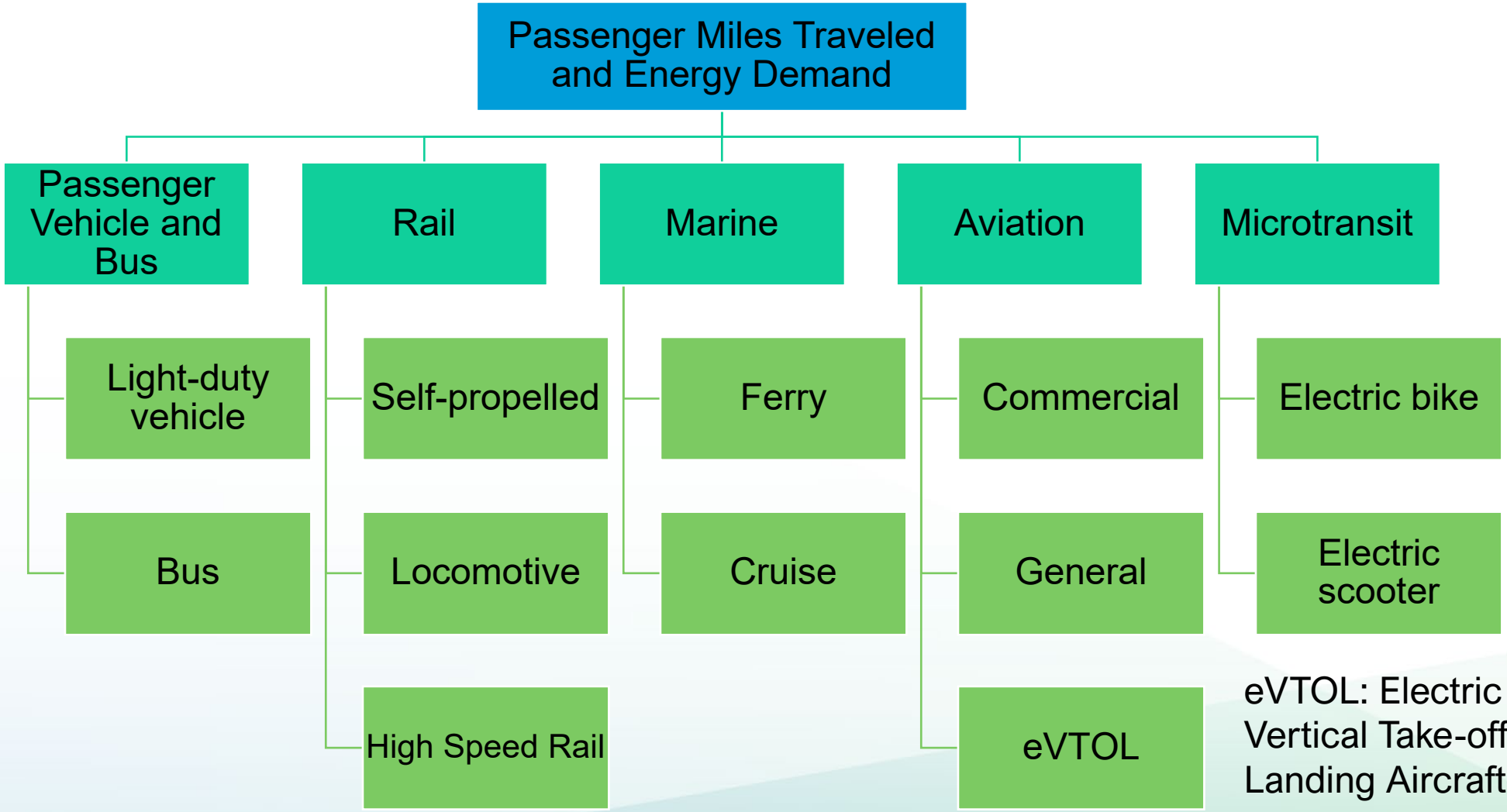
Passenger Travel Energy Demand Modeling Improvement

High Level Scope and Model Outputs



eVTOL: Electric Vertical Take-off and Landing Aircrafts

Five Activity Modules

Passenger Vehicle & Buses	Applies similar methodology as CARB's EMFAC model but with more detailed vehicle categories and fuel technologies that estimates vehicles miles traveled (VMT) and energy demand. Does not model LDV vehicle choice.
Rail	Develops a passenger rail model that estimates the energy demand in unit of MW-hr by different fuel types (e.g., electricity, or diesel or hydrogen)
Aviation	Leverages CEC's Aviation Model and will integrate it to the extent possible into the existing platform, with more aviation modes included
Marine	A marine model comprising of ferries and cruise ship (only passenger travel) that estimates the energy demand in unit of gallon of fuel or kWh of electricity
Microtransit	A model that mainly estimates the energy demand in kWh and the passenger miles traveled (PMT) for ebikes and e-Scooters.

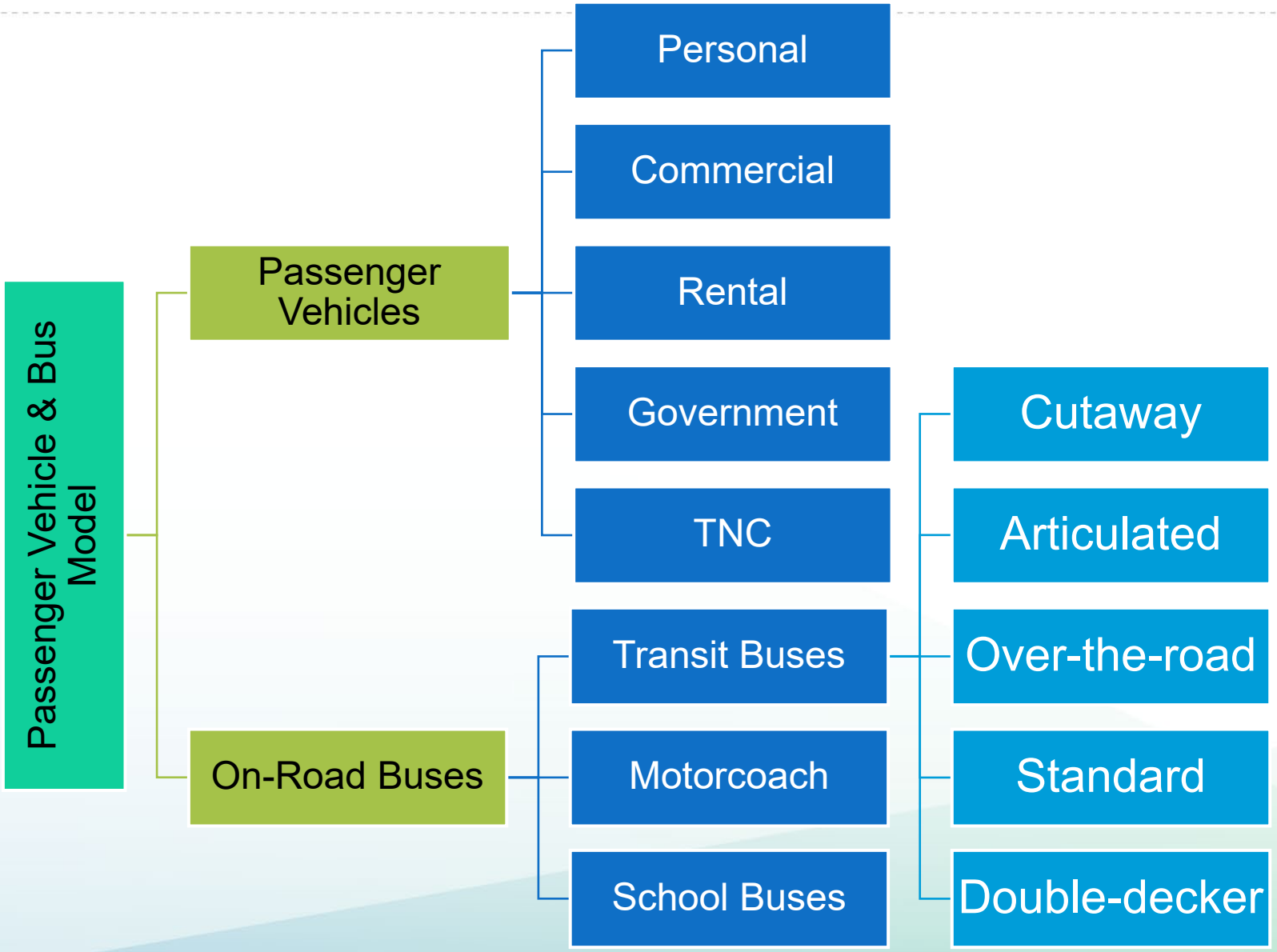
Passenger Vehicle and Bus

Passenger Vehicles and Bus Model Overview

Purpose: To estimate and project vehicle miles traveled (VMT) and energy demand (liquid fuel, electricity, hydrogen) from on-road vehicles

- Overall methodology consistent with EMFAC
  - Bottom up VMT estimates using DMV registration data and usage data from BAR Smog Check
- Vehicle categories and fuel technologies consistent with those in the Urban and Intercity Model
  - Added Transportation Network Company (TNC) & Connected and Automated Vehicles (CAV)
- Regional resolutions
  - Use EMFAC County-Air Basin-Air District (COABDIS) regional resolution: 69 areas
- Activity Projections
  - Vehicle population consistent with CEC latest results from Integrated Energy Policy Report (IEPR)
  - VMT forecast based on regional econometric model developed by the project team

Passenger Vehicles and Bus Model



Light Duty Vehicle Classifications

Vehicle Type
Car-Compact
Car-Large
Car-Midsize
Car-Sport
Car-Subcompact
Pickup-Compact
Pickup-Heavy
Pickup-Std
SUV-Compact
SUV-Large
SUV-Midsize
SUV-Subcompact
Van-Heavy
Van-Minivan
Van-Std

Trim
Standard
Premium
CAV

Fuel Technologies
Diesel
Electric
Ethanol
Gasoline
Hybrid
Hydrogen
Plug-In HFCV
Plug-In Hybrid

Ownership
Personal
Commercial
Government
Rental
TNC

Example of Combinations

Vehicle Type	Trim	Fuel Technology	Ownership
Car-Large	Standard	Gasoline	Personal
Car-Large	Premium	Electric	Personal
Car-Large	CAV	Electric	TNC
SUV-Large	Standard	Gasoline	Commercial
SUV-Large	Premium	Electric	Government
SUV-Large	Premium	Hydrogen	Rental

Data Sources

DMV Vehicle Registration

CPUC's TNC Data Portal

CEC's IEPR Forecast

CARB's Rule-Making Documents

Bus Vehicle Classifications

Vehicle Type/Ownership
Standard Bus
Articulated Bus
Over-The-Road Bus
Double Decker Bus
Cutaway Bus
Motorcoaches
School Buses

Fuel Technologies
Diesel
Electric
Gasoline
Diesel Electric Hybrid
Gasoline Electric Hybrid
Hydrogen
Natural Gas
Propane

Data Sources

National Transit Database (NTD)

