Global Demand Model to Support the Inter-center Systems Analysis Team (ISAT) Passenger Demand Forecasts

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ISAT Global Demand Modeling Studies Background

In 2017, the PAMO/ISAT has sponsored a global aircraft emissions study with the Virginia Tech Air Transportation Systems Laboratory through a contract with the National Institute of Aerospace. As part of this work, Virginia Tech developed the Global Demand Model (GDM), which forecasts global commercial aviation passenger demand out to 2040.

GDM Description:

An economic regression model that predicts the number of air passenger seats worldwide using GDP, population, and airline market share as inputs

ISAT Global Demand Modeling Studies Background

In FY21, ISAT proposed building a model architecture that could start with global future worlds scenarios, convert the qualitative scenarios descriptions into quantitative inputs for a macroeconomic model, feed the socio-economic outputs from the macroeconomic model into a global demand model, feed the global demand forecast into a fleet operations/retirement model, compute global fuel consumptions and emissions.

A study was initiated to revive GDM and explore if it could be used as a component in this proposed architecture by adding more socio-economic inputs that impact the GDM passenger demand forecast. We brought in subject matter experts from the U.S. DOT Volpe Center to advise.

The study was successful in improving/validating the GDM demand predictions. Several global scenarios were examined. However, the datasets the GDM utilizes ultimately did not support adding more explanatory variables. As a result, we were unable to increase the flexibility of the GDM by adding more socioeconomic inputs.

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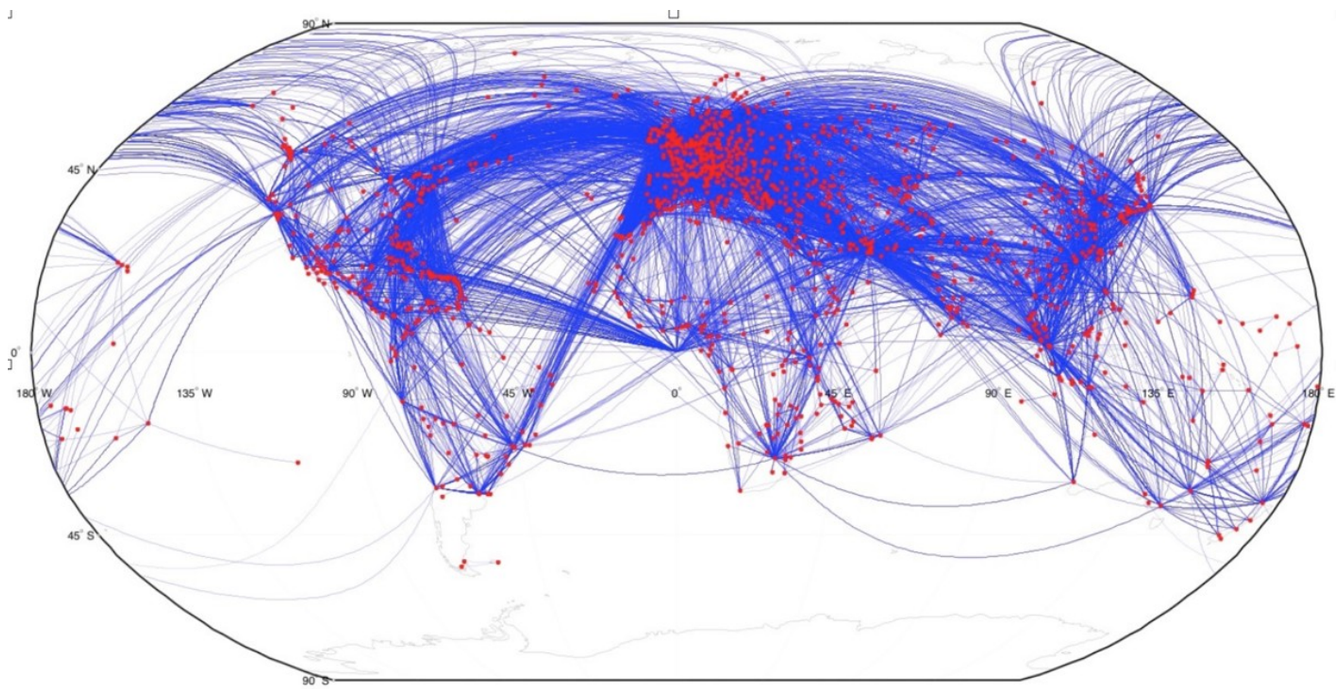
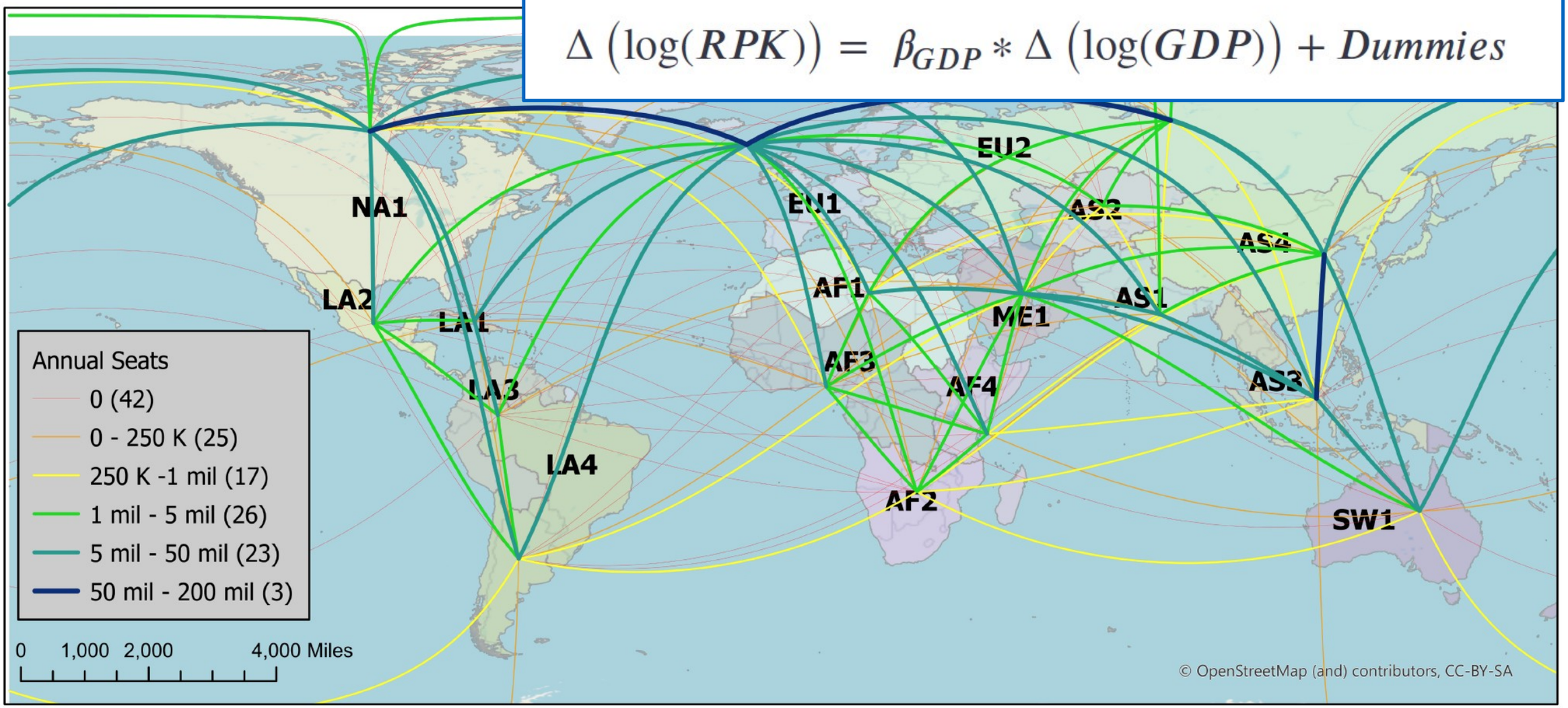


