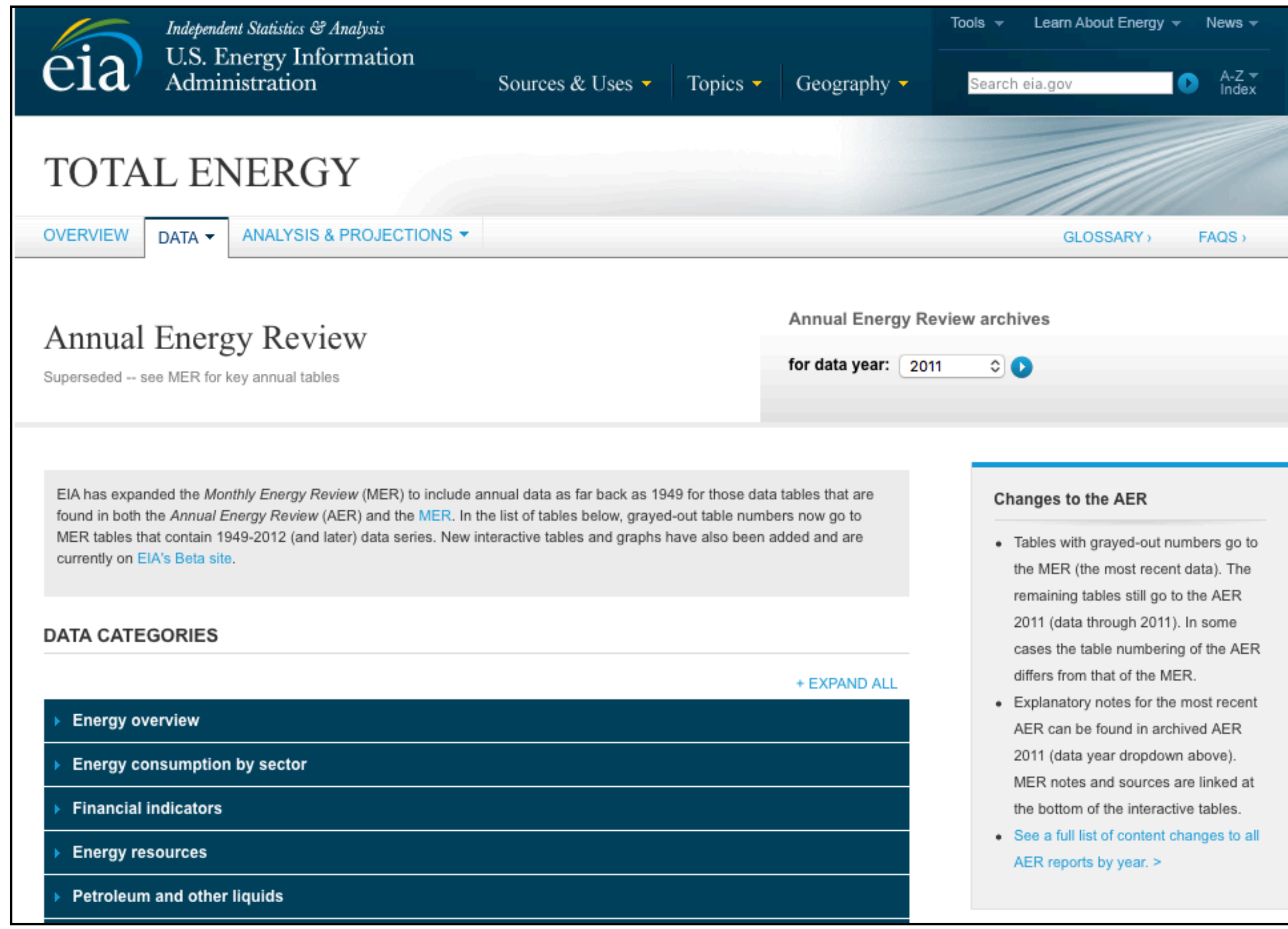
CEE 5614

Important Issues in the Future of Air Transportation

Energy and Aviation Issues

Environmental Impacts of Transportation

- Energy consumption
- Air pollution
- Noise impacts
- Land use
- Loss of wildlife



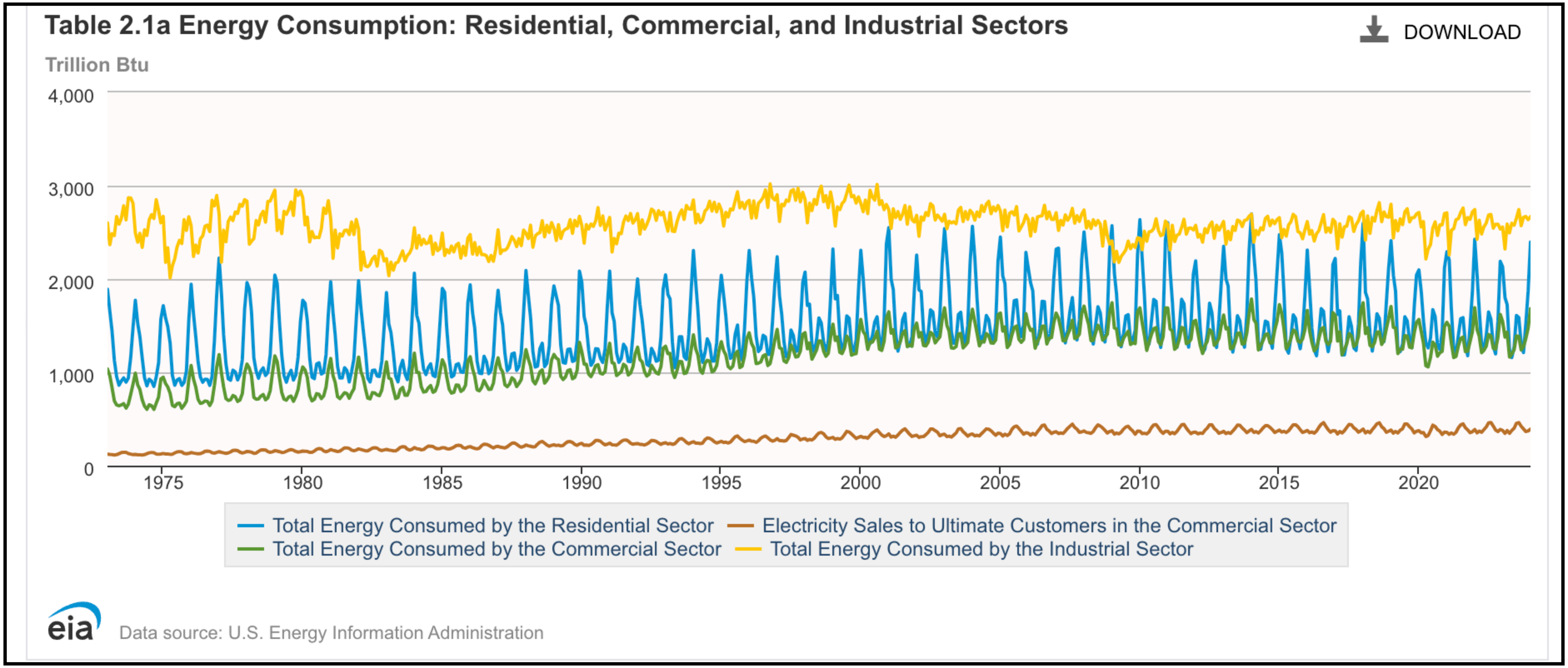
https://www.eia.gov/totalenergy/data/annual/

Definition of Btu to interpret the Graphs

- Btu = British thermal unit
- Amount of heat required to raise the temperature of one pound of water by one degree Fahrenheit (from 39.1 to 49.1 degrees)
- 1 Btu = 252 calories, 1055 Joules, 778 ft-lbf (foot-pounds of force) or 0.29307 Watt-hours

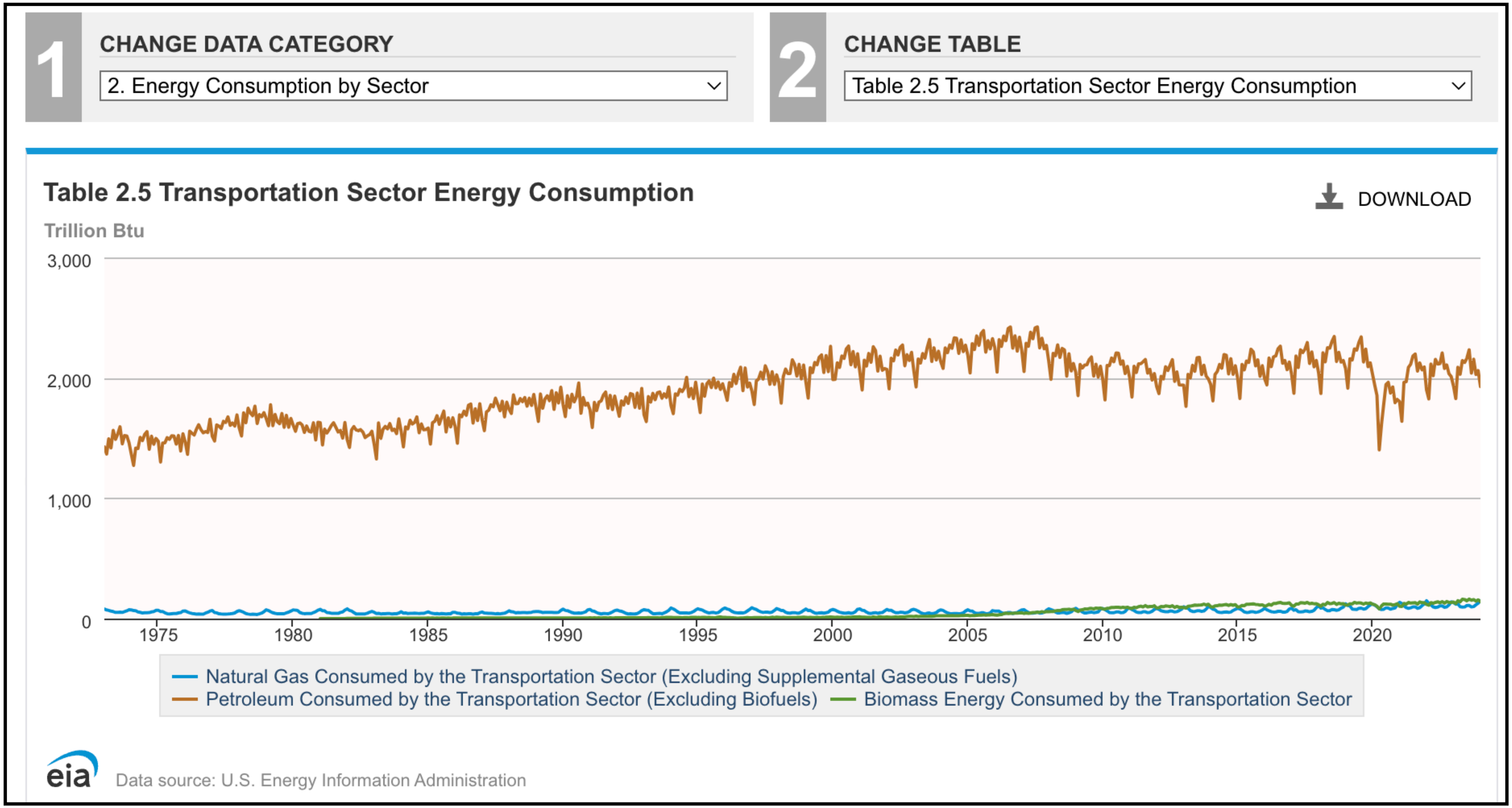
Energy Consumption Trends

- Energy flow consumed by three sectors



source: EIA 2024

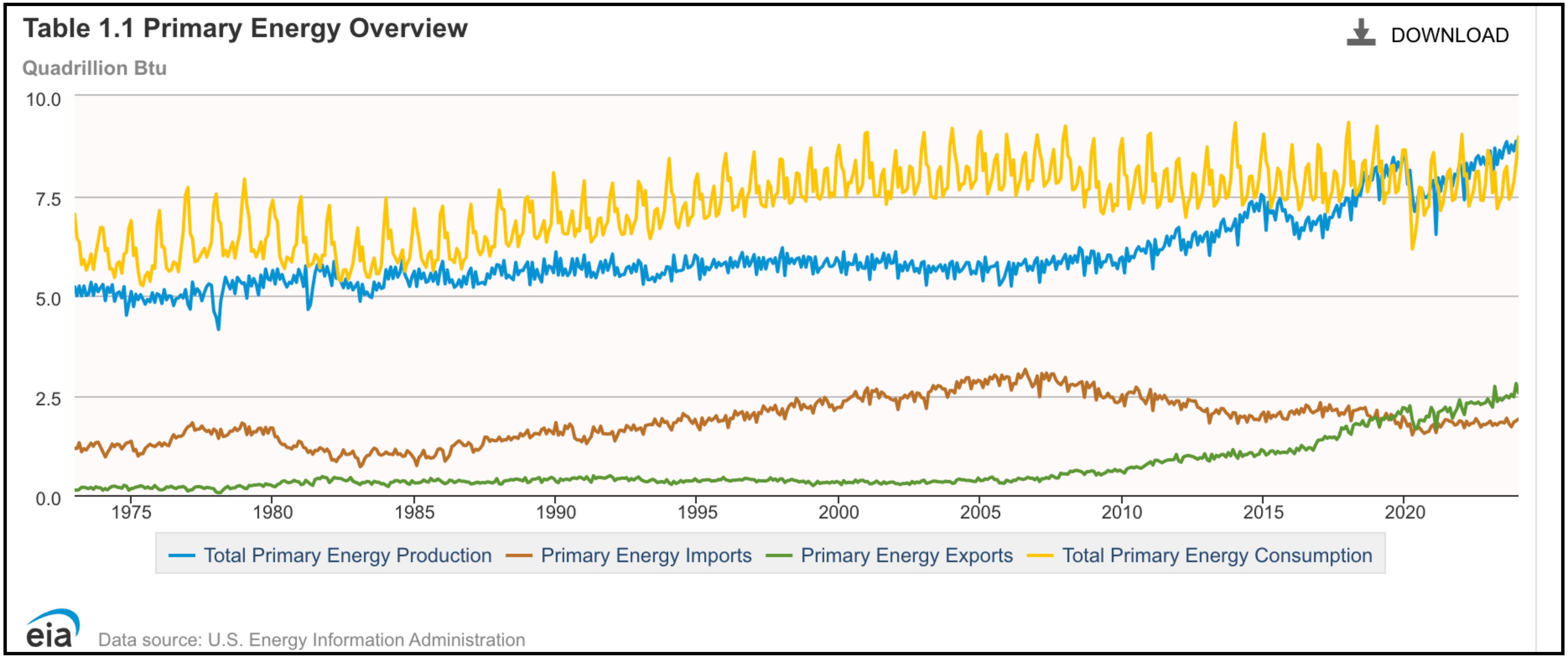
Energy Consumption in the Transportation Sector



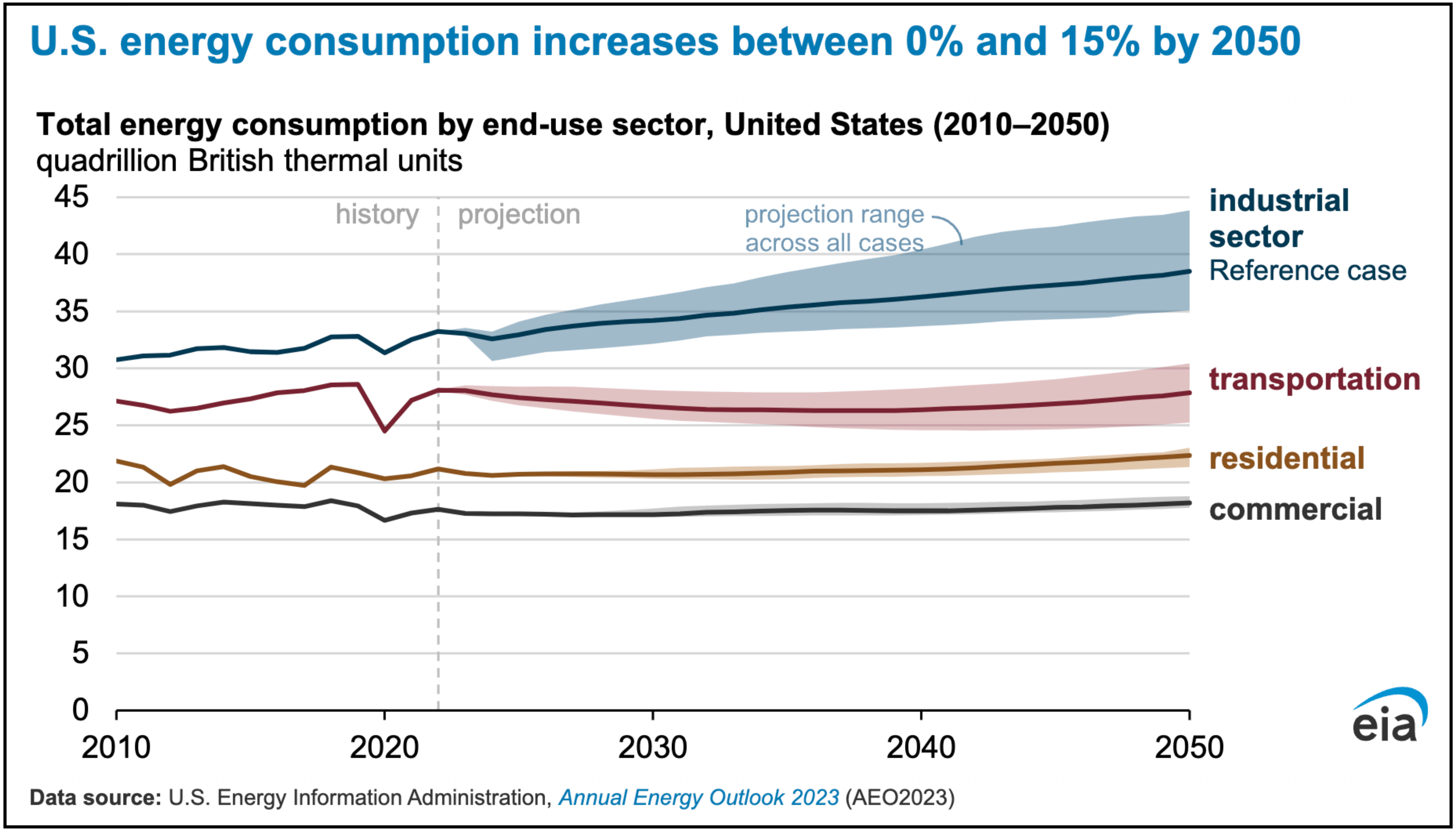
source: EIA 2024

Energy Consumption Trends (US)

- US exports more energy than imports
- Energy consumption is less than energy production



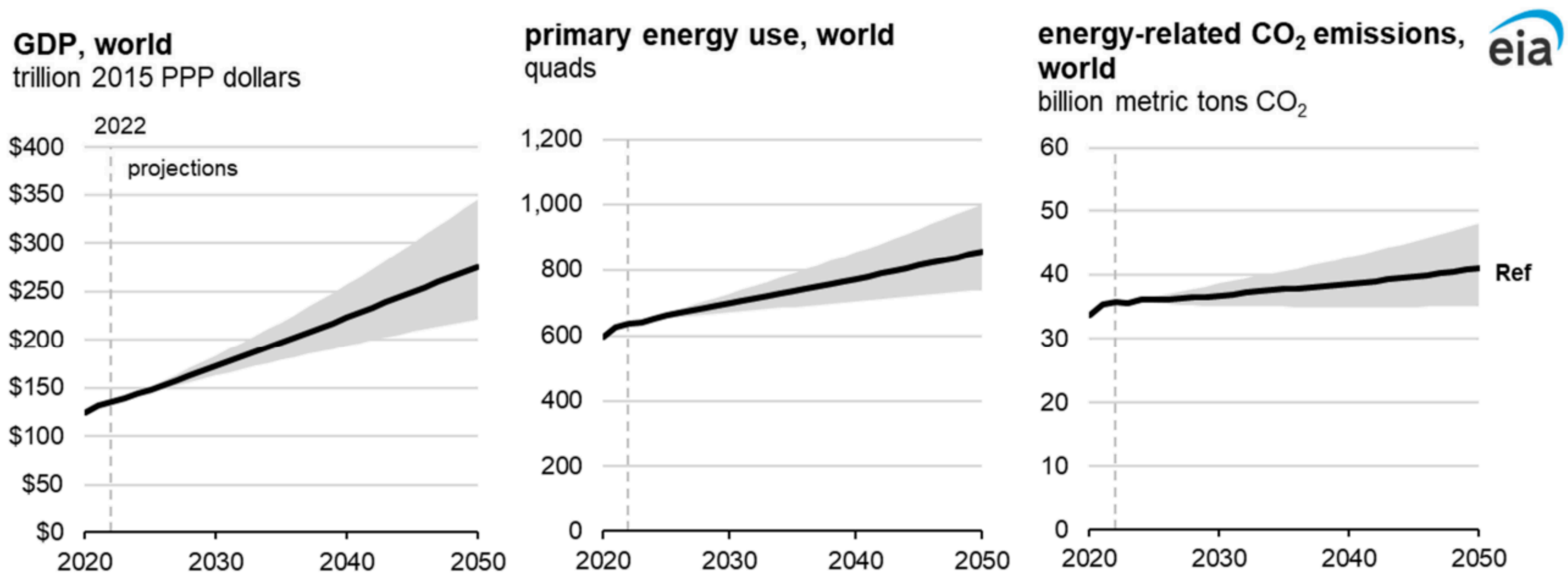
Energy Consumption Forecast (US)



Energy Use Outlook (World)

- Unless we do some drastic changes to our lifestyle, the energy use will continue to grow worldwide

Across most cases, energy-related CO_2 emissions continue to rise through 2050 under current laws

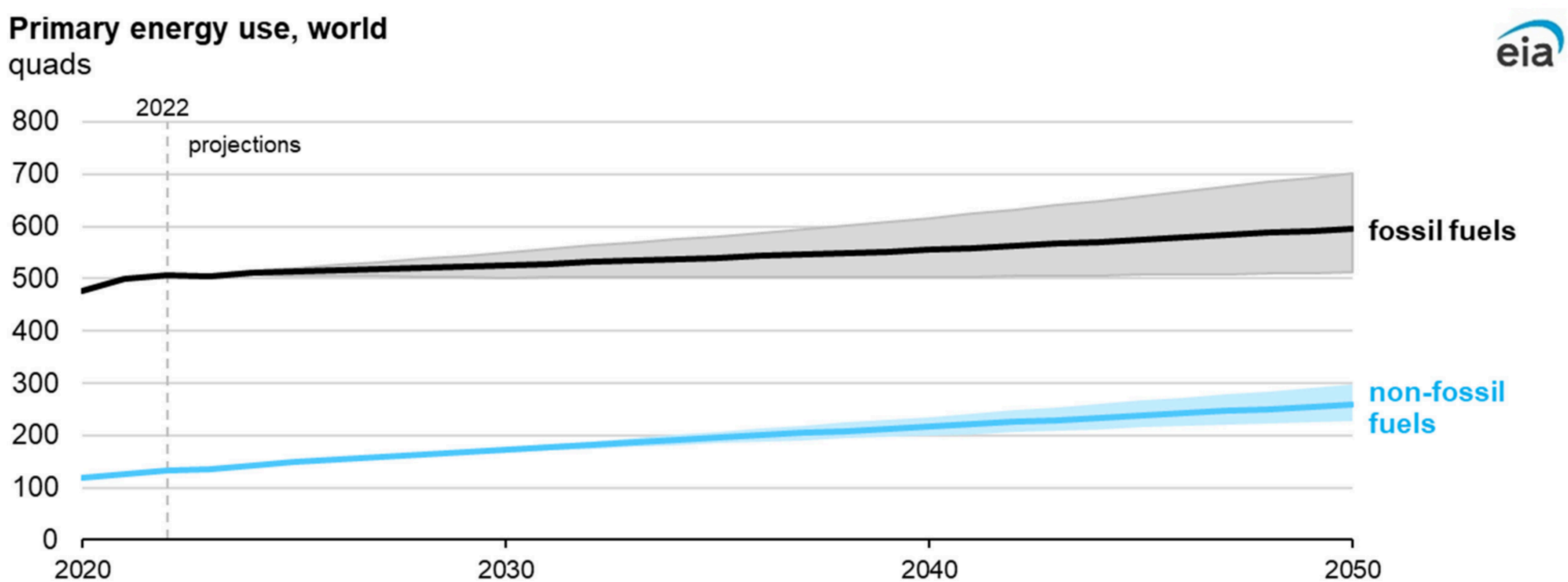


Data source: U.S. Energy Information Administration, *International Energy Outlook 2023* (IEO2023)
Note: Shaded regions represent maximum and minimum values for each projection year across the IEO2023 Reference case and side cases. Ref=Reference case; GDP=gross domestic product; quads=quadrillion British thermal units; PPP=purchasing power parity.