Federal Transit Administration

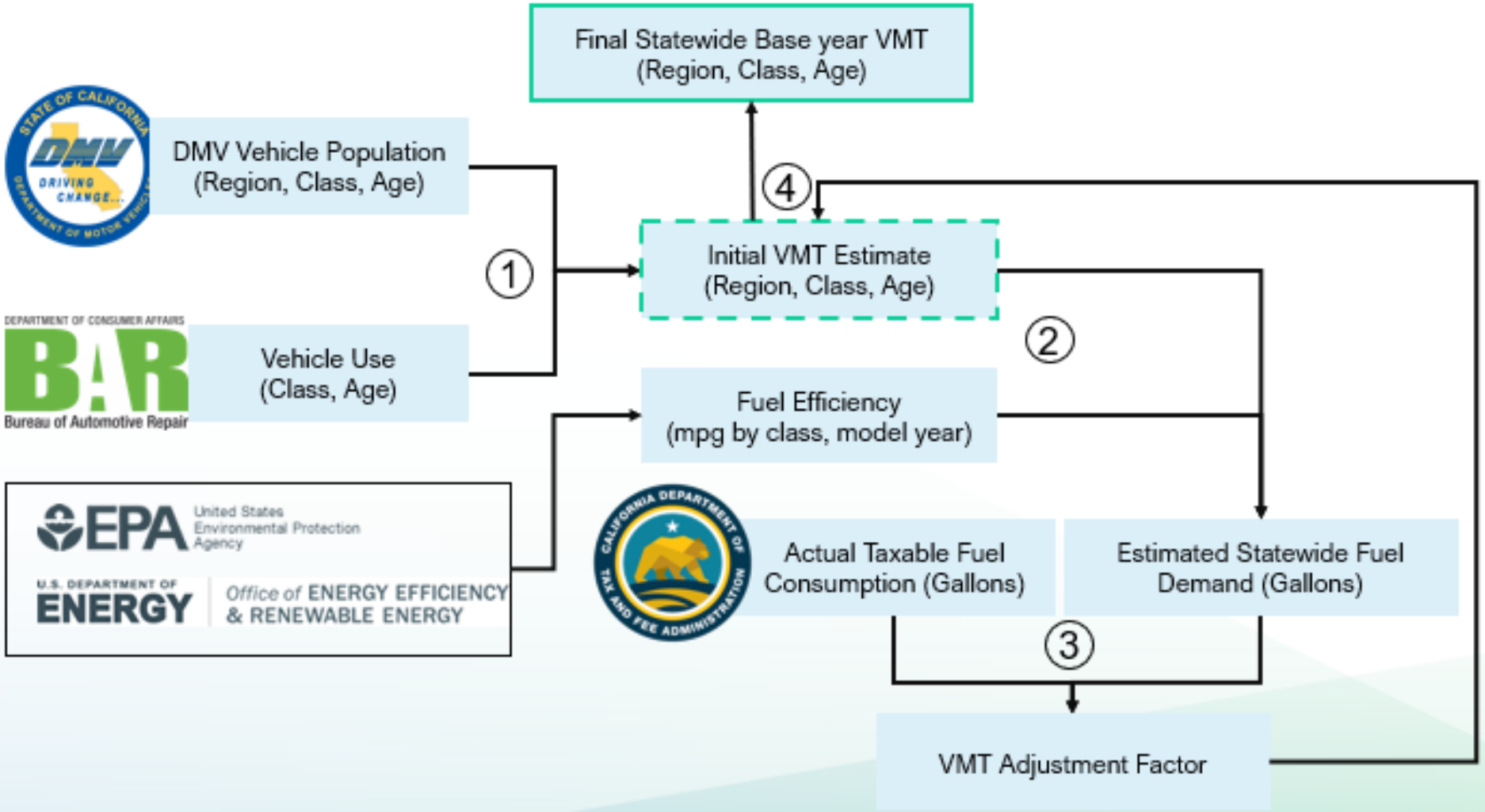
CEC's IEPR Forecast

CARB's EMFAC Inventory & Innovative Clean Transit (ICT) Reporting

CARB

- Fuel technologies are different from passenger vehicles
- It is assumed that all transit buses are owned by transit agencies (ICT & NTD reported)
- Motorcoaches are assumed to be all International Registration Plan (IRP) commercial, consistent with CARB's EMFAC inventory

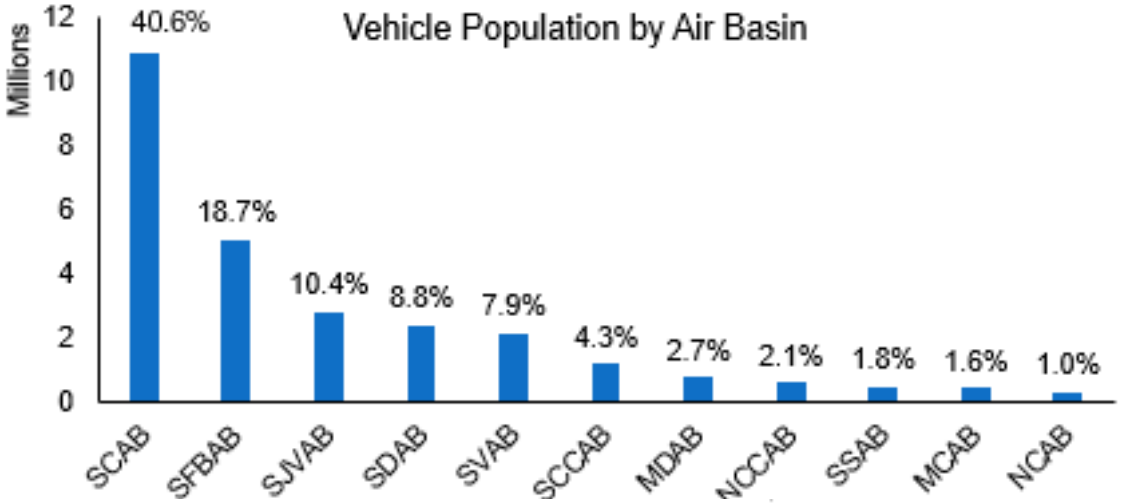
Base Year VMT Estimation Methodology

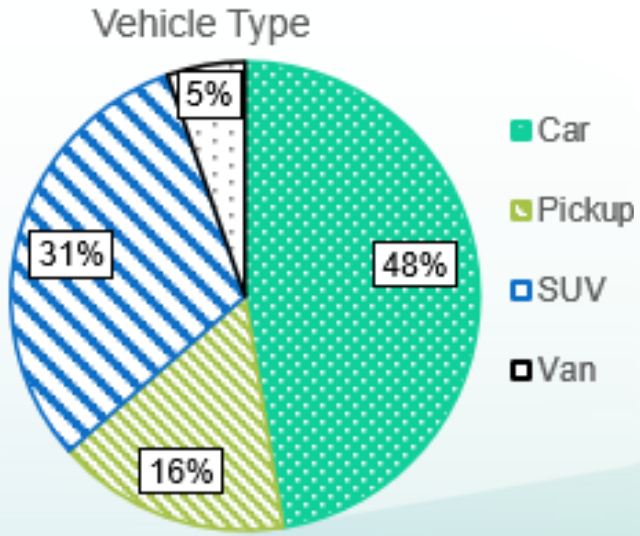


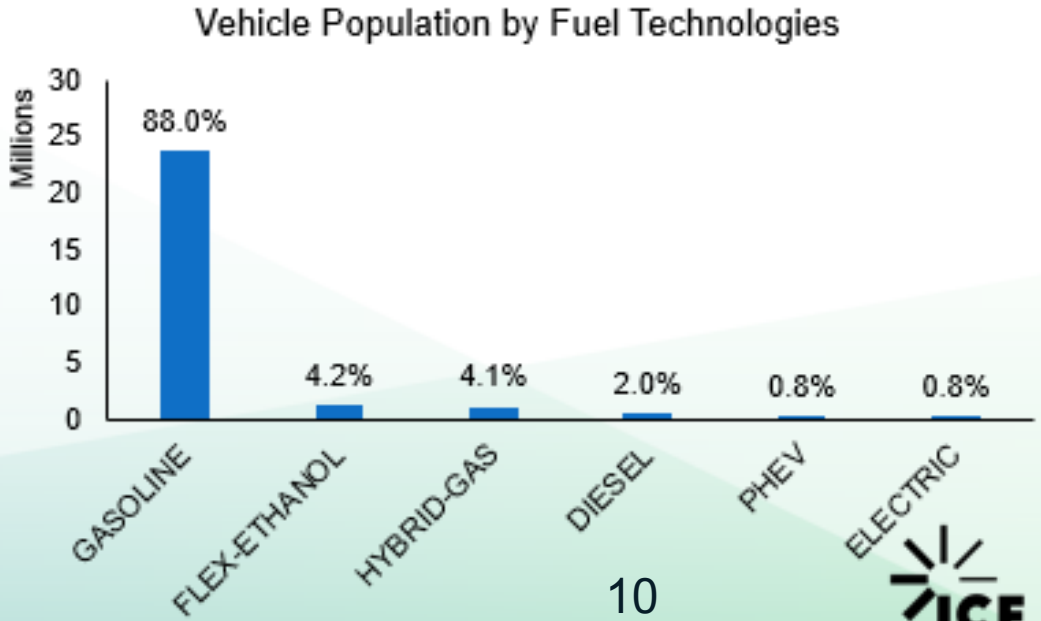
Base Year (2021) Data Summary

- Final statewide base year VMT = **~326 Billion Miles**
- Regional counts for 16 vehicle classes
- Vehicle MY between 1982 – 2022

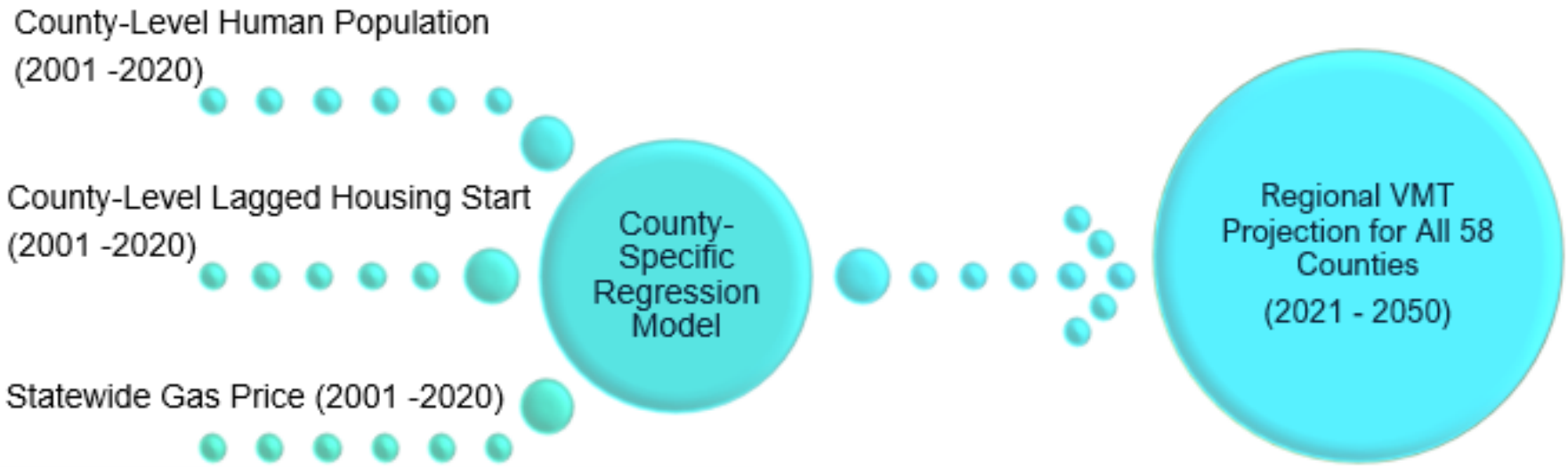
Ownership	% of Total
Personal	92.37%
Commercial	6.49%
Government	0.78%
Rental	0.36%