Global Demand Model 2

- Uses regression panel data analysis
- Models interactions between 103 regional (OD) pairs worldwide (17 world regions)

- Difference Log Model:

$$\Delta\left(\log(RPK)\right) = \beta_{GDP} * \Delta\left(\log(GDP)\right) + Dummies$$



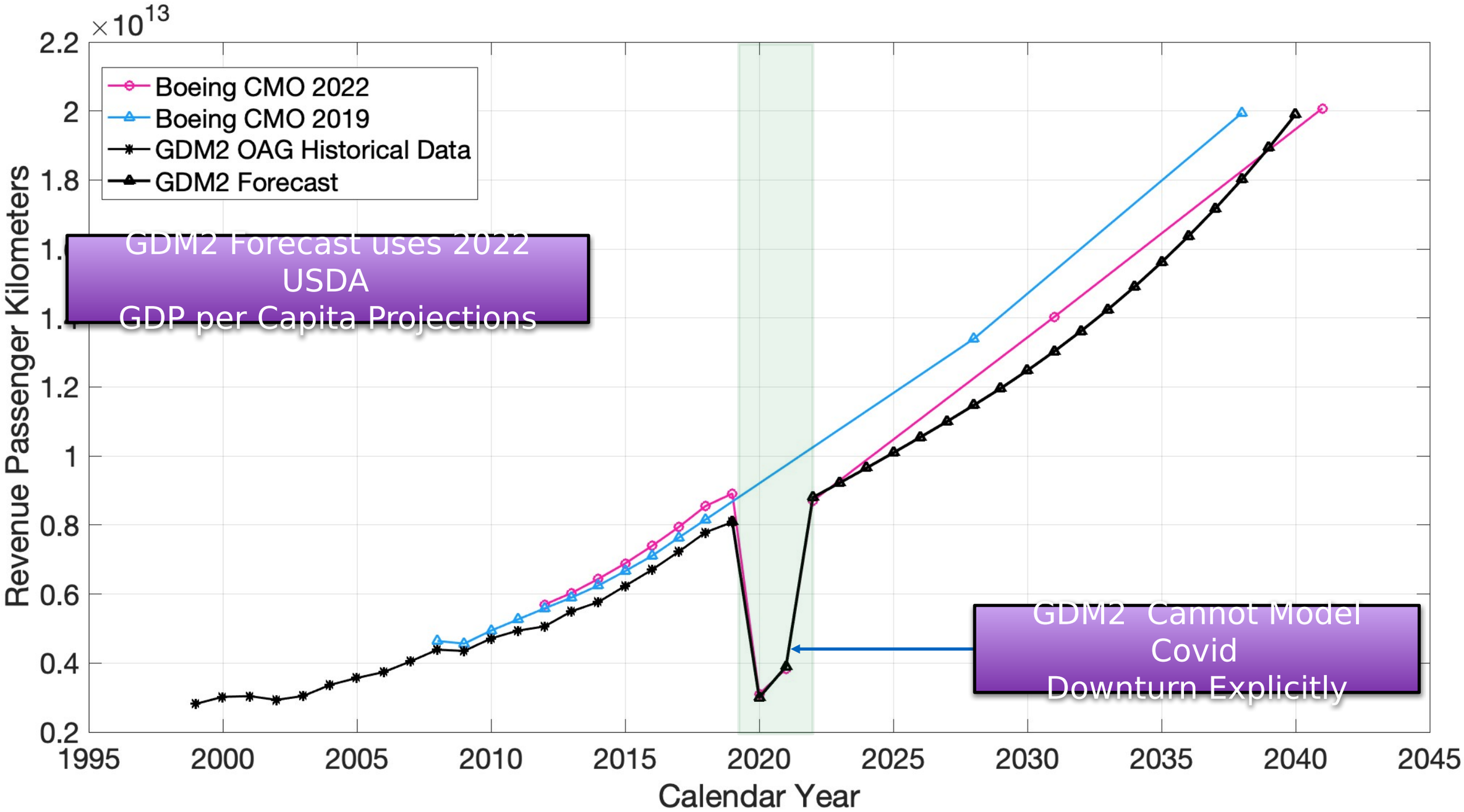
Analysis and Map: Virginia Tech Air Transportation Lab with Matlab with OpenStreet Map Layer

