Higher, Faster, Farther & Greener?
Low Carbon Aviation Technology Challenges & Opportunities

David Tew
Program Director

July 8, 2019
## Historical Perspective

### New York to Paris (Le Havre) Example

<table>
<thead>
<tr>
<th></th>
<th>1925 (SS Paris)</th>
<th>2015 (767-300ER)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Passengers</strong></td>
<td>2100</td>
<td>350</td>
</tr>
<tr>
<td><strong>Duration</strong></td>
<td>6 days</td>
<td>6 hours</td>
</tr>
<tr>
<td><strong>Fuel Consumption</strong></td>
<td>Coal, 5400 tonnes</td>
<td>Kerosene, 24 tonnes</td>
</tr>
<tr>
<td><strong>Emissions Rate (g CO₂/pkm)</strong></td>
<td>&gt;1000</td>
<td>&gt;100</td>
</tr>
</tbody>
</table>
Aviation Passenger Traffic

Global Passenger Traffic Forecasts

- **Forecast**
  - 2012-2042: 4.5%
  - 2012-2032: 4.6%

- **History**
  - 1995-2012: 5.2%
  - 2015: 38%
  - 2020: 59%
  - 2025: 62%
  - 2030: 58%
  - 2035: 42%
  - 2040: 8 billion passengers

- **Scheduled Services**

- **Revenue Passenger Kilometres (RPK)**
  - (trillions)

- *International* vs *Domestic*
Distance-Specific Emissions

$CO_2$ Emissions (g / km / passenger)

<table>
<thead>
<tr>
<th>Mode</th>
<th>Emissions (g / km / passenger)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rail</td>
<td>14</td>
</tr>
<tr>
<td>Bus</td>
<td>68</td>
</tr>
<tr>
<td>Car</td>
<td>104</td>
</tr>
<tr>
<td>Van/SUV</td>
<td>158</td>
</tr>
<tr>
<td>Aircraft</td>
<td>285</td>
</tr>
</tbody>
</table>

Market Challenge – Speed

FAA moves to support growth of civil supersonic air industry

WASHINGTON (Reuters) - The U.S. Federal Aviation Administration (FAA) said on Monday it is moving to rewrite testing rules to allow for the eventual return of civil supersonic air travel.

At an event in Paris on Monday, Acting FAA Administrator Dan Elwell said the agency is working to “enable the return of civil supersonic travel, while ensuring the environmental impacts are understood and properly addressed.”

Higher Speed

- More Interconnected World
- Higher Energy Consumption
**CO₂ Emissions Drivers**

\[
\hat{M}_{CO₂} = \frac{W_{Total}}{N_{Passengers}} \frac{L}{D} \eta_{propulsion}
\]

**Fuel Carbon Intensity**

[kg₇₀₂/kWh]

**Aircraft Performance**
- Total weight / passenger [N/p]
- Lift to drag ratio

**Propulsion System Efficiency**

**Also need high energy density [kWh/kg] and low cost [$/kWh] fuel for attractive aircraft performance**
Technology Needs

1. Energy storage
   a) Low carbon intensity
   b) High specific energy (w/storage)
   c) Low cost

2. Efficient, light weight & low cost
   a) Aircraft
   b) Propulsion Systems

https://www.nasa.gov/feature/aviation-renaissance-nasa-advances-concepts-for-next-gen-aircraft
Next Steps

› Please talk to us
  – Grigorii Soloveichik: grigorii.soloveichik@hq.doe.gov
  – Micheal Ohadi: michael.ohadi@hq.doe.gov
  – Isik Kizilyalli: isik.kizilyalli@hq.doe.gov
  – Greg Thiel: gregory.thiel@hq.doe.gov
  – David Tew: david.tew@hq.doe.gov

› Watch for upcoming workshops & programs
https://arpa-e.energy.gov