing flying as there are for some other climate change-related lifestyle related activities. For example, switching to a vegan diet can not only help reduce the production of greenhouse gases but can have major personal health benefits as well as soothing the consciences of animal lovers. Riding a bike or walking instead of driving a car can also have health benefits. Driving an electric car might induce some range anxiety but overall simply replaces the mobility offered by fossil fuelled vehicles. Reducing flying generally involves some sacrifice.

Removing incentives?

There are a number of incentives for flying. One is the loyalty schemes that most airlines run. The more you fly the more you earn. Potentially, those travelling on business trips can keep the points themselves thus gaining a tax free incentive. This can be partially stopped by businesses requiring their staff not to use these schemes. Frequent-flier mileage programs can be valuable to airlines, as business travellers and other first-class passengers will often link their credit cards to the programs and allow their consumption behaviours to be monitored.

Organisations such as Z Energy promote sustainability. For example Z runs an offsetting scheme investing in permanent forests.⁶³ Yet, in a mixed message, Z also supports the Fly Buys and Airpoints tax free reward schemes. This may not only encourage flying but also mean that one group of customers are subsidised by those not belonging to or using such schemes.

Figure 13: Z Energy promotions

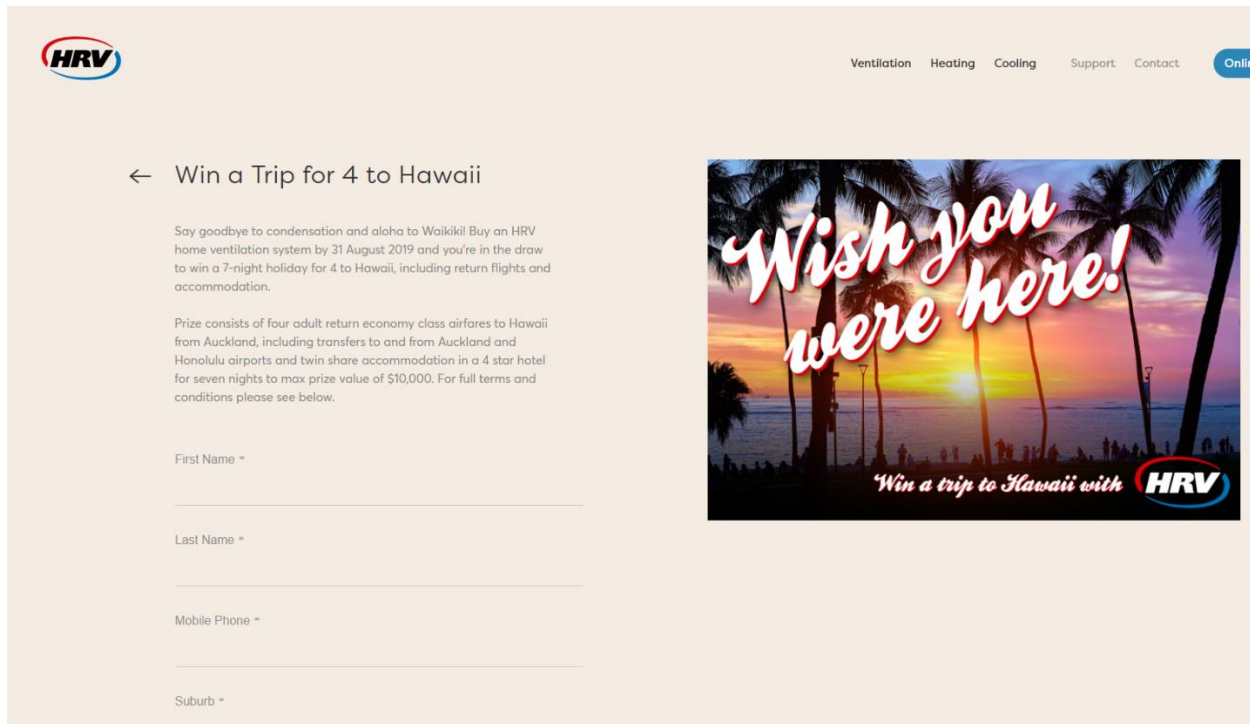


⁶² https://en.wikipedia.org/wiki/Chicago_Convention_on_International_Civil_Aviation

⁶³ <https://z.co.nz/about-z/news/sustainability-news/z-energy-invests-heavily-in-permanent-forest-sinks/>

Increasingly, overseas holidays are being offered as incentives for taking up various offers including home loans and house purchases.⁶⁴ There is even a New Zealand website dedicated to competitions to win holidays, many of which involve overseas flights.⁶⁵

Figure 14



← Win a Trip for 4 to Hawaii

Say goodbye to condensation and aloha to Waikiki! Buy an HRV home ventilation system by 31 August 2019 and you're in the draw to win a 7-night holiday for 4 to Hawaii, including return flights and accommodation.

Prize consists of four adult return economy class airfares to Hawaii from Auckland, including transfers to and from Auckland and Honolulu airports and twin share accommodation in a 4 star hotel for seven nights to max prize value of \$10,000. For full terms and conditions please see below.

First Name *

Last Name *

Mobile Phone *

Suburb *

Wish you were here!

Win a trip to Hawaii with HRV

Internationally, there is a concern that flying is subsidised in various ways including governments supporting uneconomic airports.⁶⁶

In New Zealand, Regional Development Minister Shane Jones has criticised Air New Zealand for dropping regional services and attempted to garner support from the Provincial Growth Fund to boost two small regional airlines.⁶⁷ More recently Jones suggested that the taxpayer should offer support to struggling regional airports such as Whanganui, an airport that is within an hour's drive of Palmerston North airport.⁶⁸ In Kapiti, the local council has provided some

⁶⁴ <https://www.stuff.co.nz/life-style/homed/latest/115273467/incentives-to-buy-a-house-are-offered-for-all-price-ranges?fbclid=IwAR0upY2DKUrxrSBHILkpeqJ3TIC9CmG1KbpfqwxSE04f3YUc17XA16bzSyc>

⁶⁵ <https://winstuff.co.nz/win-holiday/>

⁶⁶ <https://www.transportenvironment.org/press/24-ryanair-airports-likely-be-propped-subsidies-%E2%80%93-fueling-rapid-emissions-growth?fbclid=IwAR3o4KvIOHW-bcMG6TEdeThXQuZ2y3W-zuixPykNzuxUb7PoDuzNkQoVPLA>

⁶⁷ <https://www.stuff.co.nz/business/industries/112266312/provincial-fund-plan-to-spend-30-million-on-airlines-gets-the-chop>

⁶⁸ <https://www.stuff.co.nz/national/politics/114096731/taxpayerfunded-bailouts-on-the-cards-for-cashstrapped-regional-airports>

support to Air Chathams to commence services to the area.⁶⁹ Such support is likely to most benefit the middle class.