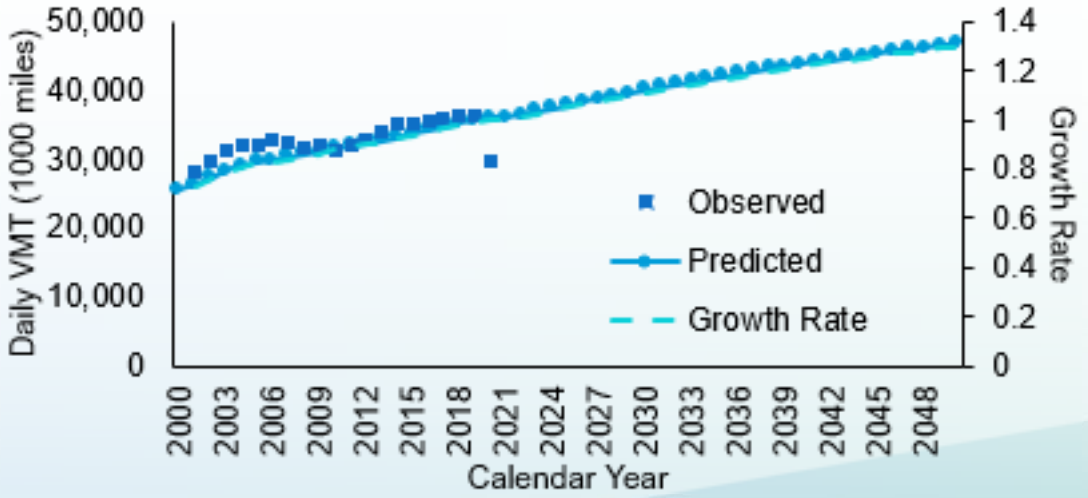




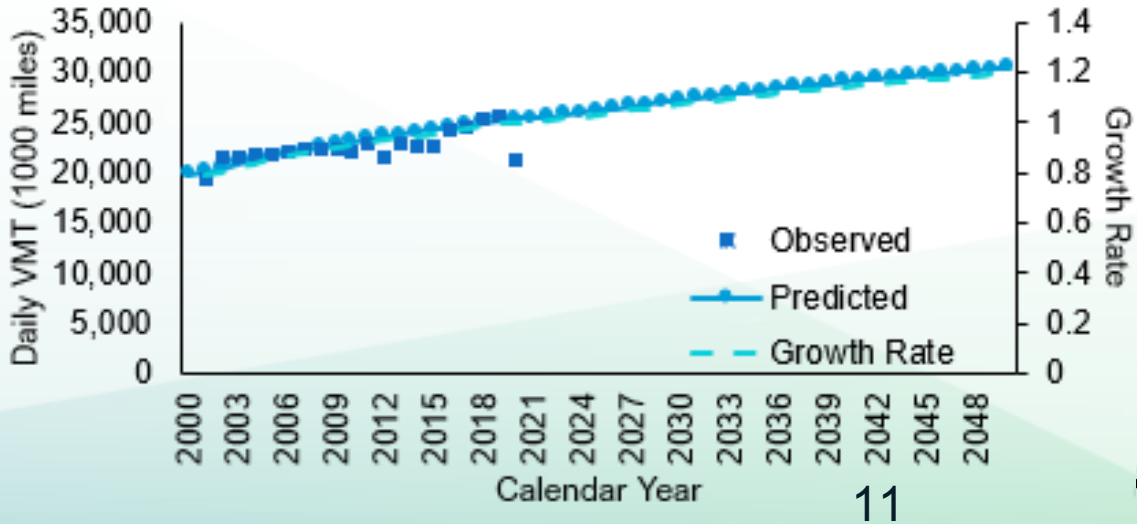
Regional VMT Growth



Sacramento County VMT Projection

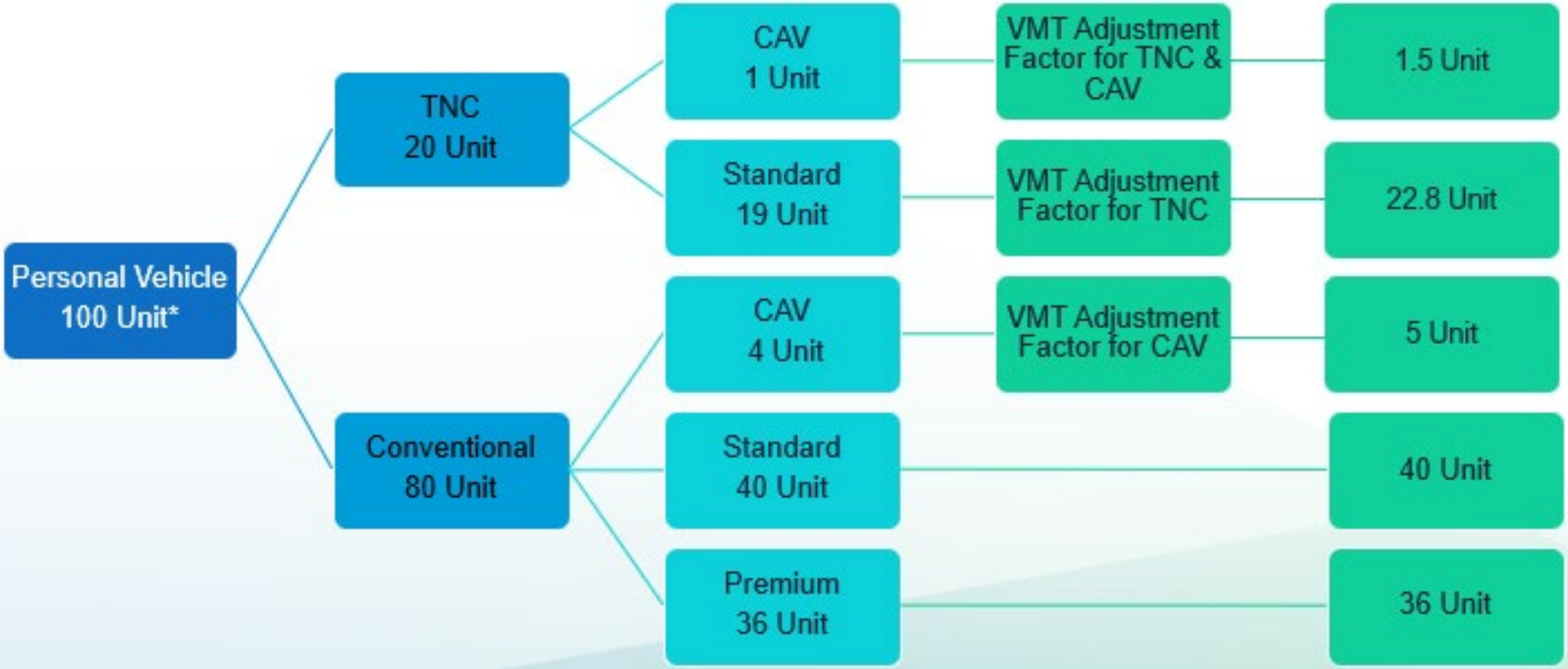


Fresno County VMT Projection



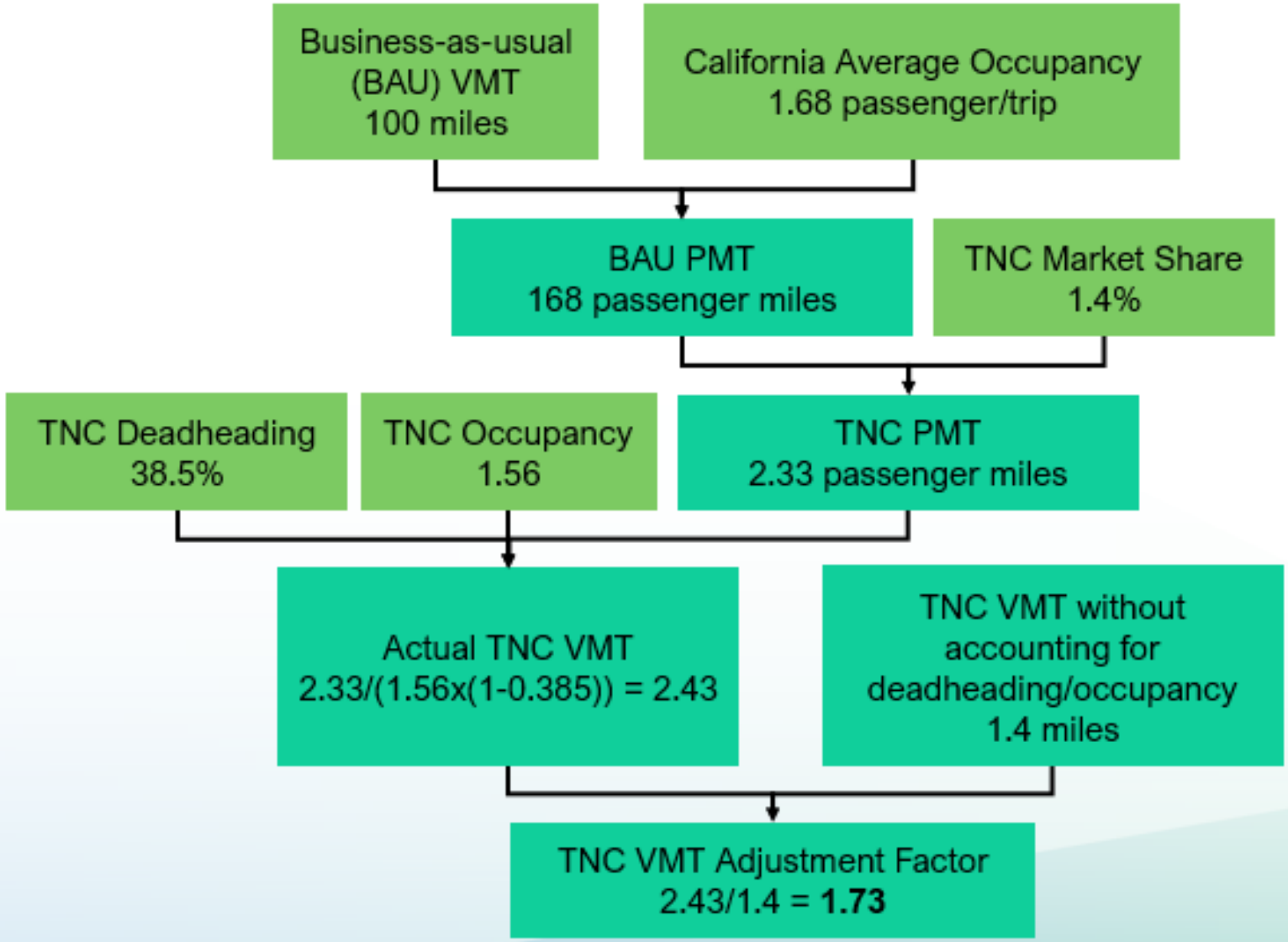
TNC/CAVs

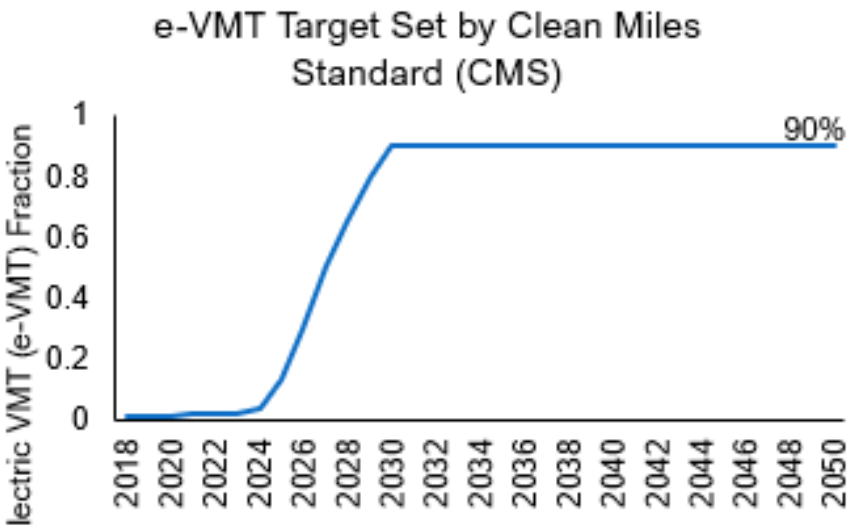
- To reflect the impact of TNC and CAVs we can build assumption on the VMT share of TNC and CAVs as part of the conventional modes and trims.
- Since TNC and CAVs will likely increase the VMT due to deadheading and induced VMT, or decrease the VMT through increased occupancy, their VMT will be further adjusted.



*Unit outputs will not necessarily equal to the inputs.