Energy Use Outlook

- Fossil fuel energy is expected to grow worldwide
- Energy derived from non-fossil fuels is expected to grow at a faster pace

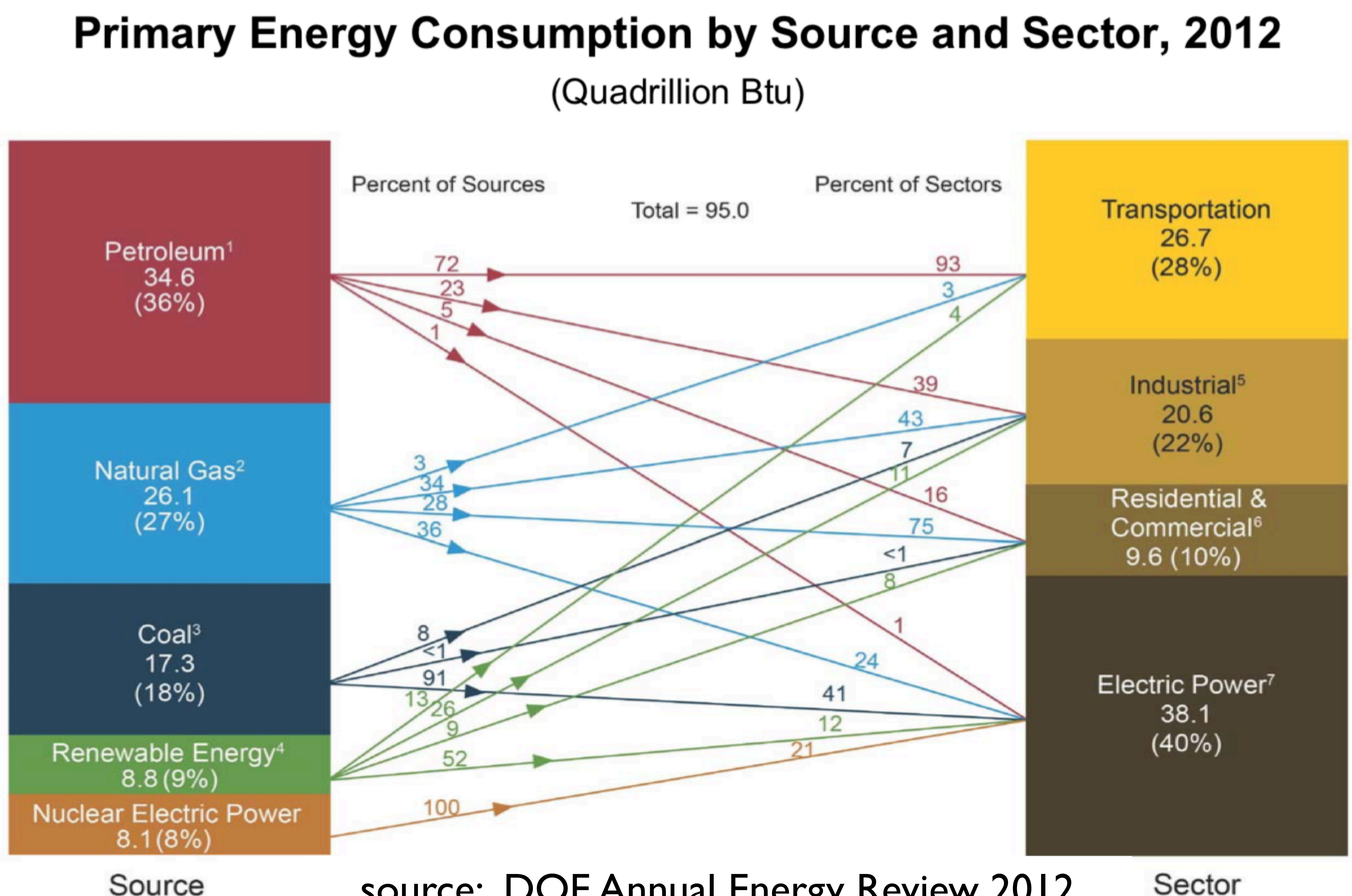
Increasing demand and current policies drive steady growth in fossil fuel energy—and faster growth in non-fossil fuel sources



Data source: U.S. Energy Information Administration, *International Energy Outlook 2023* (IEO2023)
Note: Each line represents IEO2023 Reference case projections. Shaded regions represent maximum and minimum values for each projection year across the IEO2023 Reference case and side cases. Quads=quadrillion British thermal units.

Where is Transportation?

- Transportation accounted for 28% of the total energy consumed in the U.S. in 2012

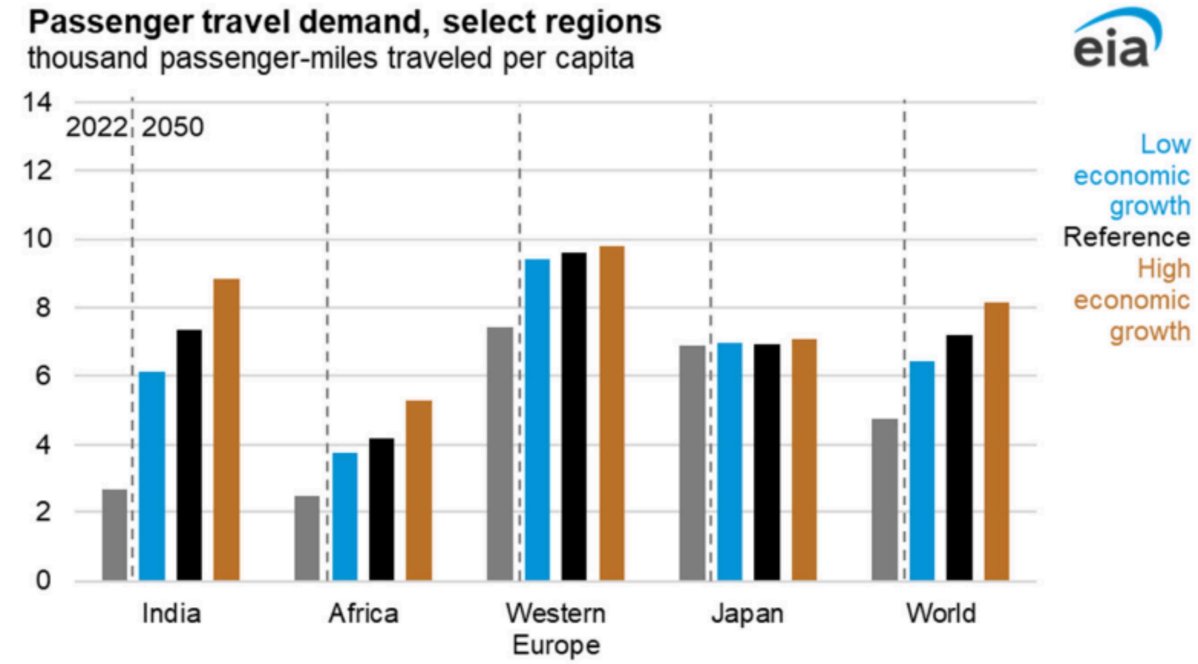


source: DOE Annual Energy Review 2012

Energy Used by Transportation

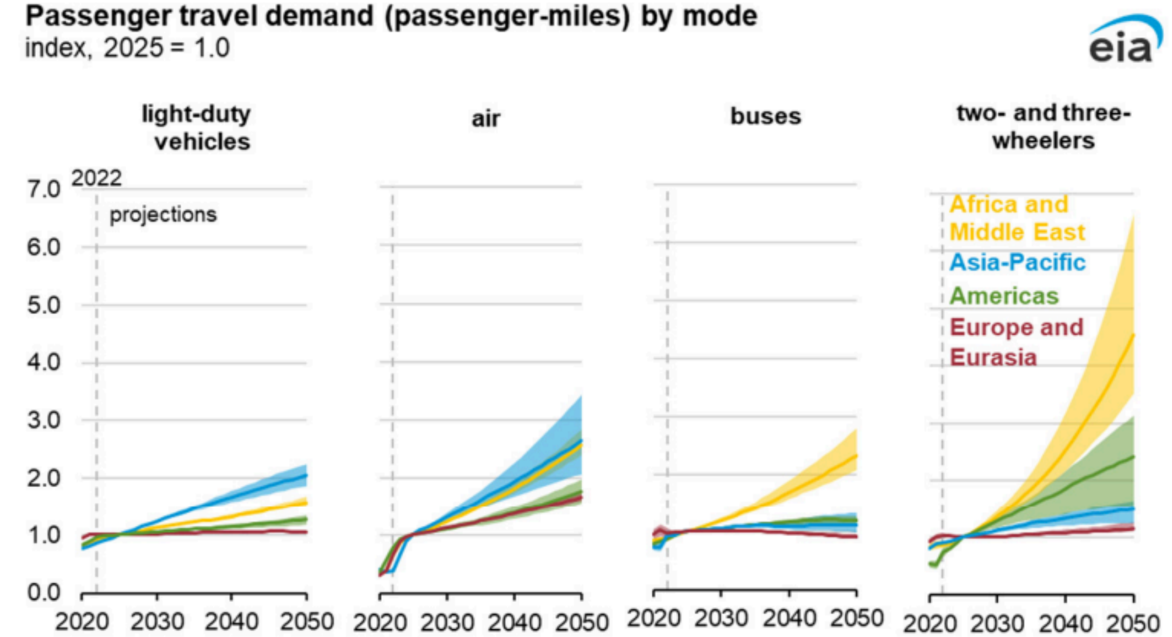
Increasing passenger demand drives global transportation consumption; Rising income enables travelers to shift from inexpensive, more efficient modes to more convenient, less efficient modes

Passenger travel demand, select regions
thousand passenger-miles traveled per capita



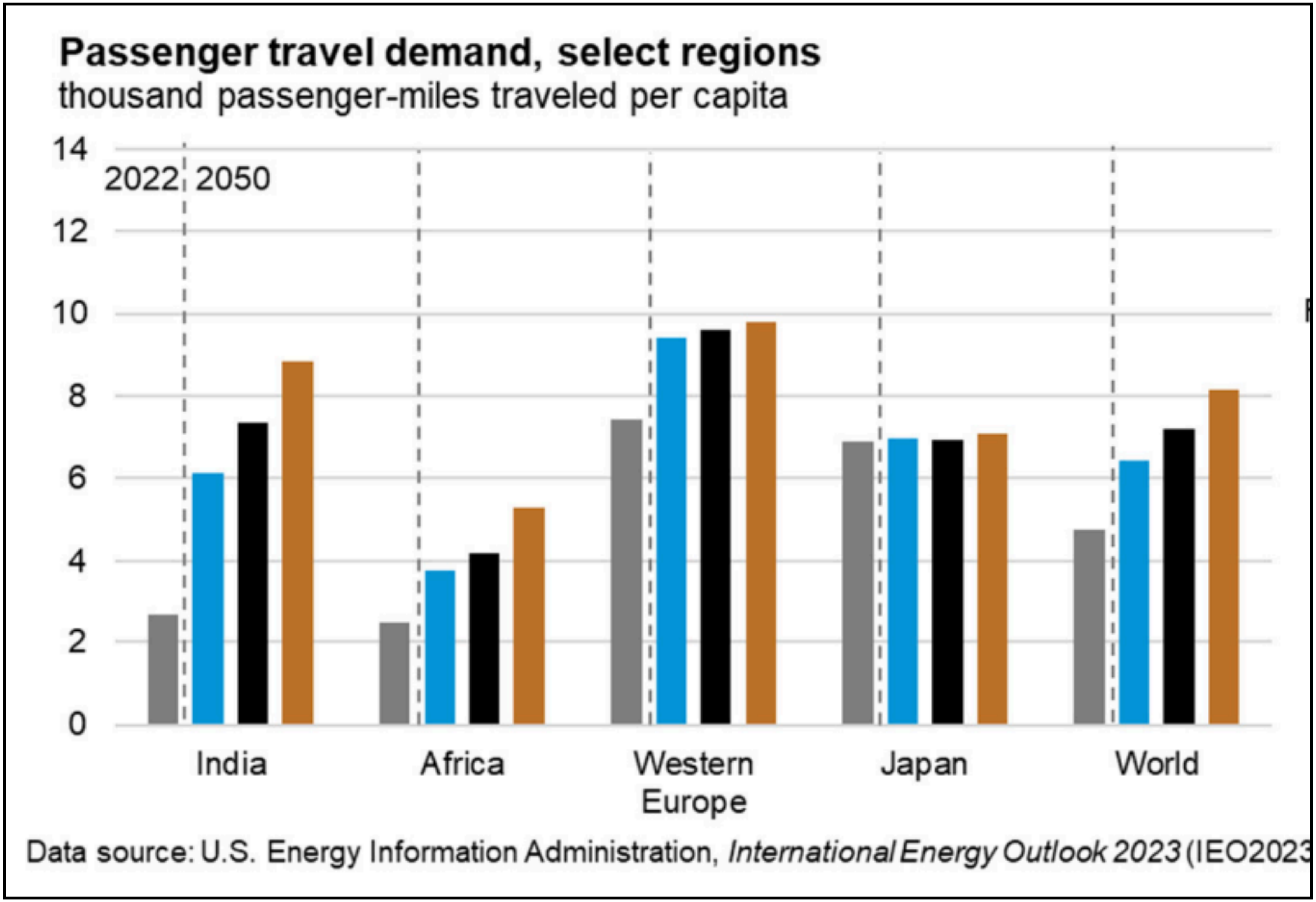
Data source: U.S. Energy Information Administration, *International Energy Outlook 2023* (IEO2023)

Passenger travel demand (passenger-miles) by mode
index, 2025 = 1.0

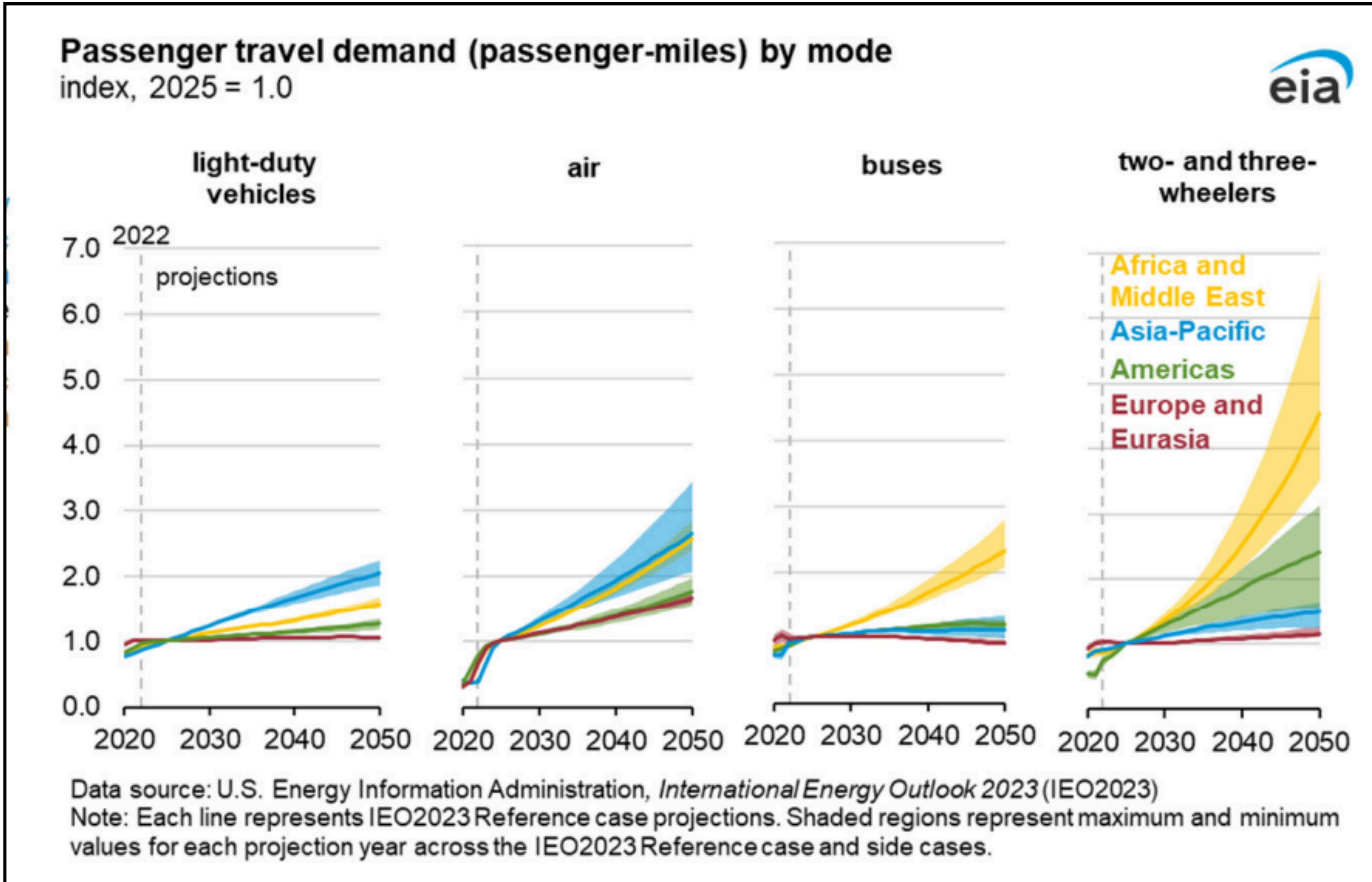


Data source: U.S. Energy Information Administration, *International Energy Outlook 2023* (IEO2023)
Note: Each line represents IEO2023 Reference case projections. Shaded regions represent maximum and minimum values for each projection year across the IEO2023 Reference case and side cases.

Worldwide Passenger Travel Demand



Worldwide Passenger Travel Demand



Fuel Consumption Metrics

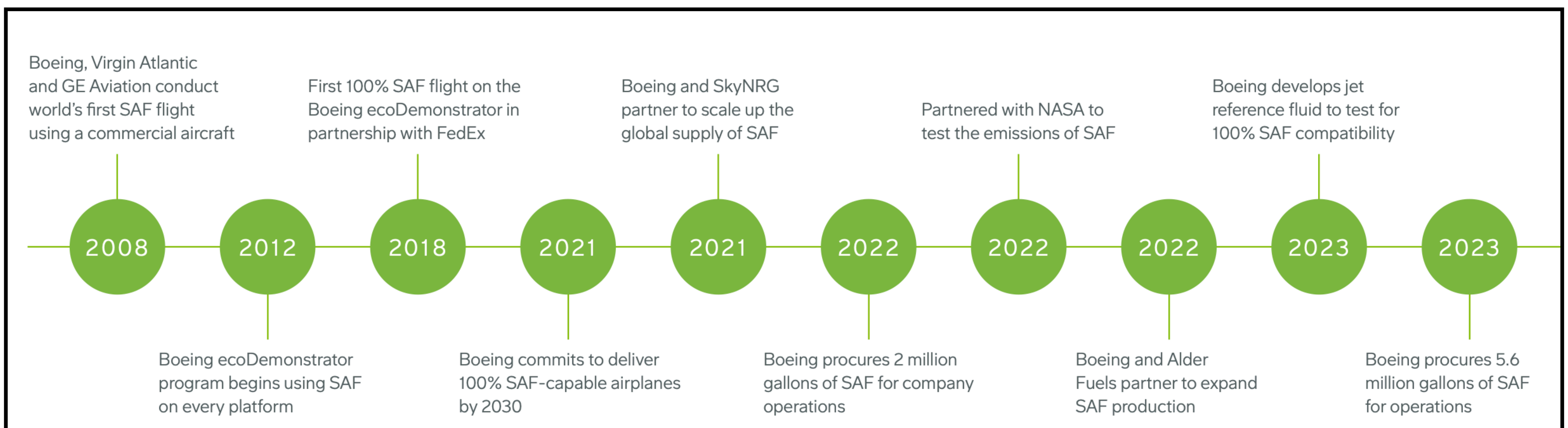
Transportation Vehicle	Fuel Used (gallons)	Typical Load Factor	Effective Seat-mile/gallon
Hybrid Car (Prius)	9.09	0.4	70.4
SUV (H2)	33.34	0.32	19.2
Coach Bus	66.67	0.6	144
Superheavy Aircraft (A380)	64,000	0.8	48.2

Autos become quite inefficient when operated at low load factors

Can Aviation be Sustainable in the Long Run?

- Air transport accounts for 2-3% of global human-induced Green-House emissions
- Sustainable fuels can reduce carbon emissions by 50-80%
- Requires investments in large production of SAF fuels

All Airbus aircraft are capable of flying on a maximum 50% blend of SAF and conventional fuel. By 2030, all our aircraft and helicopters will be capable of flying with up to 100% SAF.



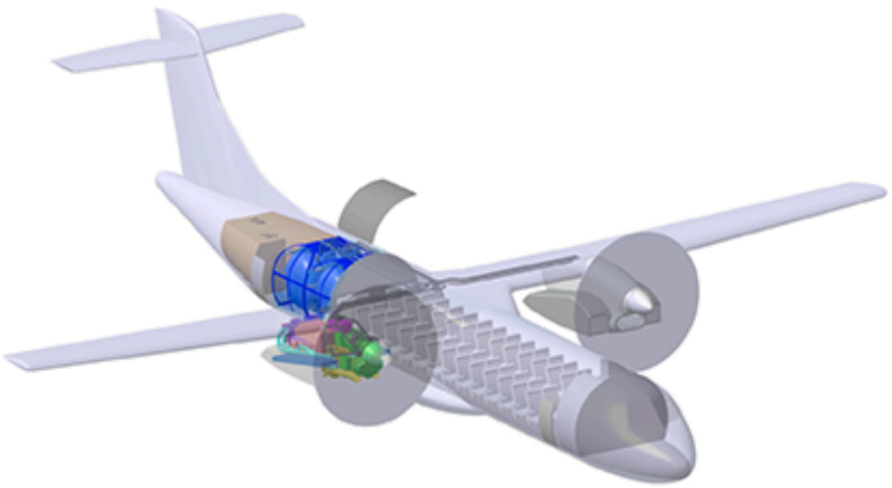
Boeing steps to make air travel more sustainable

Sustainable Fuels (Source: Airbus)

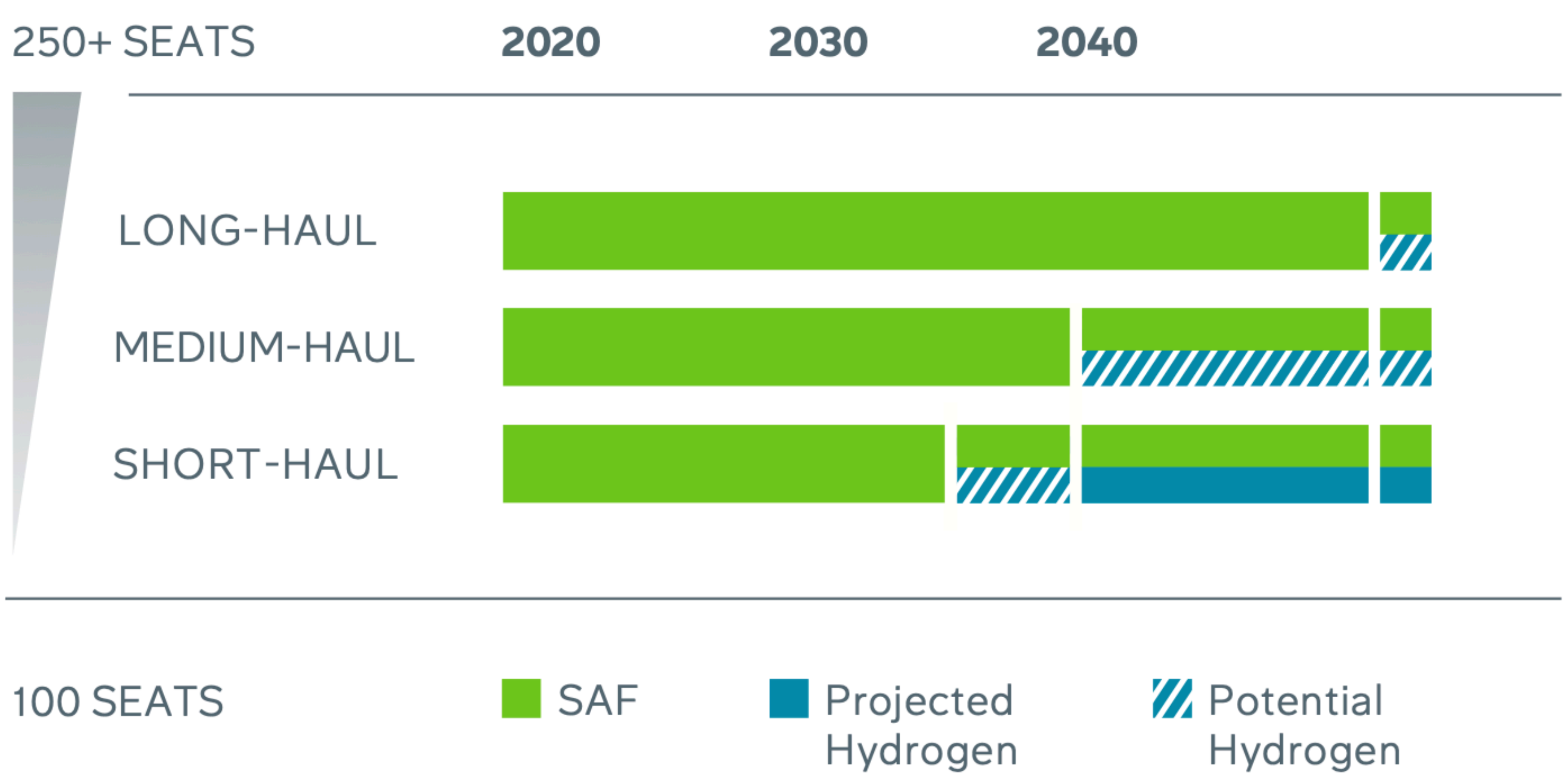
- *"**HEFA** (Hydrotreated Esters and Fatty Acids): The HEFA process refines vegetable oils, waste oils, or fats into SAF through hydrotreating and hydroprocessing"*
- *"**Alcohol to Jet: Alcohol to Jet (AtJ)** converts alcohols such as ethanol and iso-butanol into SAF by removing the oxygen and linking the molecules together"*
- *"**eFuels:** SAF can be produced using green hydrogen, capturing carbon dioxide, and using renewable electricity to create synthetic fuels. This type of SAF is sometimes referred to as eFuel or Power-to-Liquid (PtL)"*