Scenarios Modeled with Global Demand Model 2

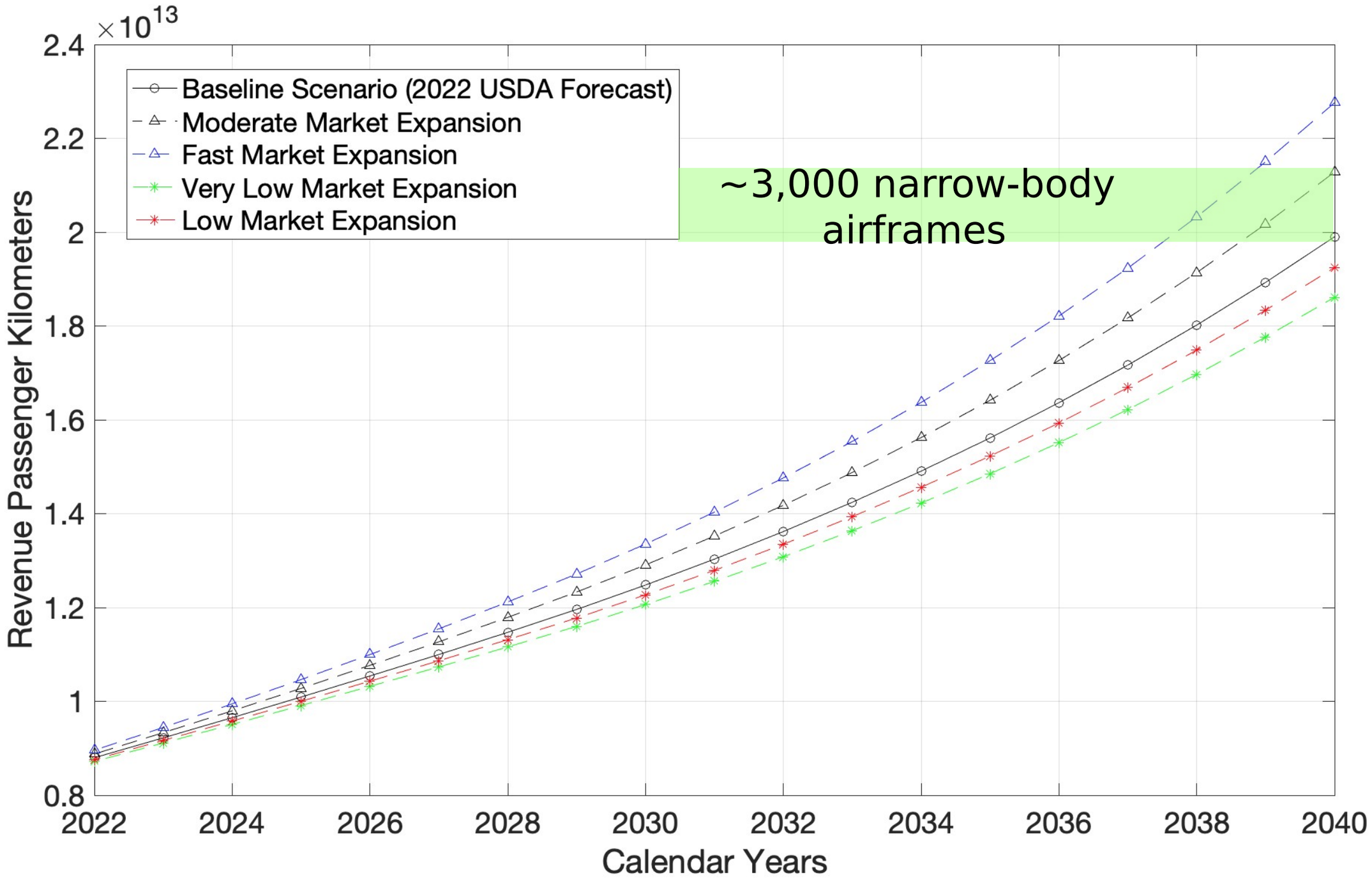
Scenario	Economic Projections	Remarks
Baseline (Business as Usual)	Uses USDA 2022 GDP per Capita Projections	USDA 2022 projections before Russia-Ukraine war
Market Expansion	+0.4%, +0.2% (compounded) from baseline -0.2% and -0.1% (compounded) from baseline	US Federal Reserve uncertainty in GDP projections for US
War Scenario	20% reduction in GDP per Capita for Russia and Ukraine over five years Baseline - 0.5% (compounded for other nations)	Cato Institute Study of the effect of War on GDP and OECD GDP reduction projections due to Russia-Ukraine war
Introduction of Highly Efficient NASA N+2 Aircraft	Introduction of Five classes of NASA Advanced Aircraft into the world fleet	Uses Nickel and Haller design point projections and VT analysis to estimate fuel savings over a wide range of market applications
Sustainable Fuels in the United States Market	Introduction of Five classes of NASA Advanced Aircraft into the North American Market	Uses the GDM2 model North American projections to estimate sustainable fuel impact
Economic Recession Scenario	GDP per Capita reductions observed in 2007-2008 and models an economic recession in 2032	Simulates a recession in the future with similar characteristics in 2007-2008

Global Demand Model 2 Baseline and Market Expansion Scenarios

Global Demand Model Baseline Model Projection Compared to Boeing Commercial Outlook Projections



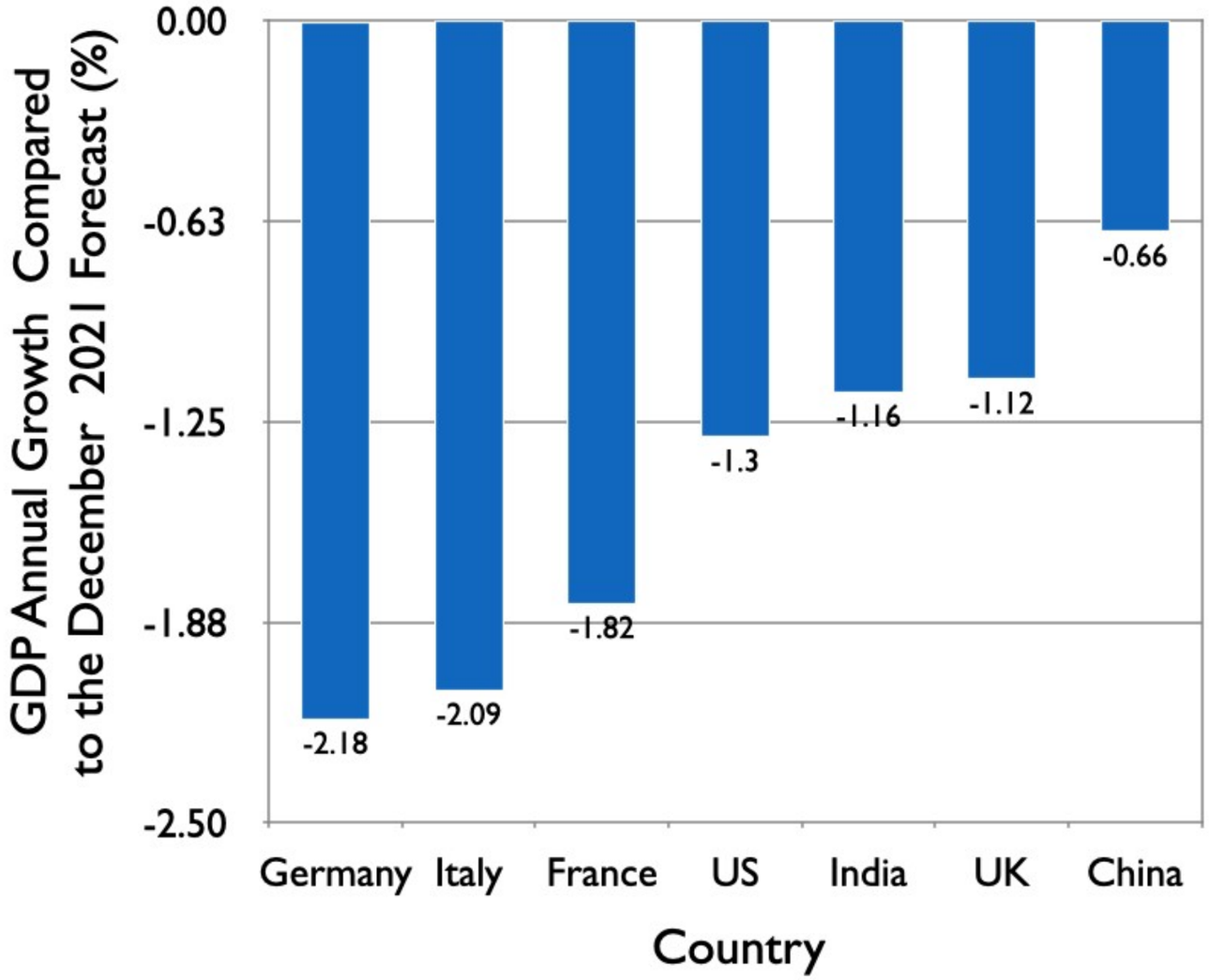
GDM2 Model Sensitivity: 0.1% (compounded) Increase in GDP per Capita Increases RPKs by 3.5%