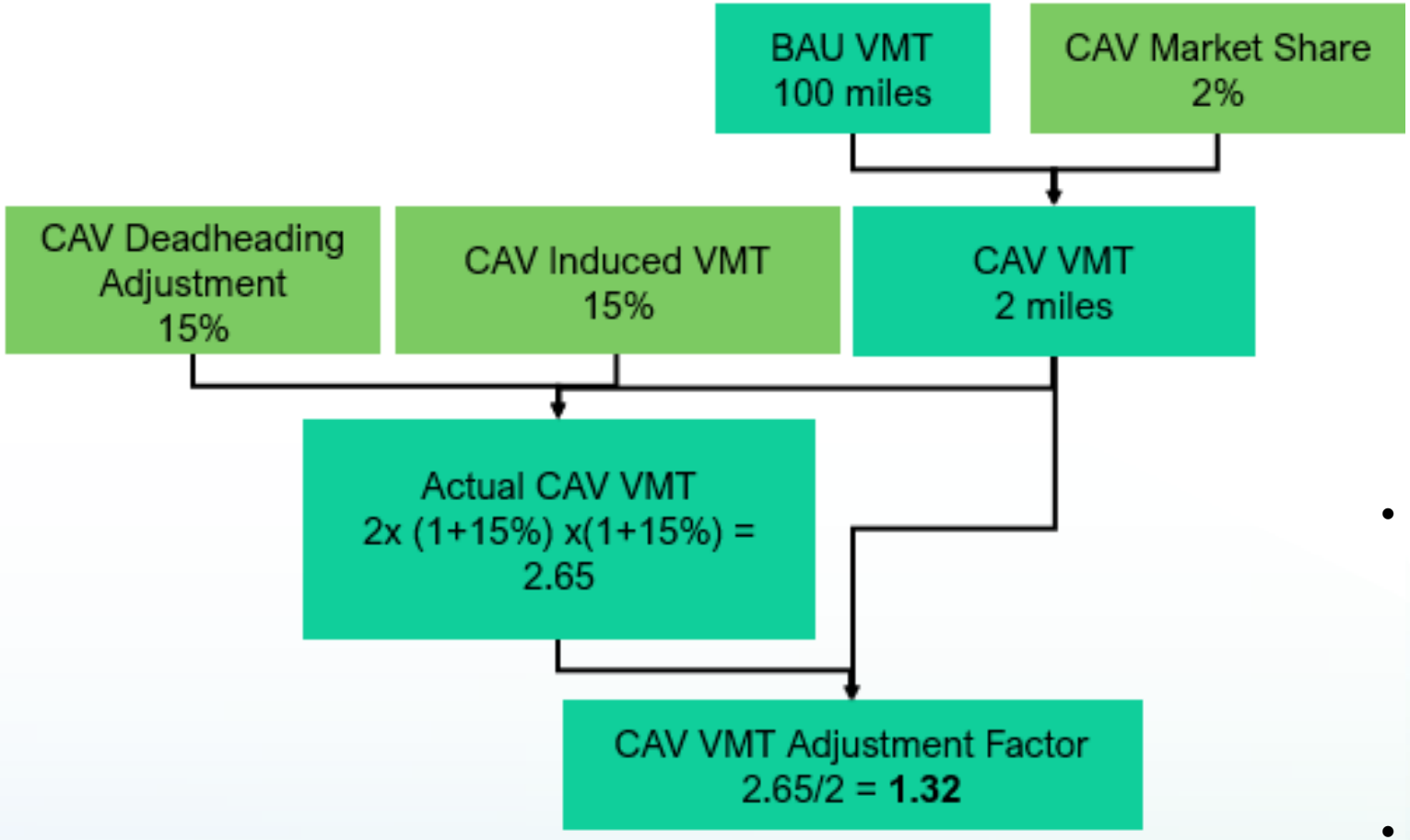
TNC – VMT Adjustment Factors and CMS Targets

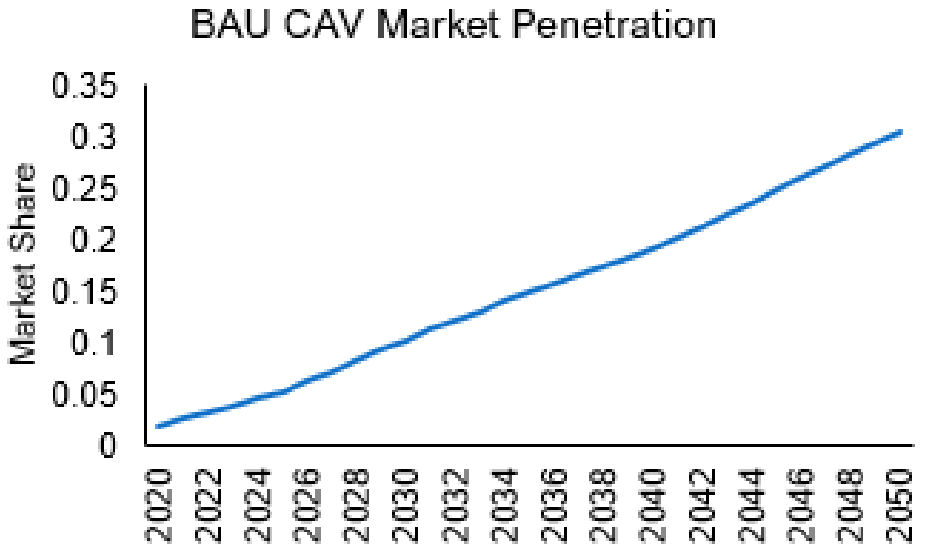




- Based on the latest financial report of Uber and Lyft – the total usage of TNC is up by **16% in 2021, and 38% in 2022 compared to 2018** level.
- According to 2019 BNEF Electric Vehicle Outlook, TNC share is expected to grow to 19% by 2040. Of course, this study was conducted pre-pandemic and projections could very likely be different now.

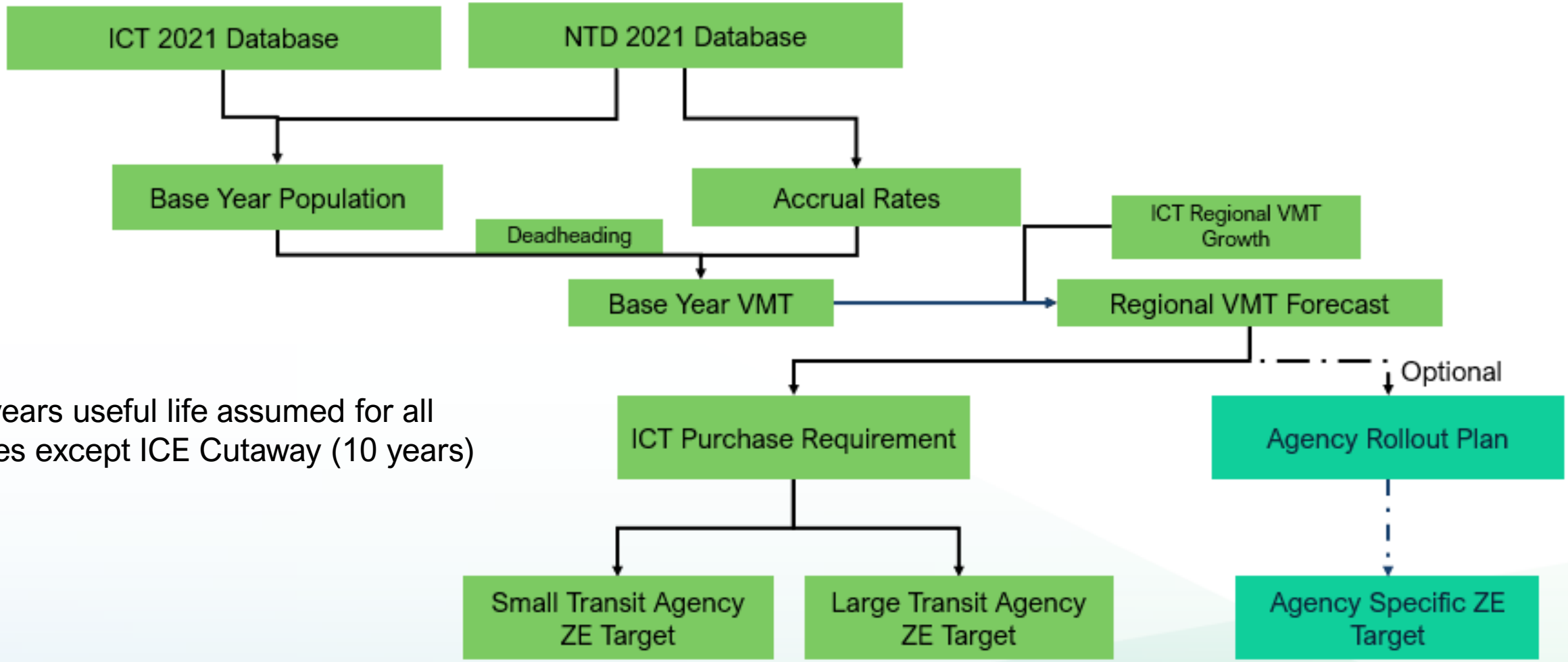
CAV – VMT Adjustment Factors and BAU Market Share





- BAU market share was derived from Bansal & Kockelman (2017), assuming low market adoption for Level 4+ automation with no annual increase in willingness-to-pay and minimal annual technology price reduction;
- Given the technology characteristics, the model assumes all CAVs are electric (BEV only).

Transit Bus Model Diagram



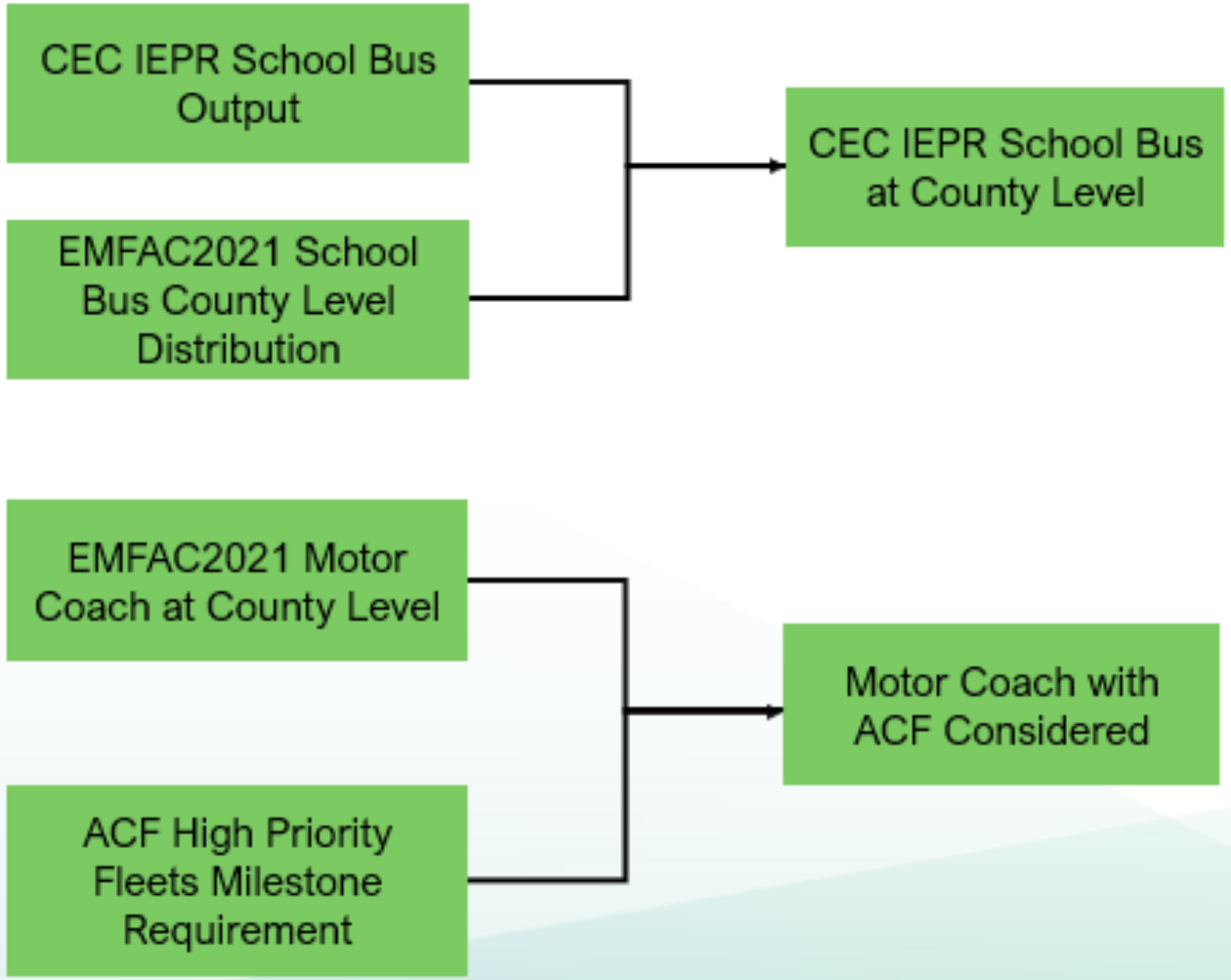
14 years useful life assumed for all buses except ICE Cutaway (10 years)

