Aircraft Technology Modeling and Assessment

Project 10

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CLEEN Consortium Meeting

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ASCENT

AVIATION SUSTAINABILITY CENTER

Project 10

Aircraft Technology Modeling and Assessment

Georgia Institute of Technology & Purdue University

PI: William Crossley, Daniel DeLaurentis (Purdue)

PM: Sandy Liu

Cost Share Partner(s): Purdue University, OAG

Objective: Model and assess potential evolution of commercial airline fleet due to the introduction of future supersonic aircraft and how technology development could affect the environmental impacts of aviation (e.g., fleet-level fuel burn, emissions and noise). *The effort will examine SST vehicle modeling; fleet route simulation; fleet simulation, and AEDT supersonic modeling.*

Project Benefits: Provide an understanding of how introduction of new supersonic transports that could enter into commercial airline service and private use will affect fleet-wide fuel burn, noise and emissions.

Research Approach:

- Use Fleet-Level Environmental Evaluation Tool (FLEET) to model airline operations and predict evolution of fleet utilization along with environmental impacts
- Purdue's three major tasks for current effort:
  - Expanding FLEET's US-touching route network to a global network
  - Assess impact of introducing SST into airline fleet for a variety of demand evolution scenarios
  - Develop prototype business jet analog to FLEET to analyze the fleet-level impacts of supersonic business jet aircraft

Major Accomplishments (to date):

- Expansion of FLEET to accommodate use of alternate SST concepts
- Generated worldwide cost coefficients for alternate SST concepts
- Analysis of worldwide network using all SST concepts
- Assessment of impact of sustainable aviation fuels of subsonic and supersonic aircraft

Future Work / Schedule:

- No future work planned for A10
- Continue to expand FLEET capabilities for SAF analyses and for business jet operations

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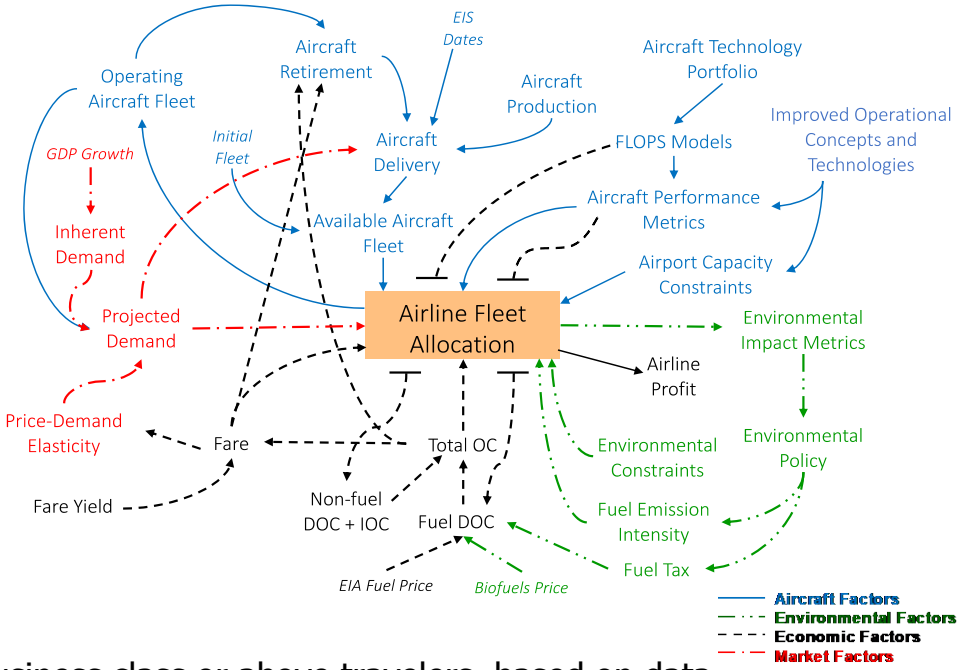
Fleet-Level Environmental Evaluation Tool (FLEET) and Supersonic Demand Prediction

- FLEET is a system dynamics-inspired simulation tool to evolve airline fleet, passenger demand, and environmental impacts over time
  - Maximize profit while allocating aircraft on routes to meet passenger demand
  - Introduce technologically advanced aircraft and retire aircraft from the fleet
  - Explore environmental and operational impacts of demand and fleet evolution