Scenario: Effects of War between Russia and Ukraine

Reductions in GDP Growth in a War Scenario

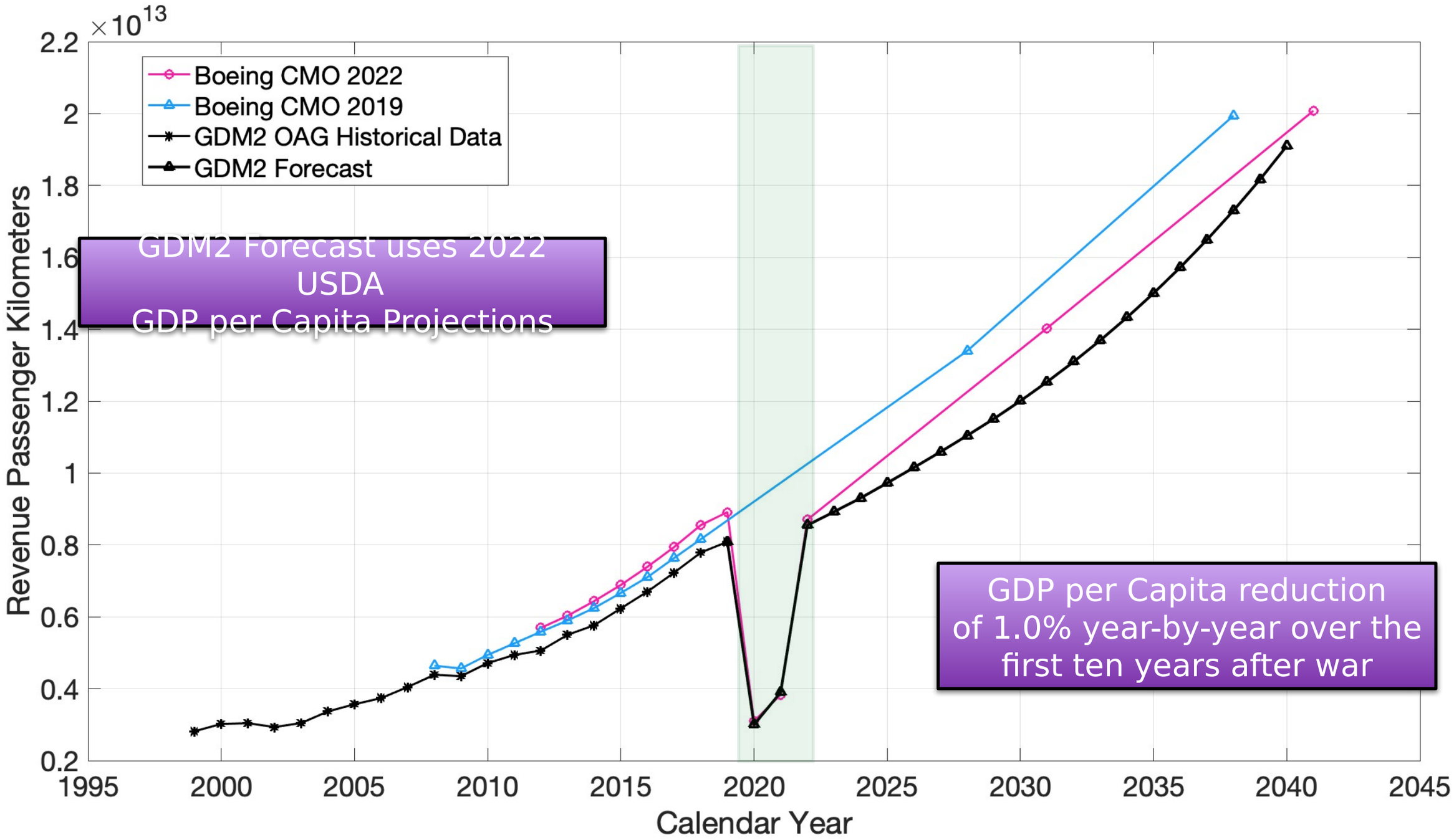
- 16-24% reduction in GDP per Capita due to a Magnitude 7 war scenario (Theis and Baum, 2020)[1]
- Commodity prices change
- OECD projects rapid deceleration of GDP for European countries and the United States
- Most countries GDP growth is around 1% below the December 2021 forecast



Source of OECD Data: https://www.oecd-ilibrary.org/sites/62d0ca31-en/index.html?itemId=/content/publication/62d0ca31-en