10.8% deadheading estimated (NTD Reported Total Revenue Miles: 3,370,530,215; Total Actual Miles: 3,777,458,409)

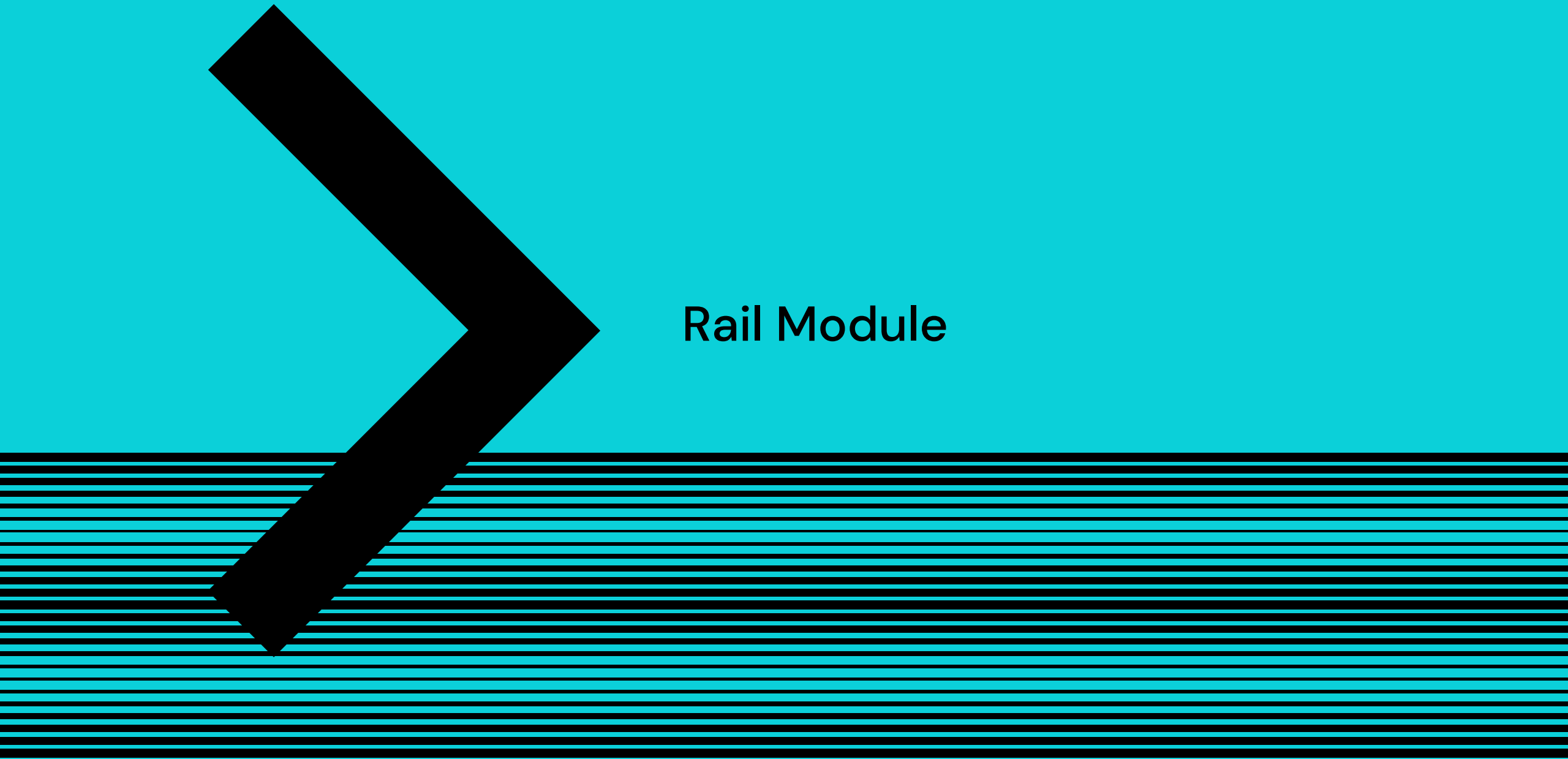
School Bus and Motorcoach Model Diagram

School Bus

Motor Coach



ACF: Advanced Clean Fleets Regulation



Rail Module

Rail Model Overview

Purpose: To create a rail model which estimates and projects energy demand in unit of MW-hr by different fuel types (e.g., electricity, diesel, or hydrogen)

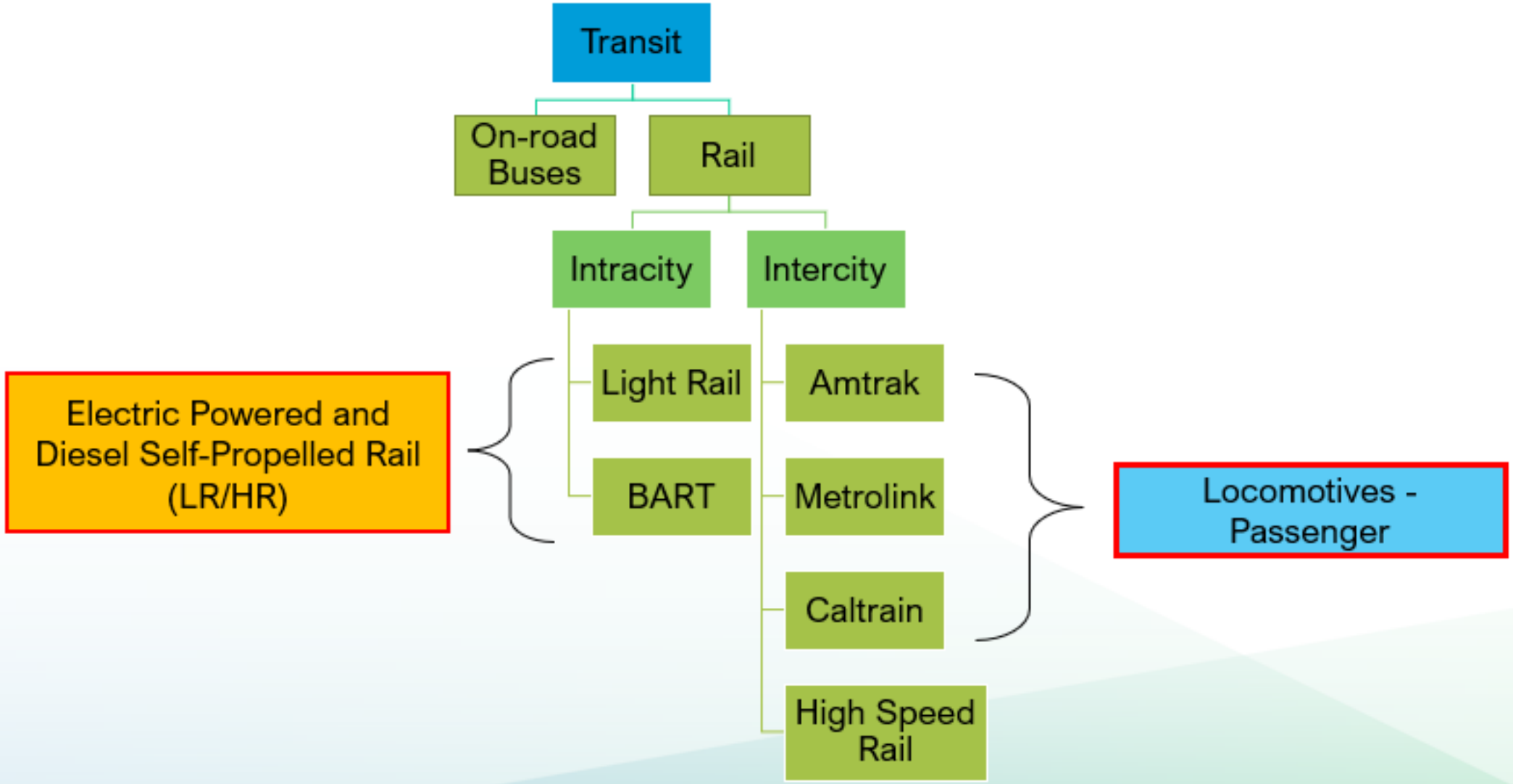
- **Three categories of rail are modeled**
  - Locomotives - Passenger:
  - Electric Powered and Diesel Self-Propelled Rails (LR/HR)
  - High Speed Rail
- **Regional resolutions**
  - Statewide