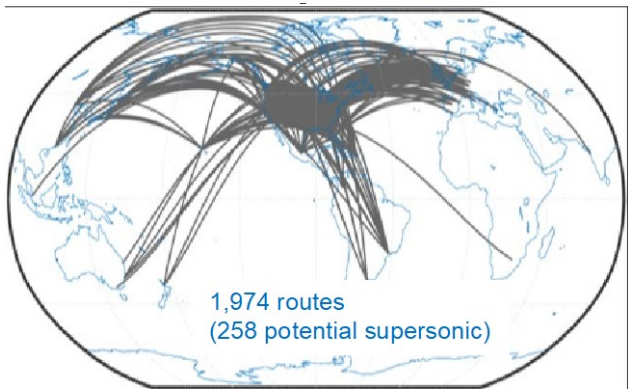
- Introducing supersonic aircraft to FLEET
  - Assume 5% of passengers on a route are business class or above travelers, based on data for historic domestic flights – these are potential passengers
  - Consider A10 Notional SSTs (55-pax @ M1.8, M2.0, M2.2; 75-pax @ M2.2, 100-pax M1.6, M1.8, M2.0) provided by Georgia Tech colleagues, with performance and block time and fuel coefficients from FLOPS, ground path of route flown from GT's algorithm
  - Analyze operations on all global routes, including potential routes for supersonic operations
  - Assess potential impact of sustainable aviation fuels (SAF) on emissions with SSTs in fleet (still in progress)

Supersonic demand includes both passenger demand and routes

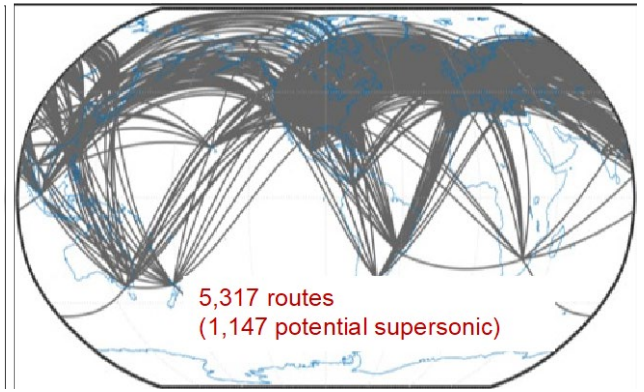
FLEET US-touching to Worldwide network

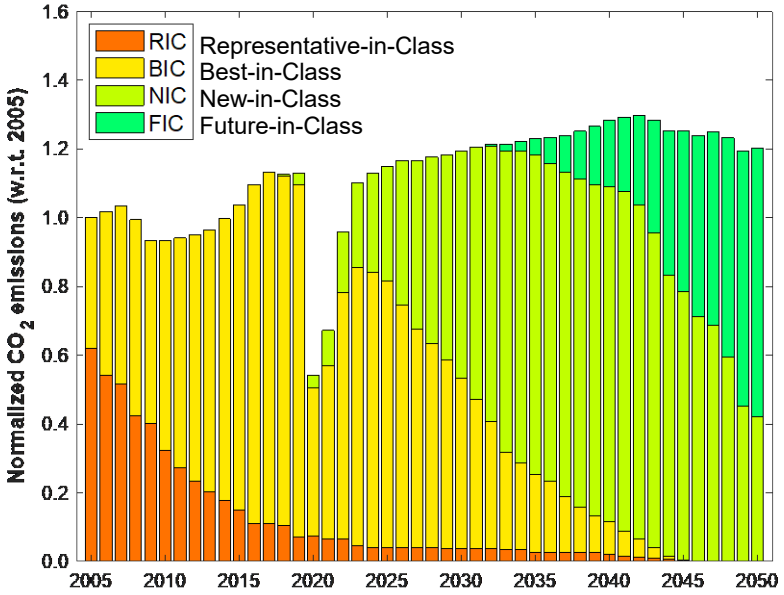
- OAG data represents airline worldwide network (2011 baseline)
  - Estimate fleet size and mix for worldwide airline operations
  - Update historical demand to 2019 and model COVID impact and recovery on travel demand
- Estimate fleet evolution and projected emissions