Sustainable Fuels and Other Sources

- *Hydrogen is a possible substitute for traditional fuels*
- *Requires large investments to develop reliable technology*



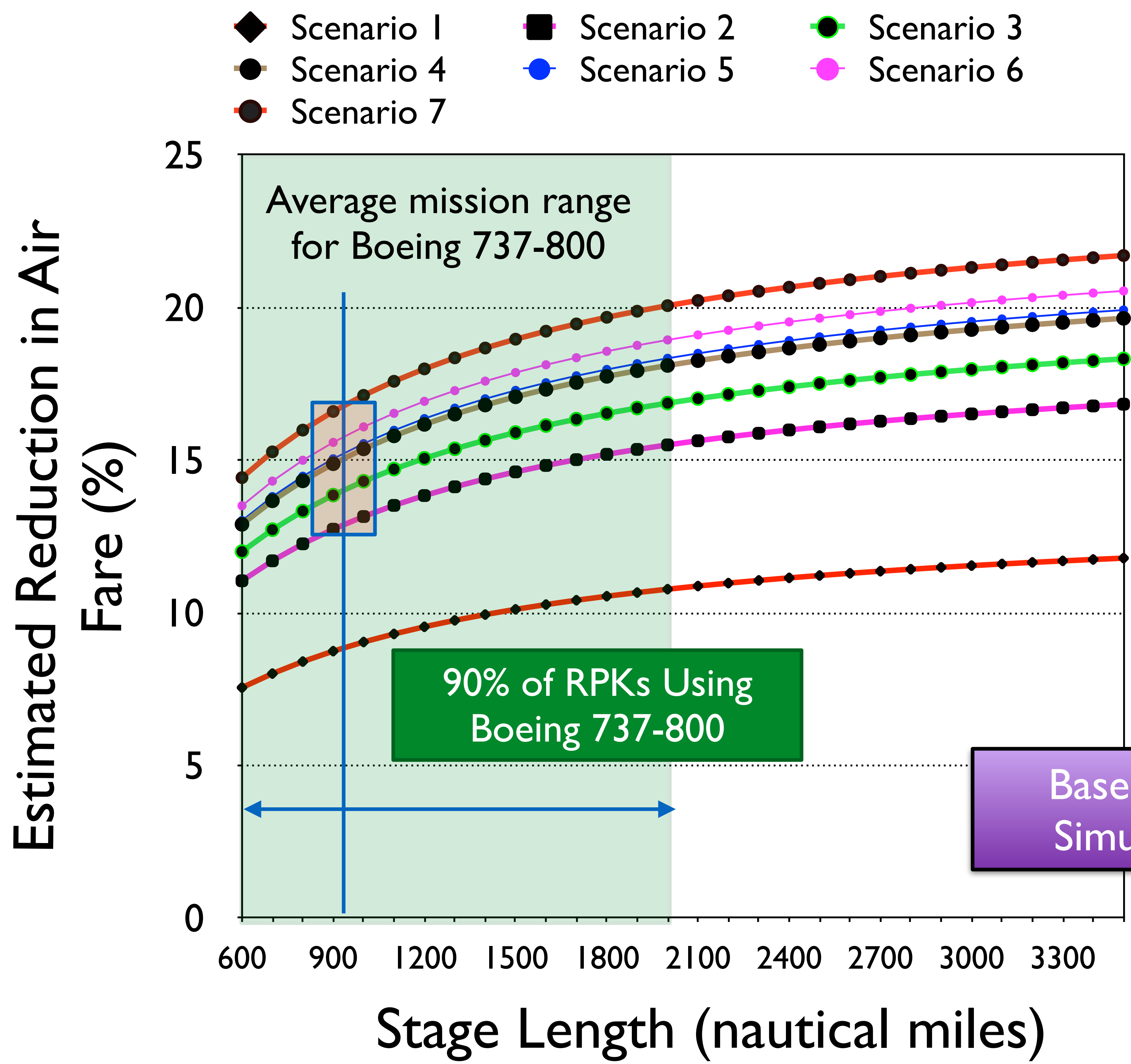
Universal Hydrogen Turboprop concept



Source: Boeing

Example of Path to Sustainability Introduction of NASA Advanced Aircraft

12-17% Air Fare Reductions with Truss-Braced Transonic Aircraft



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

Craig L. Nickol[1]
NASA Langley Research Center, Hampton, VA

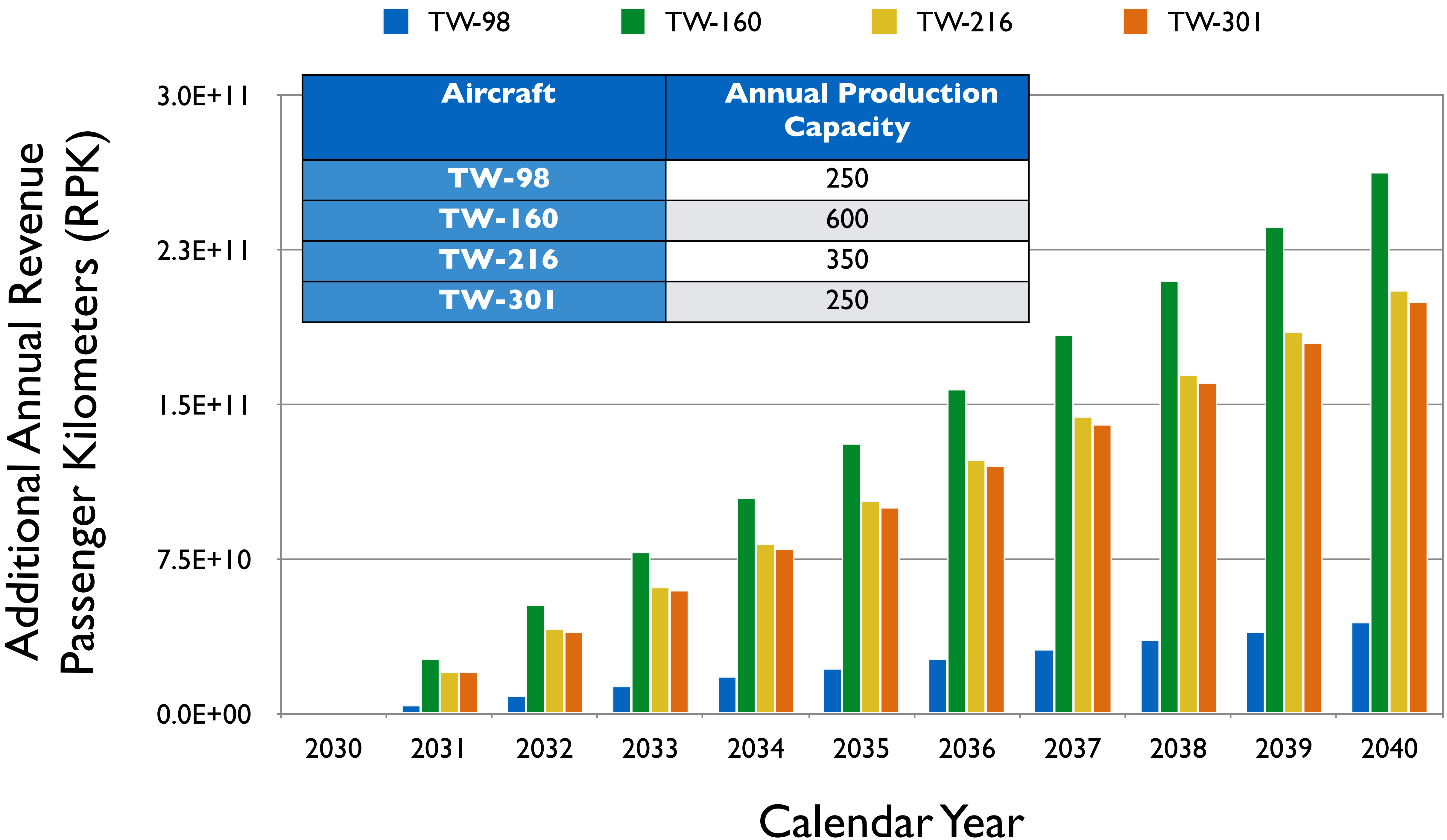
William J. Haller[2]
NASA Glenn Research Center, Cleveland, OH

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)

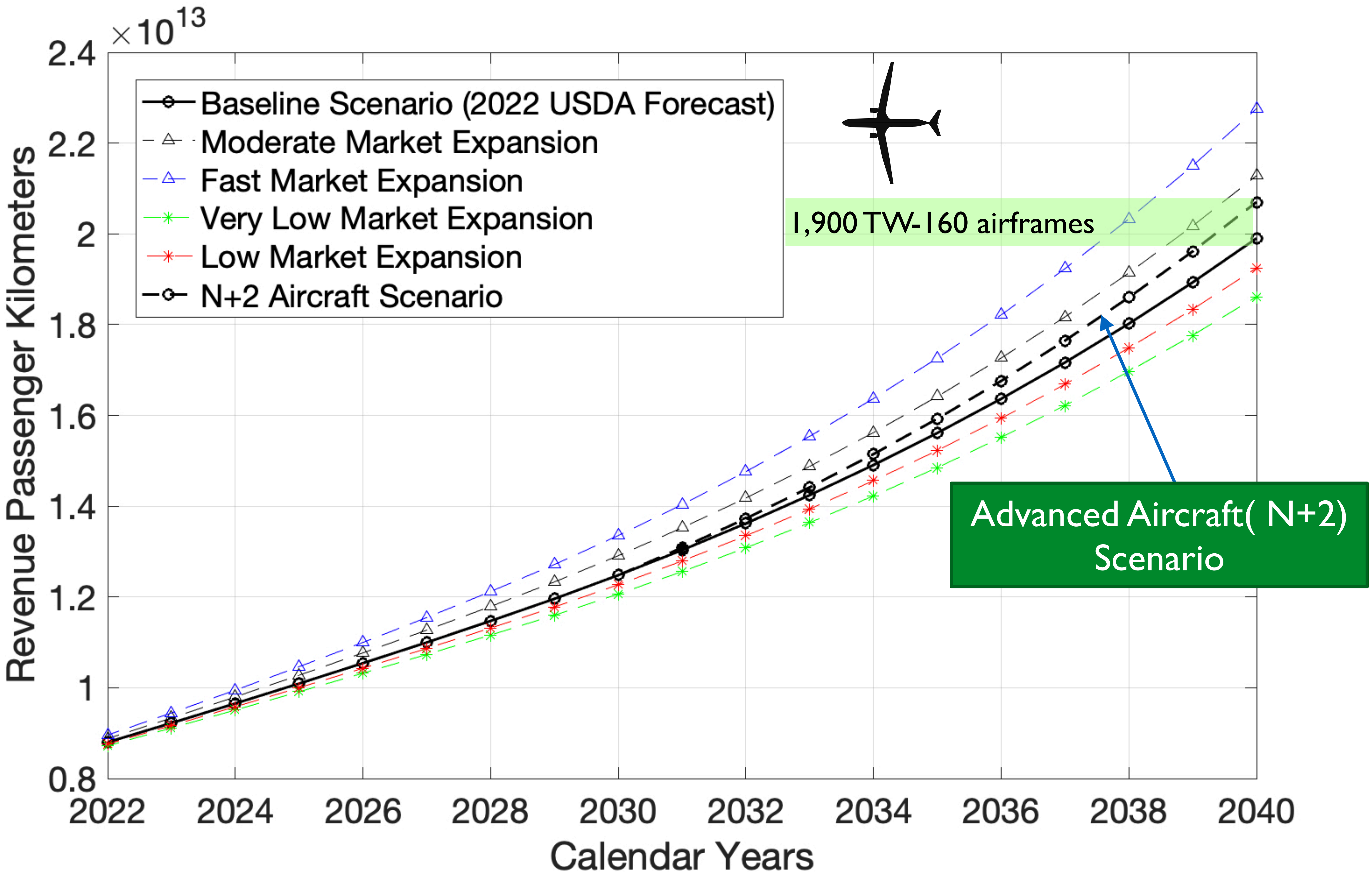
Baseline Aircraft is a Boeing 737-800
Simulation Analysis uses BADA 3.16

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

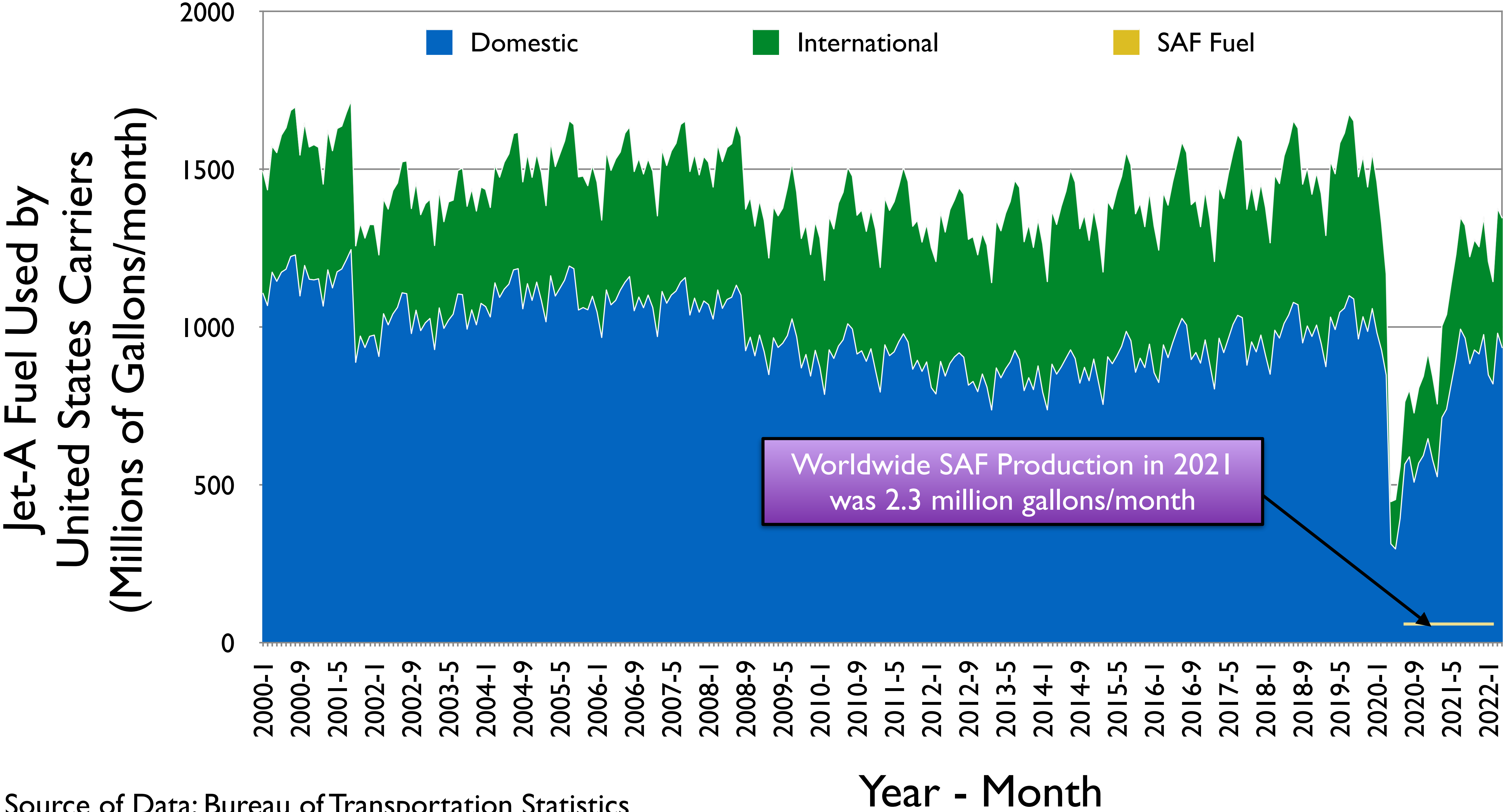
N+2 Advanced Aircraft Could Increase RPKs by an Additional 4% in 2040



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

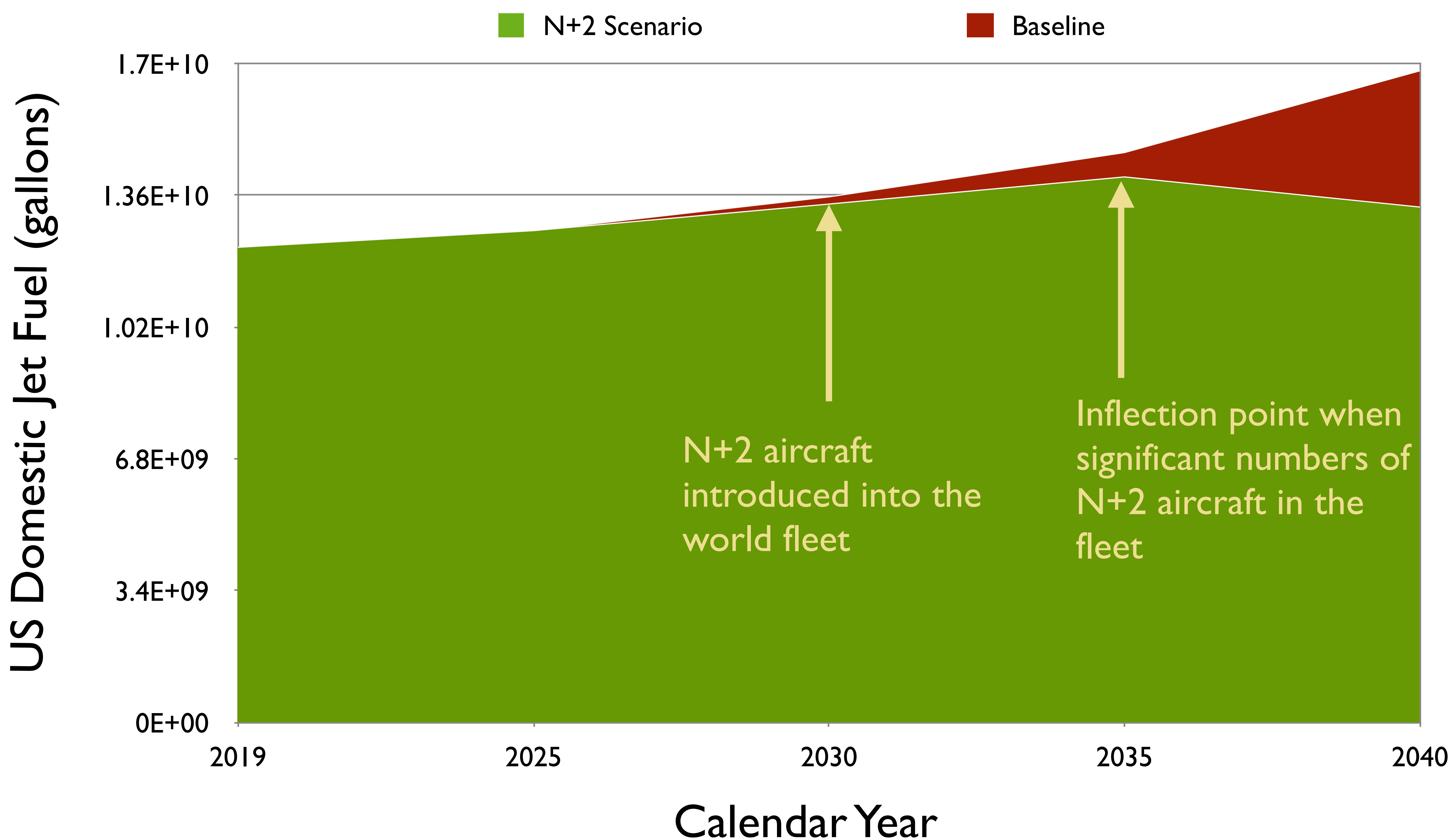
Source: A.A. Trani (Atlanta International Airport Fuel Farm)

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



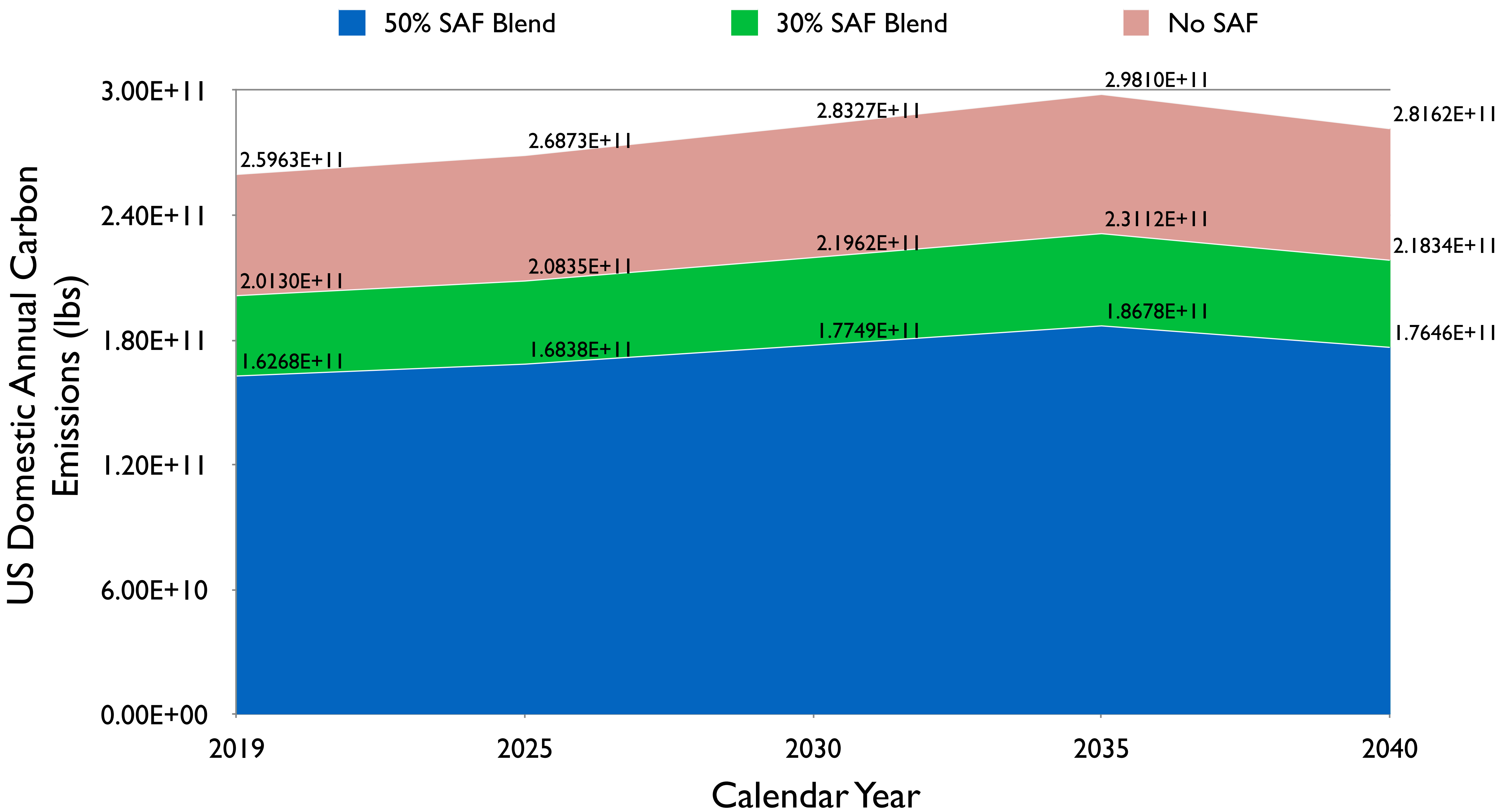
Source of Data: Bureau of Transportation Statistics
Plot: Virginia Tech Air Transportation Laboratory