There is also a high level of promotion for international travel through various media outlets. Even environmentally focussed magazines, such as the Forest & Bird magazine, are supported by advertisements for such travel. The Department of Conservation has close links with Air New Zealand.⁷⁰

Finally, global inequalities can be an incentive for long distance travel. If there is a big difference in wage rates and prices for goods and services between countries, then people from well off nations will be prepared to travel long distances for cheap holidays. Reducing inequalities, and/or increasing the cost of travel, may encourage more local travel.

Offsets

Corsia⁷¹ is a UN agreement designed to help the aviation industry make all growth in international flights after 2020 “carbon neutral”. It is effectively an offset scheme.

As argued by the New Zealand Parliamentary Commission for the Environment, offsetting carbon produced from fossil fuels is not an effective decarbonisation strategy.⁷² In fact, a focus on offsetting has delayed real carbon reductions.

There is growing evidence around the problem of aviation related carbon offsets. These include:⁷³

- Schemes have not worked. Many offset schemes have been based on unrealistically low carbon prices and ineffective offsets.⁷⁴
- Offsets cannot act quickly enough
- Offsets distract from the real issue of necessary reductions
- Offsets shift our moral responsibility to reduce to someone else
- Offset programmes may have happened regardless
- Difficulty in measuring offsets’ contributions
- Carbon storage in trees is temporary
- Offsets’ impact on indigenous communities
- No incentive for reducing emissions or decarbonising air travel

⁶⁹ <https://www.kapiticoast.govt.nz/whats-on/news/2018/air-chathams-to-bring-back-kpiti-coast-to-auckland-air-service/>

⁷⁰ <https://www.doc.govt.nz/about-us/our-partners/our-national-partners/air-new-zealand/>

⁷¹ <https://www.icao.int/environmental-protection/CORSIA/Pages/default.aspx>

⁷² <https://www.pce.parliament.nz/publications/farms-forests-and-fossil-fuels-the-next-great-landscape-transformation>

⁷³ https://www.responsibletravel.com/copy/carbon-offsets?fbclid=IwAR3Z5u_4QvCz8lLSsGZH4LT07ZQq4MN8vZN5sJafjp2ZIO1IAgRVVed2Yvg

⁷⁴ <https://www.theguardian.com/travel/2019/aug/02/offsetting-carbon-emissions-how-to-travel-options>

- Take up rates are insignificant. If in fact offset rates increased from the current takeup of 1-2% it is doubtful whether schemes such as tree planting could expand sufficiently.

As an indication of the problems with offsets, a paper by Smith and Rodger (2009) calculated the forest offsets which would be required for visitors to New Zealand in 2005.⁷⁵ When considering these estimates, any calculations for recent years would have to be much higher given the growth in tourism.

Regenerating New Zealand forests absorb 3 tonnes of CO2 each year per hectare of forest (Landcare Research, n.d.). By setting aside land for forest to regenerate, some of the emissions produced by visitors to New Zealand could be offset. In order to offset the 2005 visitor emissions, 26,300km² of regenerating forest would be required. This is the size of 15 Stewart Islands, or 10% of the country's total land area. It would require increasing New Zealand's total forested area by one third, probably by decreasing the 50% of New Zealand land area used for pasture (Ministry for the Environment, 1997).

Offsetting at this level is likely not to be feasible given the difficulties the Billion Trees programme is facing. But perhaps more importantly, it would have a major negative impact on agricultural production.

As an indication of why offsetting take up rates are insignificant, a US survey shows environmental concerns about flying are low on the list of considerations when choosing an airline.

Figure 15

When Choosing an Airline, Leisure Travelers Value Affordability Above All Else
 2017 Rankings Identical to 2016 (Schedule Solidly Second, Followed by Reliability)

When traveling for personal reasons, how would you rank the following in terms of choosing which airline to fly, with 1 being your first priority and 8 being your last priority?

(Base = all 2017 flyers with at least 1 personal leisure trip)

Criteria	2017 (2016)	Score
Affordability (airfare / ancillaries / taxes)	1 (1)	2.50 (2.65)
Flight schedule (routes, timings)	2 (2)	3.12 (3.23)
Reliability of on-time departure and arrival	3 (3)	4.22 (4.28)
Airline seat comfort	4 (4)	4.54 (4.45)
Customer service (reservation/gate agents, flight attendants)	5 (5)	4.82 (4.95)
Airline frequent flyer program (earn / redeem / upgrade / status)	6 (6)	5.19 (5.00)
Quality of inflight amenities (food / entertainment / WiFi)	7 (7)	5.32 (5.17)
Environmental responsibility	8 (8)	6.28 (6.26)

Source: Ipsos survey of American adults (January 2018)



⁷⁵ Smith, I. J. and Rodger, C. J. (2009) Carbon emission offsets for aviation-generated emissions due to international travel to and from New Zealand, *Energy Policy*, 3438-3447.

Alternatives to flying

Greta Thunberg has attracted worldwide attention through speaking at climate change forums throughout Europe. She has not flown to these but travelled by train, passenger ferry and electric car.⁷⁶ But while Greta can reach many of the world's capital cities by these modes of travel, a New Zealander can only reach one. When Greta decided it was important to speak at the UN in New York she faced the problem New Zealanders come up against: how to travel overseas without flying. High carbon emission cruise liners were rejected and Greta used a racing yacht.⁷⁷ This is a great publicity stunt but not a practical solution.

Some locally publicised New Zealand experiments in reducing flying using land-based low carbon forms of domestic travel show real difficulties.⁷⁸ Such land transport, especially regional rail, has been run down over a number of decades. Unlike many European cities, we do not have rapid rail linking our major centres.⁷⁹ There is no overnight train between Auckland and Wellington. In Europe such services are being re-instated.⁸⁰ In the past there used to be an overnight ferry between Wellington and Christchurch.⁸¹ There are opportunities in the short term to convert trains, buses and ferries to run on fuels such as hydrogen or electricity.^{82 83}

Some land-based companies are starting to emphasise the carbon savings for their form of travel.