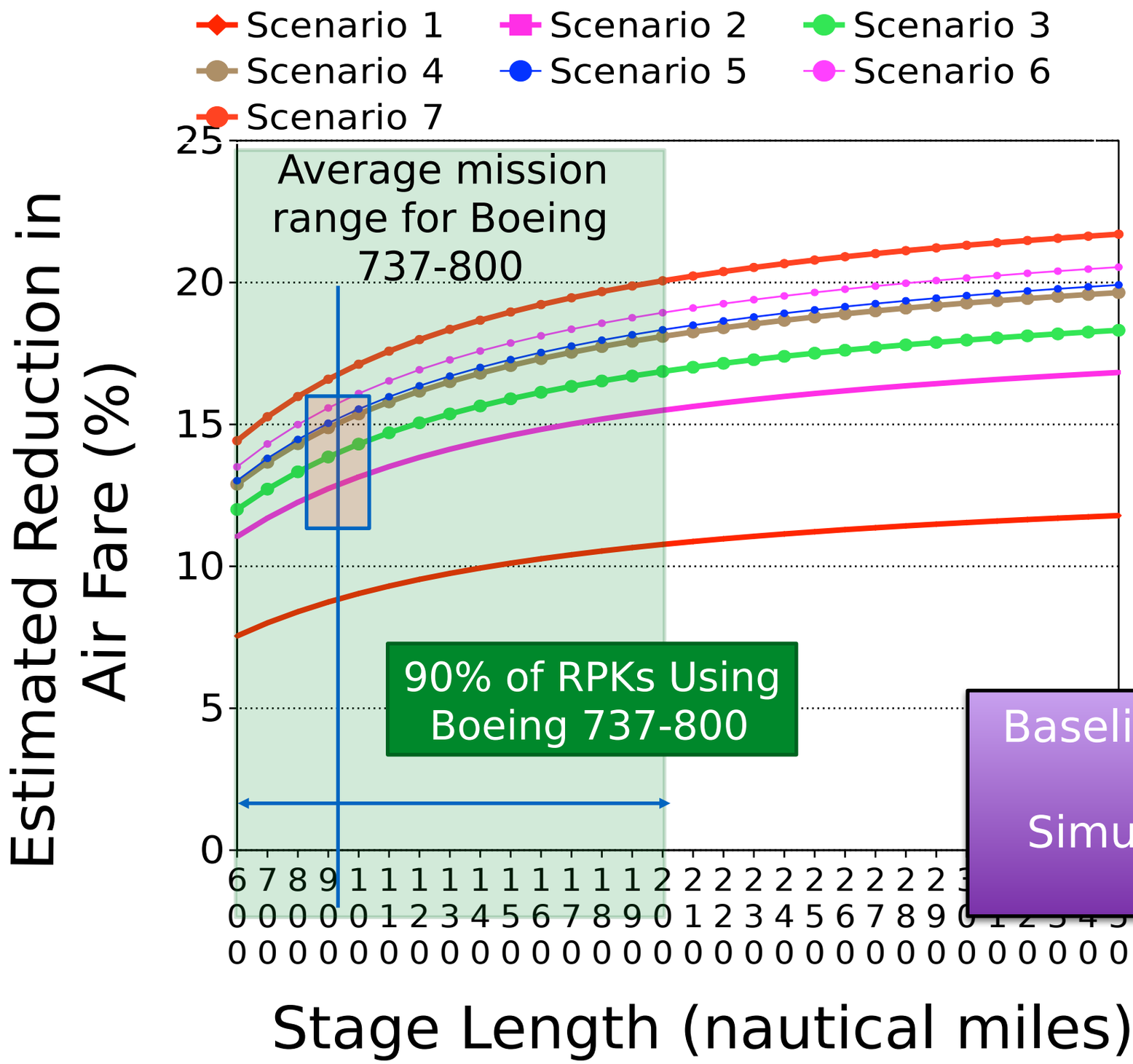
1 Theis, C. and C. Baum, The Effect of War on Economic Growth, CATO Institute Journal, Winter, 2020.

GDM2 War Scenario Projects a Loss of 4.1% in RPKs Worldwide in 2040



Scenario: Introduction of NASA Advanced Aircraft

12-17% Air Fare Reductions with TW-160-GTF



Assessment of the Performance Potential of Advanced Subsonic Transport Concepts for NASA's Environmentally Responsible Aviation Project

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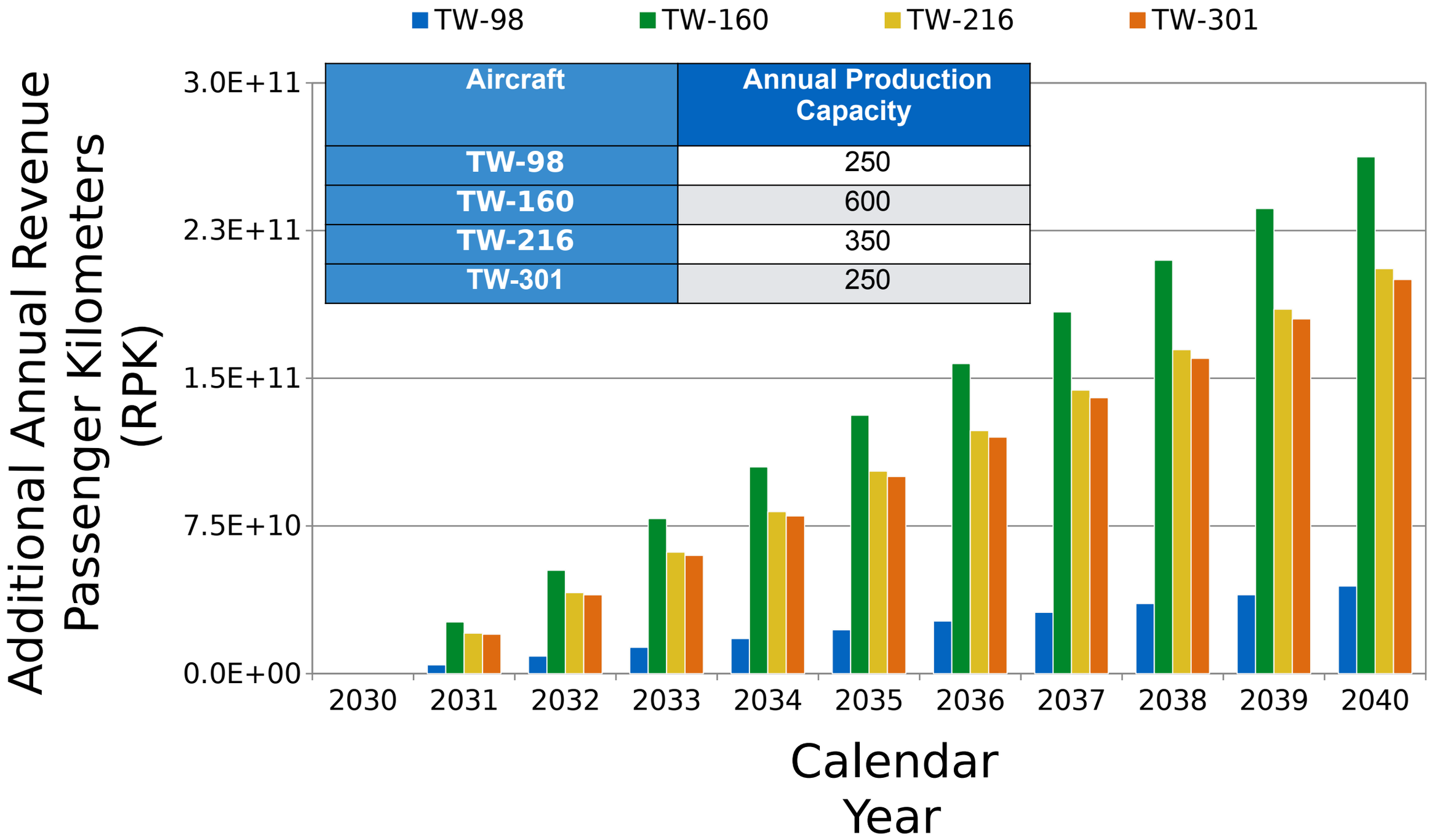
NASA's Environmentally Responsible Aviation (ERA) project has matured technologies to enable simultaneous reductions in fuel burn, noise, and nitrogen oxide (NOx) emissions for future subsonic commercial transport aircraft. The fuel burn reduction target was a 50% reduction in block fuel burn (relative to a 2005 best-in-class baseline aircraft), utilizing technologies with an estimated Technology Readiness Level (TRL) of 4-6 by 2020. Progress towards this fuel burn reduction target was measured through the conceptual design and analysis of advanced subsonic commercial transport concepts spanning vehicle size classes from regional jet (98 passengers) to very large twin aisle size (400 passengers). Both conventional tube-and-wing (T+W) concepts and unconventional (over-wing-nacelle (OWN), hybrid wing body (HWB), mid-fuselage nacelle (MFN)) concepts were developed. A set of propulsion and airframe technologies were defined and integrated onto these advanced concepts which were then sized to meet the baseline mission requirements. Block fuel burn performance was then estimated, resulting in reductions relative to the 2005 best-in-class baseline performance ranging from 39% to 49%. The advanced single-aisle and large twin aisle T+W concepts had reductions of 43% and 41%, respectively, relative to the 737-800 and 777-200LR aircraft. The single-aisle OWN concept and the large twin aisle class HWB concept had reductions of 45% and 47%, respectively. In addition to their estimated fuel burn reduction performance, these unconventional concepts have the potential to provide significant noise reductions due, in part, to engine shielding provided by the airframe. Finally, all of the advanced concepts also have the potential for significant NOx emissions reductions due to the use of advanced combustor technology. Noise and NOx emissions reduction estimates were also generated for these concepts as part of the ERA project.