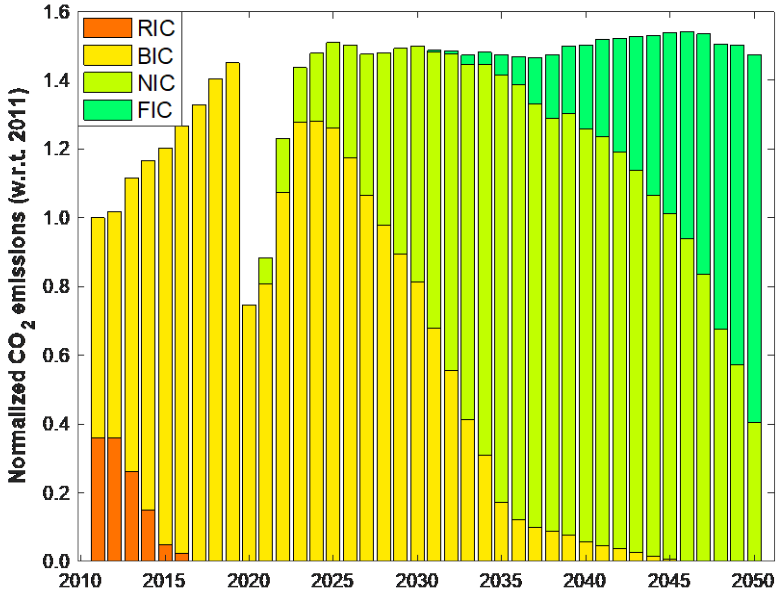
"US-touching" route network



Worldwide route network



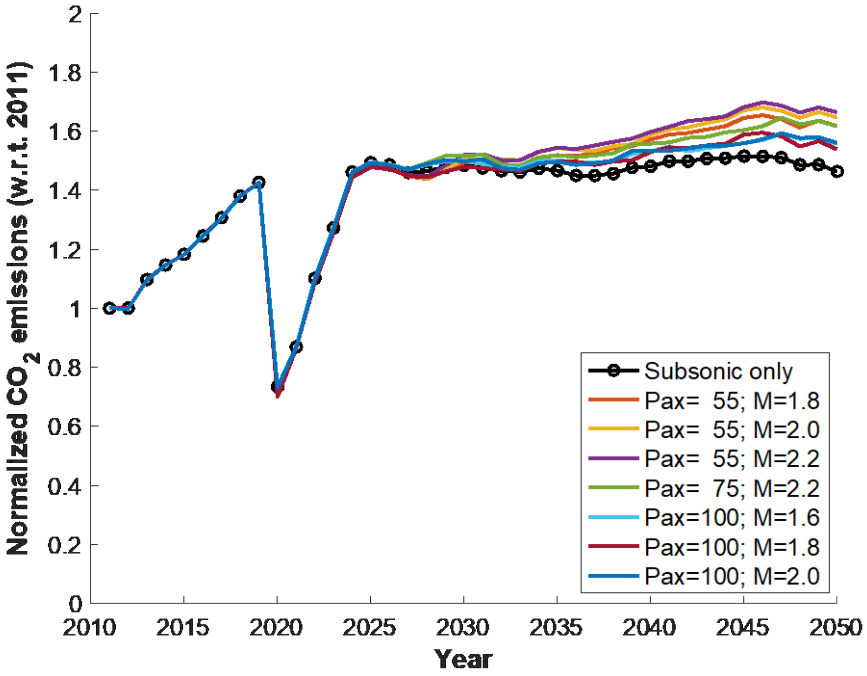


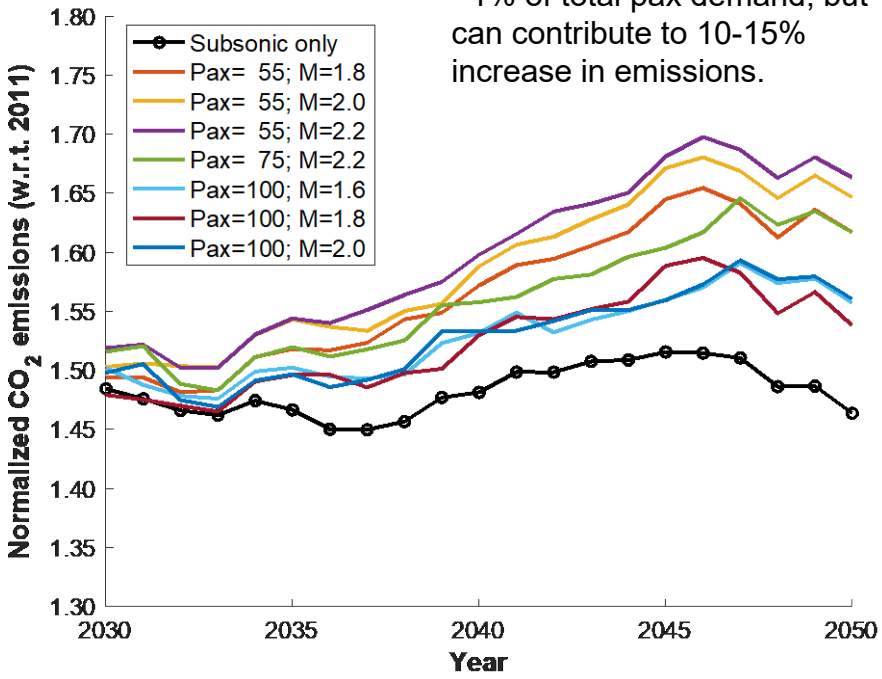


Impact of SST Concepts on WW Network and Emissions

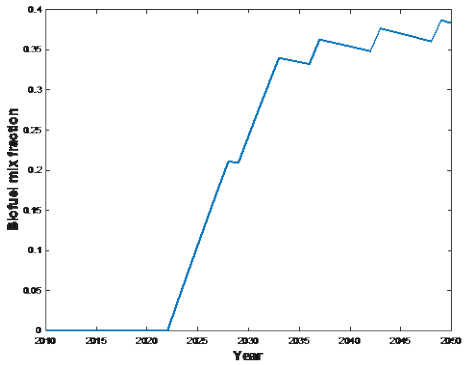
- Seven SST concepts analyzed, independently (one at a time)
- Two classes of SST modeled
  - New-in-class (EIS 2024)
  - Future-in-class (EIS 2038): 10% fuel burn improvement
- Significant emissions increase expected due to higher fuel burn of SST
  - However, lower fleet-level emissions associated with use of higher pax-capacity SST concepts due to lower levels of service
  - Profit considerations of SST, given the available demand, drives lower utilization of high capacity SST aircraft

By 2050, SST demand is only ~1% of total pax demand, but can contribute to 10-15% increase in emissions.