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



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

Conclusions

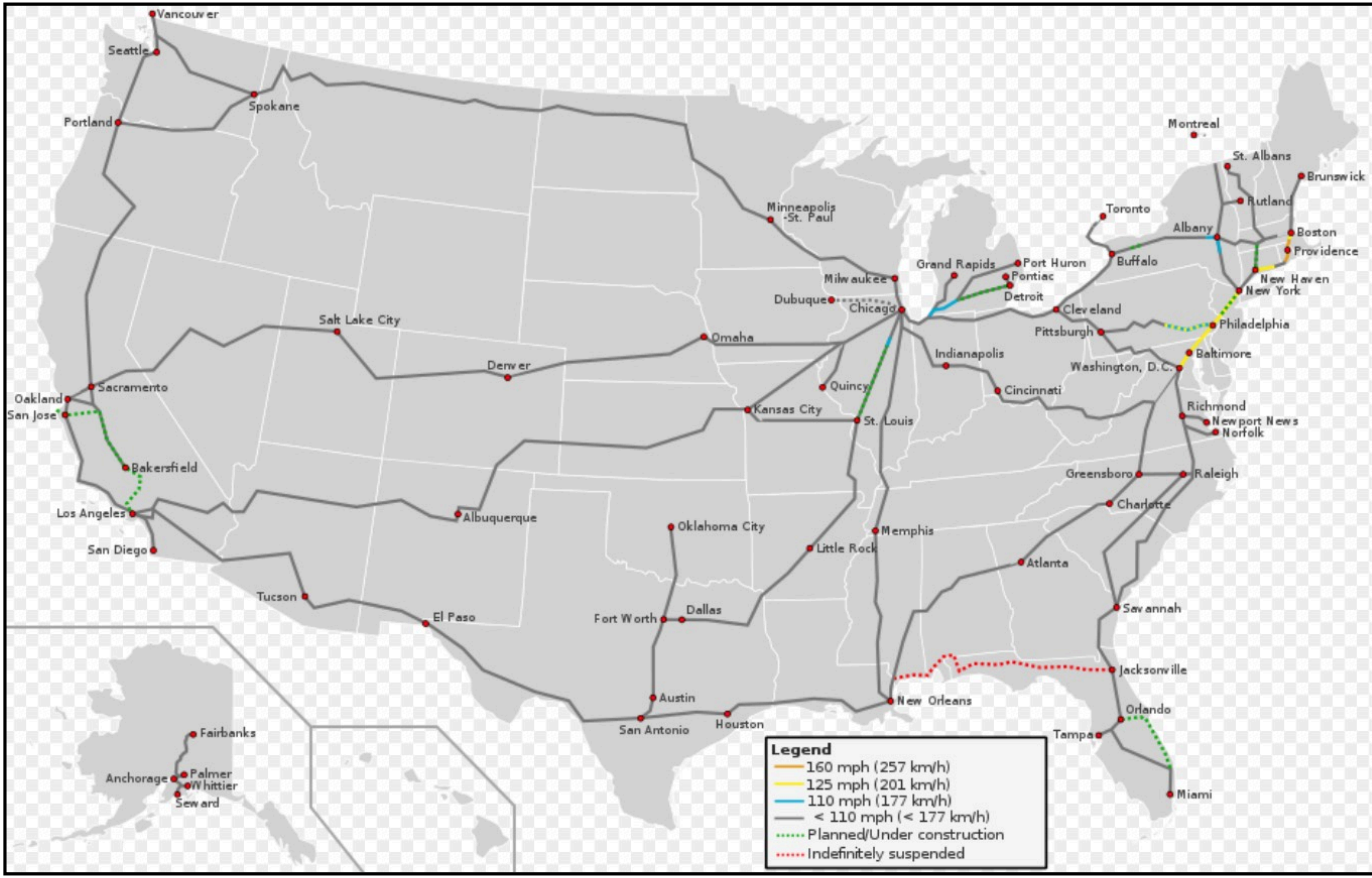
- Path to sustainability is difficult but not impossible
- Number of plants to produce SAF fuels needs to ramp up quickly
- Requires large increases in Sustainable Aviation Fuel (SAF) Production
- Long-term, aviation needs to migrate to other sources of energy including hydrogen and all-electric power plants

Basic High-Speed Rail Performance

Air Transportation vs. High-speed Rail Transportation

- Rail is a competitor to air transportation (city center to city center)
- Rail is complementary to air transportation (feeder service or substitute in bad weather)
- Recent studies suggest congested corridors in the U.S. could support high-speed rail (assuming the infrastructure supports high speeds)

United States High-Speed Rail Lines



https://en.wikipedia.org/wiki/High-speed_rail#/media/File:High_Speed_Railroad_Map_of_the_United_States_2013.svg

Potential High-Speed Rail Service in The U.S.

High-Speed Rail Technology

- France - TGV technology
- Japan - Shinkansen technology
- Germany - Siemens Velaro technology

Shinkansen

TGV

Valero D

source: Wikipedia, 2010

Performance Formulas for HS Rail Technology

- A quadratic formula (Davis) has been used for over 80 years to approximate rail vehicle resistance
- von Borries Formel, Leitzmann, Barbier and Davis worked on this equation

$$R = A + BV + CV^2$$

- where *R* is the rail vehicle resistance (N), *V* is the velocity of the vehicle (m/s), and *A* (N), *B* (N s/m) and *C* (Ns^2/m^2) are regression coefficients obtained by fitting run-down test to the Davis equation

Observations

- The coefficients A and B in the Davis equation account for mass and mechanical resistance
- The coefficient C accounts for air resistance (proportional to the square of the speed)
- The Davis equation has been modified over the years for various rail systems and configurations . A few examples are shown in the following pages.

Davis Equation - Committee 16 of AREA (American Railway Engineering Association)

$$R_u = 0.6 + \frac{20}{w} + 0.01V + \frac{KV^2}{wn}$$

- where:
- R_u is the resistance in lb/ton, *w* is the weight per axle (*W*/*n*), *n* is the number of axles, *W* is the total car weight on rails (tons), *V* is the speed in miles per hour and *K* is the drag coefficient
- Values of K are 0.07 for conventional equipment, 0.0935 for containers and 0.16 for trailers on flatcars

Additional Terms to the Davis Equation (Gradient Forces)

$$R_G(kN) = \frac{Mg}{X}$$

- where:
- R_G is the resistance (kN) due to gradients, *M* is the mass of the train in tons, g is the acceleration due to gravity (m/s^2) and X is the gradient in the form 1 in X

Additional Terms to the Davis Equation (Resistance due to Curvature)

$$r_c(kN/t) = 0.01\frac{k}{R_c}$$

- where:
- r_c is the resistance due to curvature (kN/ton), *k* is dimensionless parameter depending upon the train (varies from 500 to 1200), R_C is the curve radius in a horizontal plane (meters).

Application of Davis Equation to a High-Speed Rail System (Japan Shinkansen Series 200) per Rochard and Schmid[1]

$$R = 8.202 + 0.10656V + 0.01193V^2$$

- where:
- R is the total resistance (kN), *V* is the speed of the train (m/s) train

[1] A review of Methods to Measure and Calculate Train Resistances (Proceedings of the Institute of Mechanical Engineers, Vol. 214 Part F)

Matlab Script to Calculate Resistance Forces (Shinkansen Series 200)

```
% Script to estimate the total resistance of a Series 200 train

% Equations provided by Rochard and Schmid (2000)

% Coefficients of Davis equation applied to Japanese Shinkansen system
% Series 200

A = 8.202;         % units are kN
B = 0.10656;    % units are kN s/m
C = 0.0119322;  % units are kN s-s/m-m

% Create a speed vector
V = 0:1:90;               % speed in meters/second

% Calculate Resistance (in KiloNewtons) according to modified Davis equation

R = A + B * V + C * V.^2;

% Make a plot of total resistance vs speed
plot(V,R,'o--')
xlabel(' Speed (m/s)')
ylabel('Resistance (kN)')
title('Reisistance of Series 200 Shinkansen Rail System')
```

Shinkansen Series 200 Tractive Effort Curve

- The tractive effort can derived from knowledge of the shaft horsepower delivered by the rail engine(s)
- Literature on the Shinkansen indicates that the series 200 locomotives deliver 15,900 HP of power
- Lets assume that a single locomotive pulls a 6-car train unit

Tractive Effort vs Power

- A fundamental equation to convert power to tractive force (or effort) is shown below
- This equation can be modified to convert units correctly (from HP to Newtons)

$$P = \frac{VT}{\eta}$$

- where: P is the power output delivered by the engine, T is the tractive force or effort, η is the efficiency in converting power output to tractive force and V is the velocity of the vehicle

Tractive Force or Tractive Effort in Typical Units

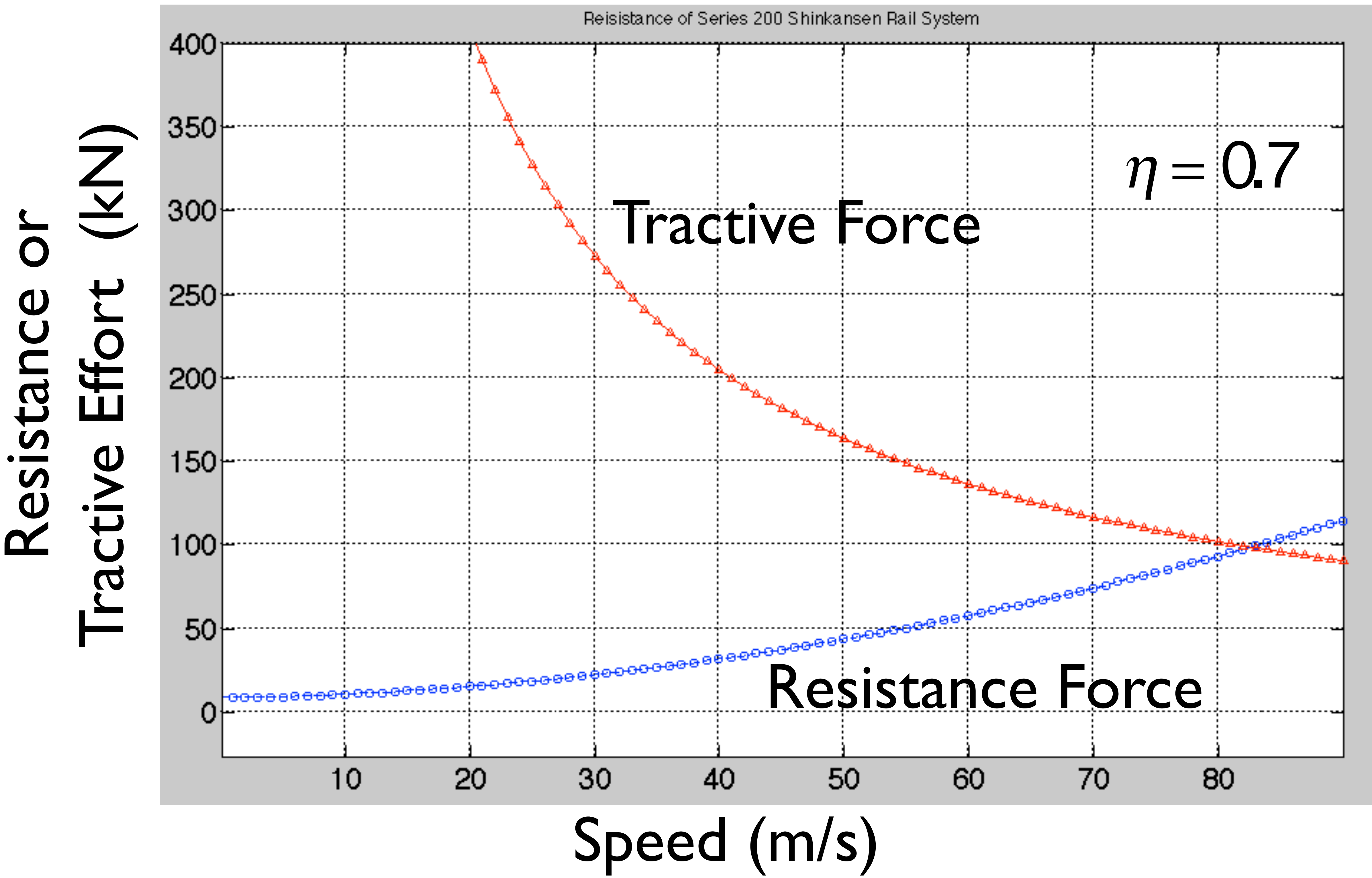
$$T = 2650\frac{\eta P}{V}$$

- T in Newtons
- P in horsepower
- V in km/hr

Matlab Script to Calculate Tractive Effort (Shinkansen Series 200)

```
% Coefficients of Davis equation applied to Japanese Shinkansen system
% Series 200

plot(V,R,'o--')
xlabel(' Speed (m/s)')
ylabel('Resistance (kN) or T (kN)')
title('Reisistance of Series 200 Shinkansen Rail System')
grid

hold on

% Calculate the Tractive Effort (T) profile

P = 15900;          % horsepower (hp)
Vkmhr = V*3.6;   % velocity in km/hr (needed in the TE equation)
nu = 0.7;             % efficiency

T = 2650 * nu * P ./ Vkmhr / 1000;     % in kN

plot(Vkmhr/3.6,T,'^-r')

grid
```

Plot of Resistance and Tractive Force vs Speed



Observations

- According to these plots, the high-speed rail system will reach its maximum velocity at 83 m/s (298 km/hr)
- The number correlates well with the actual performance quoted for the Shinkansen 200 trainset
- The value of efficiency has been assumed to be 0.7 (conservative)
- The plot applies to level ground (zero gradient)

Energy Comparison (HSR vs. Aviation)

- Modeled HSR and Airplane travel between Boston and Washington, DC (Alex VanDyke's work)
- Trains: Shinkansen 100-200 series, TGV-R, TGV-D
  - 13 Stops on route
- Airplanes:
  - Airbus A319: Fuel used = 2434 kg [1]
  - Embraer 135: Fuel used = 1124 kg [1]
- Air Transportation Systems Lab calculations by Maria Rye

Sources

- A: “A Review of Methods to Measure and Calculate Train Resistances” by Rochard and Schmid
- B: “Efficiency Comparisons of the Typical High Speed Trains in the World” by Shoji

Shinkansen 100

- Resistance Coefficients (Davis Equation) [A]
  - A= 11060 (N)
  - B=109.44 (N*s/m)
  - C=15.6168(N*s^2)/(m^2)
- Tractive Coefficients
  - Power=15900 horsepower (assumed)
  - Engine Efficiency= 0.75 (assumed)
  - Mass = 886000 [B]
- Capacity = 1285 (calculated for 16 car set)
- Load Factor=0.8

Shinkansen 100
Source: Wikipedia

Shinkansen 200

- Resistance Coefficients (Davis Equation) [A]
  - A= 8202 (N)
  - B=106.56 (N*s/m)
  - C=11.9322 $(N*s^2)/(m^2)$
- Tractive Coefficients
  - Power=15900 horsepower (assumed)
  - Engine Efficiency= 0.75 (assumed)
  - Mass = 712000 [B]
- Capacity = 720 (calculated for a 12-car set)
- Load Factor=0.8

Shinkansen 200

Source: Wikipedia

Notes on Japanese HSR Trains

- Performance equations have been found in the open literature for two of the oldest systems running in Japan
- The new Shinkansen trains (N700 and series 500) are considerably more aerodynamic than their predecessors
- They operate 40-60 km/

Source: Wikipedia

Tokyo-Osaka Ridership

- Tokyo-Shin/Osaka corridor (516 km / 320 miles)
- Tokyo-Shin/Osaka route recorded 151 million passengers per year in 2009
- The aviation mode captures a small fraction of passengers with 30 frequencies (large aircraft Boeing 777 and Boeing 767 fly the route)
- ~ 5-6 million seats offered per year

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TGV- Davis Equations A

- A=(0.00001*[λ*M*sqrt(10000/m)])*1000
  - Λ= 0.9 (based on rolling stock type)
  - M=Mass of Train (kg)
  - m= Mass/axle (kg) (assumed 24 axles for both TGV's)
- B=((3.6*10^{-7}) *M)*1000
- C=(0.1296*[(k_1*S)+(k_2*p*L)])*1000
  - k_1=(9*10^{-4}) (based on shape of train)
  - S=10 m^2 (Cross Sectional Area)
  - k_2=(20*10^{-6}) (based on surface condition)
  - L= Length of Train (meters)

TGV-Réseau (-R)

- Resistance Coefficients (Davis Equation) [A]
  - A= 2843 (N)
  - B=149.76 (N*s/m)
  - C=6.3504 (N*s^2)/(m^2)
- Tractive Coefficients
  - Power=11800 horsepower [B]
  - Engine Efficiency= 0.75 (assumed)
  - Mass = 416000[B]
  - Length= 200 m [B]
- Capacity = 377 [B]
- Load Factor=0.8

Source: Wikipedia

TGV-Duplex in Paris Gare de Lyon

TGV-Duplex (-D)

- Resistance Coefficients (Davis Equation) [A]
  - A= 2870 (N)
  - B=152.64 (N*s/m)
  - C=6.3504 $(N*s^2)/(m^2)$
- Tractive Coefficients
  - Power=11800 horsepower [B]
  - Engine Efficiency= 0.75 (assumed)
  - Mass = 424000[B]
  - Length= 200 m [B]
- Capacity = 545 [B]
- Load Factor=0.8

TGV-Duplex in Paris Gare de Lyon

Source: Wikipedia

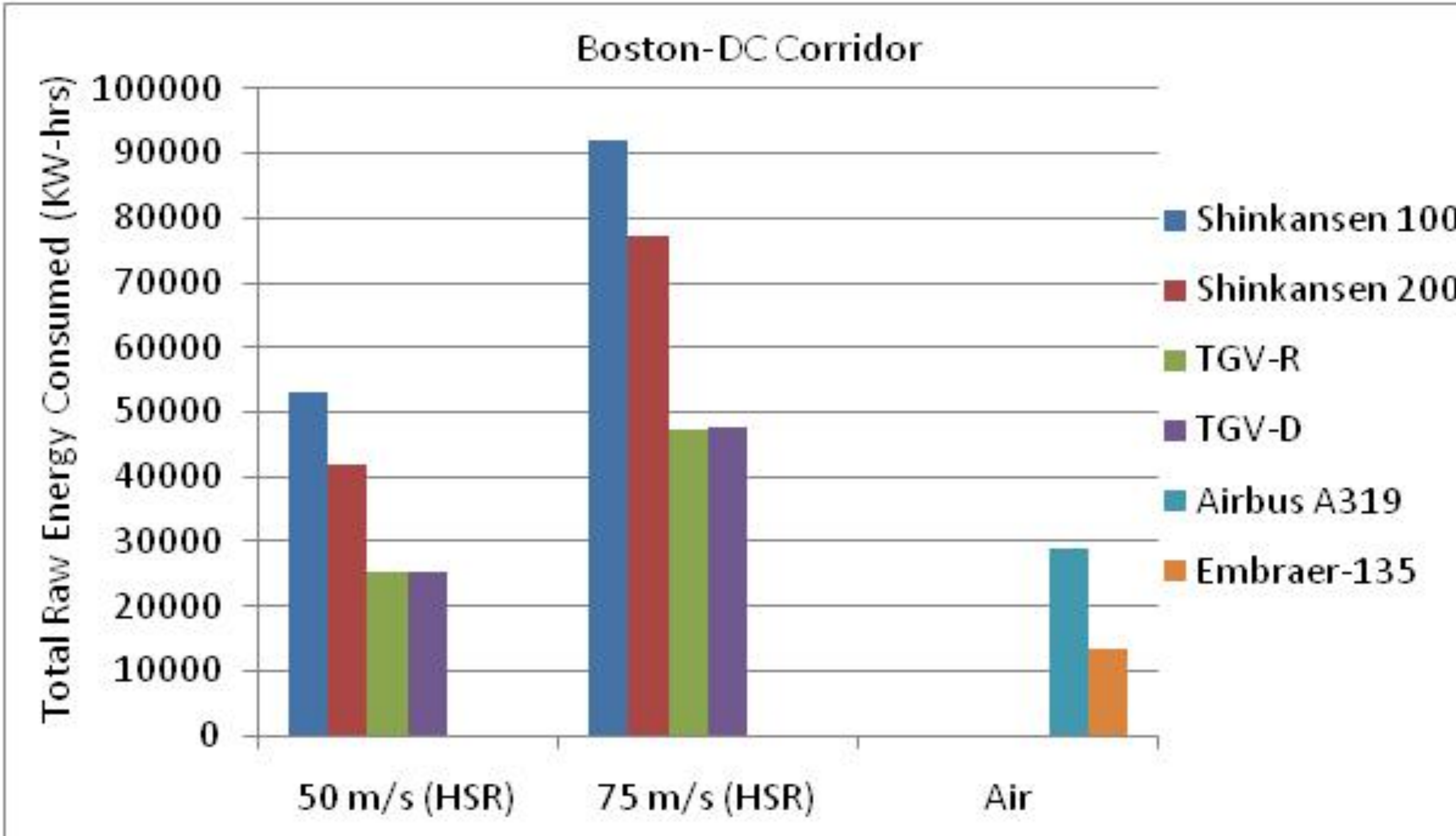
Assumptions – Train Energy

- 5% loss in pantograph (assumed)
- No energy regeneration
- Load Factor = 0.8

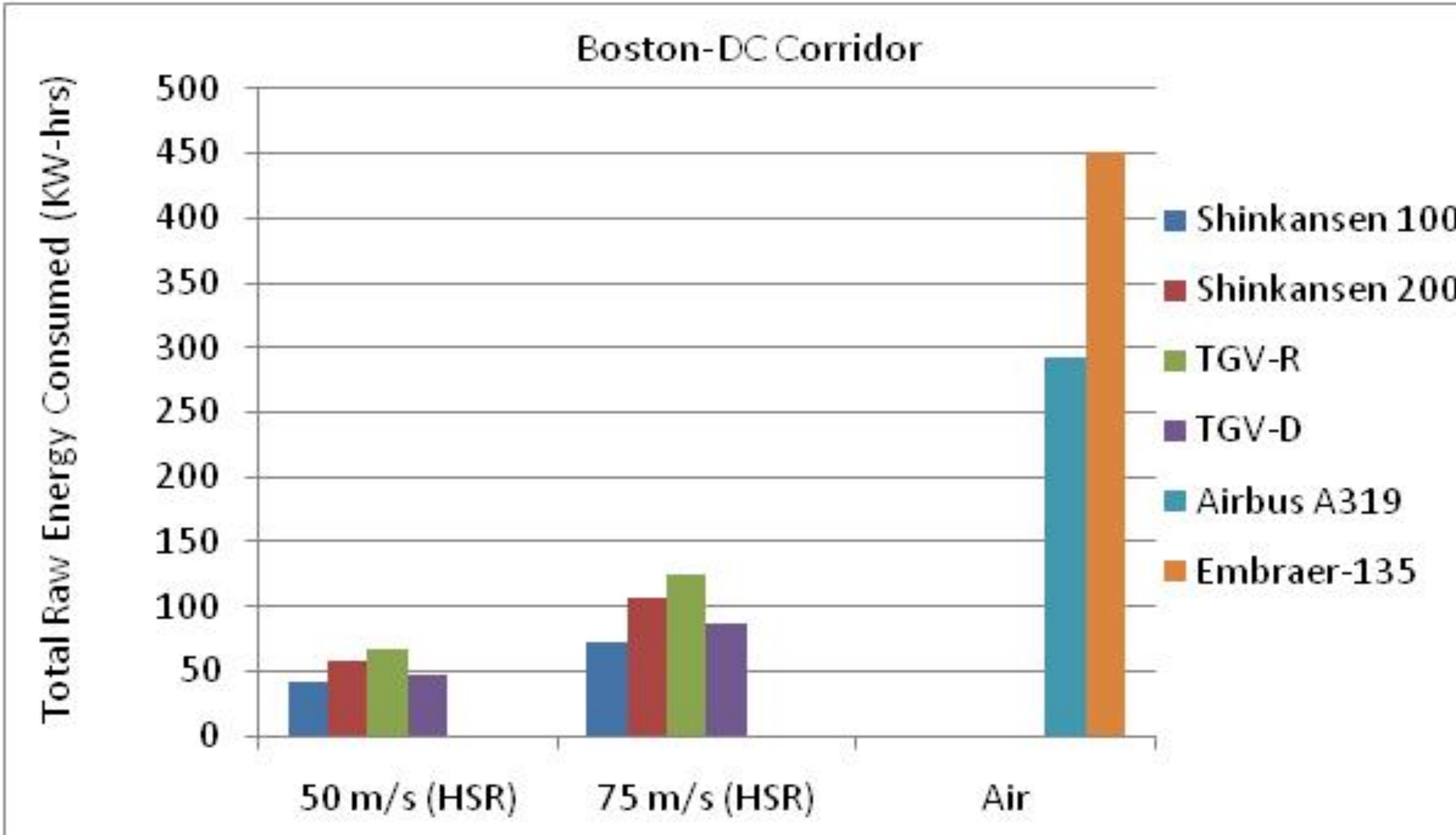
Notes

- Each Train has multiple capacities depending on number of cars
- Capacities were chosen based on length of train used to determine Davis coefficients or most utilized setup in real applications

Total Raw Energy Consumption



Raw Energy Consumed/Passenger



Assumptions-Train Energy

- Energy: (KW Source/KW Delivered) =3.443 [C]
  - National Primary Energy Mix: 71% Fossil, 20% Nuclear, 7% Hydro, 2% Renewable
  - Use Energy Factor for Eastern Region
  - Accounts for losses of
    - Electricity Generation
    - Transmission and Distribution
    - Pre-combustion (Extraction, Processing, Transportation) = 5%
- C: "Source Energy and Emission Factors for Energy Use in Buildings" by National Renewable Energy Laboratory-Dept of Energy

Emissions Factors

- Emissions factors presented as Kg's of pollutant released for each kilowatt-hr of delivered electricity
- CO_2 = 0.788 [C]
- NO_X = 0.00136 [C]
- SO_X = 0.00389 [C]
- C: "Source Energy and Emission Factors for Energy Use in Buildings" by National Renewable Energy Lab. (Dept. of Energy)