⁷⁶ <https://www.theguardian.com/environment/2019/apr/26/greta-thunberg-train-journey-through-europe-flygskam-no-fly>

⁷⁷ <https://www.theguardian.com/environment/2019/jul/29/greta-thunberg-to-sail-across-atlantic-for-un-climate-summits>

⁷⁸ <https://www.stuff.co.nz/environment/climate-news/111873871/climate-change-is-an-auckland-professors-nofly-movement-beginning-to-soar>

⁷⁹ <https://www.greatauckland.org.nz/2019/06/28/a-history-of-regional-and-long-distance-buses-in-new-zealand/>

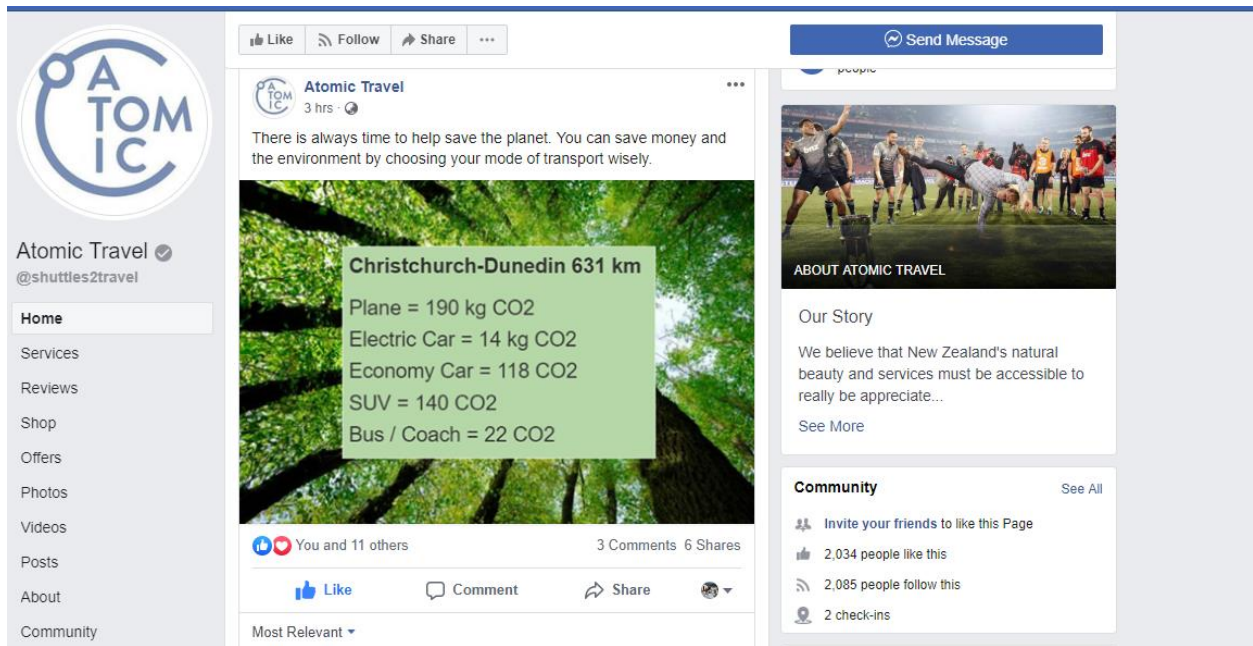
⁸⁰ <https://www.msn.com/en-us/news/world/europe-revives-night-trains-e2-80-94-to-fight-climate-change/ar-AAG9NFh>

⁸¹ <https://nzhistory.govt.nz/culture/lyttelton-wellington-ferries>

⁸² https://www.forbes.com/sites/jamesellsmoor/2019/08/18/the-worlds-largest-electric-ferry-has-completed-its-maiden-voyage/?utm_source=FACEBOOK&utm_medium=social&utm_term=Paulie%2F&fbclid=IwAR214VuFQeUy0oxGrOeUOD8BX0r2eshNXYtAiz0ElcnehgFOsA5E1f9DURNc#6409b53f556a

⁸³ <https://www.theguardian.com/environment/2018/sep/17/germany-launches-worlds-first-hydrogen-powered-train>

Figure 16



We believe developing and supporting alternative forms of domestic low carbon ground-based travel is crucial to any effort to reduce the impact of aviation.⁸⁴

Finding alternatives to flying to overseas countries is far more challenging with no solutions on the horizon. Wind powered freighters have been proposed and potentially there could be wind powered passenger ships.⁸⁵ Using such services from New Zealand would change travel time from about a day to many weeks. Trips to Australia and Pacific islands such as Fiji or Tonga would be much shorter but still days rather than hours. This requires much more research nationally and internationally.

Figure 17



⁸⁴ <https://www.greaterauckland.org.nz/2019/05/21/a-national-public-transport-network/>

⁸⁵ <http://www.dykstra-na.nl/designs/wasp-ecoliner/>

Better aviation technology?

Generally, evolving technology has been reducing greenhouse gas emissions per flight. There have been many innovations, including engine design, changing the way air flows over wings to reduce drag, using advanced materials to make engines and airframes lighter, and better air traffic control reducing flight times and on the ground fuel saving techniques. These small gains are likely to continue.^{86 87} But the growth in the number of people flying keeps outstripping these gains.

There are also some surprises when it comes to technology. One example is that turboprop planes create fewer emissions than jets and out to a range of 500 NM (926 km) are more fuel efficient.⁸⁸ As well as lower CO₂ emissions, there is less radiative forcing due to the lower altitude at which these planes fly.⁸⁹

Where technology could make a much larger difference is in the replacement of fossil fuels.

Alternative fuels

On the [Air Transport Action](#) website (representing a consortium of aviation interests) it is stated in August 2019 that a third of the operating costs of airlines is spent on fuel, up from 13% in 2001.⁹⁰ This suggests that airlines, and their fare structures, will be very sensitive to any changes in fuel costs.