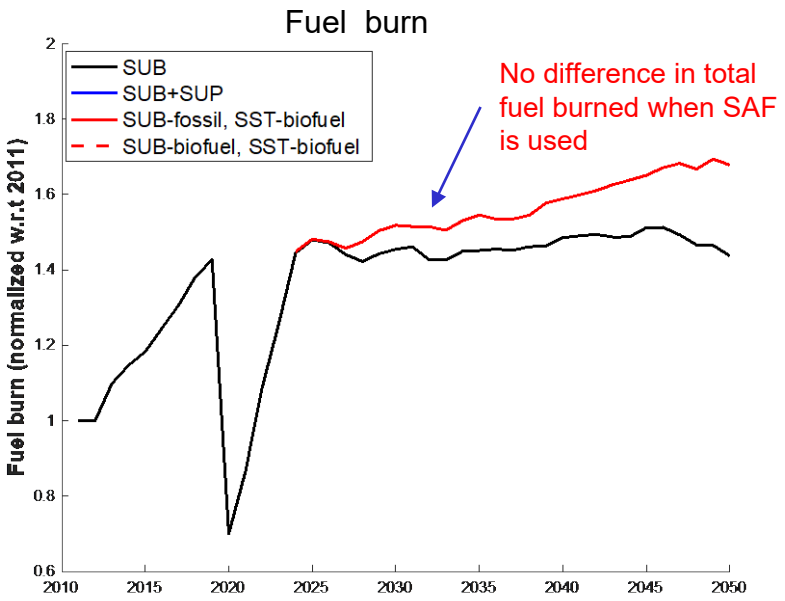


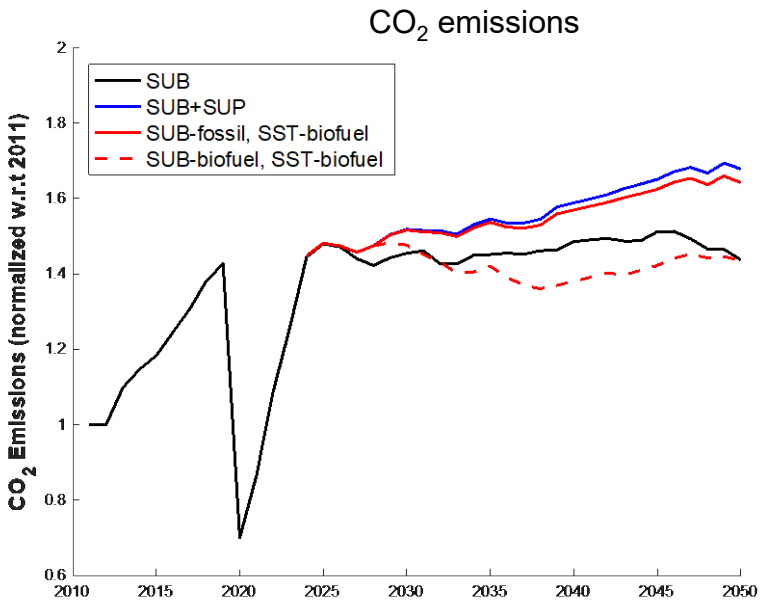


Effect of SAF Allocation Schema



- Case-1:
  - Biofuel available for subsonic and supersonic fleet
- Case-2:
  - Biofuel available only for supersonic fleet
- Assumptions:
  - Ratio of SAF to total fuel starts at zero in 2022 and increases to 38% by 2050
