Aviation, shipping & the Paris Agreement

@AliceClimate
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University of Manchester & Tyndall Centre for Climate Change Research
Sept 2017, Royal Society, London
Why aviation & shipping are interesting..

- Excluded from Kyoto, absent from Paris
- Contribute 4-5% annual global CO₂ (equiv. all S America!)
- Slow progress made by bodies mandated to deliver policy
- Sectors face very different mitigation challenges
- Service very different markets/activities

Derived demand (passenger)

- Leisure (53%)
- Shopping
- Celebrations
- Holiday
- Education & other (6%)
- Business (14%)
- Employment
- Friends and family (27%)
- Health
- Religious activity

Very much in public consciousness
And tend to fly much further
Derived demand (freight)

Consumption of goods & materials

International trade (e.g. fossil fuels; food)

Distribution of consumable goods

Just in time logistics

Largely unnoticed by public
Global trade in fossil fuels

Figure 4.4
Major seaborne trades by commodity

Source: Fearnley's Review

40% of trade by weight fossil fuel

1963–73
Trade doubled

1973–85
No growth

1986–2005
80% growth

Crude oil
Products
Iron ore
Coal
Grain
Other
Crude oil is the largest commodity traded by sea.
Mid-term goal: Carbon-neutral growth post 2020

Delivered primarily through

- A strong focus on market based mechanisms
- A heavy reliance on global offsetting

Long-term goal: to halve the industry’s current emissions by 2050

- Using offsetting/MBMs
- Ongoing efficiency drive & alternative fuel strategy
Recent International Chamber of Shipping proposal

Shipping should have a set GHG INDC equiv. inline with Paris
Called “premature & unscientific” by some – so not approved

Agreements at recent IMO Marine Environment Protection Committee (MEPC) meetings

- IMO’s legally binding efficiency index (EEDI) implemented in 2013
  \textit{NB: new ships already exceed the standards}
- Mandatory fuel consumption data collection approved – starts 2019
- MEPC 72 in 2018 set to adopt initial IMO GHG strategy & timelines

Emission projections
IMO’s own study anticipates a significant rise in shipping CO$_2$ by 2050
Airbus ‘Global Market Forecast’

Grown at higher rate than GDP growth – expected by the industry to continue.
3rd GHG Study from the IMO: GDP & fuel growth

**World Seaborne Trade (billion tonne-miles)**

Source: UNCTAD Review of Maritime Transport, 2014
Historical CO₂ emissions from aviation

<table>
<thead>
<tr>
<th>Year</th>
<th>Int'l aviation share*</th>
<th>Total aviation share*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>1.2%</td>
<td>2.4%</td>
</tr>
<tr>
<td>2000</td>
<td>1.4%</td>
<td>2.7%</td>
</tr>
<tr>
<td>2010</td>
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</tr>
<tr>
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</table>

*share of fossil + ind exc LU
Data: IEA detailed fuel est.
### Historical CO₂ emissions from shipping

<table>
<thead>
<tr>
<th>Year</th>
<th>Intl shipping share*</th>
<th>Total shipping share*</th>
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</thead>
<tbody>
<tr>
<td>1990</td>
<td>1.7%</td>
<td>2.1%</td>
</tr>
<tr>
<td>2000</td>
<td>2.0%</td>
<td>2.5%</td>
</tr>
<tr>
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</tr>
<tr>
<td>2013</td>
<td>1.7%</td>
<td>2.2%</td>
</tr>
<tr>
<td>2007-2012 ave IMO</td>
<td>2.6%</td>
<td>3.1%</td>
</tr>
</tbody>
</table>

*share of fossil +ind exc LU
Data: IEA detailed fuel est.

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**Graph:**
- **x-axis:** Year (1970-2020)
- **y-axis:** int'l aviation CO₂ emissions [MtCO₂]
- **Label:** Global CO₂ (ffi + lu) int'l shipping

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**Logo:**
- Manchester University
- Tyndall Centre for Climate Change Research
Combined aviation & shipping growth

<table>
<thead>
<tr>
<th>Year</th>
<th>Share of global incl LU</th>
<th>Share of total excl LU</th>
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<tbody>
<tr>
<td>1990</td>
<td>3.7%</td>
<td>4.6%</td>
</tr>
<tr>
<td>2013</td>
<td>4.2%</td>
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</table>

Data: IEA detailed fuel est.
What does 1.5°C mean for aviation & shipping?

The Future?
Global CO$_2$ emissions budgets

Cumulative CO$_2$ budget (2016-2100) in GtCO$_2$

<table>
<thead>
<tr>
<th>p</th>
<th>$\Delta T$</th>
<th>$&lt;1.5^\circ C$</th>
<th>$&lt;2^\circ C$</th>
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<tbody>
<tr>
<td>33%</td>
<td>650</td>
<td>1300</td>
<td></td>
</tr>
<tr>
<td>50%</td>
<td>350</td>
<td>1100</td>
<td></td>
</tr>
<tr>
<td>66%</td>
<td>200</td>
<td>800</td>
<td></td>
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</table>

Data from WG1, AR5, removing 2011-2015 est. CO$_2$
Assuming aviation & shipping...