Electric and hydrogen powered planes

There appear to be two theoretical options to maintain air travel while simultaneously reducing greenhouse emissions. The first is using electric planes with the electricity supplied from renewable sources. In 2018 Norway announced an aim for all short haul flights to be electric powered by 2040.⁹¹

In the medium term, some short flights may be made by a new breed of electric planes. But there are many problems with electric powered planes, mainly the energy density of their batteries and weight.⁹² To store the same amount of energy in a kilogram of kerosene requires 43 kg of the best lithium batteries which must be carried for the full duration of the flight. The full magnitude of this penalty becomes clear once you consider that the power required to keep

⁸⁶ <https://www.bbc.com/news/business-48185337>

⁸⁷ <https://aviationbenefits.org/newswire/2019/04/easyjet-and-derwent-technology-will-reduce-aircraft-emissions/>

⁸⁸ <https://aviation.stackexchange.com/questions/1814/which-engine-is-more-efficient-between-turboprop-vs-jet>

⁸⁹ <https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2016JD025051>

⁹⁰ <https://www.atag.org/facts-figures.html?fbclid=IwAR3qNkKObBkiDxK0mfmGuU1-UM4zaHYkWy9j199M1uwzSliiDkNKYAqMNFg>

⁹¹ <https://www.theguardian.com/world/2018/jan/18/norway-aims-for-all-short-haul-flights-to-be-100-electric-by-2040>

⁹² <https://doi.org/10.2514/6.2014-0535>

an aircraft aloft is proportional to 2 times mass². That is, doubling the mass will increase the power requirement eight fold.⁹³

Figure 18



Zunum Aero Seattle had plans to develop a 1,000 km range, short-haul aircraft (able to carry six to 12 passengers) powered by two electric turboprops. Power would have been supplied by wing batteries supplemented by a 500kw turbo generator, with plans to upscale to a 50-seater with a 1,600 km range by 2027. However, this company is experiencing funding difficulties and recently laid off dozens of employees and brought its operations to a halt.⁹⁴

Airbus, in partnership with Siemens and Rolls Royce, had been using the 200 seat BAE 146 as a test bed. One of the four engines was replaced by an electric turboprop.⁹⁵ In mid 2019 Rolls-Royce acquired Siemens' electric and hybrid-electric aerospace propulsion activities.⁹⁶

At the 2019 Paris airshow Israeli startup Eviation Aircraft was reported as taking orders for a \$US4 million electric plane.⁹⁷ The aircraft is rated to fly 1,046 km at around 805 km/h with three electric motors on the tail and one on each wingtip. The prototype carries a 900 kWh lithium-ion battery. This was noted as being about nine times bigger than Tesla's largest automotive battery. However, the plane carries just nine passengers.

⁹³ <https://www.youtube.com/watch?v=VNvzZfsC13o>

⁹⁴ <https://www.geekwire.com/2019/seattle-area-electric-aircraft-maker-zunum-aero-facing-financial-trouble-reported-layoffs/>

⁹⁵ <https://www.airbus.com/newsroom/press-releases/en/2017/11/airbus--rolls-royce--and-siemens-team-up-for-electric-future-par.html>

⁹⁶ <https://www.flightglobal.com/news/articles/paris-siemens-sells-eaircraft-business-to-rolls-roy-459092/>

⁹⁷ <https://qz.com/1650449/electric-airplanes-take-flight-at-the-paris-air-show/>

One of the first customers is Cape Air, a regional airline in the state of Massachusetts that completes hundreds of short flights each day. Cape Air is reported as having 92 planes serving about half a million passengers annually, making it one of the largest regional airlines in the US. The air show writeup noted for flights under a few hundred miles electric propulsion is much cheaper. With lower maintenance, faster turnaround, and more durable systems, electric aircraft may save millions of dollars for short-haul airlines each year. The article went on to note:

But large jet aircraft makers aren't waiting for the electric revolution. Hybrid technology, in which electric-assist kicks in throughout the flight, will be ready in the next few years. Boeing and JetBlue have invested in Zunum Aero to roll out a hybrid craft later this year. Right behind is the merged United Technologies-Raytheon releasing a hybrid retrofit of its regional turboprop, and Airbus's entry is due out in 2022. Meanwhile the number of electric aircraft under development keeps growing. Consultancy Roland Berger expects the number to jump from 170 to 200 by year's end.

The fact that Zunum Aero is now in financial difficulties shows some of this optimism needs to be tempered.

While electric hybrid planes seem unnecessarily complicated, they may begin to have some small impact on domestic aviation in the medium term. But all the electric options would require significant increases in production of electricity from renewable sources, an issue we will return to shortly. The cost of flying would likely increase too, simply through having to abandon the current fleet of aircraft and replace them with a new fleet.

A more feasible approach might be small electric planes powered by hydrogen fuel cells, making short, regional trips. ZeroAvia has conducted a number of successful flight tests using a Piper M-class airframe with a target of producing a low cost commuter plane of 10 to 20 seats and a range of 800 km.⁹⁸

Another highly innovative approach to air travel is a back-to-the-future-airship with 50% of the lifting capacity provided by helium and the remainder by winged powered flight with normal landing and takeoff.⁹⁹

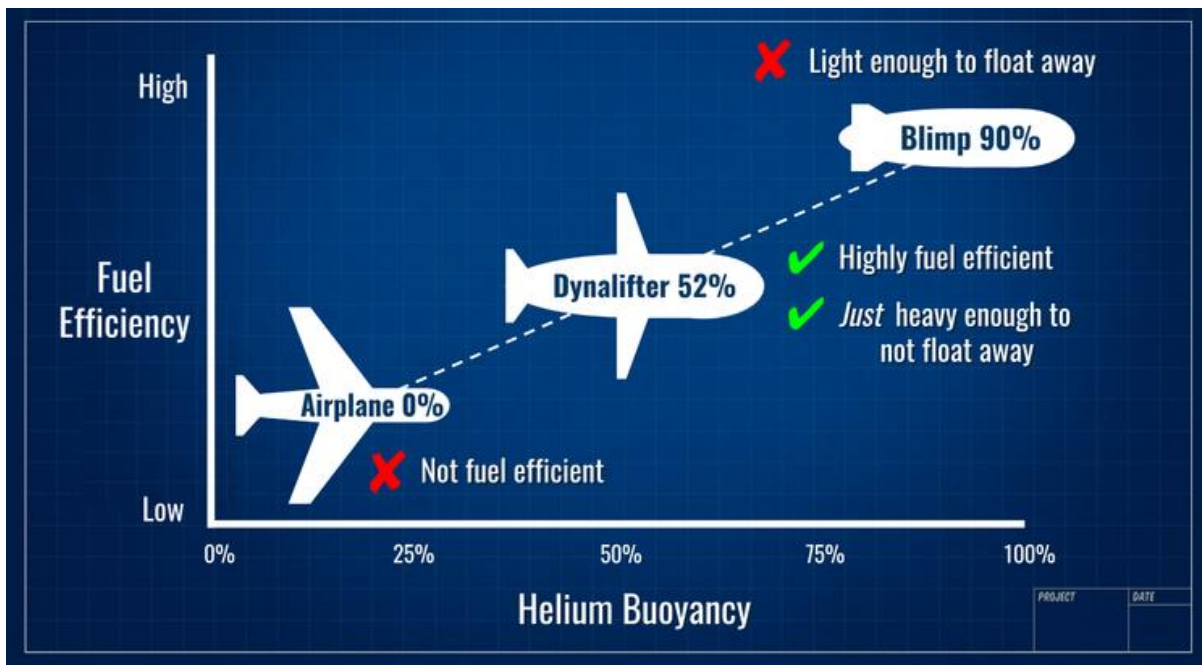
⁹⁸ <https://www.theverge.com/2019/8/14/20804257/zeroavia-hydrogen-airplane-electric-flight>

⁹⁹ <http://www.ohioairships.com/dynalifter--drone-runner-.html>

Figure 19



Figure 20



While electric planes offer some potential to transform regional airlines, unless there is some significant scientific breakthrough in the foreseeable future, international flights in and out of New Zealand will continue to use liquid fuels.