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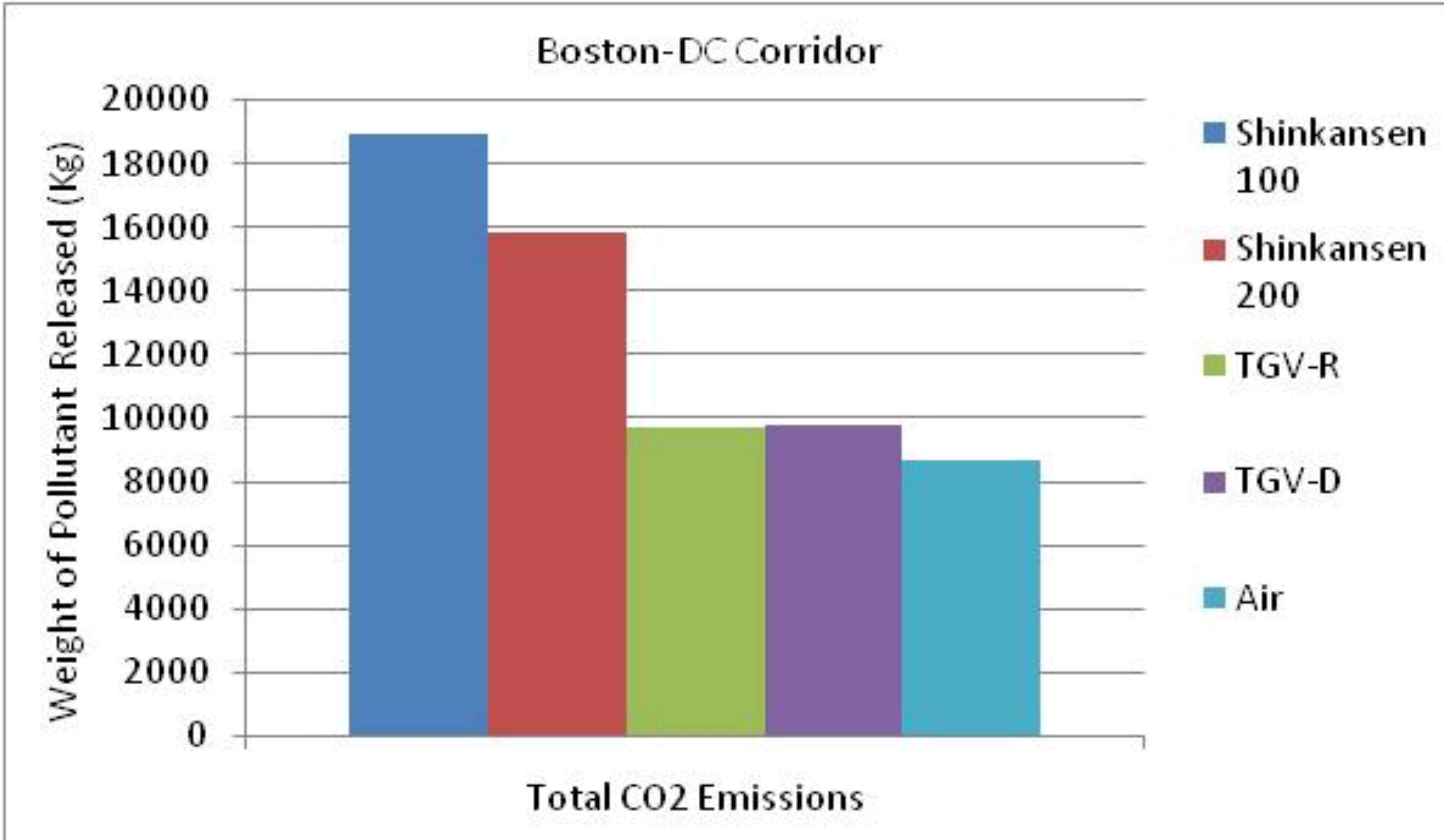
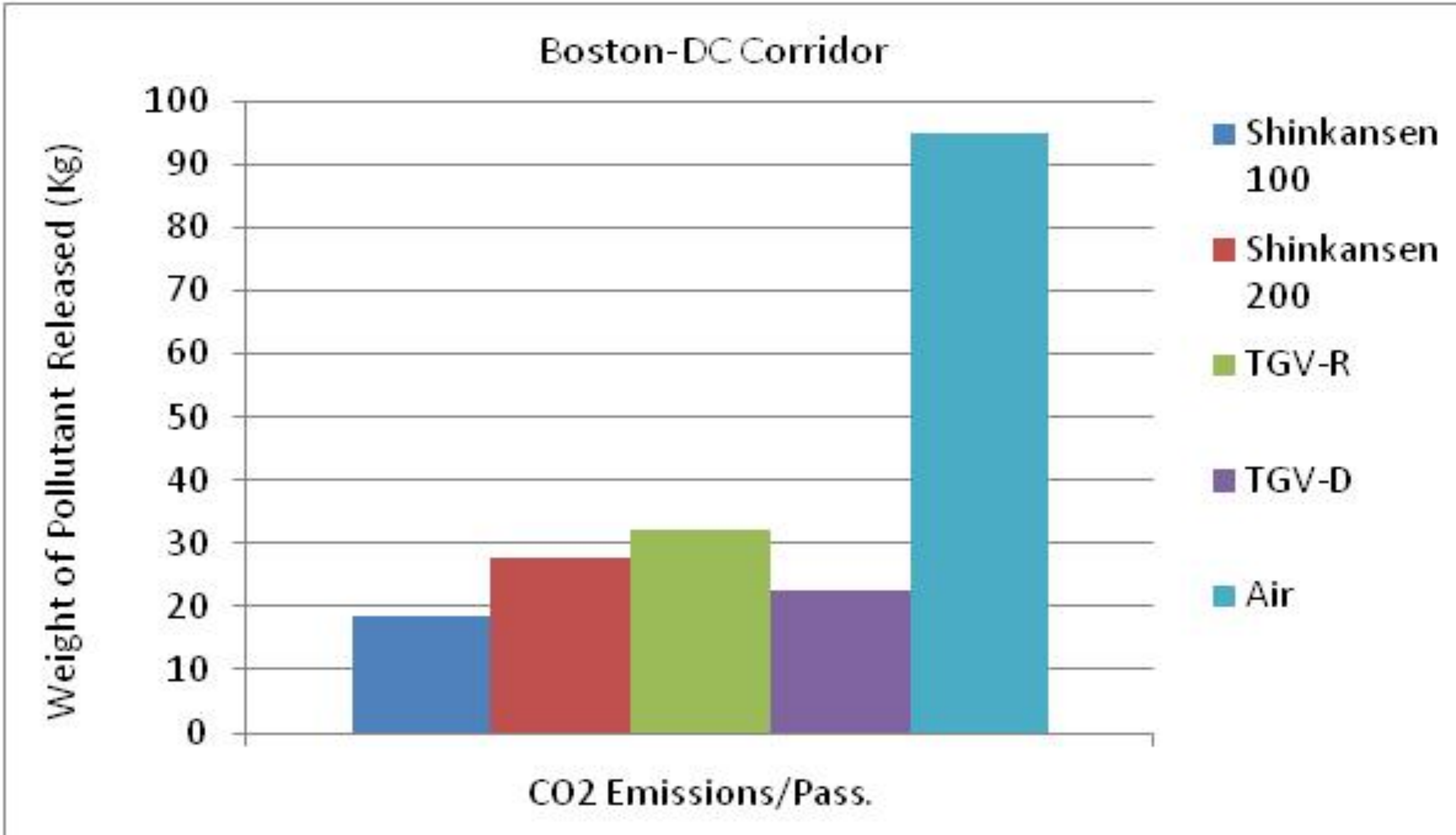
Total CO_2 Emissions (Rail:75 m/s)



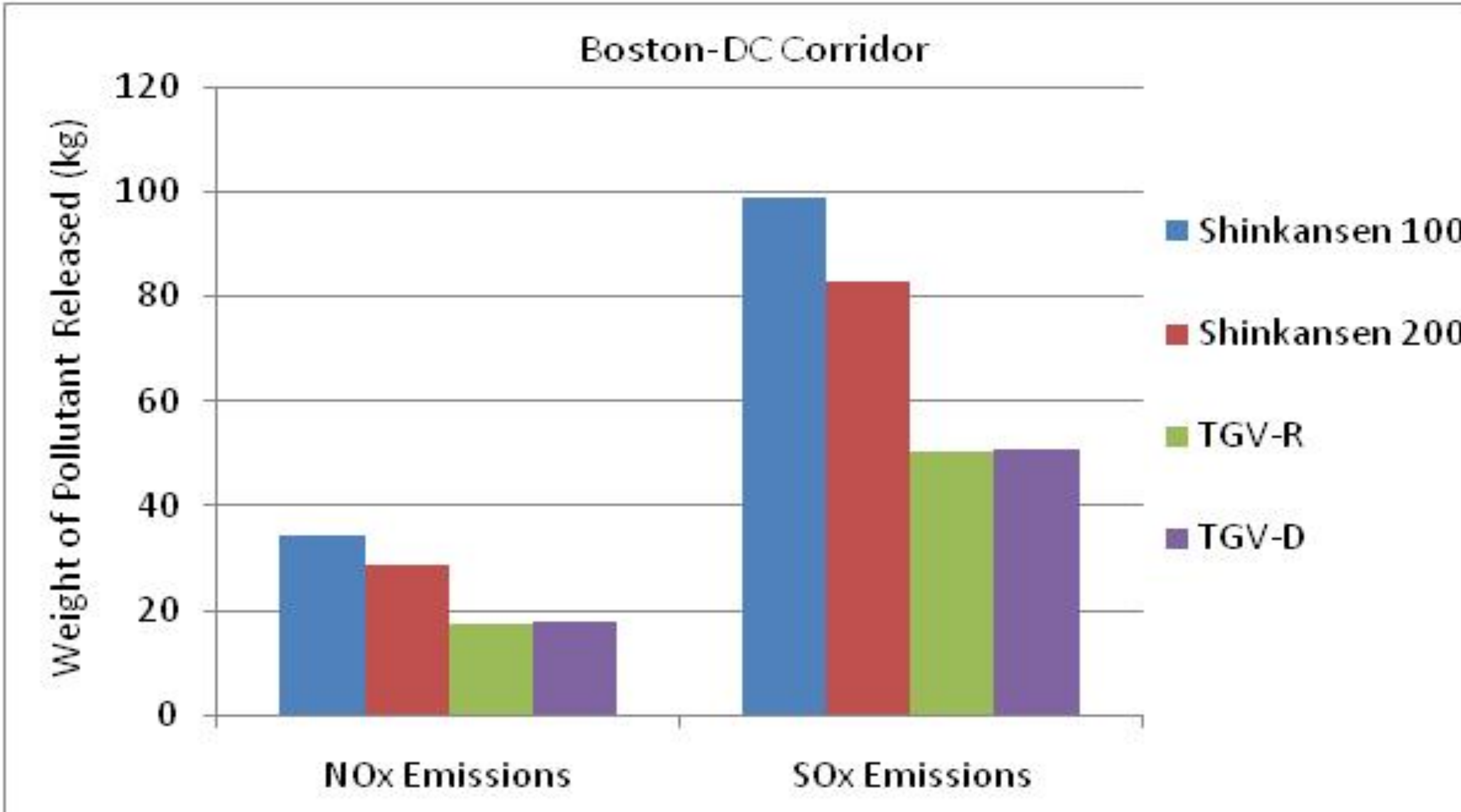
Airplane CO_2 Emission Info.

- BOS-DCA emissions calculated using ICAO emissions calculator
  - Calculation uses average emissions from Airbus A320, CRJ-200, CRJ-900
  - 94.89 Kg's CO_2 / passenger
    - Load Factor = 0.797
    - Avg. Capacity=115
- Total = 94.89*(115*0.797)=8697 kg's CO_2
- Material Extraction, Fuel Creation/Mixing, & Transportation Energy not included

CO_2 Emissions/Pass. (Rail:75 m/s)



Total NO_X and SO_X Emissions (Rail:75 m/s)



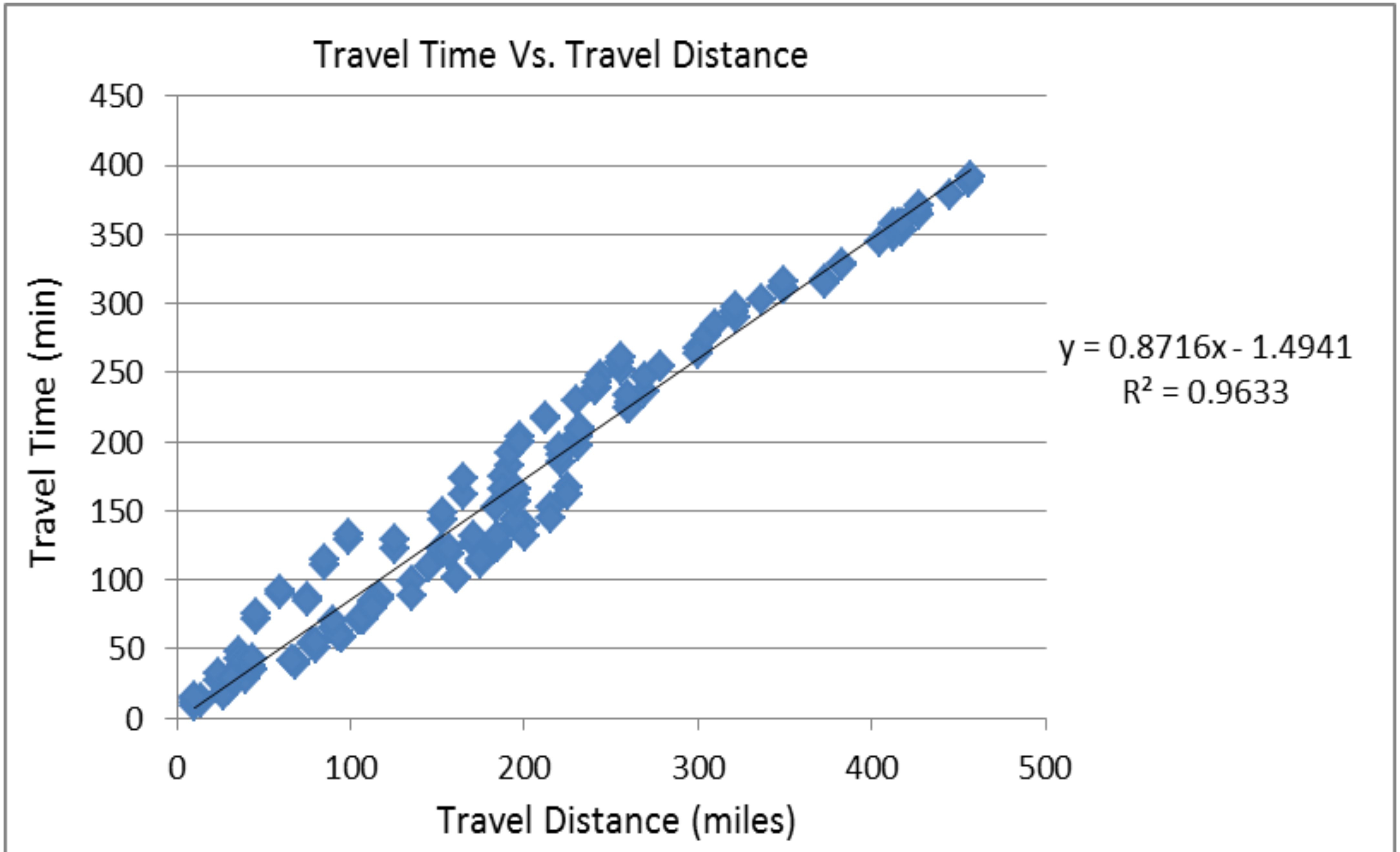
High-Speed Rail Systems

High-Speed Rail in The U.S.

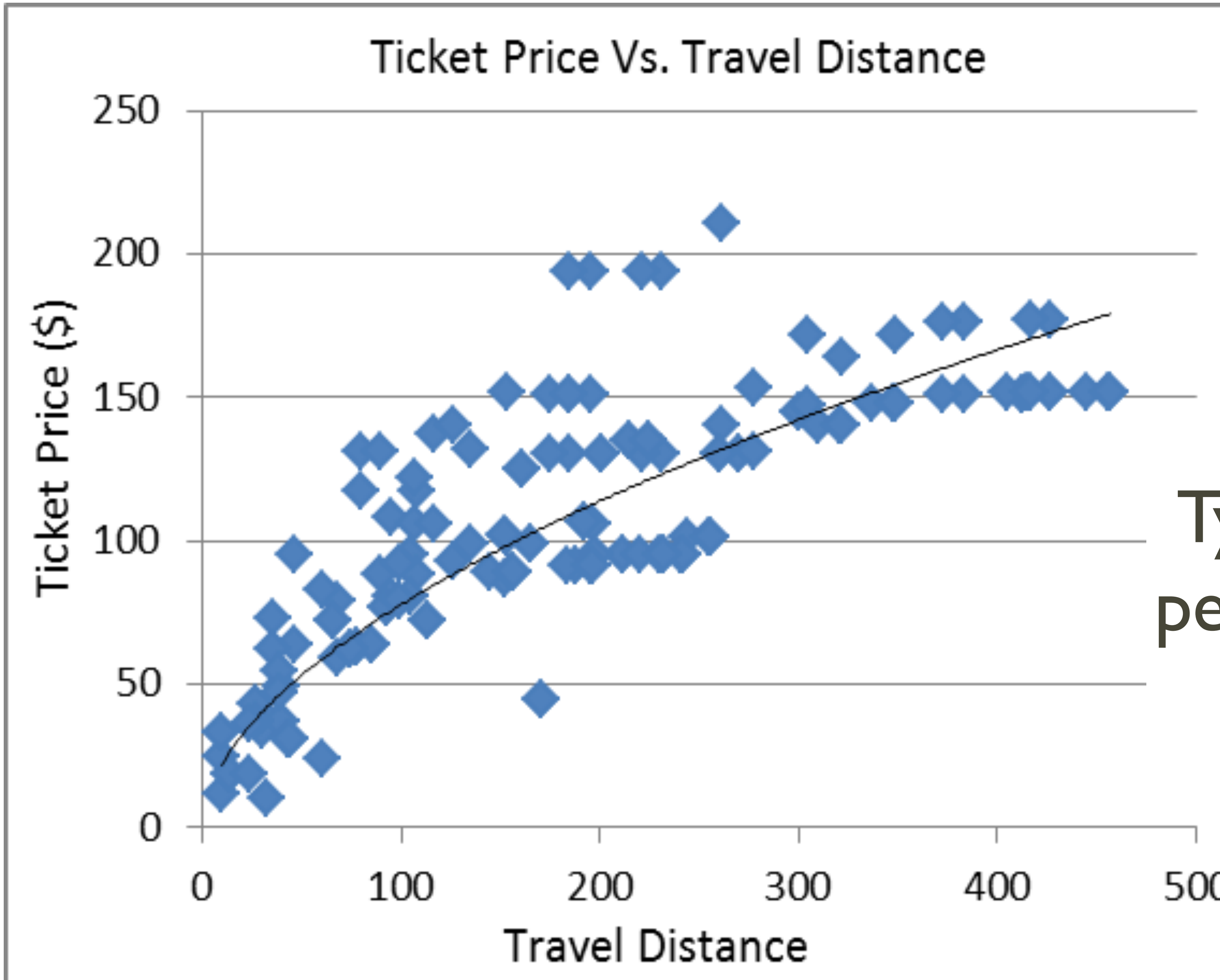
- Today limited in scope to the NE corridor (DC-NY-Boston route)
- Acela trains use the French TGV technology (albeit with higher weights due to stricter crashworthiness standards in the US compared to France)
- Guideway is not really designed for high-speed

Travel Time vs. Distance (Northeast Corridor)

- The average speed in the corridor is 71 mph



Amtrak Cost vs. Distance (Northeast Corridor)



Typical cost per seat-mile is $0.46

High-Speed Rail in Other Countries

Country	In operation (km)	Under	Total Country (km)
China	25000	16155	41155
Spain	3100	1800	4900
Germany	3038	330	3368
Japan	2765	681	3446
France	2647	670	3317
Sweden	1706	0	1706
United Kingdom	1377	230	1607
Italy	999	116	1115
Turkey	802	1208	2010
South Korea	1104	376	1480
Taiwan	345	0	345
Belgium	326	0	326
The Netherlands	175	0	175
United States	54	160	214

source Wikipedia, 2018

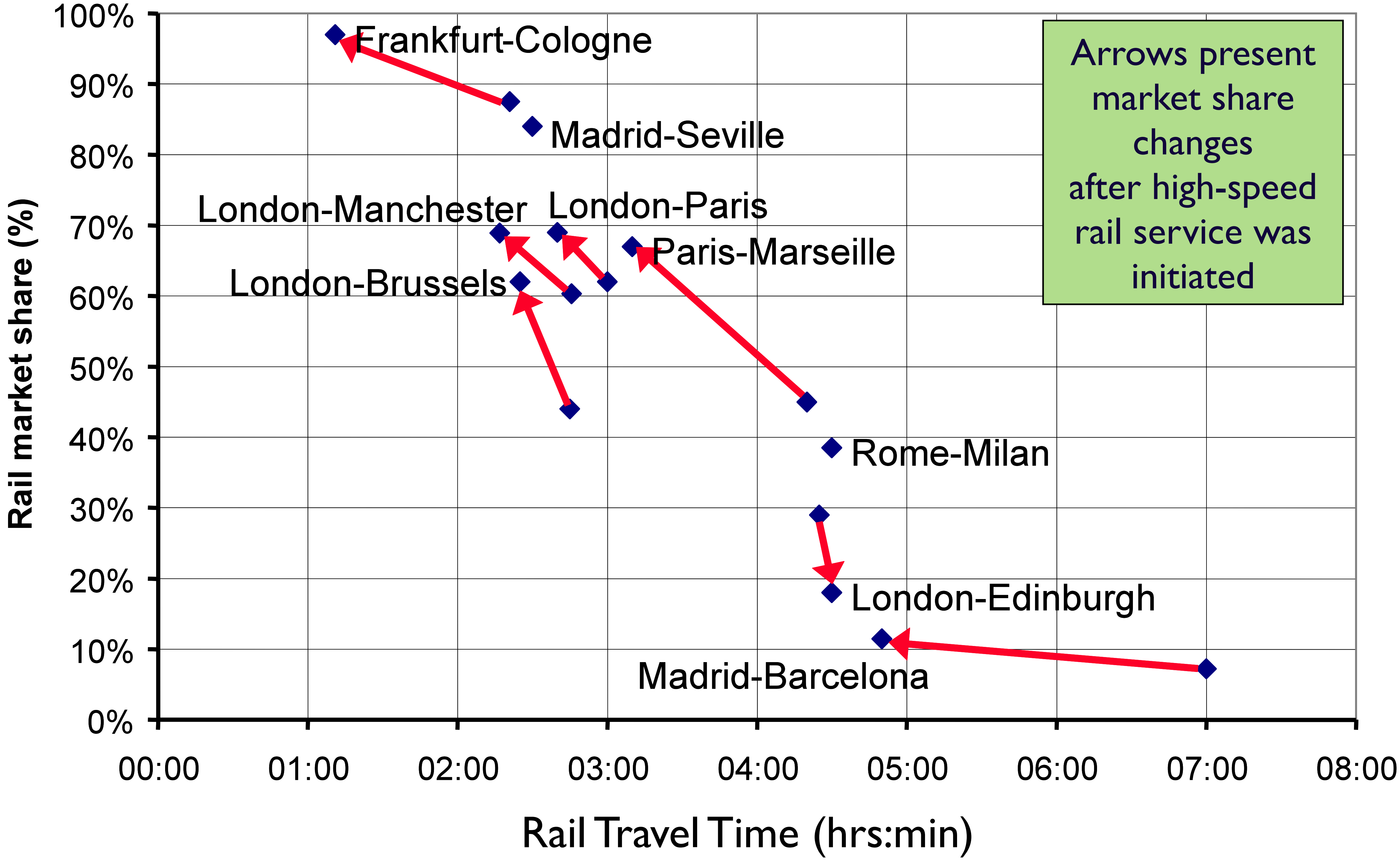
Europe's High Speed Rail Network

- A total of 3,600 mi are available in Europe (> 200 km/hr)