  - SAF emissions intensity 2.312 lb/lb (vs. 3.775 lb/lb of fossil fuels)
  - Post-processing of emissions calculations; i.e., cost of SAF is same as petroleum-based Jet A and demand is not affected





MORE DETAILS (NEXT SLIDES)…

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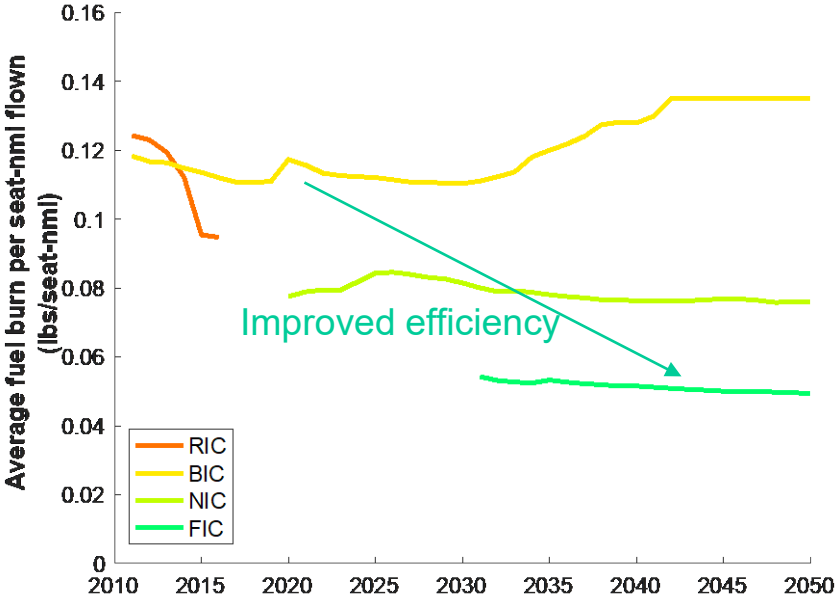
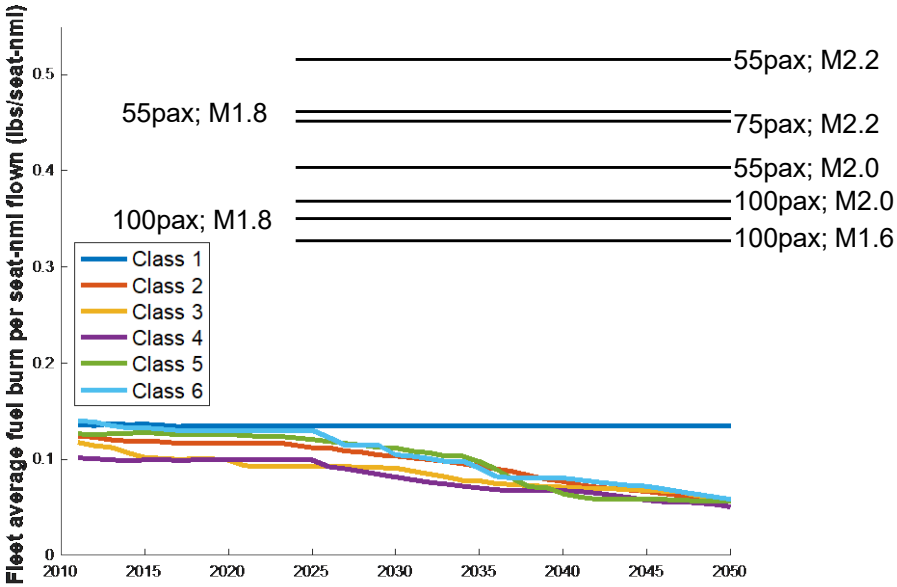
Average Fuel Efficiency Comparison