Liquid fuels

Liquid fuels appear more attractive for New Zealand. With our current stock of aircraft reliant on liquid fuels, increasingly blending lower carbon synthetic biofuels with fossil jet fuel will be essential to beginning to decarbonise aviation.

CAAFI, (Commercial Aviation Alternative Fuels Initiative) was formed in 2006 in response to three concerns regarding aviation fuels: 1) supply security, 2) affordability and price stability, and 3) environmental impacts. Membership is diverse but includes few airlines outside the US, notably Cathay Pacific and Lufthansa. Air New Zealand is not listed as a member. However Air New Zealand is a member of SAFUG (Sustainable Aviation Fuel Users Group) who have signed a Sustainability Pledge, and believe that a key driver to a carbon neutral industry is advancing and adopting sustainable aviation biofuels. This will significantly reduce the life cycle GHG emissions over conventional petroleum-based aviation fuels. A decade has passed since the first biofuel-powered flight which raises the question of why progress has been so slow.

Members of SAFUG aim to use fuels that:

- Exhibit minimal impact on biodiversity
- Meet a sustainability standard with respect to land, water, and energy use
- Do not displace or compete with food crops
- Provide a positive socioeconomic impact
- Do not require any special fuel handling equipment, distribution systems, or changes to engine design

The EU and Nordic countries are mandating biofuel content for transport fuels. The Finnish Parliament has (6 February 2019) approved a law that sets a gradually increasing proportion to 30 percent biofuels as a target for 2030. Many other countries, such as Sweden and Norway, are also walking the talk on climate change mitigation in the transport sector. To help jump-start this transition, the Norwegian government announced last October that airlines operating in Norwegian airspace will have to use 0.5 percent biofuels in their jet fuel by 2020.¹⁰⁰

If biofuel is going to be mandated in the near future, what is the state of the production and supply chain? First, the requirements are defined by an ASTM specification D7566. Broadly, jet fuel is a kerosene fraction of mainly paraffinic C8 to C16 hydrocarbons and a minor amount of aromatics. Sustained flight at temperatures of -50°C requires a freezing point of less than -48°C. The usual process of simply esterifying a vegetable oil to make a biodiesel will not meet this specification. Additional refinery capacity to hydrogenate, crack and isomerise the vegetable source is required. Current permitted maximum blending ratios of these synthesised biofuels are 50%.

¹⁰⁰ <https://bioenergyinternational.com/policy/norway-to-introduce-0-5-sustainable-aviation-fuel-quota-from-2020>

Meeting a modest 2% of demand would require as much as \$10 billion investment in new refinery capacity. Alt Energy, now World Energy, has just completed a refinery conversion to produce 600 million litres of jet biofuels per annum.¹⁰¹

Only five airports have regular biofuel distribution today (Bergen, Brisbane, Los Angeles, Oslo and Stockholm). The 15 million litres produced in 2018 comprised less than 0.1% of total aviation fuel consumption. There have also been criticisms that much biofuel has been produced from environmentally damaging feedstocks such as palm oil.¹⁰²

Converting rainforests, peat lands, savannas, or grasslands to produce food crop-based biofuels in Brazil, Southeast Asia, and the United States creates a “biofuel carbon debt” by releasing 17 to 420 times more CO₂ than the annual greenhouse gas (GHG) reductions that these biofuels would provide by displacing fossil fuels.¹⁰³

Ultimately the limitation of the biofuel scenario is the amount of land area required for cropping. Energy conversion solar to biomass is in the range of 0.5 to 1 watt/m².¹⁰⁴ For example, to supply our domestic aviation fuel requirements from an energy crop such as Jatropha or Camelina would utilise up to 70% of New Zealand’s arable land. For a country where agriculture is the largest tradable sector of the economy, this is clearly not feasible. A smaller contribution to biofuel production through using waste fats or algae based production may be possible.

A 2018 study outlines a roadmap for the production of biofuels in New Zealand.¹⁰⁵ The report addresses the longer-term problem of decarbonising the more difficult transport sectors including aviation. The Bioenergy Value Chain Model was used to consider a wide range of process technologies and feed stocks. The feed stocks would come mainly from new forests and forest residues using pyrolysis to produce crude bio oil, which with further refining could be used as a “drop in” substitute for diesel and be blended with fossil based jet fuel.

Low energy conversion of sun to biomass, a yield of log to fuel of 78kg per ton, and restraints on land use would limit the replacement of fossil fuels to an optimistic 30% of 2015 consumption. However, at scale it is estimated a generic fossil fuel could be produced at NZ\$0.89/L. But to meet the high specification jet fuel the cost increases to NZ\$2.21/L compared to the landed cost of Jet fuel NZ0.65/L (April 2019).

Could biomass wastes be a low cost biofuel feedstock? If land fill costs are taken into account, wood waste from construction and demolition and municipal solid waste could be assigned a negative cost. Harvest residues left in forests, and processing co-products from sawmills, or

¹⁰¹ <http://www.worldenergy.net/>

¹⁰² <https://www.nytimes.com/2018/11/20/magazine/palm-oil-borneo-climate-catastrophe.html>

¹⁰³ <https://science.sciencemag.org/content/319/5867/1235>

¹⁰⁴ There is potential to improve the efficiency of photosynthesis through genetic modification. However, such techniques are likely to be contentious. <https://phys.org/news/2019-01-scientists-photosynthesis-genetically.html>

¹⁰⁵ http://www.scionresearch.com/_data/assets/pdf_file/0017/63332/Biofuels_TechnicalReport.pdf

tallow from meat-processing and waste cooking oils are further examples reported in the table from the report and by biofuel producers.¹⁰⁶

Figure 21

Table 5.4: Maximum potential of residuals and by-products. Amount produced (thousand oven dry ton/yr, 2015)	Substitution potential (% of total 2015 liquid fuel demand)	
Tallow	178	2.2
Municipal solid waste	2358	0.7
Wood waste	229	0.8
Forest residues	1,240	4.5
Total		8.2