Maintain a **proportional share** of the budget


What does this mean for CO₂ budgets & intensity change?
## Cumulative CO₂ budgets for aviation

Assuming const. 2.3% aviation share of global total

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<tr>
<td>33%</td>
<td>15.0</td>
<td>30.0</td>
</tr>
<tr>
<td>50%</td>
<td>8.0</td>
<td>25.3</td>
</tr>
<tr>
<td>66%</td>
<td>4.6</td>
<td>18.4</td>
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Cumulative aviation CO₂ budget (2016-2100) in GtCO₂
**Cumulative CO$_2$ budgets for shipping**

Assuming const. 2.2% shipping share of global total

<table>
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<td>33%</td>
<td>14.3</td>
<td>28.6</td>
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<td>7.7</td>
<td>24.2</td>
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<tr>
<td>66%</td>
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<td>17.6</td>
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Cumulative shipping CO$_2$ budget (2016-2100) in GtCO$_2$
Combine with future demand projections

• Typical demand projections for **aviation** assume 4-5% annual growth in RPK (revenue passenger-km) to 2030+

• Typical demand projections for **shipping** assume 4-5% annual growth in t-km (tonne-km) to 2030+
Annual CO₂ intensity reductions - aviation

Constant year-on-year reduction rate from 2016 onwards
Demand assumed constant from 2040 onwards
Required annual % change in carbon intensity (gCO₂/RPK)

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<td>9.2%</td>
<td>5.5%</td>
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<tr>
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<td>6.2%</td>
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**Annual CO$_2$ intensity reductions - shipping**

Constant year-on-year reduction rate from 2016 onwards
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<td>66%</td>
<td>21.5%</td>
<td>8.0%</td>
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Near term mitigation options?

- Limited by long life-time of aircraft and ships
- $\text{CO}_2$ intensity improvements typically 1-2% p.a.
- If growth & share maintained ~7% $\text{CO}_2$ p.a. intensity reduction
- Slow steaming & retrofit for ships (not planes!)
  - Rigid or soft sails, kites, Flettner rotors
- Aircraft have few options other than a drop-in biofuel
- Electric hybrid aircraft not ready until 2030 (Sugar Volt)

Near term mitigation options?

- Demand-management key to both
  - Moratorium on airport expansion
  - Virtual reality/hologram meetings
  - Decarbonisation = less fossil transport

- But still scale of change doesn’t stack up under 1.5°C budget
Example 2°C energy scenario

14 Gt CO₂ in 2050 removed from the atmosphere.

OR no space in budget for transport & industry CO₂
Biofuel?

- Fuel Performance
  - Thermal stability
  - Storage stability
  - Cleanliness
  - Microbial growth
  - Lubricity
  - Freeze Point
  - Fluidity
  - Non-corrosivity
Conclusions (in Paris context)

What works?
Constraining airport expansion in wealthy nations
Some biofuel options viable but issues of competition & tech. spec
Many mitigation options in shipping (slow-steaming)
Decarbonising other sectors reduces shipping demand
Conclusions (in Paris context)

What doesn’t work?
Assuming tech. fixes for aviation fit Paris timeframe
Assuming technical fixes alone can deliver on Paris
Leaving mitigation efforts to own industry bodies
  - even if CO₂ level maintained – CO₂ intensity changes needed likely >5% p.a.
A reliance on global off-setting to incentivise sufficiently rapid innovation
Conclusions (in Paris context)

What needs to be done?

Realistic inclusion of sectors’ CO$_2$ trajectories in the global scenarios

Sectors required to deliver own ‘N’DCs

Complimentary policy instruments explored and incorporated in NDCs

Demand management discussed as a realistic element of policy portfolio
Thank you!

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What if….?

Q: What if combined aviation and shipping CO₂ grows at 2% until 2030, peaks, then reduces to a max of 6% p.a. reduction?

A: $\frac{1}{3}$ of 50% chance of 1.5°C budget consumed by these sectors
Biofuel?

- Jet fuel
  - 1000s of chemical species
  - Stringent quality control
  - Larger molecules than kero
  - Impurities: metals & sulphur
  - Little performance control

- Heavy fuel oil
  - Bio/synthetic kerosene
    - Composition depends on production & feedstock.
    - Smaller range of molecules
    - 'Drop in fuel' up to 50% blend
    - Feedstock availability key
    - Expensive
    - Oxygenates such as acids can be an issue for performance and stability
    - Engines less sensitive

- Biofuel?
  - ref: www.safug.org

- Storage stability
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