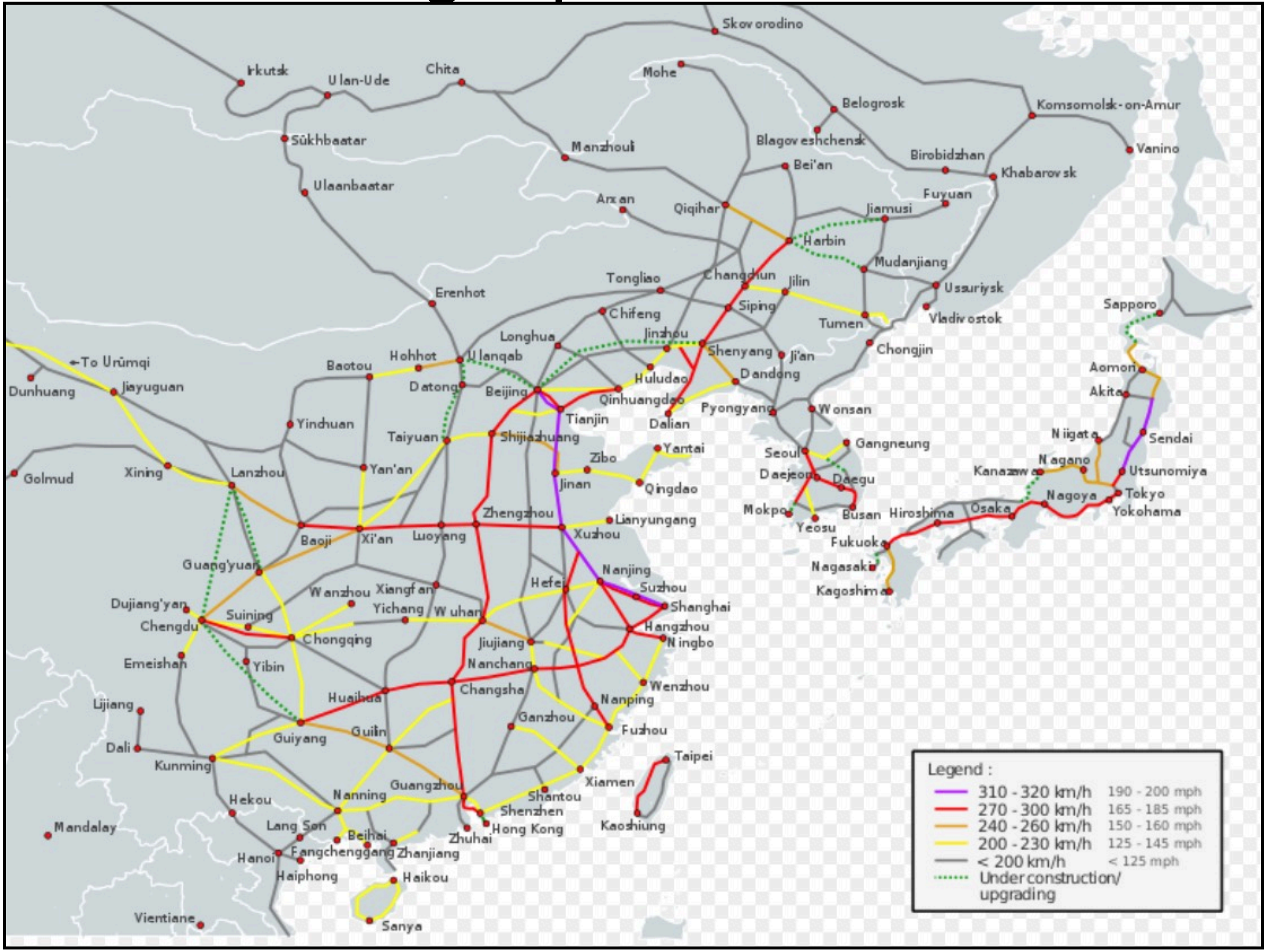
https://en.wikipedia.org/wiki/High-speed_rail#/media/File:High_Speed_Railroad_Map_of_Europe.svg

European Case Studies

Source: Steer, Davies Gleave (European Union)

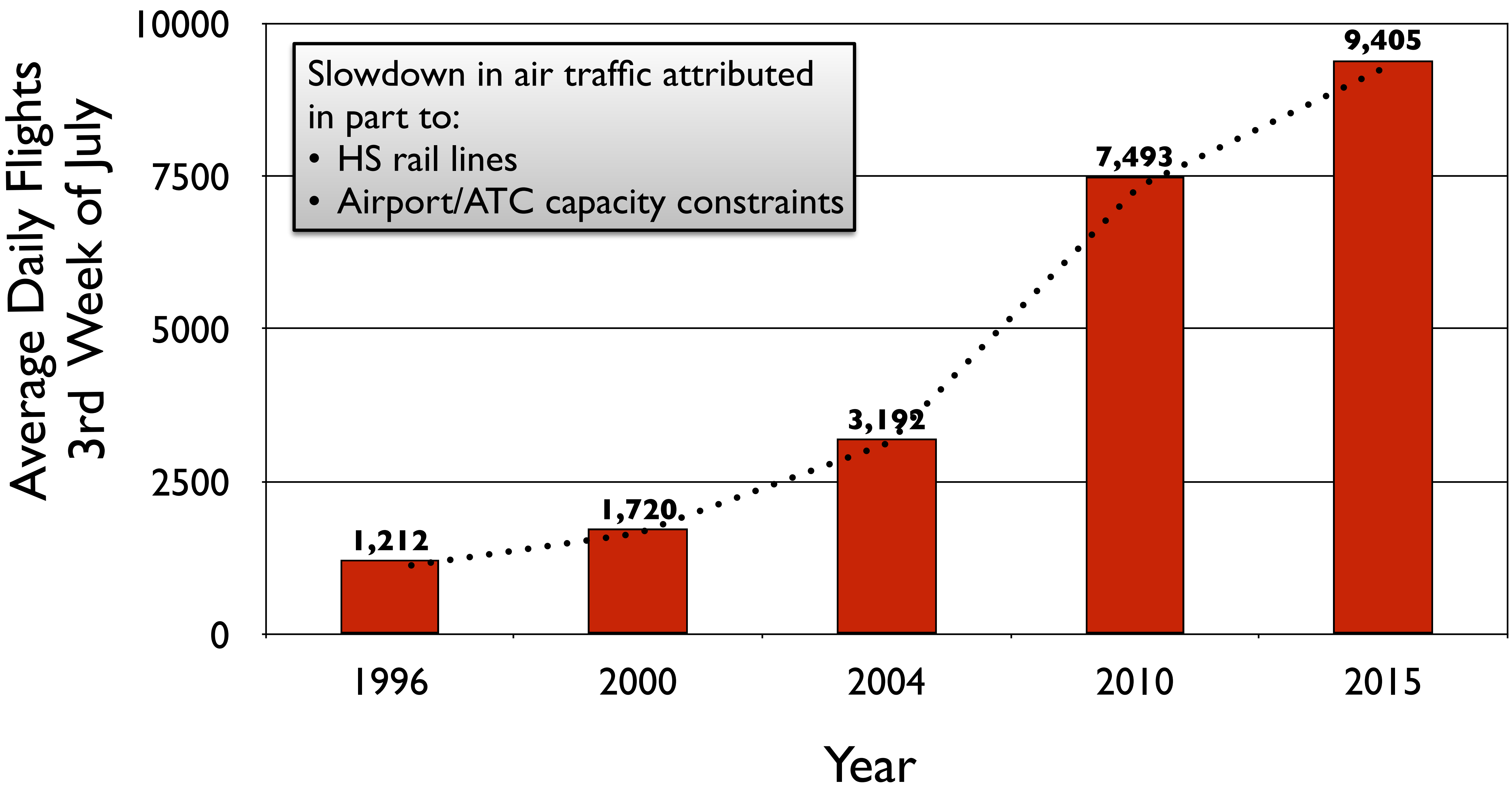


Asian High-Speed Rail Network



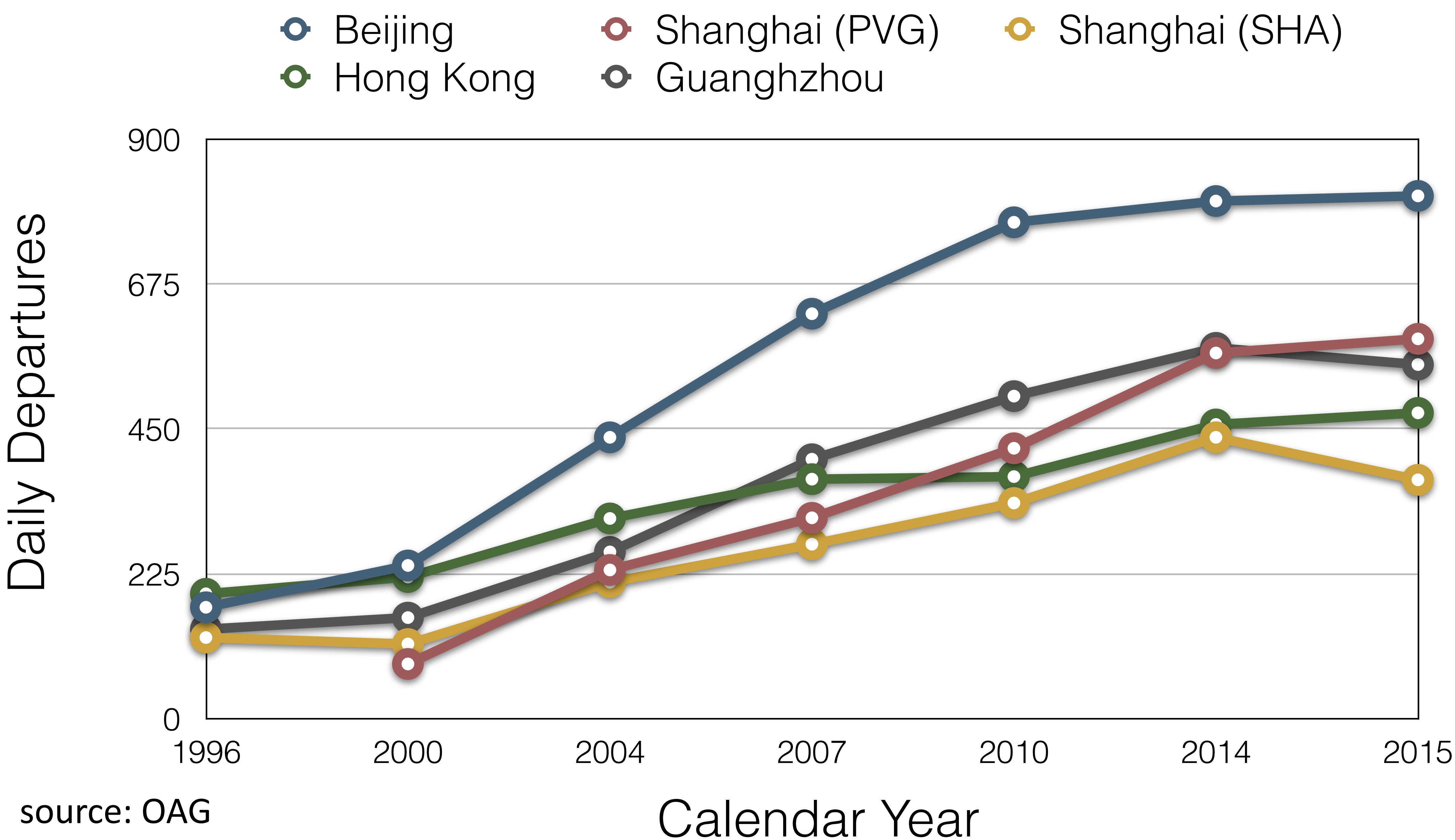
https://en.wikipedia.org/wiki/High-speed_rail#/media/File:Eastern_Asia_HSR2018.svg

: Capacity Limits China's Commercial Air Transport Network (Scheduled Flights)



source: Official Airline Guide

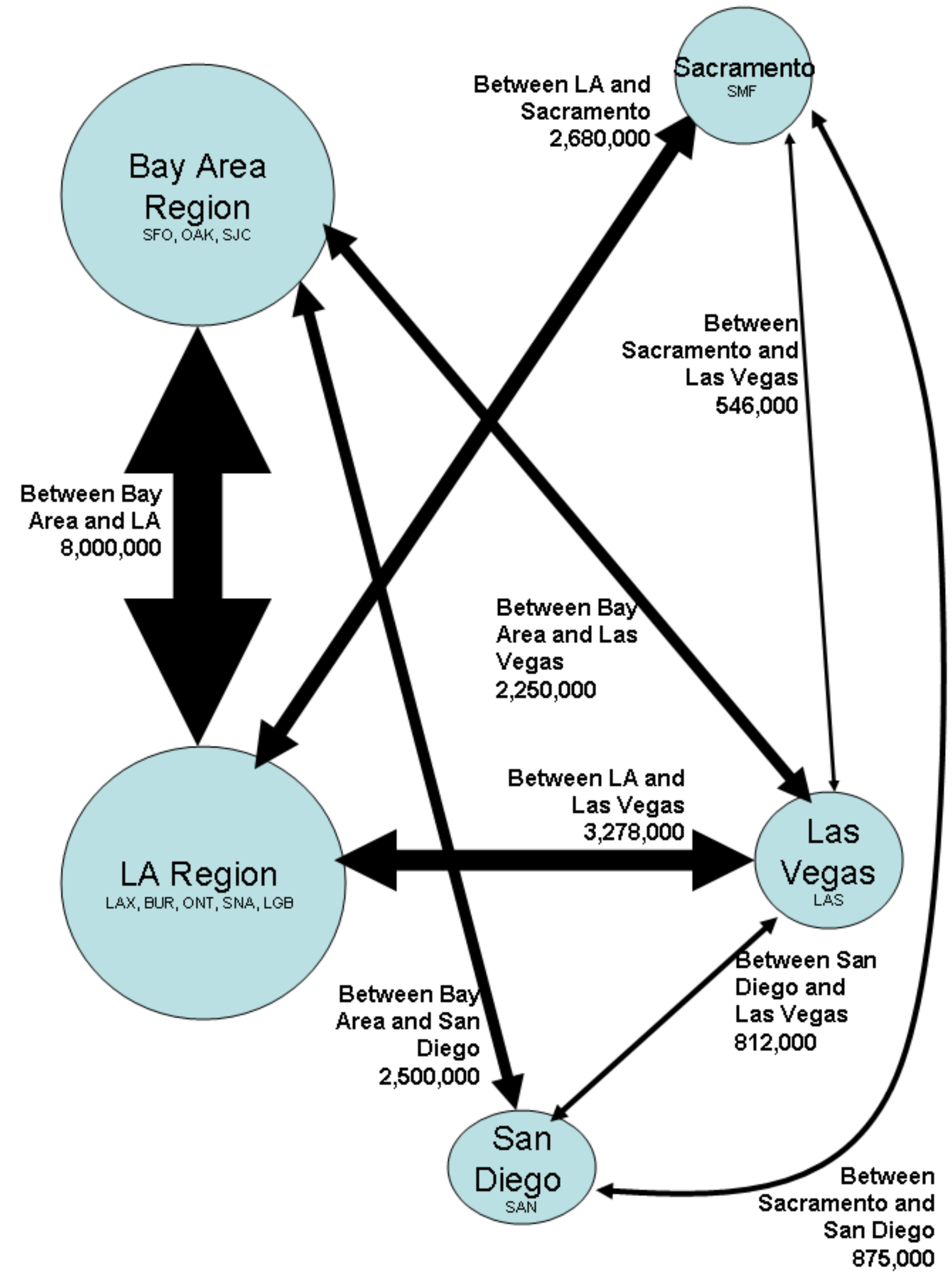
Daily Operations During 3rd Week of Busy Month of July at Key Airports in China



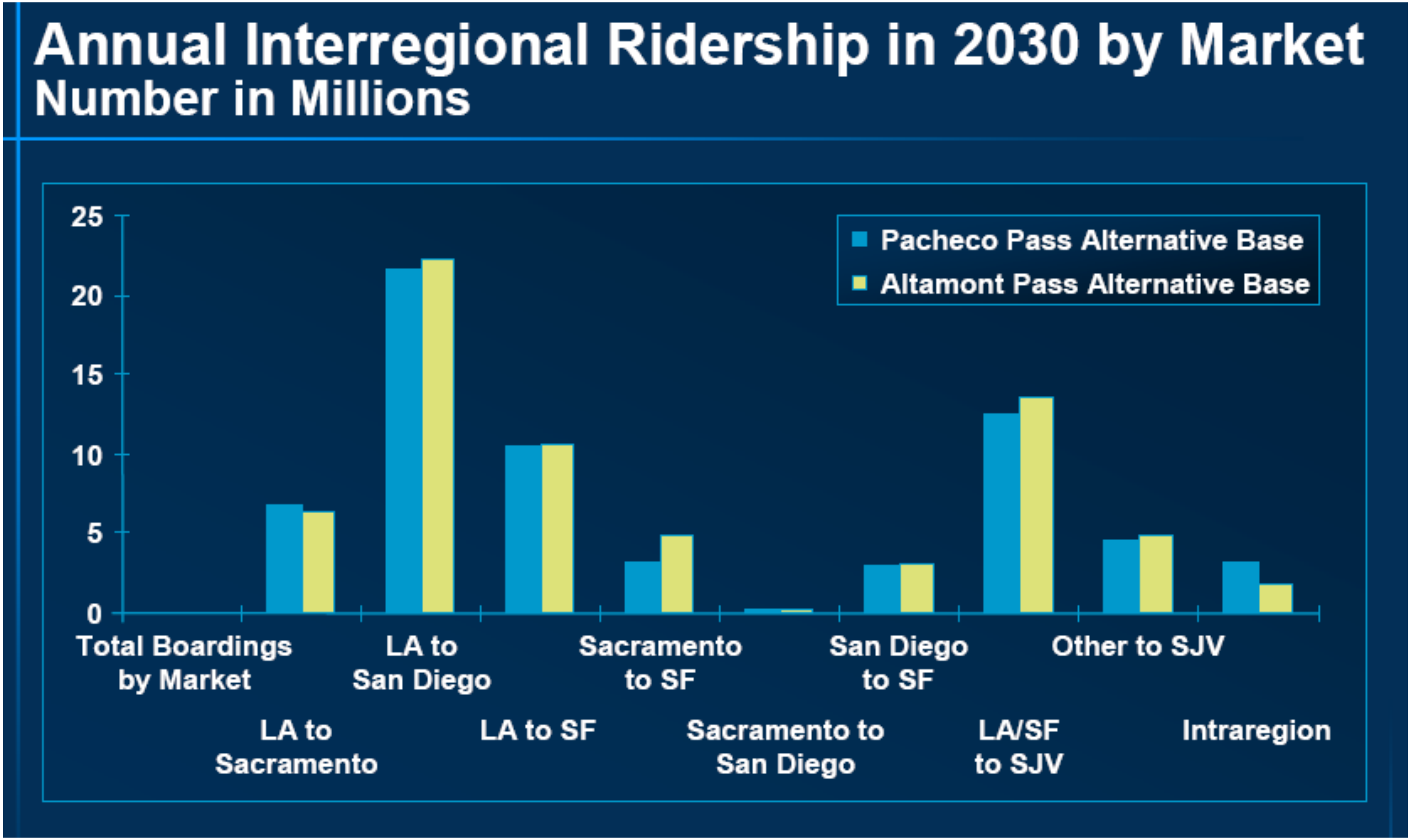
source: OAG

Future High-Speed Rail in the U.S.

California High-Speed Rail Network source: Matthew Coogan, 2009

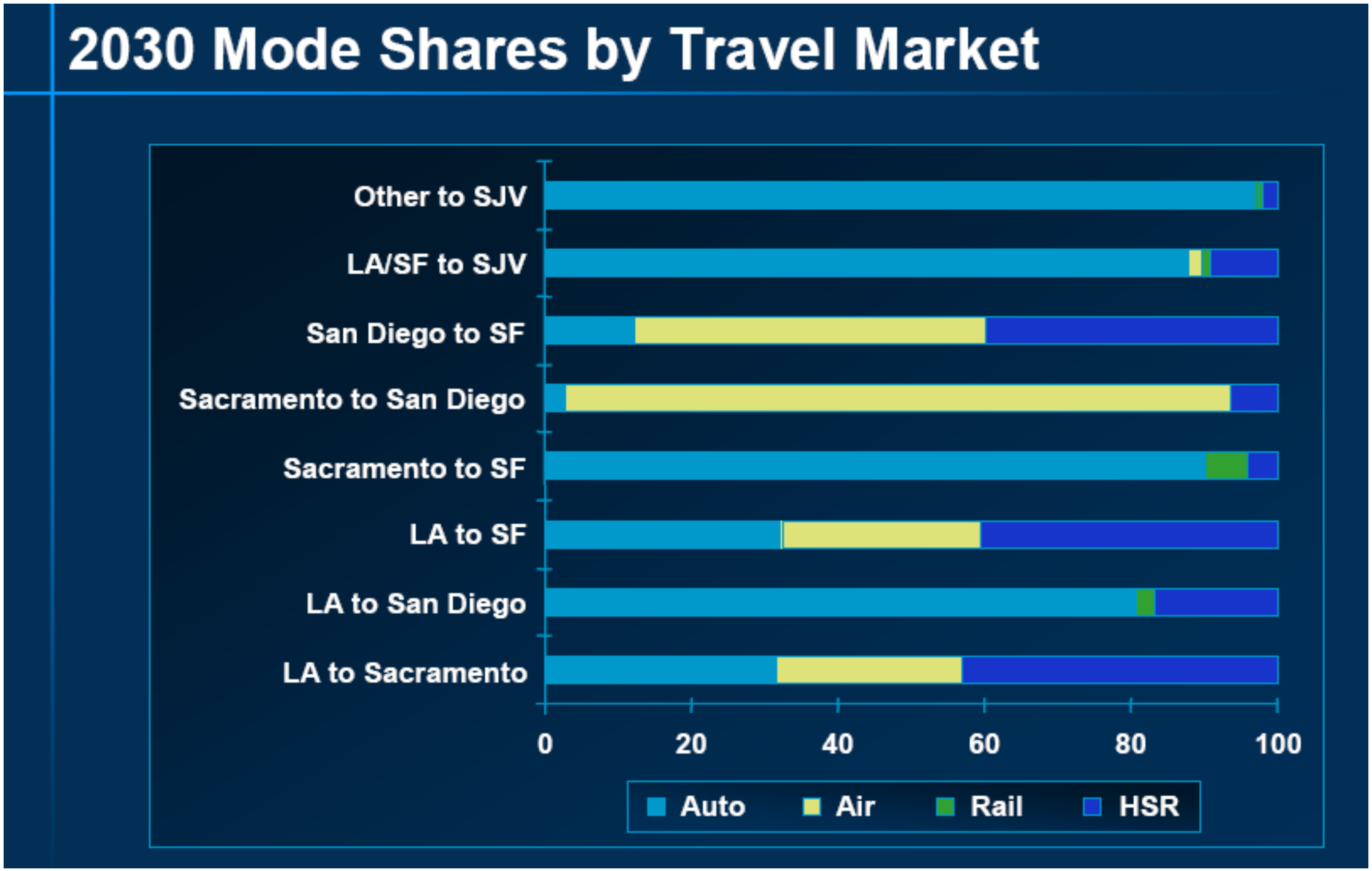


Demand Ridership Forecast in California (year 2030)



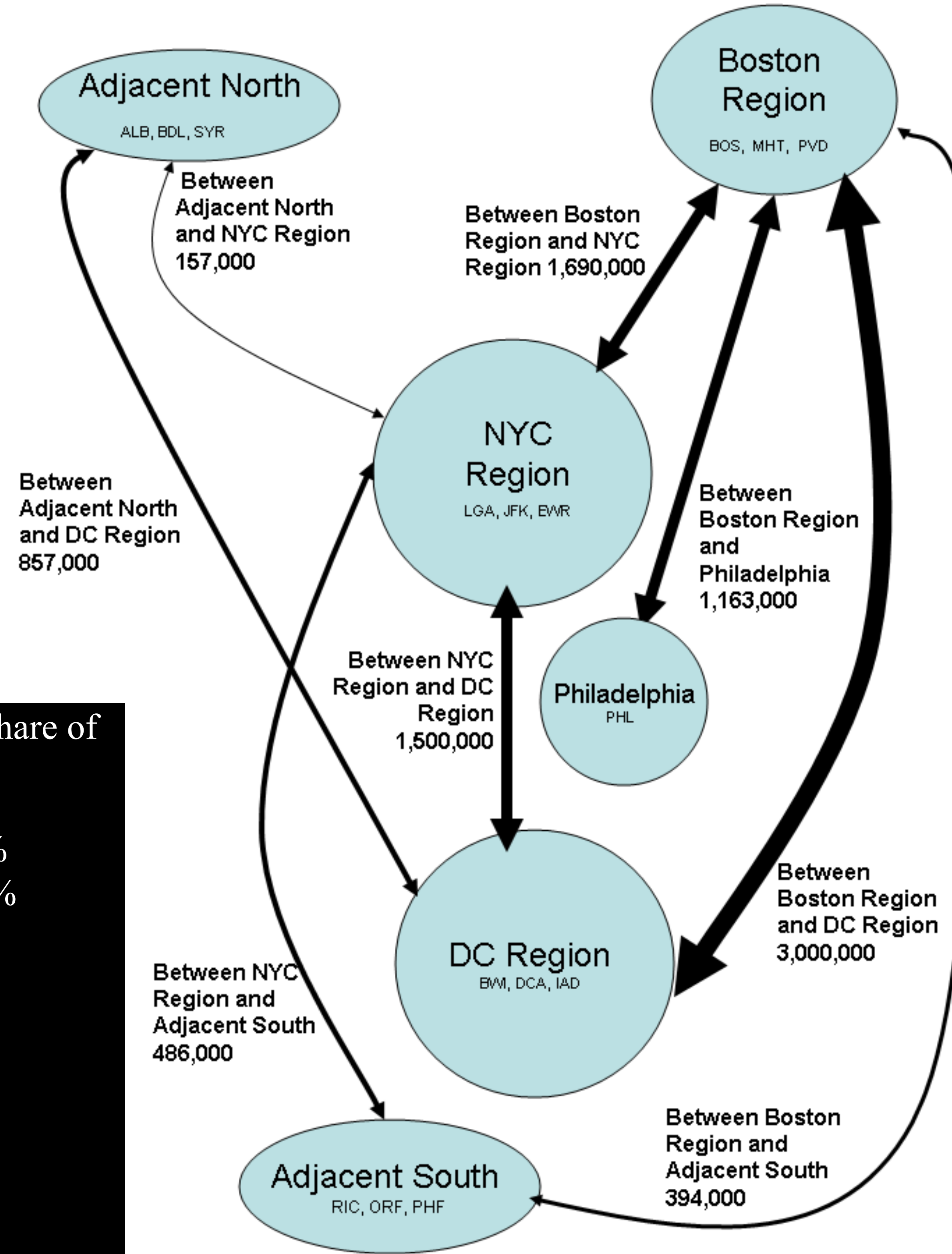
source: Matthew Coogan, 2009

Forecast Mode Choice in California



source: Matthew Coogan, 2009

What About the Northeast Corridor?