Self-Propelled

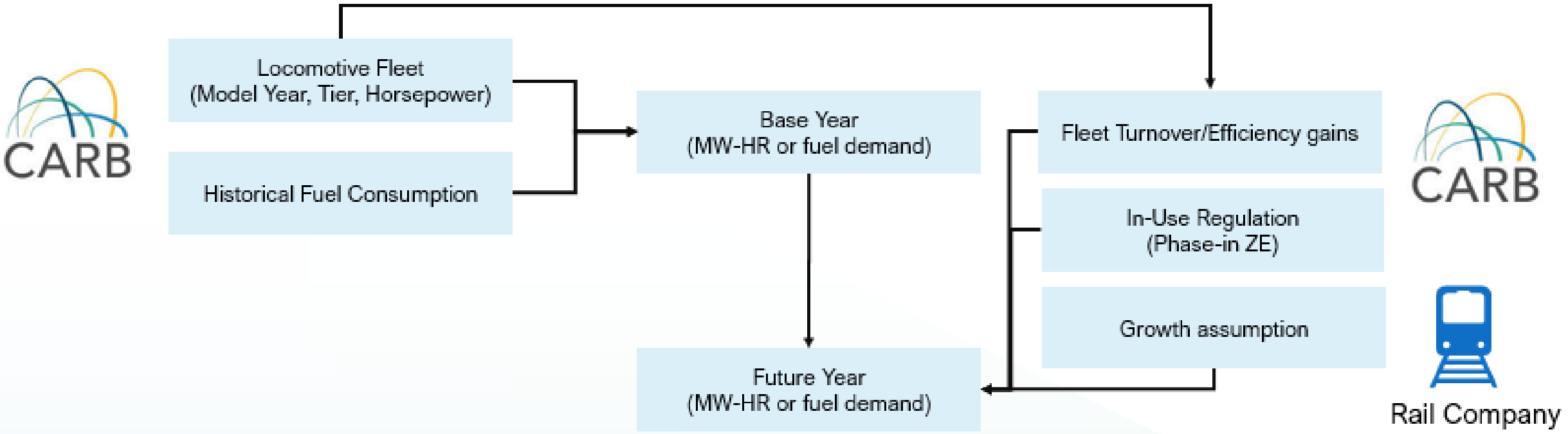
Locomotives

High Speed Rail

Rail Model: Mapping Modeled Categories vs. Conventional Groups

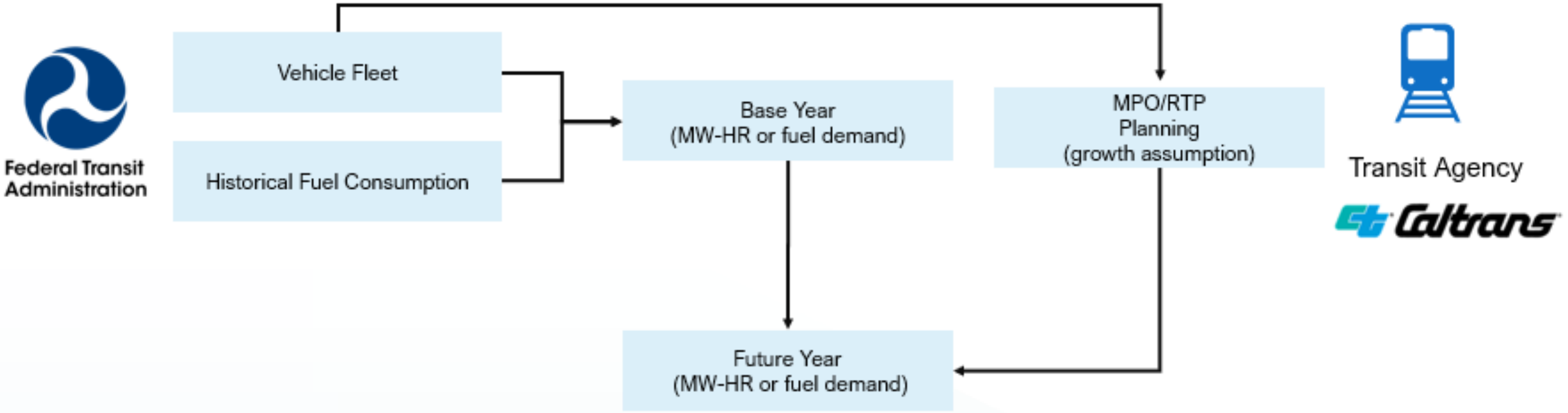


Locomotives – Passenger: Method and Data

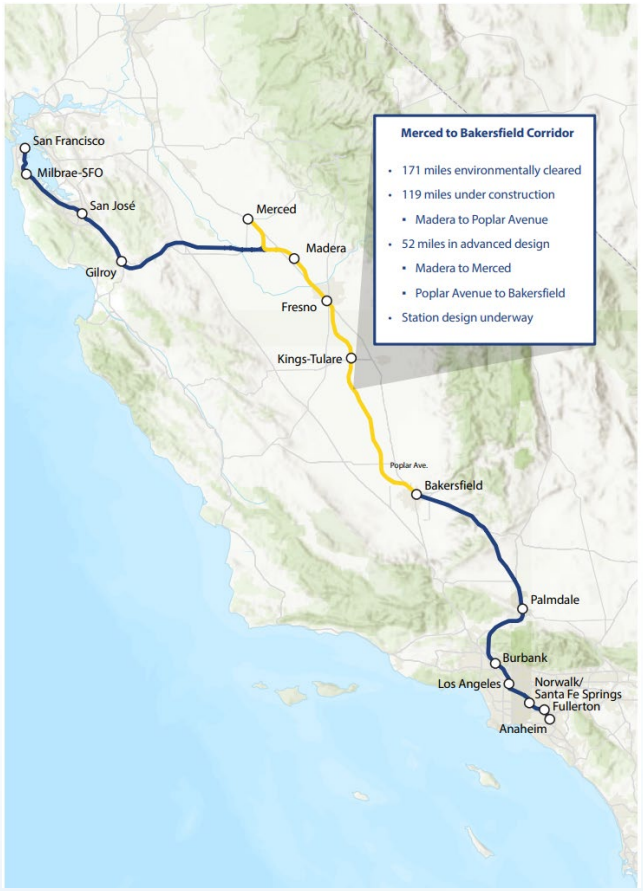


CARB's locomotive-passenger model is a bottom-up model based on rail company's confidential information

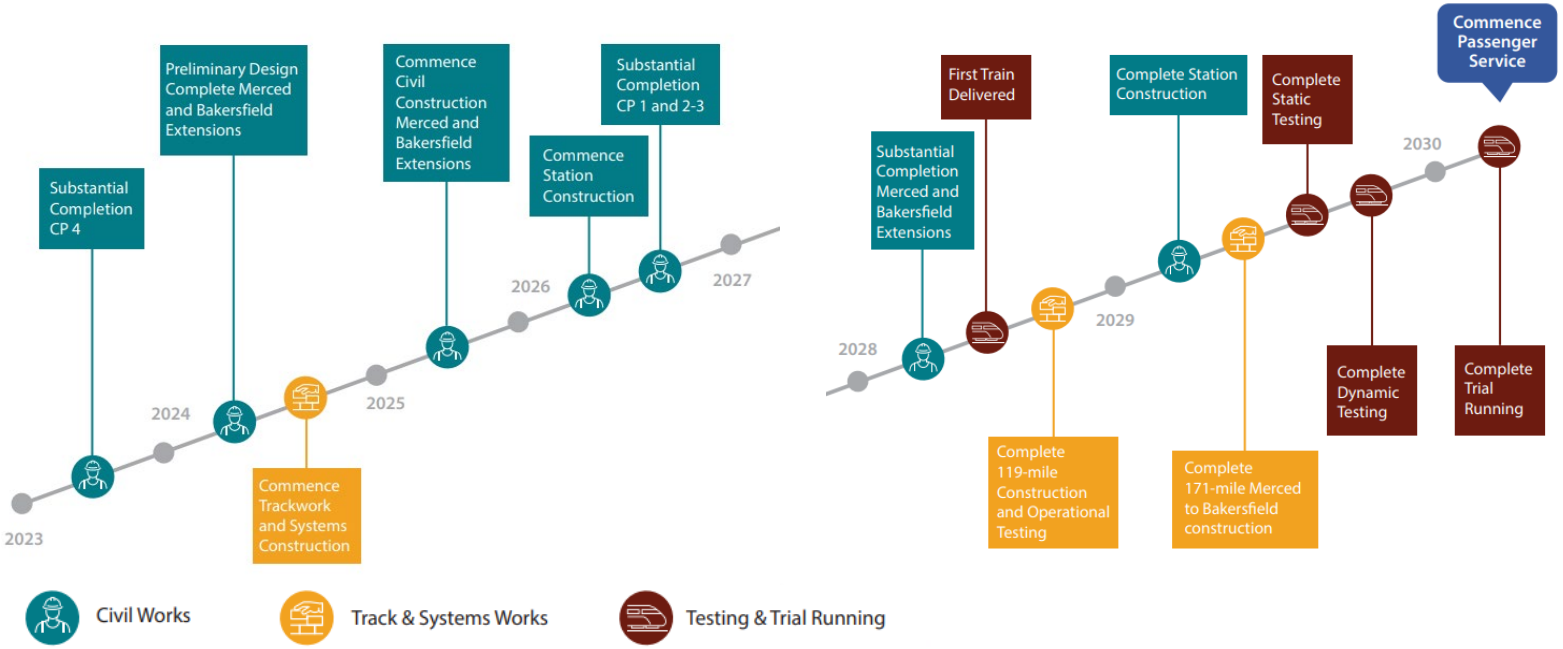
Self-Propelled Rails: Method and Data



High Speed Rail (HSR)



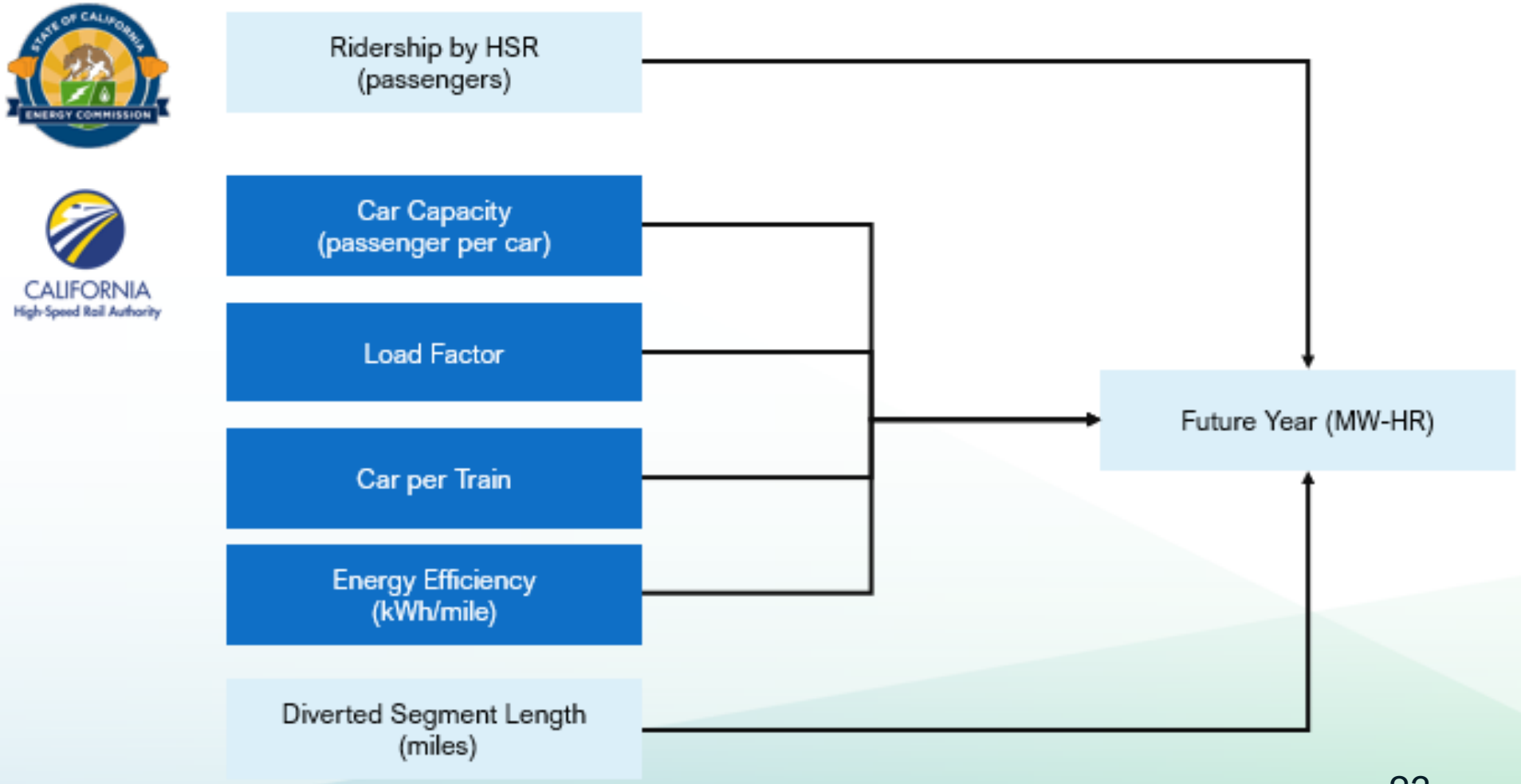
Timeline to Complete Merced to Bakersfield



https://hsr.ca.gov/high-speed-rail-in-california/project-sections-station-communities-interactive-map/

HSR: Method and Data

- Follows the same framework of DynaSim's existing "add-on" of HSR submodule



Marine Module

Marine Model Overview

Purpose: To estimate energy demand (e.g., electricity, hydrogen, and liquid fuel consumption) associated with passenger ferries and cruise vessels

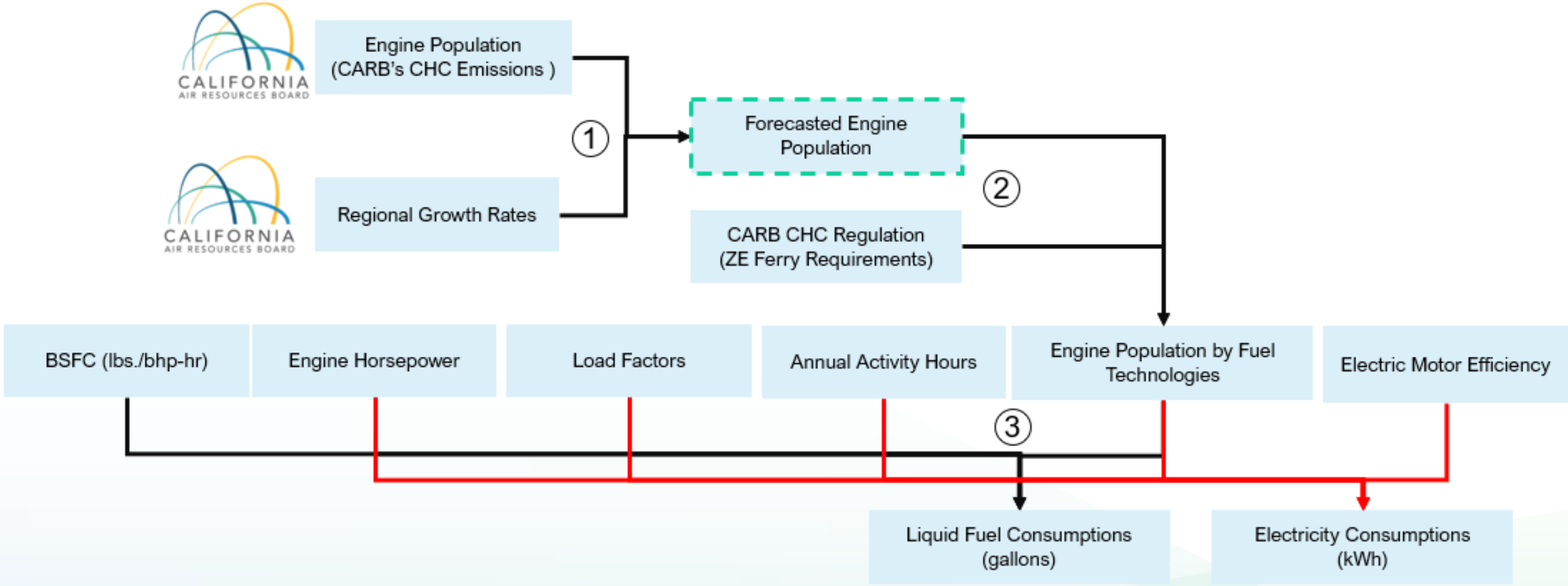
- Overall methodology consistent with CARB's Ocean-Going Vessel (OGV) and Commercial Harbor Craft (CHC) inventories.
- Spatial resolution
  - Port level for ferries
  - Port level for cruise vessels at-berth
  - Statewide for cruise vessels maneuvering, anchorage, and transit
- Estimates electricity consumption while at berth
- Projects the penetration of clean marine fuels
  - International Maritime Organization (IMO) strategies
  - Commercial shipping company targets