Source:

http://www.scionresearch.com/_data/assets/pdf_file/0017/63332/Biofuels_TechnicalReport.pdf

Although tallow and vegetable methyl esters are a possible refinery feedstock for jet fuels, the economics of this limited resource would favour the production of biodiesel.¹⁰⁷ This has been the strategy of Z Energy with its biodiesel plant.¹⁰⁸

A biodiesel grants scheme, which was in force from July 2010, subsidised fatty methyl ester production at \$0.42/L. This subsidy was discontinued in June 2012. The Biofuel Bill 2007 aimed to create a biofuel sales obligation in New Zealand, under which every fuel supplier's sales would have to include at least 0.5% biofuels. The Bill was signed into law in September 2008 and then was repealed in December of the same year after an unfavourable report by the Parliamentary Commissioner for the Environment.¹⁰⁹

With the low blending rates currently used, the ETS trading scheme is ineffective in incentivising a change to biofuels. Most early production of biofuel in New Zealand will go to decarbonising road based transport. So biofuel is not the aviation solution we are looking for.

¹⁰⁶ Nxtfuels is a New Zealand company exploring such options <https://nxtfuels.com/applications/greenfields/>

¹⁰⁷ <https://link.springer.com/article/10.1186/s13068-018-1020-4>.

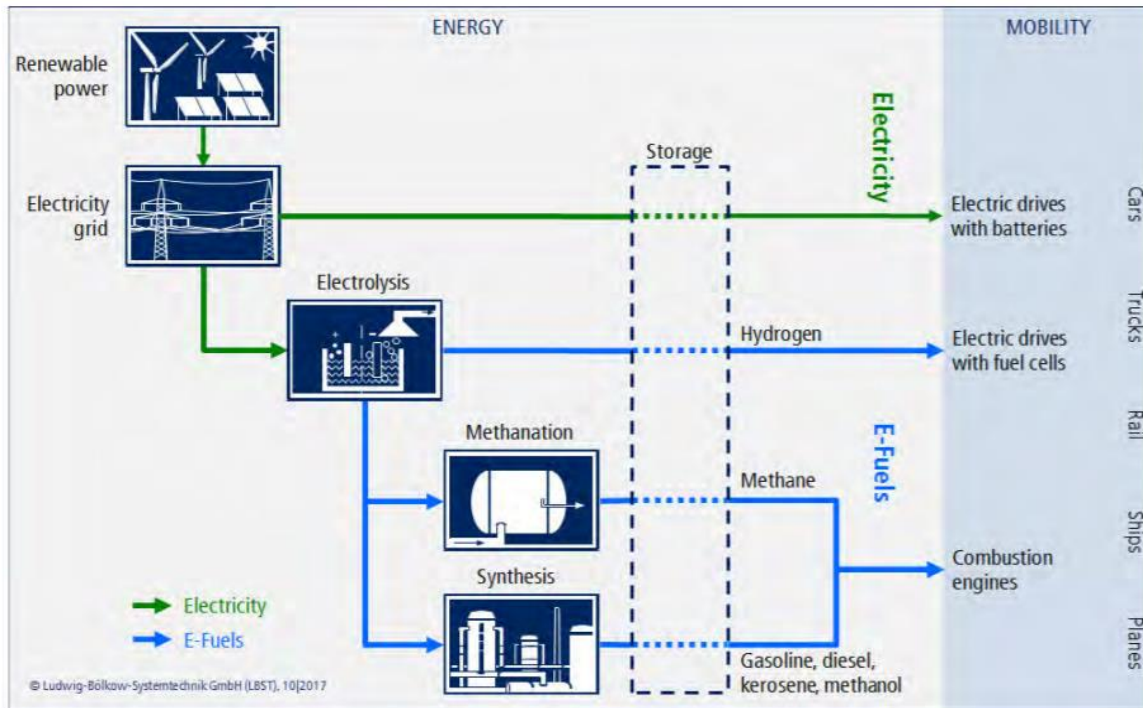
¹⁰⁸ <https://z.co.nz/keeping-business-on-the-move/fuels/z-biodiesel/info-hub/our-biodiesel-plant/>

¹⁰⁹ <https://www.pce.parliament.nz/media/1308/pce-biofuels-update2.pdf>

Emerging Fuel Technologies

There are a number of evolving technologies. Many ultimately rely on electricity so determining ways of increasing the production of renewable electricity is critical.

Figure 22



E-fuel production process and overview

Quantafuel, a start-up company, has devised a process for converting unrecyclable plastic to hydrocarbon fuels.¹¹⁰ The process, described in US pat 9199888, comprises cold plasma pyrolysis of plastic waste at 450°C. The resulting gasses are further processed via the Fischer–Tropsch process to a range of hydrocarbons suitable for jet fuel and low sulphur diesel. The technology has the potential to extend to wood and municipal waste. The business model is to quickly deploy small efficient plants to transform waste locally. The first commercial plant, a 60 tonnes per day plant in Skive Denmark, is expected to be in production this year, 2019. The process is low carbon, and cost competitive when compared with refinery production of jet fuel. The estimated fuel resource is in excess of 200Mt of waste plastic and increasing.

A similar process is used for converting biomass with supercritical high pressure steam at temperatures of greater than 350°C and up to 700°C. Gases, mainly hydrogen and methane, are suitable for conversion into liquid fuels via the Fischer–Tropsch process. A wide variety of

¹¹⁰ <https://quantafuel.com>

feed stocks may be used, from sewage sludge, to municipal waste and wood. The energy recovery is greater than either composting or anaerobic digestion to produce methane.

These options offer an opportunity to help solve another environmental problem: the reduction of waste going to landfills.

Electric Power to liquid fuels (PtL) is another alternative to sustainable fuels. Provided a low cost supply of low carbon electrical energy is available, this is a more scalable alternative. Nordic Blue in partnership with Sunfire and Climeworks AG have already begun the engineering of a PtL facility.¹¹¹

Carbon dioxide is extracted from air and reduced in a power cell by steam electrolysis to produce carbon monoxide and hydrogen. This gas mixture is transformed at high pressure and temperature in the presence of a catalyst to liquid fuels by the Fischer Tropsch process. The plant will have an annual production capacity of 8,000 tonnes and is expected to be operational in 2020. At a projected price of 2 euro/L this represents about 4 times the premium of the current jet fuel price of USD 0.5/L. Economy of scale will reduce this cost. As a proof-of-concept project it will be supported by the Norwegian and Scandinavian countries, via mandating the increased use of sustainable fuels over their airspace. Gunnar Holen, CEO of Nordic Blue Crude AS, said in a statement:

Our goal is to tenfold the capacity as soon as we have enough experience from operating the first plant in its first stage of operation with 10 million litres. In the long-term, up to ten similar plants could become reality in Scandinavia. We are proud to announce that we are now a full member of the Social Stock Exchange in London. This is an important milestone in financing the plants.