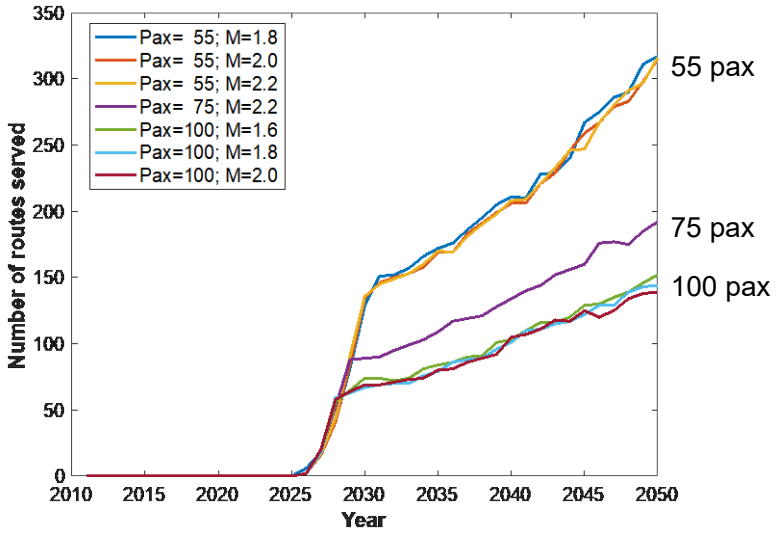
- Higher fuel burn of SST results in this observed trend, even though the fraction of demand that SST serves is small

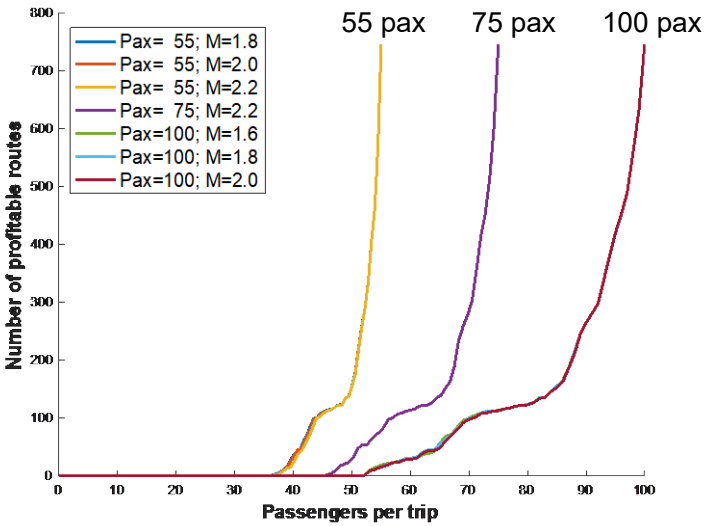




Impact of Alternate SST on WW Network

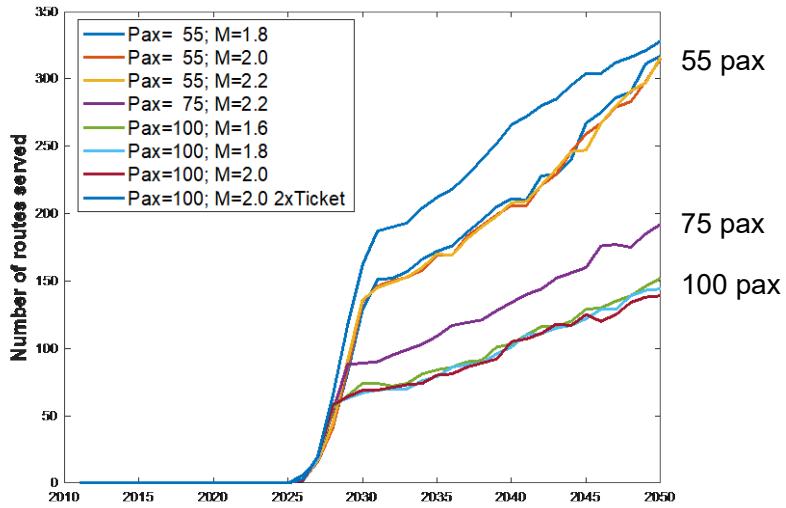
- Lower fleet-level emissions associated with use of higher pax-capacity SST concepts are a result of lower levels of service
  - Higher pax-capacity SST means less demand is served and therefore lower fuel burn
  - High pax-capacity aircraft cannot achieve sufficiently large load factor to generate profit
- Profitability of SST given the available demand drives lower utilization of SST