Marine Model Diagram

- Marine
  - Cruise ship (interstate/international)
  - Ferries (intrastate)
    - Monohull
    - Catamaran
    - Short Run

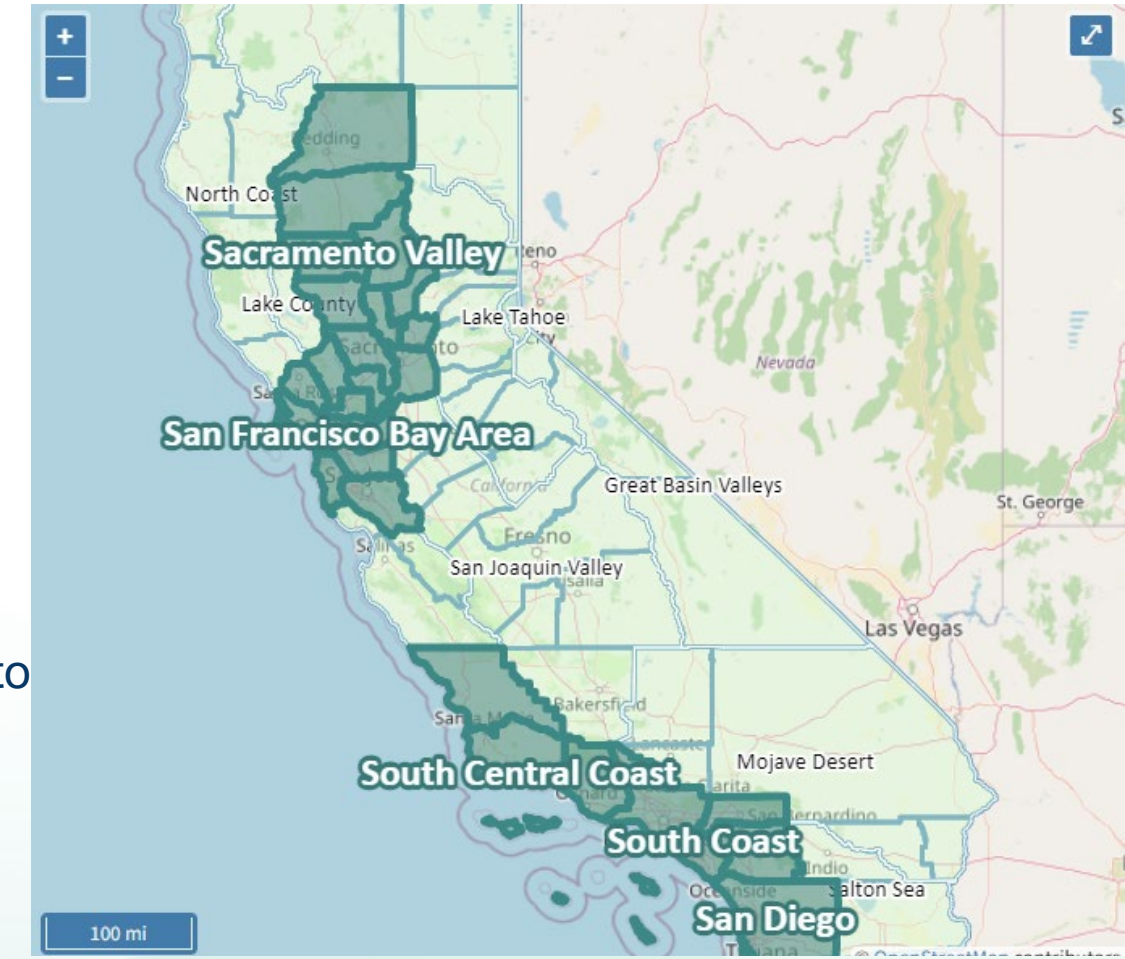
A short run is a dedicated vessel providing regularly scheduled round-trip ferry service between two points that are less than three nautical miles apart.

Model Diagram for Ferries



Overview of Ferry Data

- CARB's 2021 CHC Modeling Framework
  - CHC Emissions Data
    - 2018 Base Year
    - Main and Auxiliary Engine Counts
    - 13-Port resolution (e.g., LA/LB, Emeryville)
- Assumptions based on CHC Regulation
  - Population Growth
    - No growth except for San Francisco which is expected to grow at ~3% annually
  - Technology Mix
    - 2026+ Short-Run Ferry ZE Requirement



Source: https://arb.ca.gov/emfac/

More on Modeling Approach and Assumptions

Vessel & Engine Counts

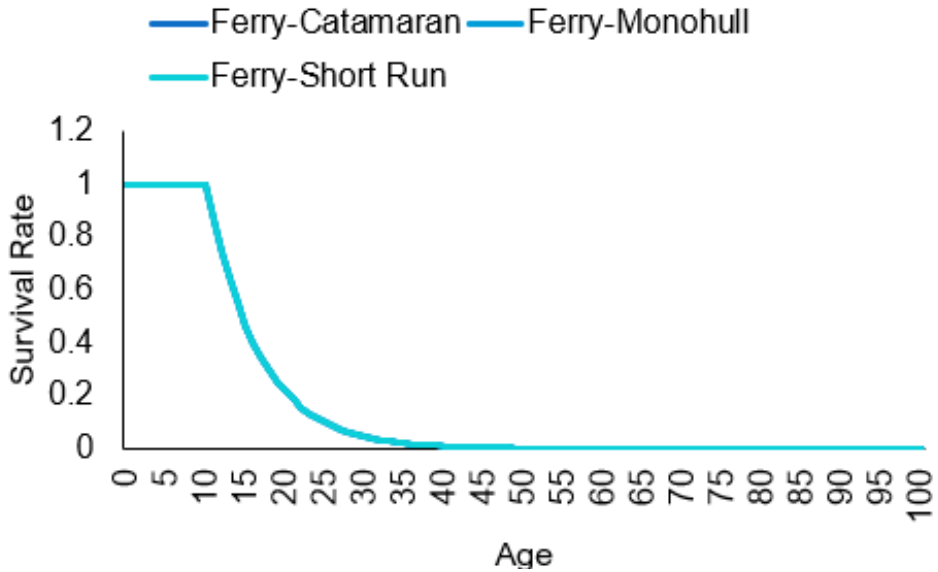
Ferry Type	Main Engine	Aux Engine
Ferry-Catamaran	78	52
Ferry-Monohull	38	26
Ferry-Short Run	24	13

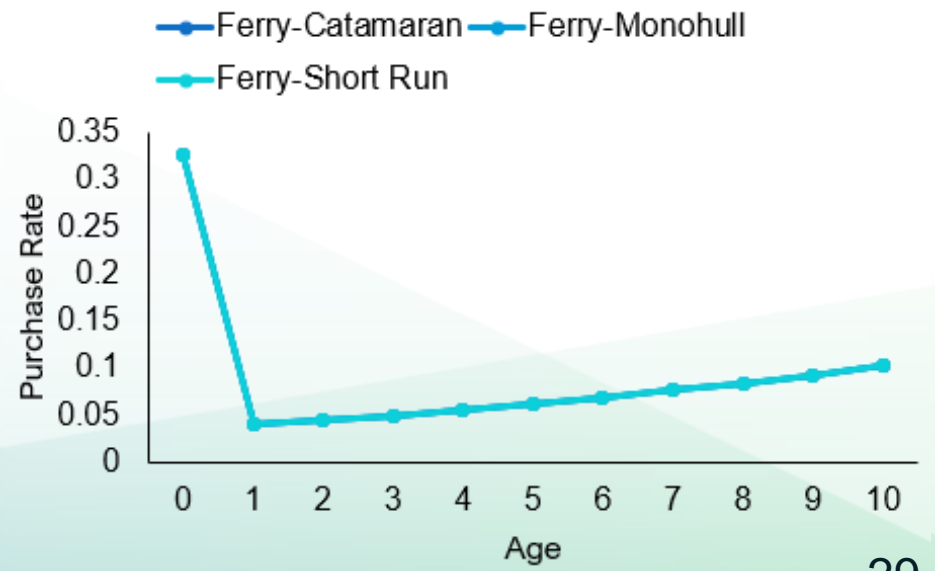
Annual Engine Activity

Engine Type	Vessel Type	Activity (hours per year)
Aux Engine	Ferry-Catamaran	1,774
Aux Engine	Ferry-Monohull	1,654
Aux Engine	Ferry-Short Run	2,605
Main Engine	Ferry-Catamaran	2,372
Main Engine	Ferry-Monohull	2,327
Main Engine	Ferry-Short Run	2,674

Load Factors

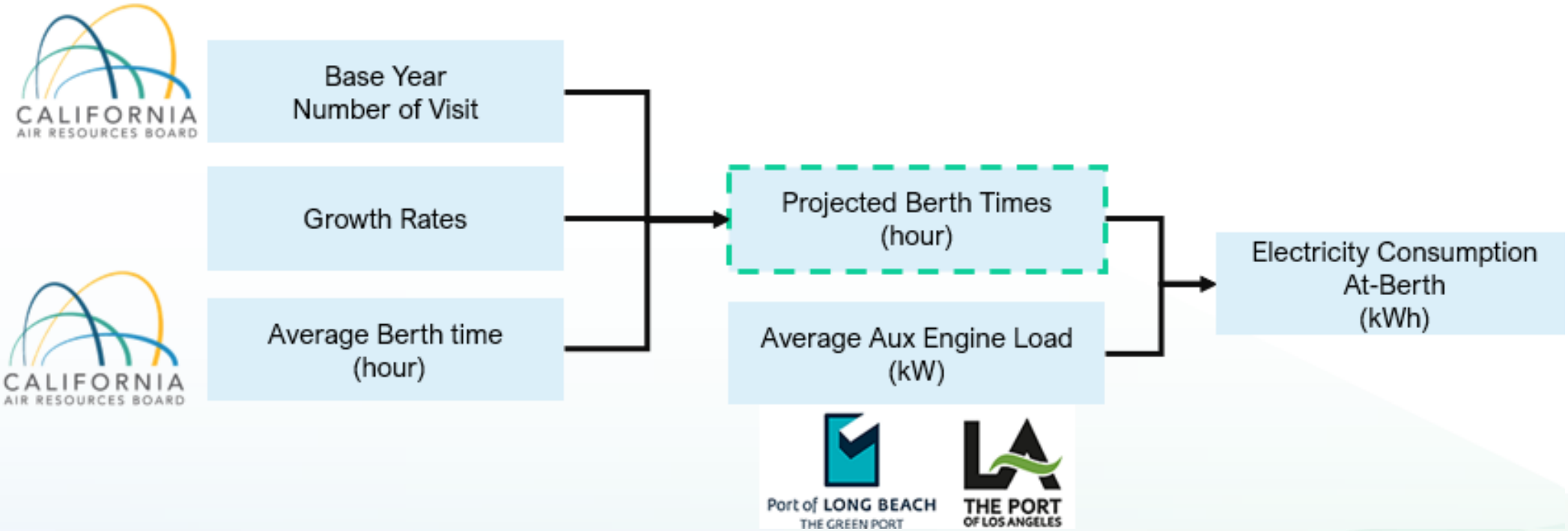
Engine Type	Vessel Type	Load Factors
Aux Engine	Ferry-Catamaran	39%
Aux Engine	Ferry-Monohull	39%
Aux Engine	Ferry-Short Run	39%
Main Engine	Ferry-Catamaran	31%
Main Engine	Ferry-Monohull	31%
Main Engine	Ferry-Short Run	31%