In the year 2017 New Zealand imported 111 kilotonnes and produced 313 kilotonnes of jet fuel. Using the Nordic Blue data this production would require 8,500 to 9,200 of GWhr of power which is 20% of current New Zealand annual electricity production. Tiwai point uses 5,000 GWhr at NZ\$60/MWhr. The electricity cost to produce New Zealand's jet fuel requirement: NZ\$1.31/kg or NZ\$1.05/L. With operating and capital expenses in addition to the power needed the cost could be easily double. Using CO2 sources such as refinery off gases or CO2 extracted from natural gas may mitigate these costs.

To offset the premium for biofuels, the EU has a compliance benefit under RED II (Renewable Energy Directive) regulations of 1.2 to 1. Although there is a target of 14% renewable transport fuels by 2030, the premium for jet fuel production is too low when compared to the production costs of biodiesel. California has a complicated system of credits which does offer some incentive for the production of jet fuel over biodiesel.

¹¹¹ <https://nordicbluecrude.no>

The Hydrogen Option – Wind Power to Fuel New Zealand?

Is there a power to fuel option based on hydrogen ideally suited to New Zealand?

The proposed goal of the current government is to achieve 100% renewable electricity by 2035. To cover seasonal variations there will be a requirement to overbuild renewable energy capacity.¹¹² A large percentage of power will be being generated from wind energy sources with intermittent and fluctuating outputs. There will be an increasing requirement for energy storage and peak power generation to balance the grid. This problem can best be solved by storing excess power as synthetic natural gas which can be stored or directly injected into existing gas networks to be used by existing gas peaking assets or converted to transport fuels.

Globally there are over 50 power to synthetic natural gas projects planned, in progress, or completed. Germany in particular has a renewable power problem. The technology is being driven by the significant gas distribution network assets, which Germany is unwilling to abandon. The technology has been extensively described and reviewed.¹¹³

Processing Kapuni and Maui natural gas is a point source of carbon dioxide gas which is extracted and exhausted to the atmosphere. As already discussed, this carbon resource can be converted into methane by reacting with hydrogen produced by electrolysis of water using excess renewable power. The co-production of oxygen provides an additional economic carbon capture offset via the Allam cycle.¹¹⁴

¹¹² https://www.nzherald.co.nz/nz/news/article.cfm?c_id=1&objectid=12243414

¹¹³ <https://about.taranaki.info/Taranaki-s-Industries/O-G.aspxhttps://reader.elsevier.com/reader/sd/pii/S0960148115301610?token=B5BC9EC9323C5ADAC53426D7AB5BD97327F8397BA3C4D12D432EE6C4B58F91DBF9C7DEC87016F7A411263DD6A7BFCA0A>

¹¹⁴ <https://www.forbes.com/sites/christopherhelman/2017/02/21/revolutionary-power-plant-captures-all-its-carbon-emissions-at-no-extra-cost/#62d196f1402d>

Figure 23: Kapuni CO2 gas extractors



From a local perspective, from 1986 to its closure in 1999 New Zealand had the only commercial gas to gasoline plant in the world.¹¹⁵ Potentially this facility could be re-commissioned to produce jet fuel. Taranaki seems particularly well set up to support new energy ventures.¹¹⁶

Nuclear energy to fuel?

Electrification of our light vehicle transport is feasible but progressing too slowly. The production of liquid hydrocarbon fuels, with the established distribution and heavy transport infrastructure, cannot be cheaply replaced in a timely manner. We cannot yet harvest sufficient energy from **low energy intensity sources** such as biofuels, solar energy and wind power to decarbonise the land based economy, even before we consider keeping New Zealanders and our increasingly numerous visitors flying to and from our shores.¹¹⁷ If we wish to keep flying, reduce our carbon footprint and secure a viable low carbon energy future, we need to consider other ways we can generate the electricity required to create liquid fuels and to power electric aircraft.

¹¹⁵ <https://www.engineeringnz.org/our-work/heritage/heritage-records/motunui-synthetic-fuels-plant/>

¹¹⁶ <https://www.stuff.co.nz/national/112546151/government-to-build-27m-clean-energy-centre-in-taranaki-20m-research-fund>

¹¹⁷ <https://drive.google.com/file/d/1tfRwuAAIUkk-WIhskfBdRSQ6auz2CUml/view>

...we can not continue drawing energy from fossil fuels and there is no chance that the renewables, wind, tide and water power can provide enough energy and in time. If we had 50 years or more we might make these our main sources. But we do not have 50 years; the Earth is already so disabled by the insidious poison of greenhouse gases that even if we stop all fossil fuel burning immediately, the consequences of what we have already done will last for 1,000 years. Every year that we continue burning carbon makes it worse for our descendants and for civilisation.¹¹⁸

The 2004 quote is from James Lovelock. Lovelock was among an early group of scientists who warned of the dangers of global warming. He is best known for his Gaia theory.¹¹⁹ Yet in many countries, including New Zealand, nuclear energy is rejected.

While clean fusion is still in a theoretical stage, cleaner fission is being promoted.¹²⁰ John Bucknell gave a presentation at the 2017 TEAC 8 conference promoting the use of a molten salt nuclear reactor (MSR) as an energy source for the conversion of CO₂ extracted from desalinated water to liquid fuels.¹²¹ For his conceptual process the calculated costs were methanol USD 0.32/L and gasoline USD 0.44/L. The projected cost of nuclear power from a MSR nuclear reactor is estimated at USD30/MWhr. The first practical MSR nuclear reactor will be the Moltex design projected to come on line in 2027. This reactor design will have a significantly lower hazard profile and environmental footprint than the current standard AP1000 water moderated reactors.¹²²

¹¹⁸ <http://www.jameslovelock.org/nuclear-power-is-the-only-green-solution/>

¹¹⁹ https://en.wikipedia.org/wiki/Gaia_hypothesis

¹²⁰ https://en.wikipedia.org/wiki/Fusion_power

¹²¹ <https://www.youtube.com/watch?v=Q1Fi3BnwL94>

¹²² https://en.wikipedia.org/wiki/Stable_salt_reactor

Final thoughts

Rather than trying to comfort politicians in their utopias, scientists should instead help them to get out of the denial of reality

G rard Bonhomme, Professor emeritus, University of Lorraine Chairman Energy/Environment commission of the French Physical Society

For all organisms it is the net energy, or the energy available to an organism or a society after investments to obtain that energy that is important, indeed that may be the most important factor in determining the long-term survival and wellbeing of humans and society.