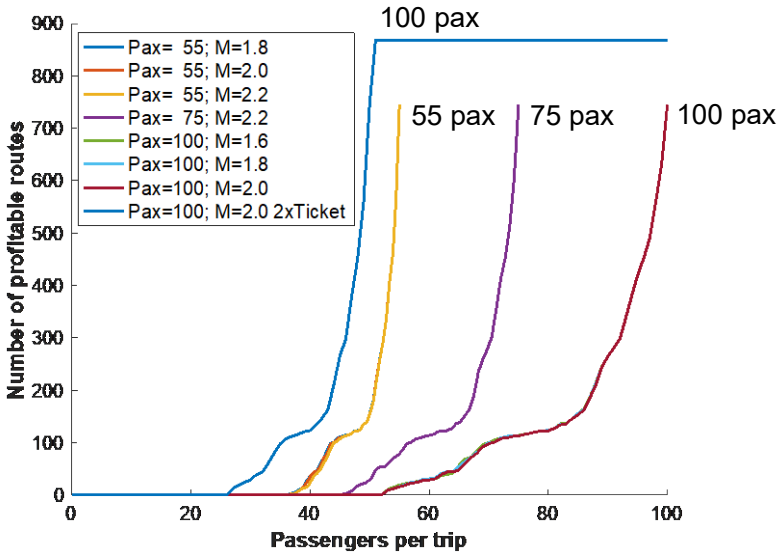




Impact of Alternate SST on WW Network

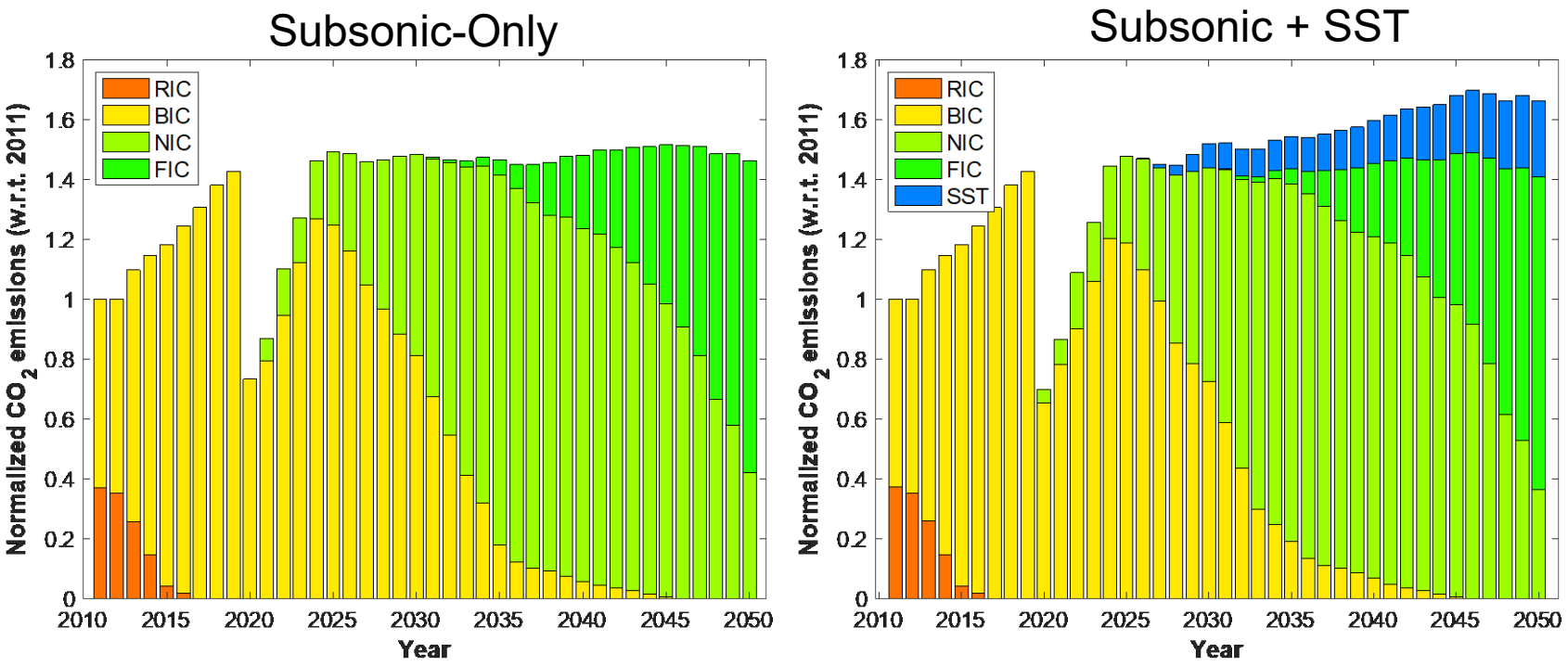
- We investigate impact of profitability by considering an example scenario in which the ticket price of supersonic travel is 2x higher
- More routes are served, at a lower load factor