(AIAA paper 2016)

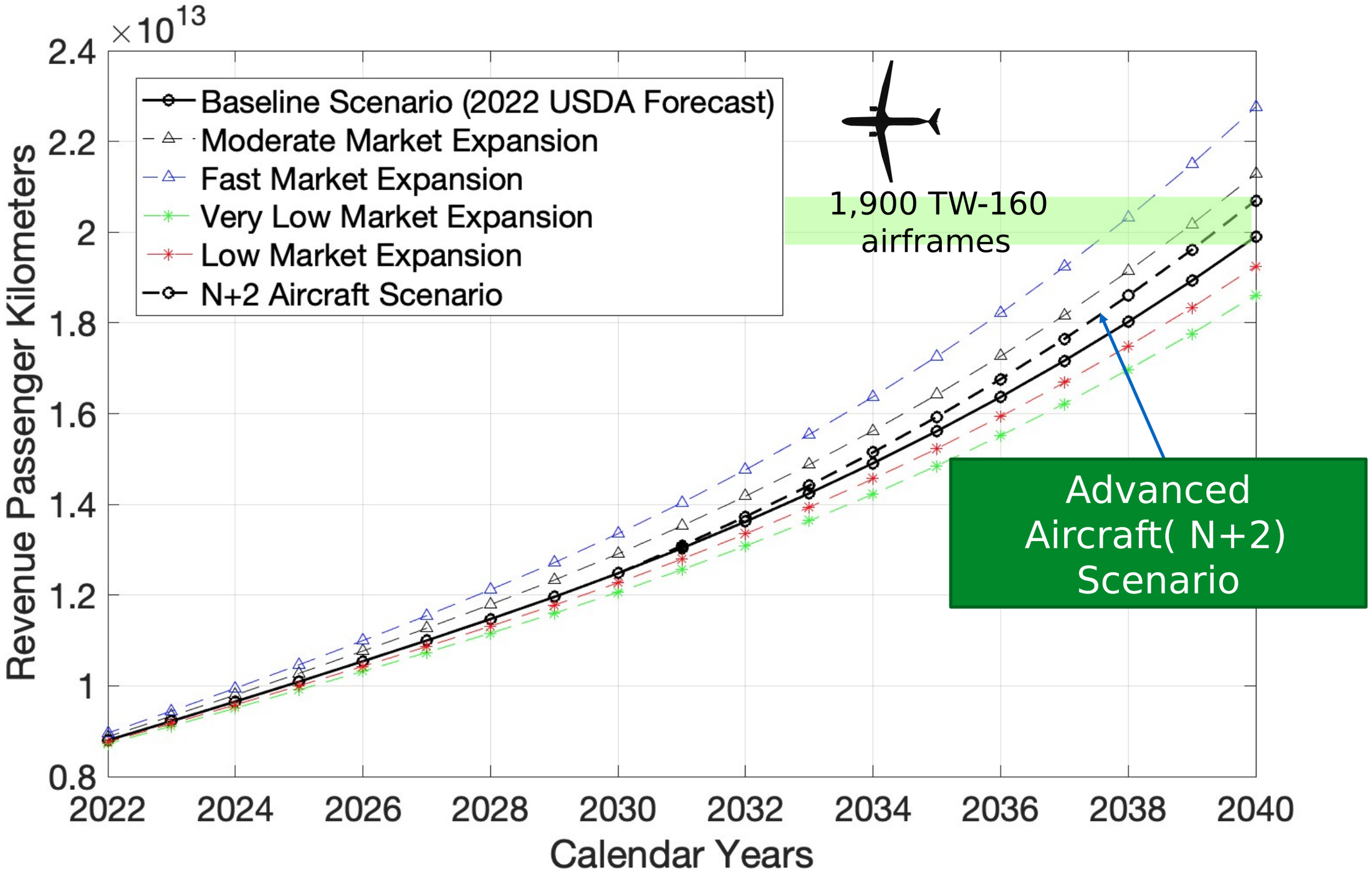
Baseline Aircraft is a Boeing 737-800
Simulation Analysis uses BADA 3.16