Energy, EROI and quality of life, Jessica G. Lambert N., Charles A.S. Hall <https://www.sciencedirect.com/science/article/pii>

Much of the New Zealand political discussion has centred on measures the farming community should be taking to reduce methane emissions. There has been less discussion on the role of our transport fuels for a zero carbon 2050 vision. In particular, in New Zealand there is a dearth of published research on ways to decarbonise aviation. We urgently need discussion and debate on this topic.

Voluntary or compulsory offsets are a distraction. In the short to medium term, reducing flying needs to be the goal if we are to begin to decarbonize aviation. Certainly it would be easy to remove many of the incentives for flying such as ratepayer subsidies for airports and scrapping airport reward schemes. Domestically a reduction in flying would need to be supported by a dramatic improvement in low carbon land and sea based travel. There is no easy way of replacing international flights so reductions in flying seems the only feasible option. But unless there is some major transformation in thinking, it would likely be a hugely unpopular goal for much of the population. Some reduction may occur through various pricing mechanisms. But even these actions are likely to be politically difficult to implement. That leaves the main option as finding alternative fuels.

New Zealand is in an isolated position in the world and it behooves us to be self-sufficient on transport fuels. We are currently signaling the decline of fossil fuel reliance within our shores. This creates the dilemma of rapidly transforming our economy to increase our indigenous sustainable energy, or suffering a catastrophic decline in our standard of living.¹²³

¹²³ The correlation between Energy and GDP is discussed by Gail Tverberg <https://ourfiniteworld.com/2011/11/15/is-it-really-possible-to-decouple-gdp-growth-from-energy-growth/> and Nikos Tsafos (Senior Fellow, Energy and National Security Program, Center for Strategic and International Studies (CSIS)) discusses the difficulty to grow without using more energy in transportation. <https://www.csis.org/analysis/energy-and-growth-exploring-nuanced-relationship>

If, as seems likely, we will retain most of our present aircraft and transport infrastructure until 2050, will we have enough sustainable energy to produce our requirement for liquid fuels? David MacKay (Former UK Chief Scientific Advisor to the Department of Energy & Climate Change) set out to find a global answer with the UK as an exemplar.¹¹¹ Much of the forensic numerical analysis with regard to the limits of harvesting wind, solar, tidal and other forms of sustainable energy are relevant to New Zealand. His conclusions starkly reveal the difficult choices that must urgently be made in spite of the lower cost penalties of carbon dioxide emission. His estimate of 1 tonne of carbon dioxide per person per year to save the planet would make overseas air travel from New Zealand a rare experience for the average New Zealander. Excluding agriculture, our current carbon dioxide footprint is about 7 tonnes per person per year.

The current estimate of our global carbon dioxide budget is 800 Gt for a 2°C climate temperature increase. At 40 Gt/per year we have approximately 2 decades not only to reduce our dependence on fossil fuels as an energy source for transport, but also to transform our transport infrastructure. We need to rapidly investigate the best use of our remaining reserves of carbon-based energy to secure our future energy needs. Profligate expenditure of fossil fuels on air travel for leisure with trivial carbon offsets does not look to be a responsible option. Globally the true costs of air travel emissions are not being costed into the price of a ticket.

One of the metrics not often discussed is EROI, the amount of energy returned on the energy invested. For example it takes 1 barrel of oil to create 15 barrels of fuel. At EROI ratios less than 10, and with its associated demands on land use, we have seen that bio-energy is unlikely to do the whole job of decarbonising transport and in particular air travel.

Power to liquid fuels, as we have seen from the Nordic Blue example, at best retains 50% of the electrical energy invested in the production of a liquid fuel. By 2040 fossil fuel usage will be in decline, but if we wish for a 'business as usual' growth scenario for domestic and international flying, power to liquid fuel seems the only viable option, but only if we invest now in significant sustainable energy infrastructure. To this end we will require a high energy intensity source of renewable energy.

Is nuclear power an option? The current modern nuclear power plant has an EROI estimated between 35 to 40. Using Brinkly C as an example, at US\$8000/ KW to build, current nuclear is unaffordable. Wind turbines have a similar EROI to current nuclear power but the range of solar energy EROI values is significantly less. The energy intensity of wind is 2.5 watts/m² and solar 4 to 20 watts/m², which limits their large scale deployment due to the constraints of land area. It is also unlikely further major hydro schemes will be acceptable in New Zealand and there is often local opposition to windfarms. However there are many innovative designs emerging in nuclear technology based on molten salt. The Moltex SSR stable salt reactor has an estimated build cost per KW lower than either coal or gas and an EROI at least an order of magnitude greater than the present technology. The first build will be before 2030 and full commercialization will follow in the decade after.

This design is a radical departure from the present Boiling Water Reactors.¹²⁴ While building such plants in a volcanic and earthquakeprone country such as New Zealand has added challenges, they do provide an answer to one major objection to nuclear: these plants can burn radioactive waste from existing reactors. They operate at ambient pressure with non-volatile salts as the working fluid. The waste stream is one twentieth of current nuclear reactors and is dangerously radioactive for only 300 years. The risk of dispersal of volatile radioactive fuel is virtually eliminated. This technology has a potential to be factory mass produced in a base unit of 300 MWe and thereafter in increments of 150 MWe modules. A 1000 MWe power station requires only a tenth of the land area of conventional nuclear at an energy intensity of 10000 w/m². It looks to be the best energy source for achieving carbon neutral aviation fuels by 2050. Yet there is no discussion of the advanced Generation IV nuclear technology in any of our “Zero Carbon by 2050” documents. If we wish to keep flying at ever increasing rates, yet decarbonise aviation, should this really be our nuclear free moment?

Whatever the remaining risks of new nuclear power, it should not be discounted as an alternative option to the uncertainty of fossil fuels come 2040. As climate scientist James Lovelock states, if we are to replace fossil fuels with low carbon alternative energy sources, it cannot be business as usual. Liquid aviation fuel produced from fossil fuels is an incredible source of energy. Replacement fuels will not be without their own risks. As economists like to say ‘there is no such thing as a free lunch’.¹²⁵

¹²⁴ <https://www.powerengineeringint.com/articles/print/volume-24/issue-9/features/a-reactor-worth-its-salt.html>

¹²⁵ https://en.wikipedia.org/wiki/There_ain%27t_no_such_thing_as_a_free_lunch