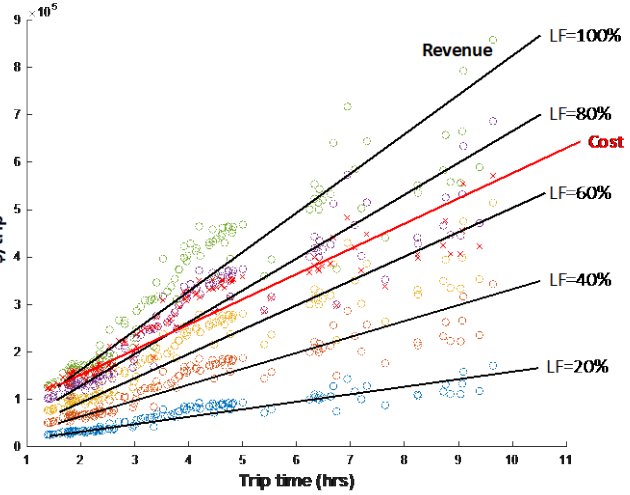
Impact of "55pax M2.2" SST on WW Network

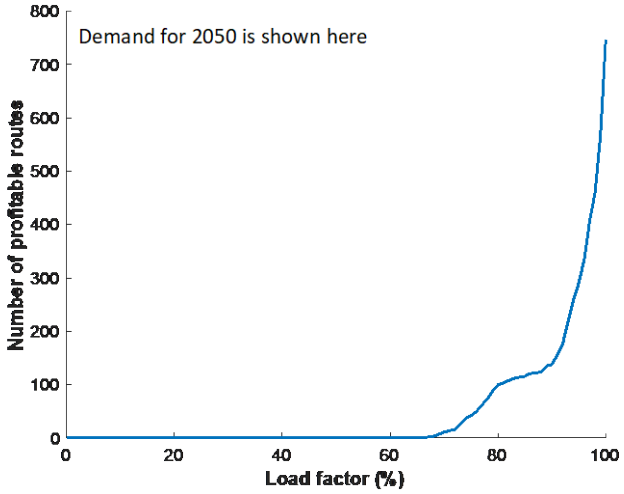
- Evolution of subsonic aircraft maintains emissions at relatively constant level
- Introduction of SST results in relatively significant increase in emissions (13% higher by 2050, compared to cases when no SST is in service

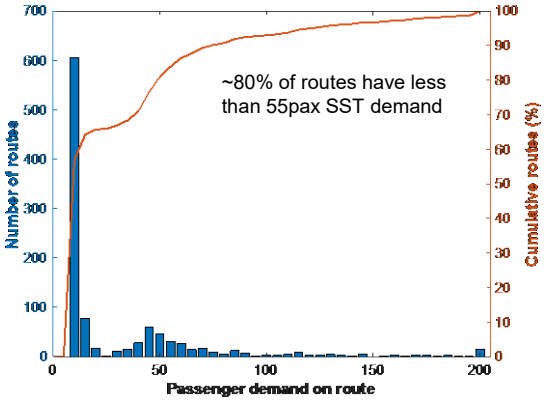


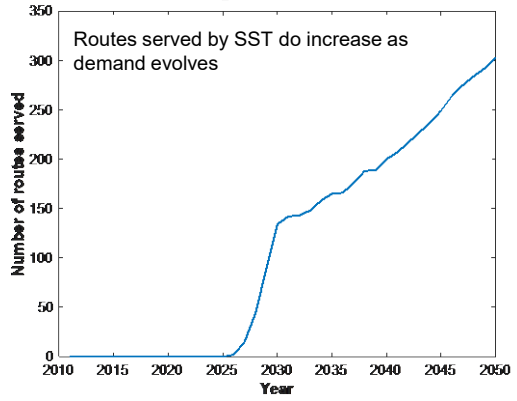
Impact of "55pax M2.2" SST on WW Network

- The small level of demand served by SST is a result of its profitability
- The breakeven load factor is relatively high, and when coupled with the available SST demand, there is insufficient demand to achieve higher load factors









Demand Price Elasticity Affects Demand and emissions

- Emissions are lower when SAF are used
  - Combination of reduced demand and emissions intensity of biofuels
- Fuel consumption, however, is higher
  - Increase in utilization of Class-5 aircraft drives increased fuel consumption
  - Class-5 aircraft has 2nd highest profit margin per trip, and changes in pax demand result in allocation results that can increase profit when Class-5 aircraft is used