In 2040, an Additional 4% RPKs Could be Generated if N+2 are Deployed in Large Numbers

Aircraft	Annual Production Capacity
TW-98	250
TW-160	600
TW-216	350
TW-301	250



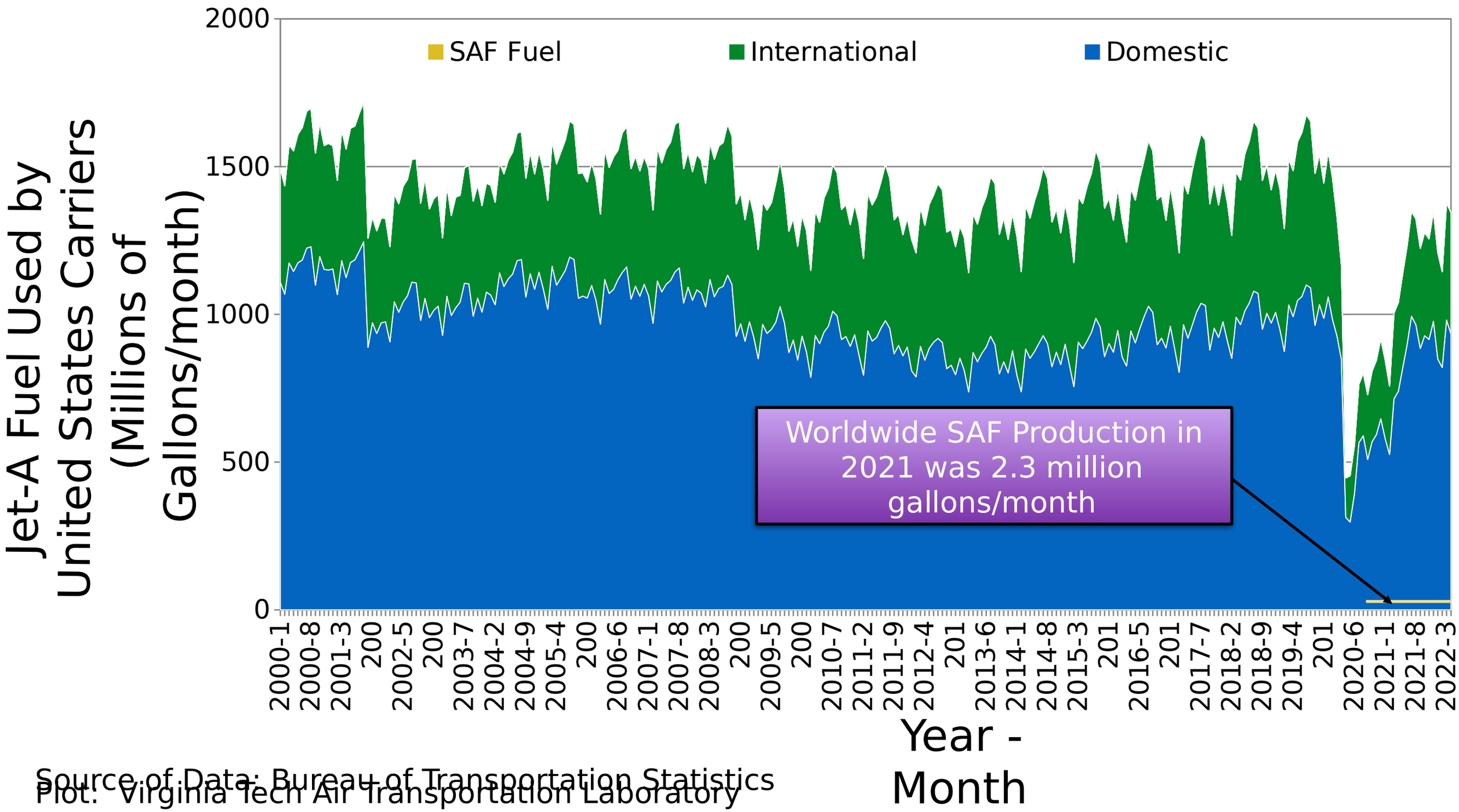
N+2 Advanced Aircraft Could Increase RPKs by an Additional 4% in 2040



Scenario: United States Sustainable Fuel Using Global Demand Model 2 Results

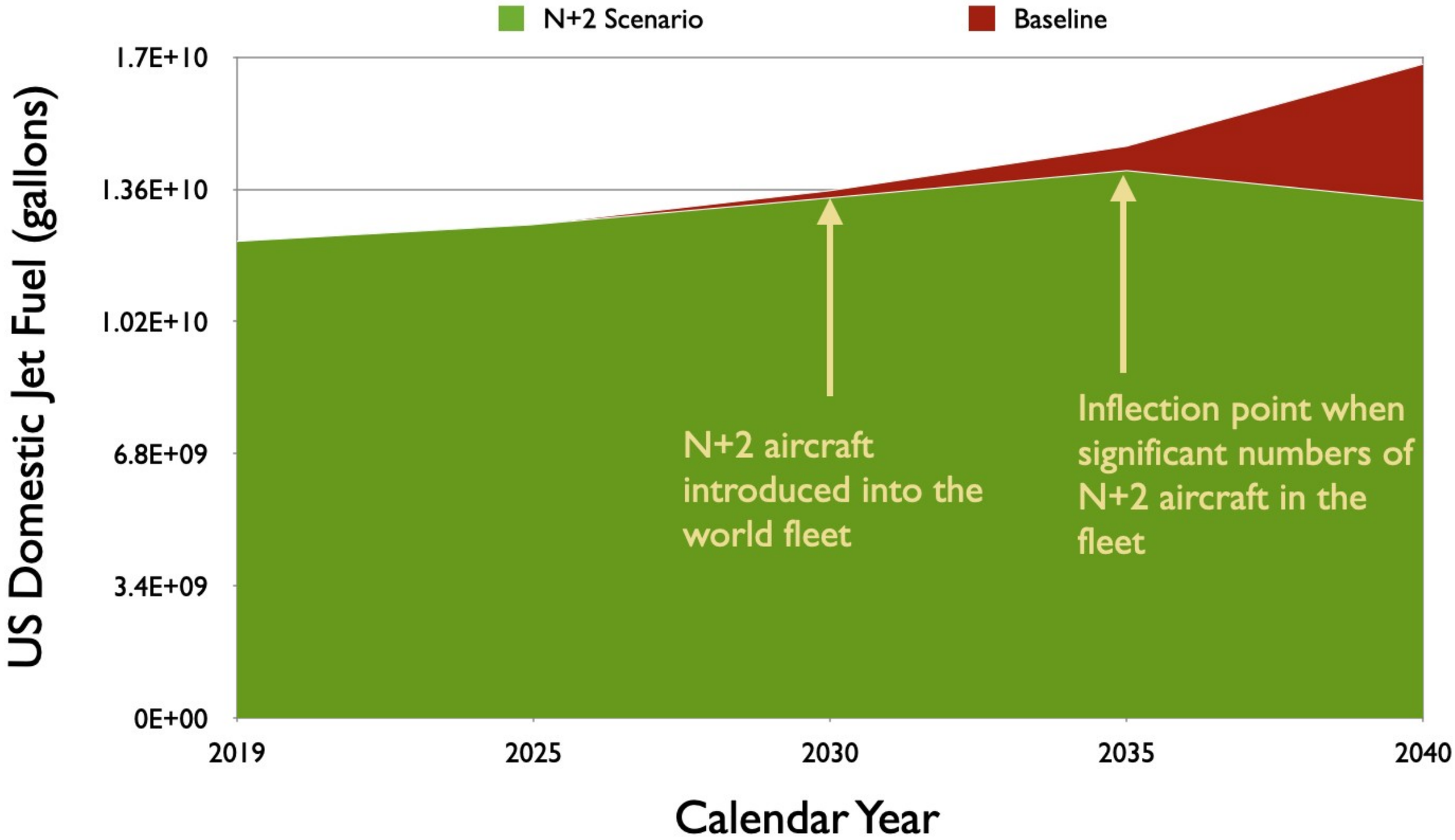
Source: A.A. Trani (Atlanta International Airport Fuel Farm)