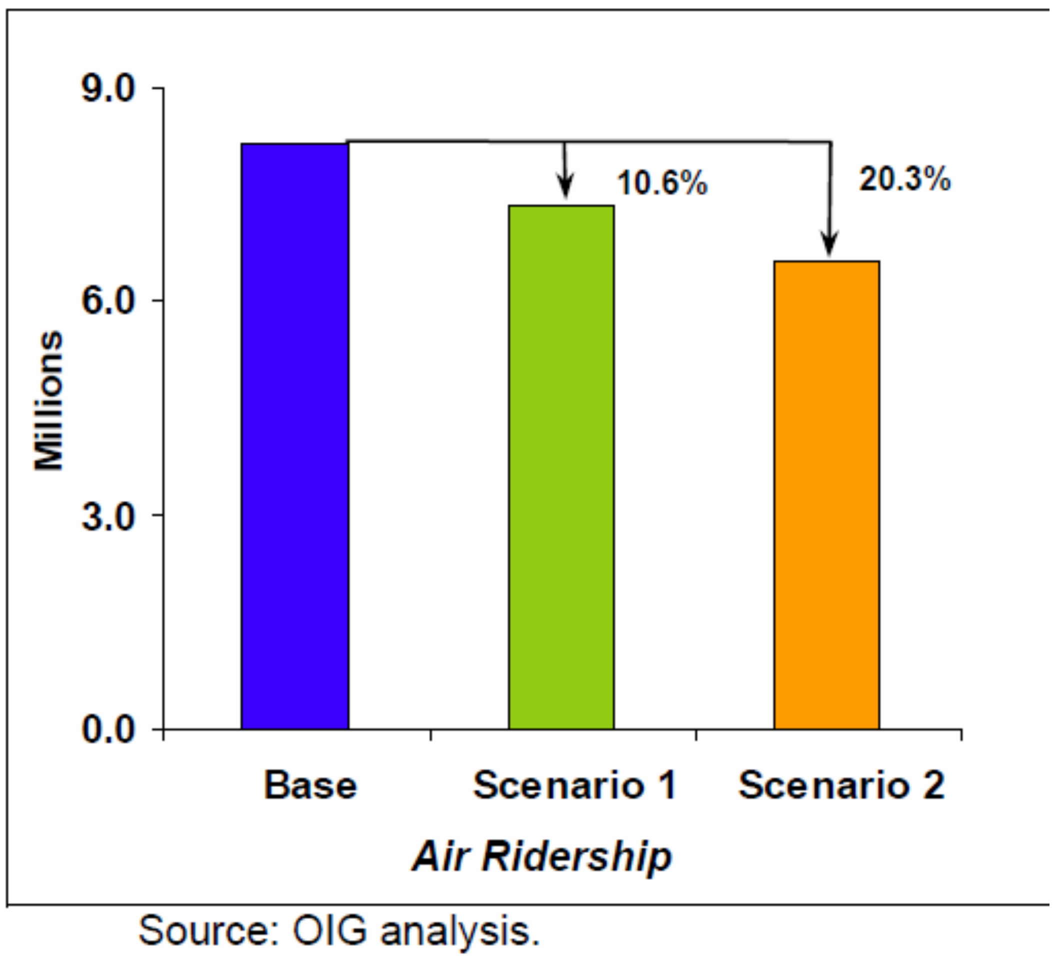
City-pair Corridor	Market Size (2008, First Quarter)	Rail Share of Air/Rail Total
Boston-New York	769,736	49%
Boston -Philadelphia	138,742	17%
Boston -Washington	321,556	7%
Providence -New York	95,154	90%
Albany - New York	174,698	97%
New York - Philadelphia	499,998	95%
New York - Washington	986,957	63%
Philadelphia - Washington	217,429	89%

- Source: Amtrak, showing results for the first quarter of 2008

Potential Diversion if High-Speed Rail is Improved in the NE Corridor

- Assume a 2.0 hour trip from DC to New York
- Currently a 2.94 hour journey via AMTRAK Acela trains

Aviation mode share will decrease by 20%



source: Matthew Coogan, 2009

Noise Issues

Noise Basics

- Unwanted sound
- Noise is typically measured in decibels (a logarithmic scale)
- Noise is a problem in many transportation systems
  - Highways
  - Airports and air transportation
  - Rails and subway systems

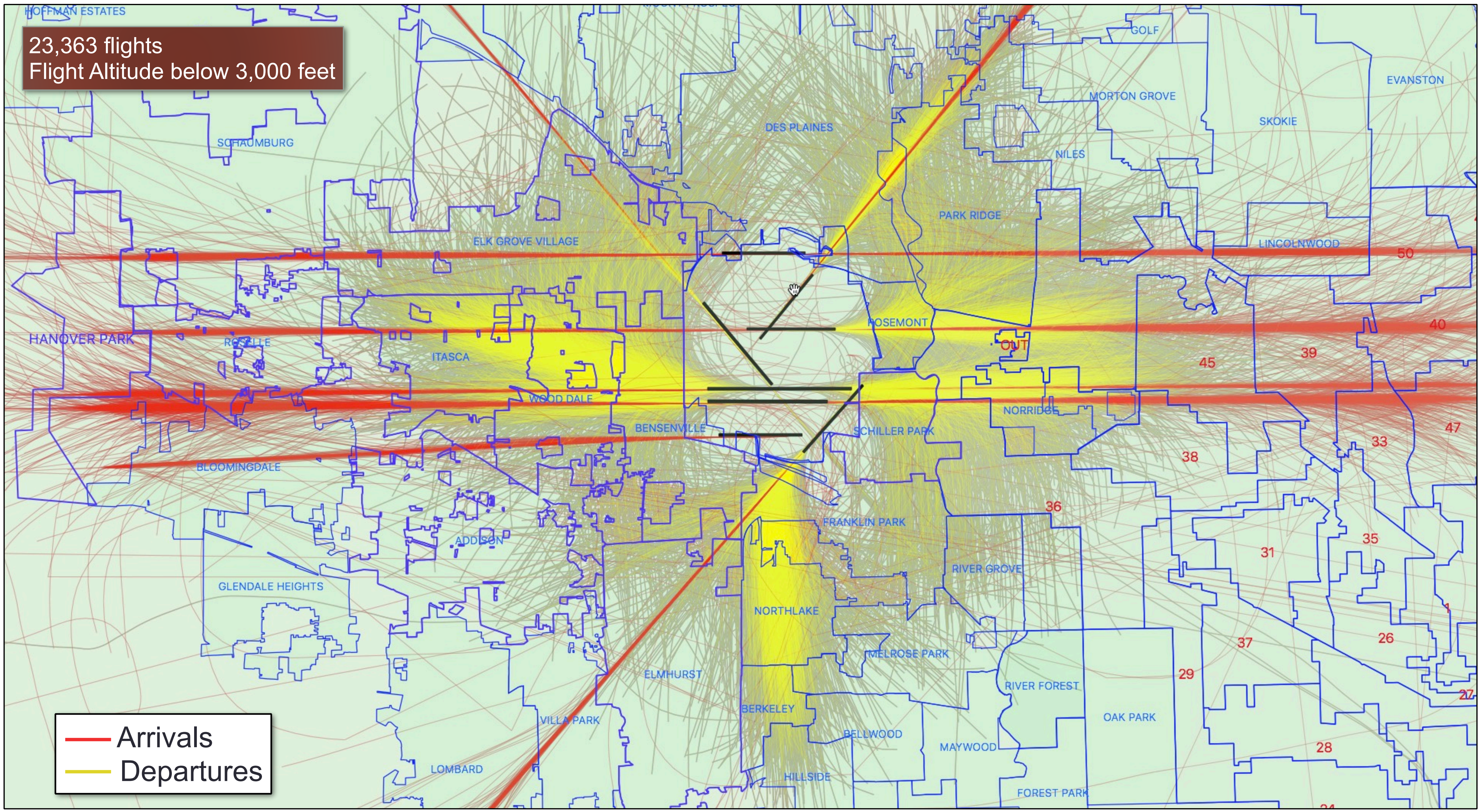
Noise Mitigation Examples: Noise Barriers

https://en.wikipedia.org/wiki/Noise_barrier#/media/File:Geluidscherm_Overschie.jpg

https://www.soundfighter.com/wp-content/uploads/2015/08/DSC00811-e1440632494320.jpg

The Problem (Community Noise)

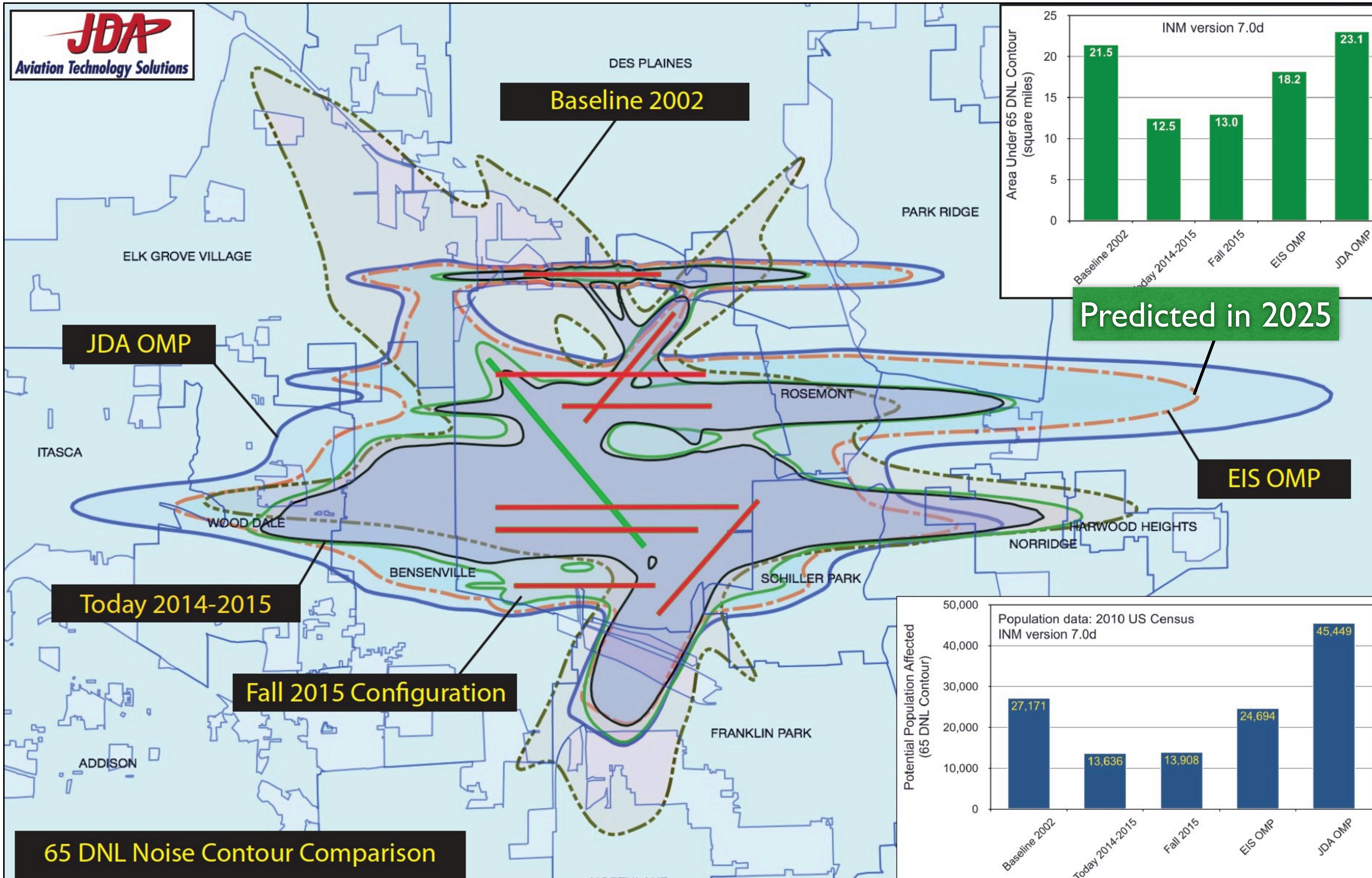
- Aircraft tracks overfly many communities around the country (example shown is for Chicago



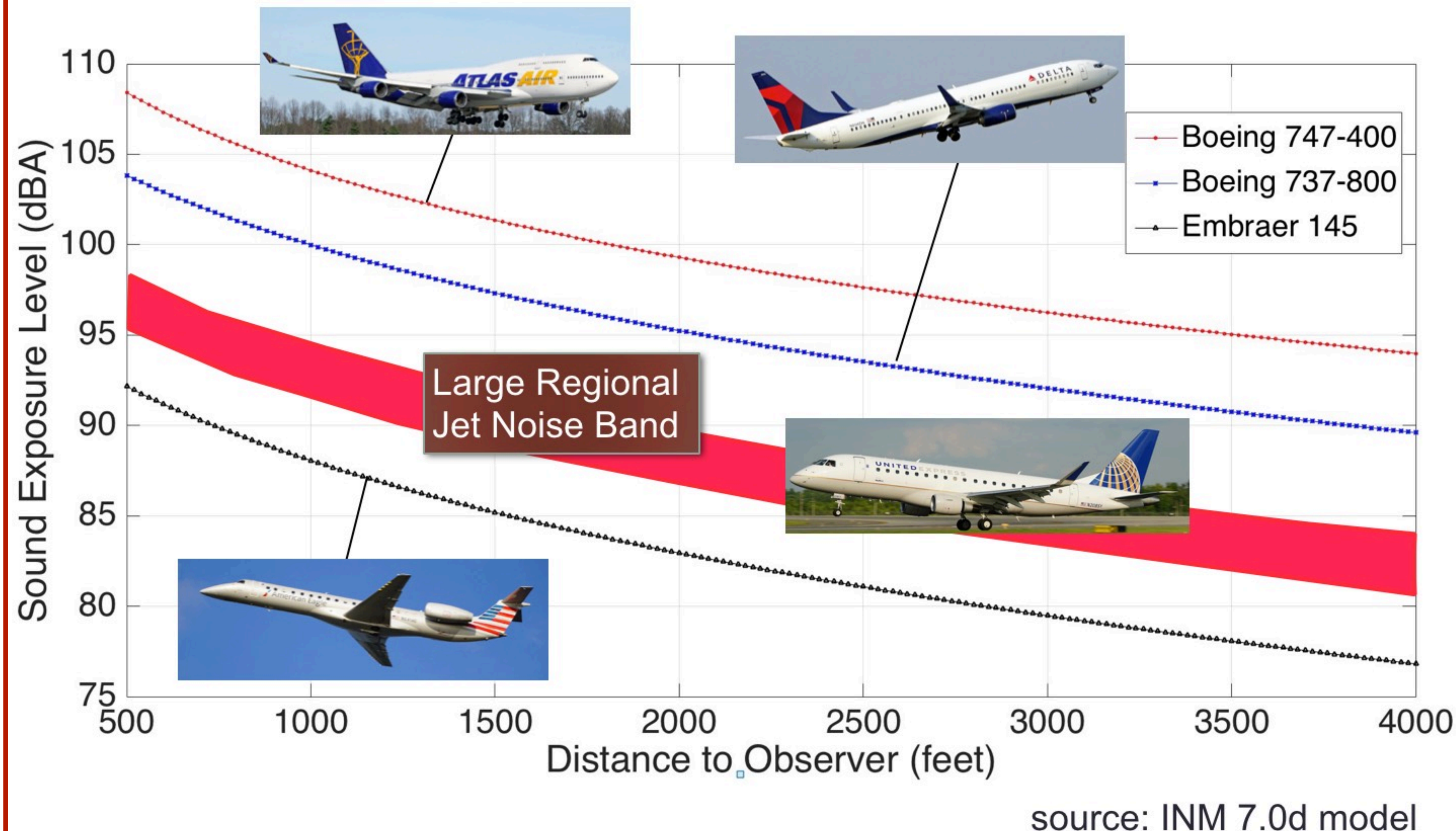
Period: July 23 to October 14, 2017

source of data: CDA

Noise Evolves Over Time
Noise Contours for Chicago O'Hare Airport



Noise Levels Generated by Various Aircraft



Airport Capacity Issues

Limited Capacity at Airports

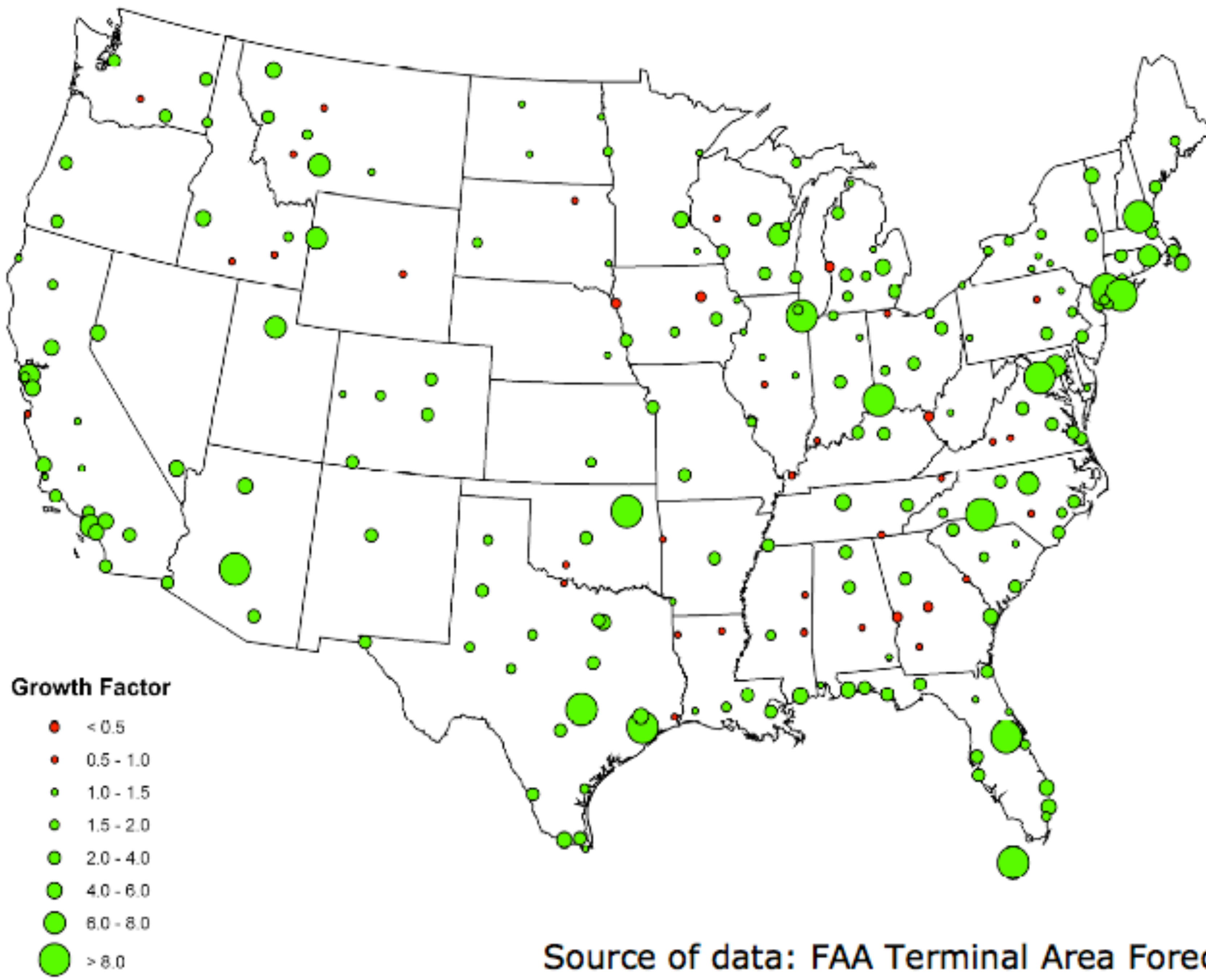
- FACT2 report is the main source for this analysis
- The FACT 2 states that in the year 2015 21 airports will have a deficit of capacity in the NAS

FACT 2 Analysis

- 14 airports will required additional capacity in 2025
- 8 metro areas are affected

Figure 5 Airports and Metropolitan Areas Needing Capacity in 2025 after Planned Improvements

Enplanements Growth



Source of data: FAA Terminal Area Forecast

GIS Plot by Virginia Tech Air Transportation Lab

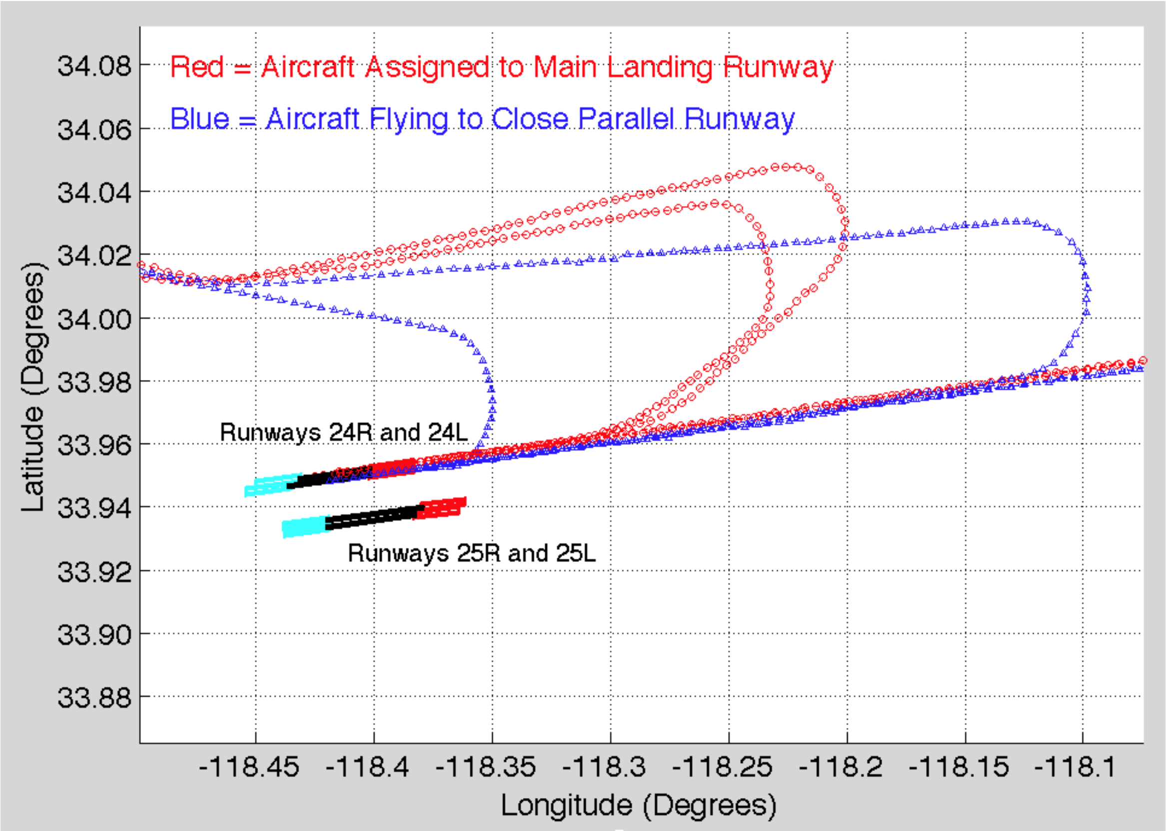
VirginiaTech Invent the Future

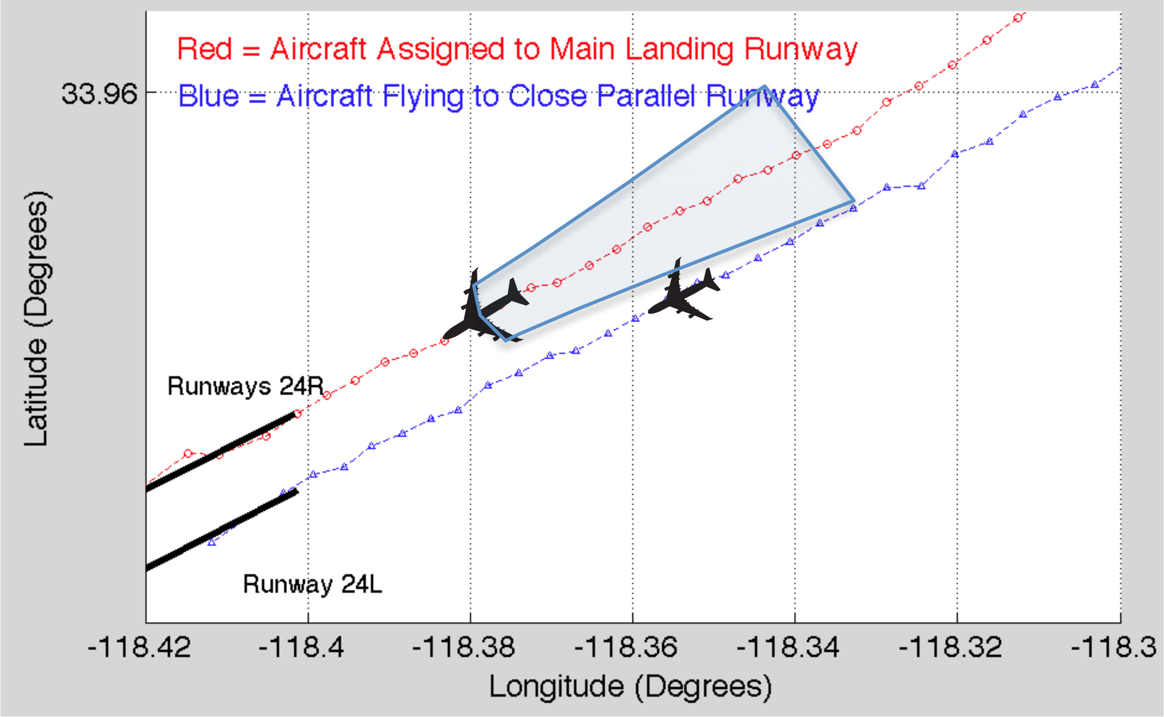
Wake Vortex - a Capacity Driver

- Wake vortices are responsible for the separations we impose in the NAS
- Wake vortices are impossible to eliminate from real aircraft (circulation is a pre-requisite for lift)