Domestic Jet-A Fuel Consumption Averages 69% of the Total Jet-A Fuel Used by U.S. Domestic Carriers



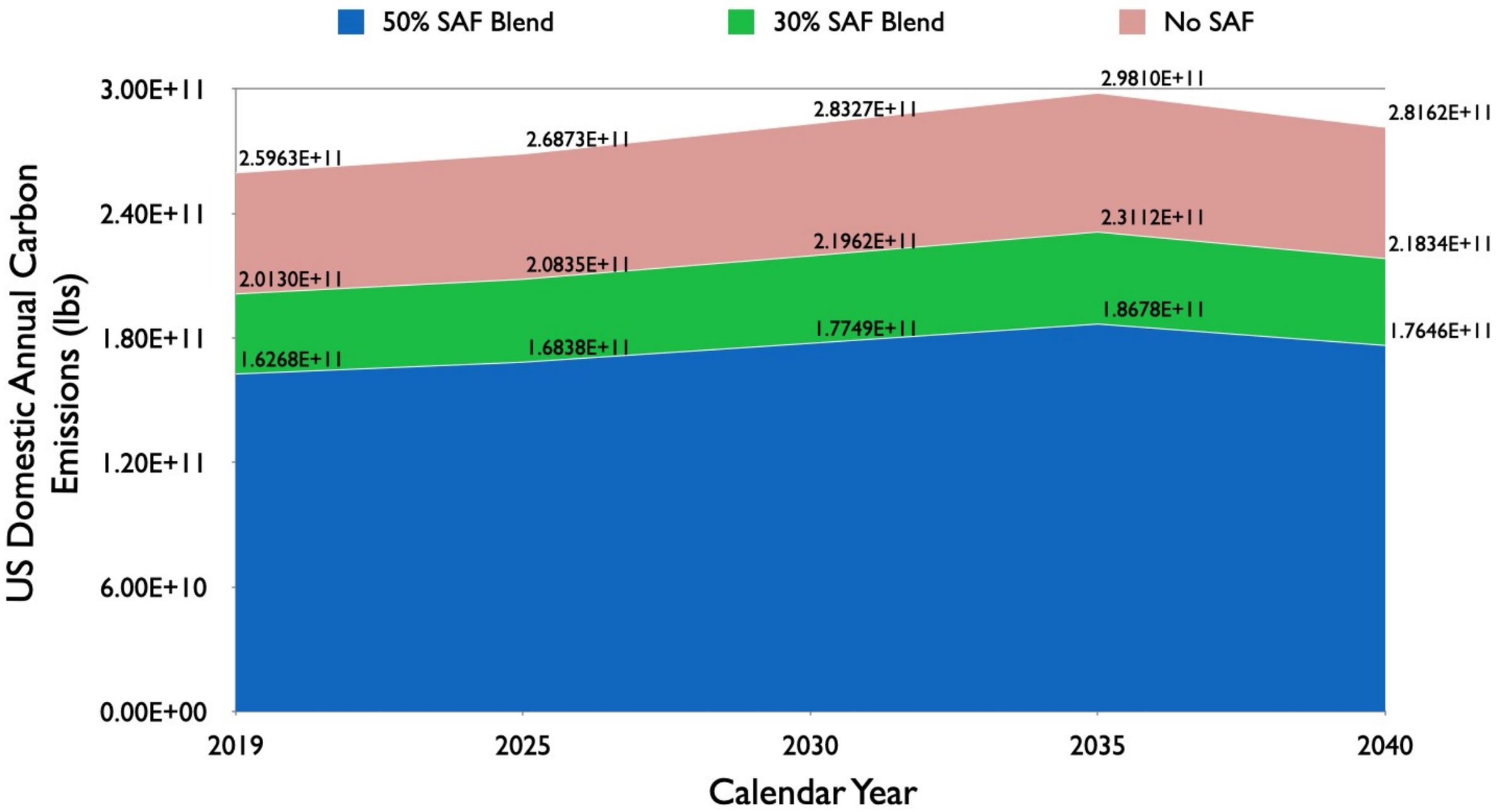
Source of Data: Bureau of Transportation Statistics
Plot: Virginia Tech Air Transportation Laboratory

Jet-A Fuel Consumption with N+2 Aircraft



RPKs estimated using the Global Demand Model

37% Carbon Emission Reductions Using SAF Fuels and N+2 Aircraft in the Year 2040



nia Tech Air Transportation Systems Lab Analysis using the Global Demand Model

Conclusions

- Global Demand Model (2) model takes a completely different approach to predicting air transportation demand
- Revenue Passenger Kilometers (RPK) is a metric used by many forecast organizations (ICAO, Boeing, IATA, etc.)
  - Panel regression model (logarithmic function to predict RPKs)
  - Model uses difference lag data to satisfy stionary properties of the GDP per Capita time series used in Economics
- The model links interactions between 103 OD regional pairs worldwide (17 OAG regions)
- Model results can also also produce detailed country or airport-level demand if desired