Part of ATSL Nextor Research

- Virginia Tech wake vortex research project is to evaluate NextGen operations exposure to potential wake vortex encounters (work by Nataliya Schroeder)
- Testing common terminal area operational scenarios using the Wake Encounter Model (WEM)
  - Close parallel approaches
  - Transition routes in the terminal area
  - Departure and arrival routes at closely located metroplex airports





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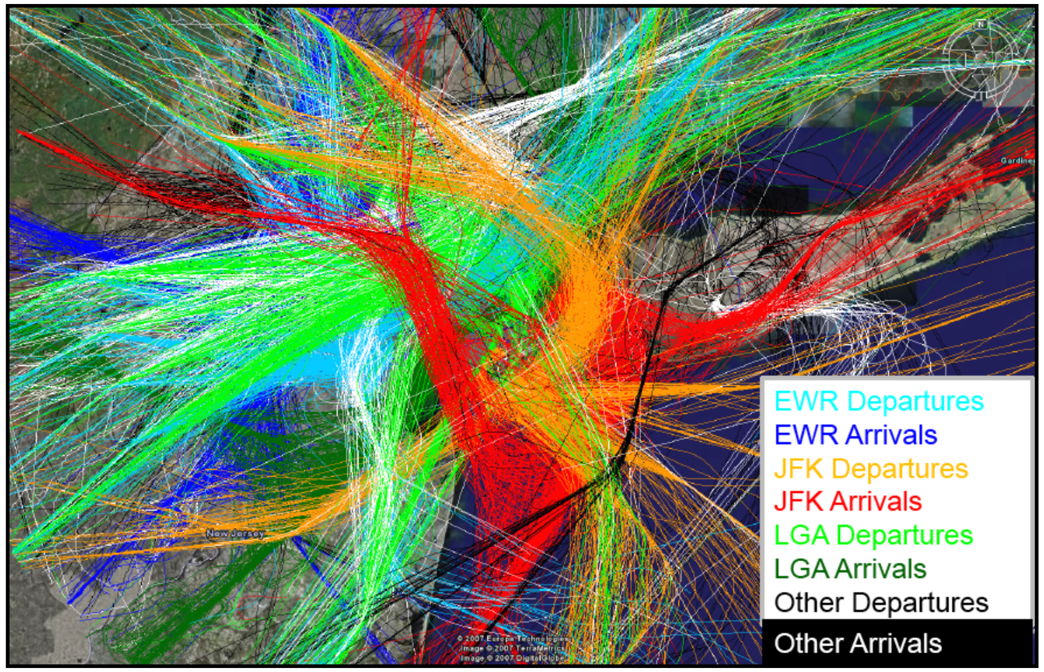
Wake Encounter Model (WEM)

- Model developed at Virginia Tech to predict potential encounters in terminal areas
- Developed by D. Swol, N. Schroeder and A. Trani
- Uses wake output from NASA's TDAWP model



Radar track data (PDARS)

EDR = 0.0001 (m^2/s^3), BVF = 0.0005 (1/s), CS = 175 (m^2/s) New York 20080319

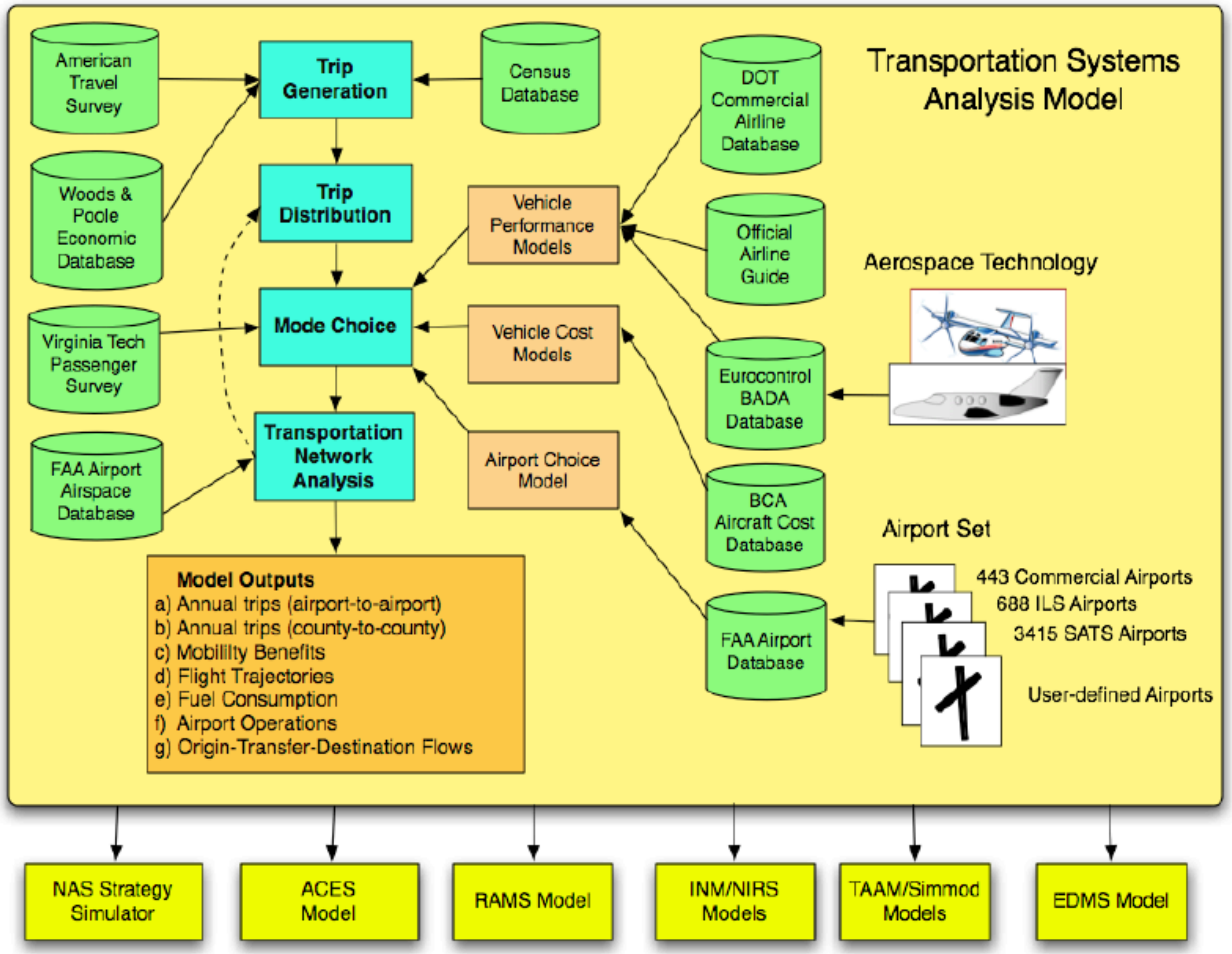
Leading Aircraft	Following Aircraft	Potential Encounter information	
Aircraft type	Aircraft type	Type	Arrival/Departure
A320	B752	in-trail	A
B764	CRJ2	in-trail	A
A319	B738	in-trail	A
B744	LJ25	in-trail	A
B752	B738	in-trail	A
B737	B737	in-trail	A
E190	A320	in-trail	A
A346	B762	in-trail	A
MD82	A320	in-trail	A

- The same potential encounters as in previous table with CS=125
- All 9 pairs were arrivals
- All 9 in-trail
- Wake Envelope produced longer than expected

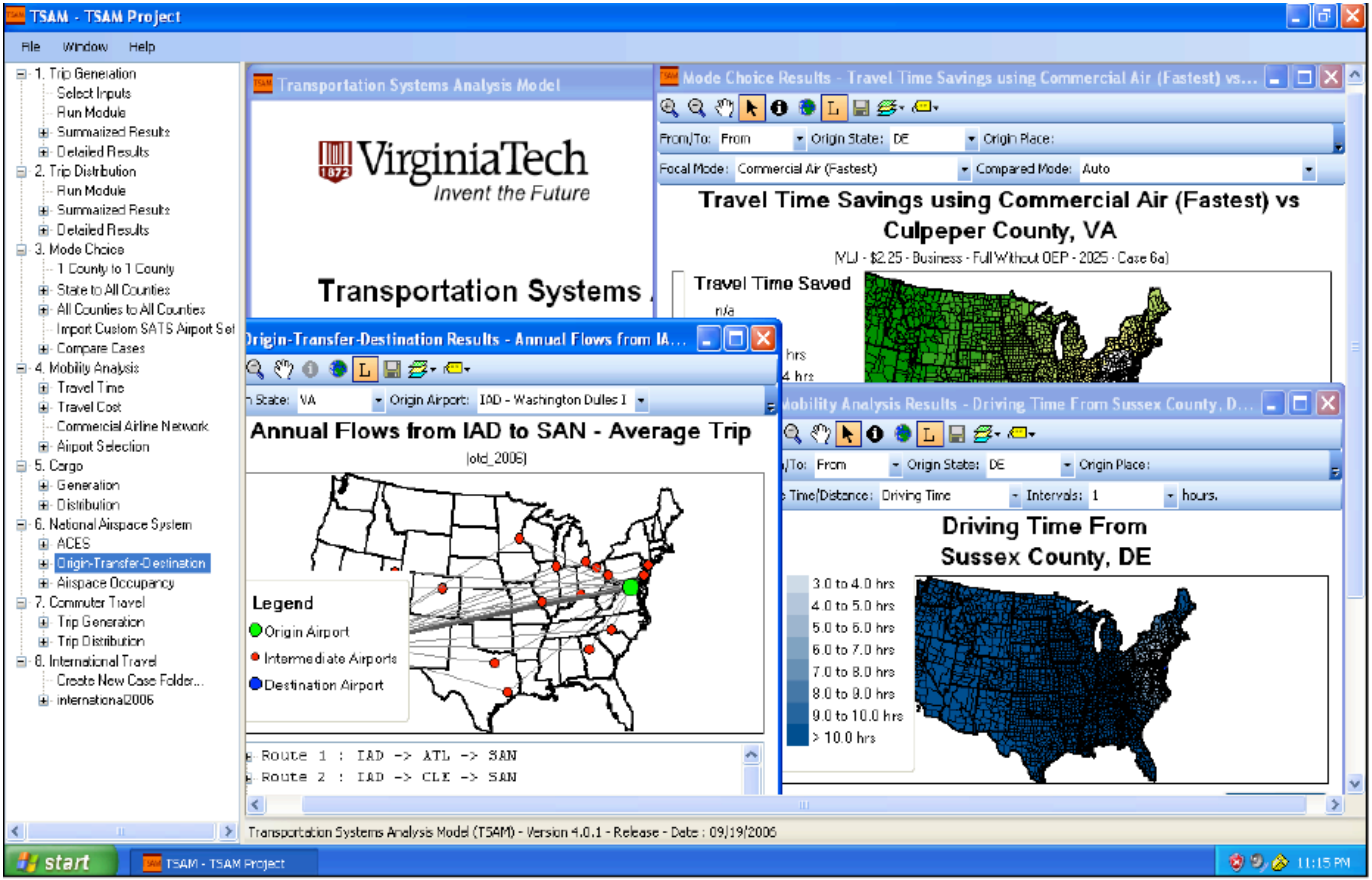
Aviation Demand Analyses

TSAM Model

- Developed at Virginia Tech for NASA Langley Research Center
- Predicts aviation, auto and other mode trips



TSAM Application



Applications

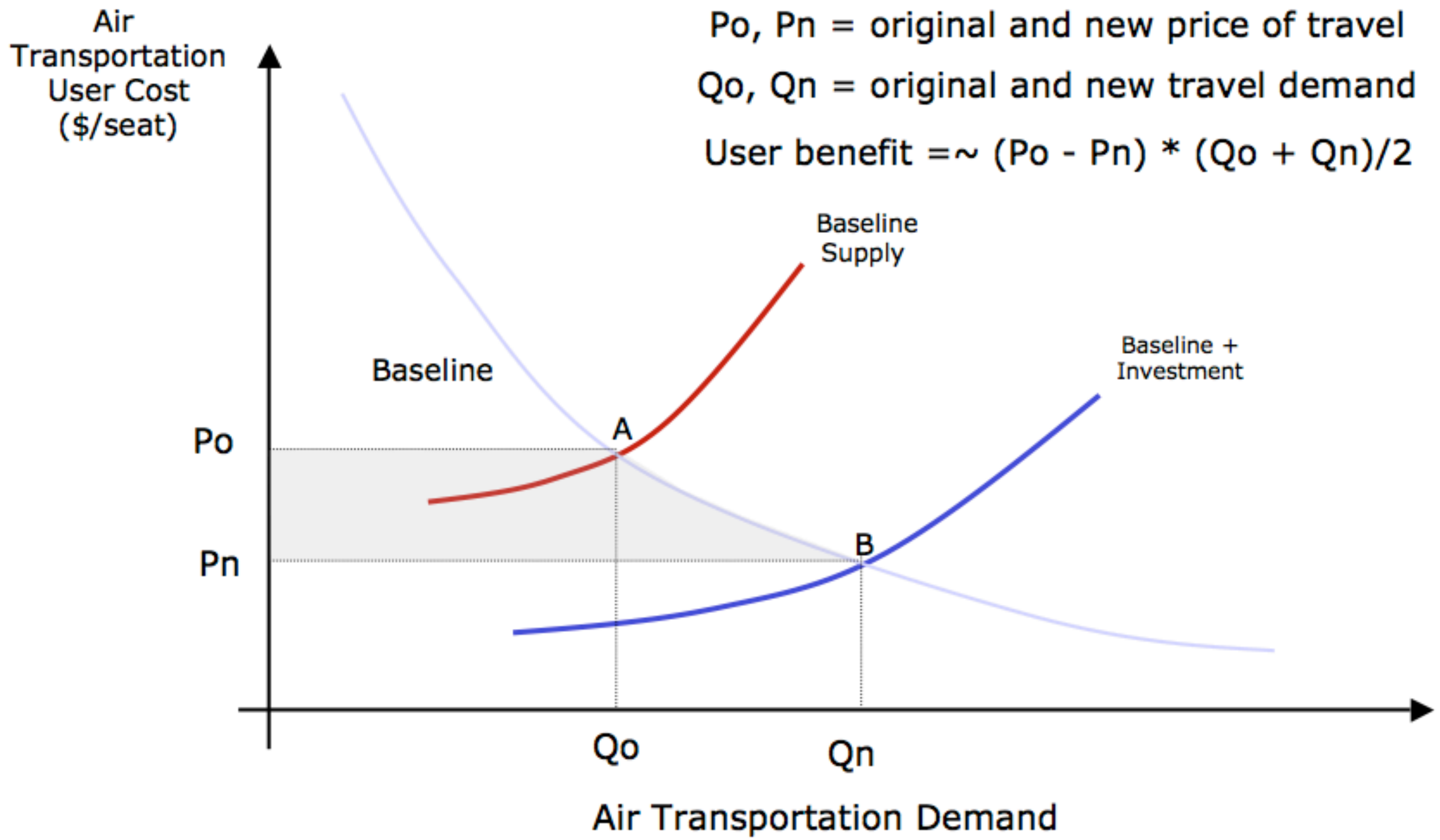
- Prediction of trips under NextGen infrastructure gains
  - 5% improvement in gate-to-gate travel times
  - Reduced airport processing times
- Aviation demand for very light jets
- Aviation demand for tiltrotor aircraft (city center to city center)
- Airline ticket price increases

Consumer Surplus Analysis

Po, Pn = original and new price of travel

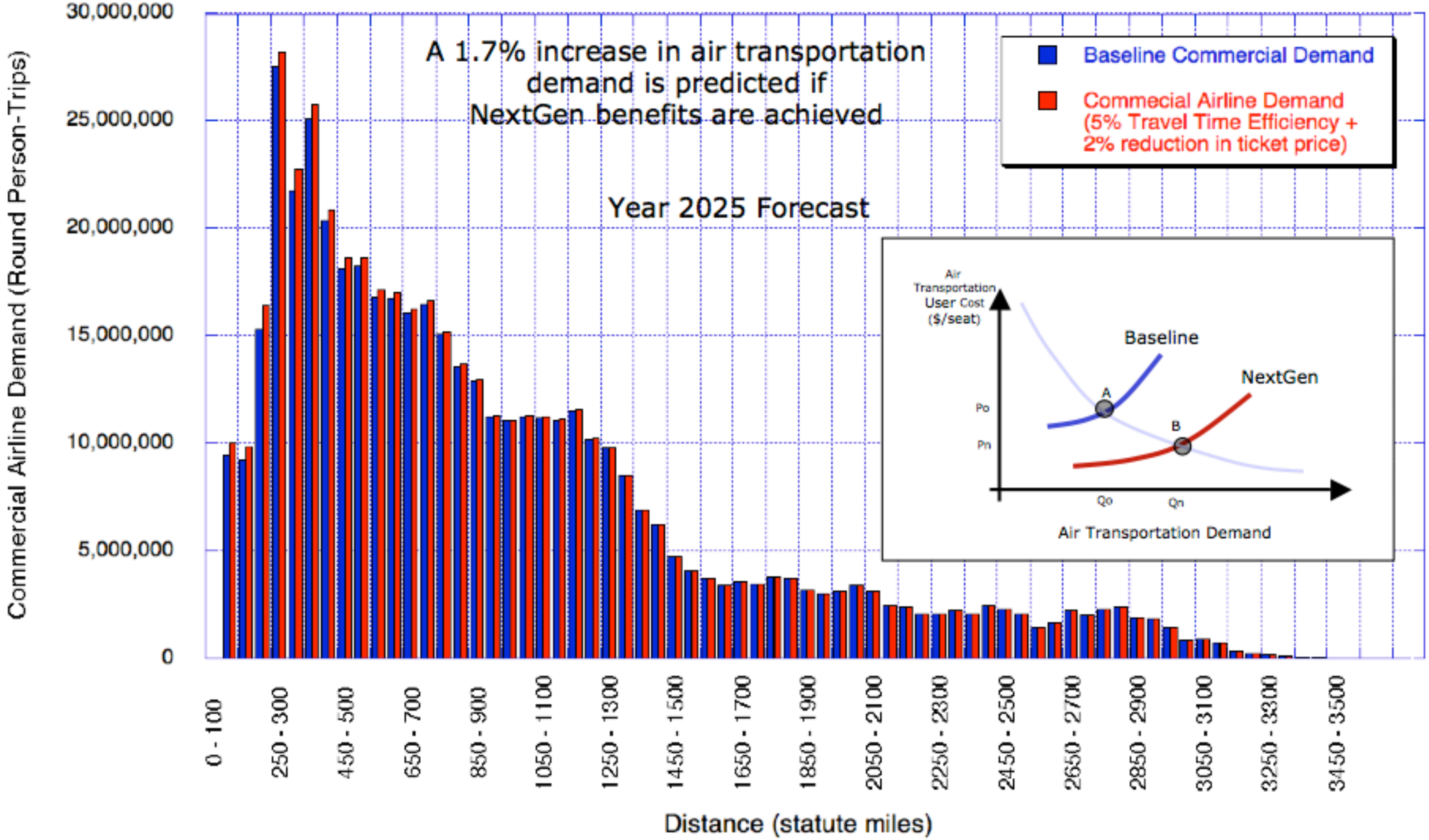
Qo, Qn = original and new travel demand

User benefit =~ (Po - Pn) * (Qo + Qn)/2

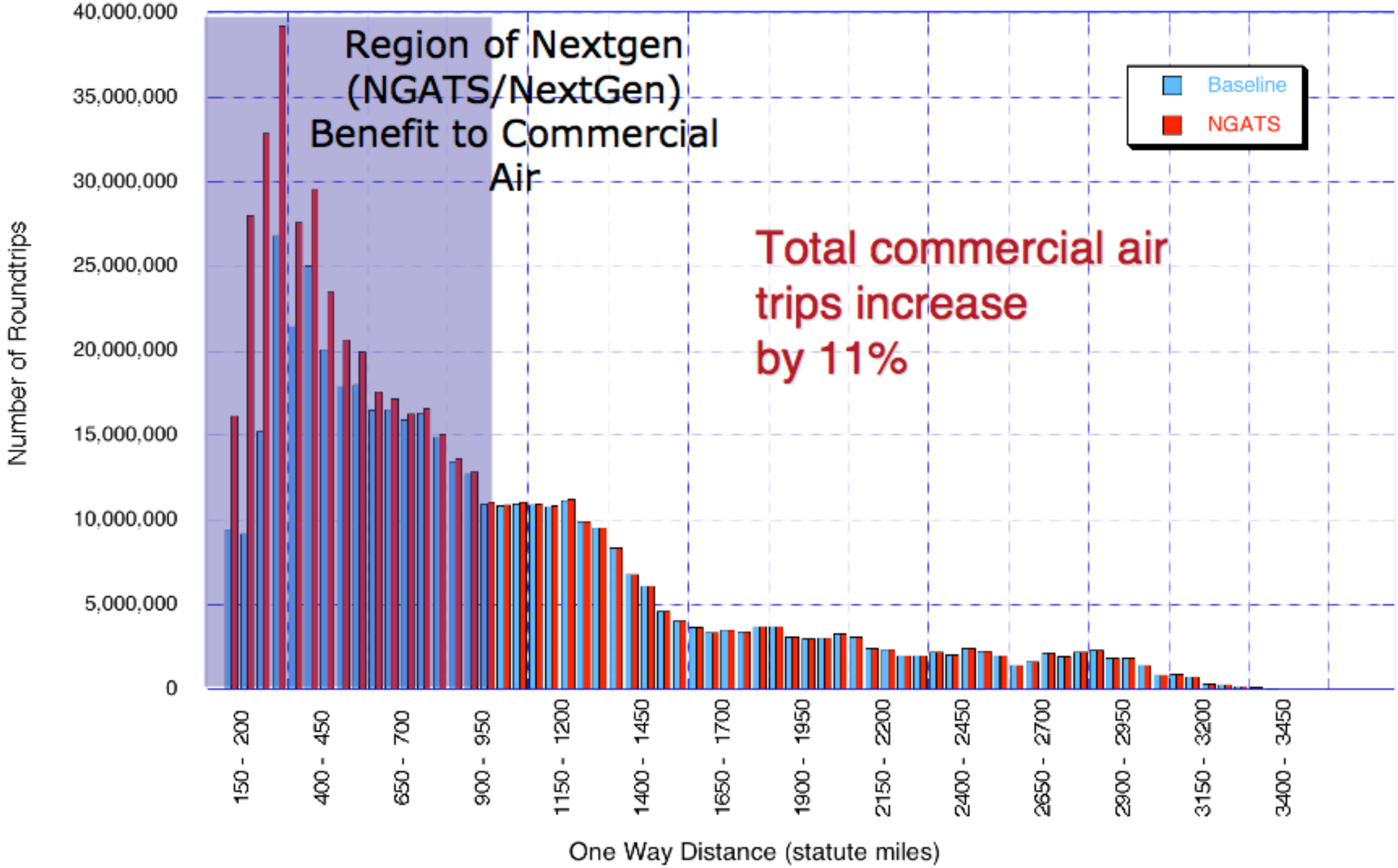


Sample Run with TSAM

(5% Reduction in Airport-to-Airport Travel Time + 2% reduction in ticket price due to NextGen Benefits)



Mature NEXTGen



Results obtained using the Virginia Tech TSAM Model