Cruise Ships – At Berth

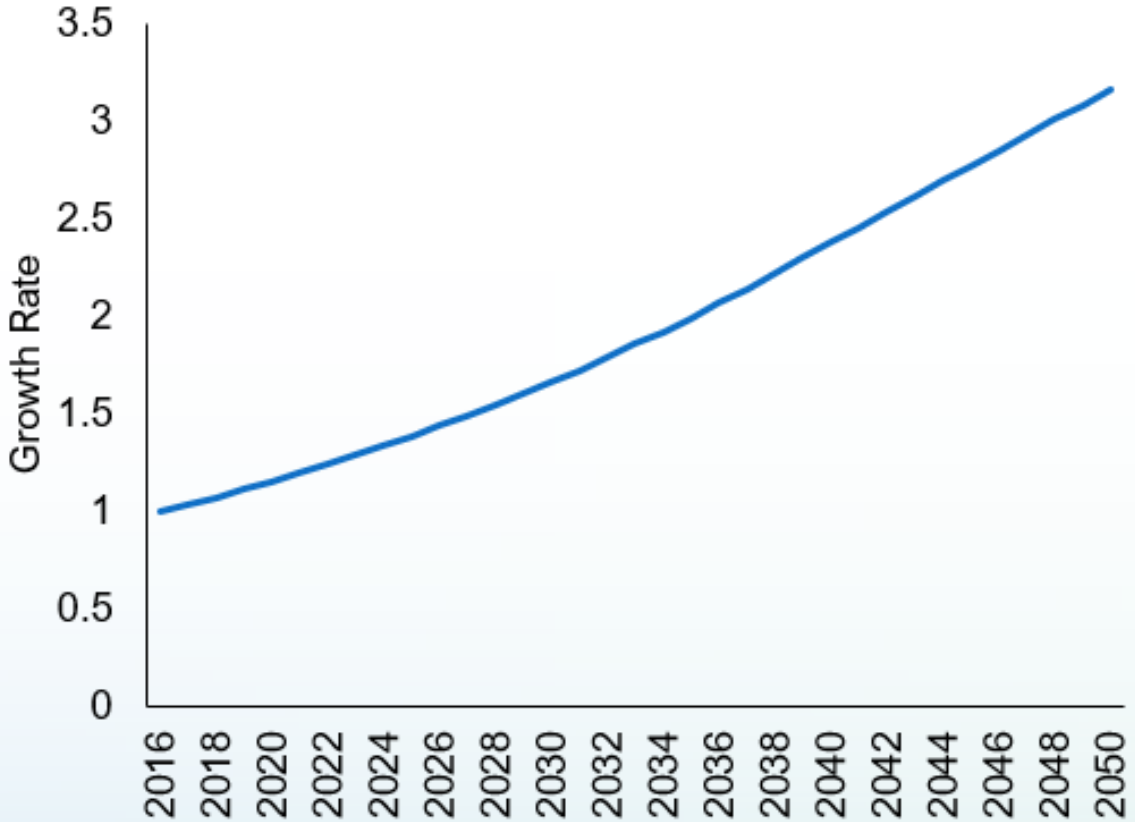
- Utilize the number of visits, duration of each visits at each port, average load for cruise vessels, to estimate the electricity consumption while at-berth assuming full compliance with CARB's 2020 At-Beth regulation

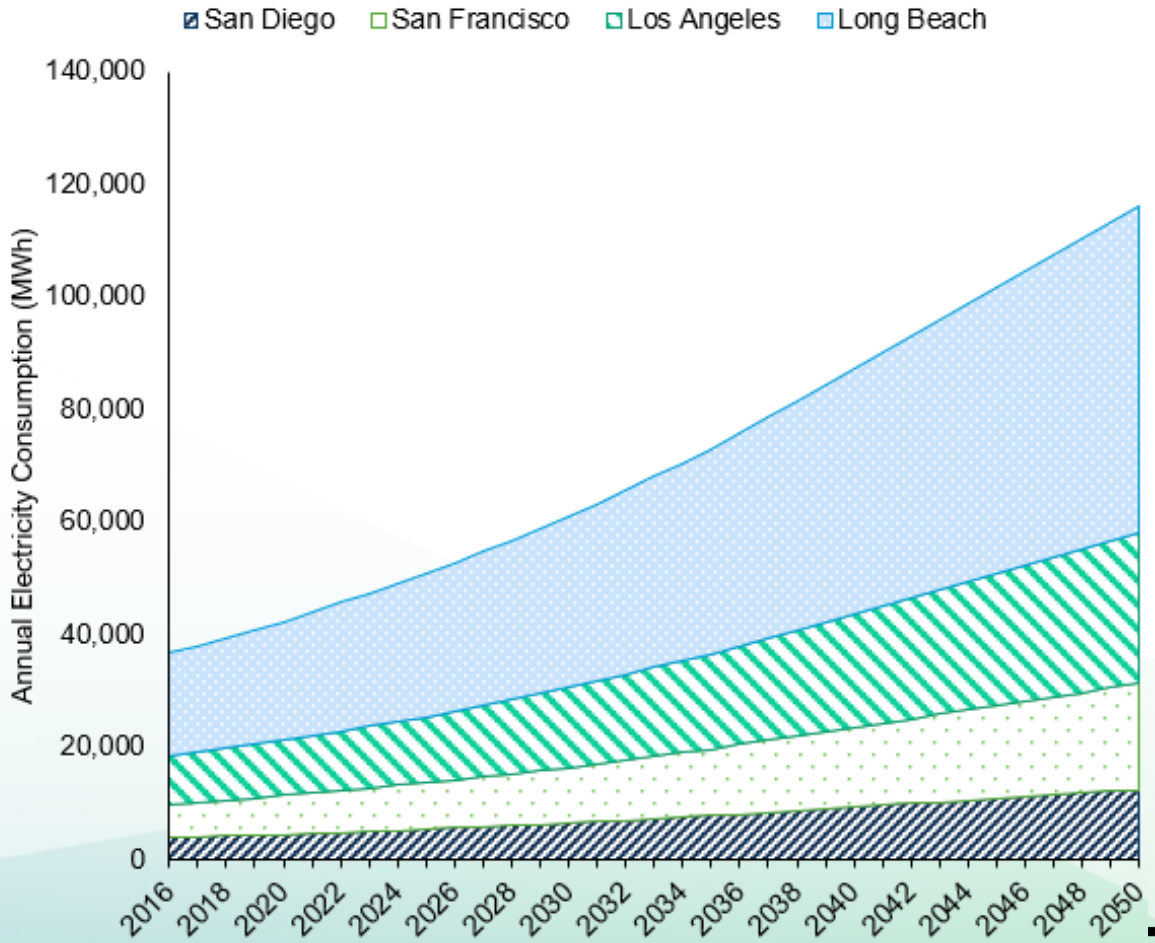


https://ww3.arb.ca.gov/regact/2019/ogvatberth2019/apph.pdf

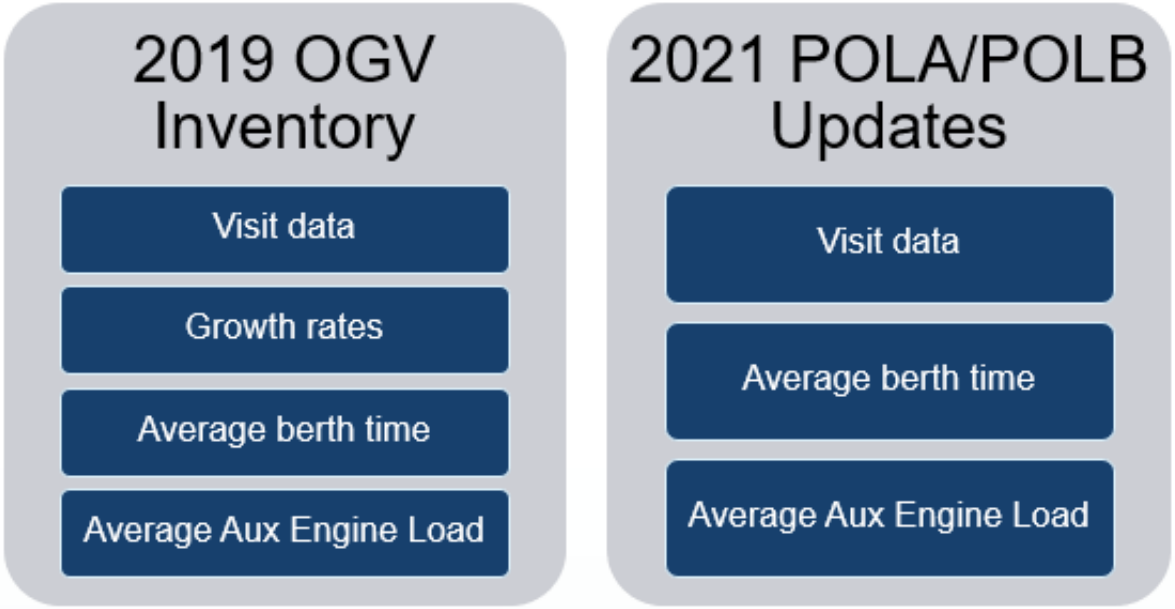
Background on At Berth Data

- CARB's 2019 OGV Inventory provides the most comprehensive data in alignment with the proposed methodology (e.g., visits, growth rates, and average berth time).





More Recent Data



POLA 2019-2021 Arrivals from Sea Comparison

Vessel Type	2019 Arrival	2020 Arrival	2021 Arrival	2021-2020 Change
Cruise	137	91	219	141%

Source: 2019, 2020, 2021 Air Emissions Inventory https://www.portoflosangeles.org/environment/air-quality/air-emissions-inventory

POLB 2019-2021 Arrivals from Sea Comparison

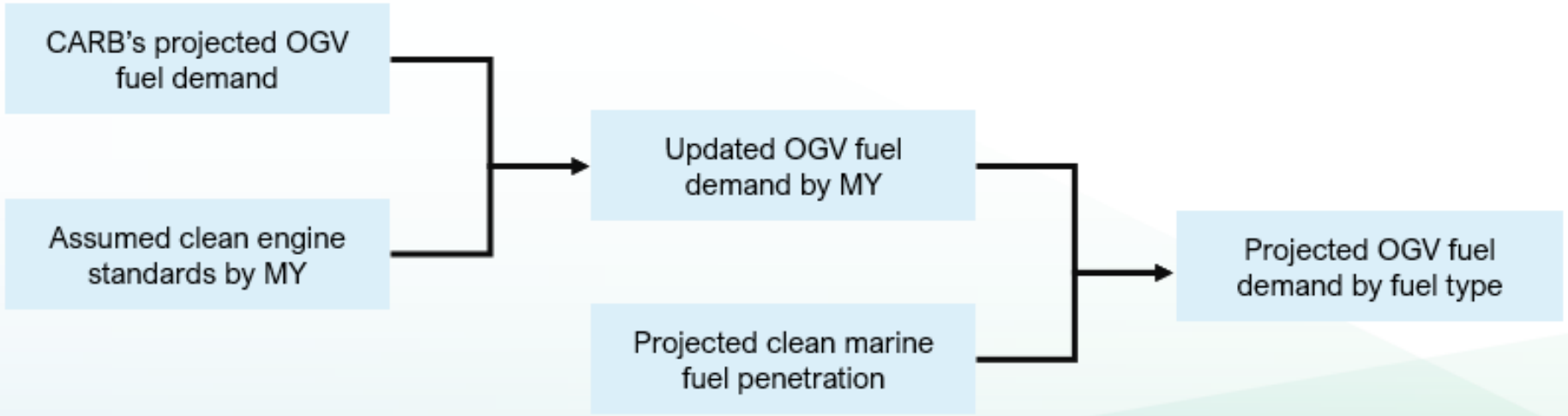
Vessel Type	2019 Arrival	2020 Arrival	2021 Arrival	2021-2020 Change
Cruise	254	72	74	3%

Source: 2019, 2020, 2021 Air Emissions Inventory https://polb.com/environment/air#emissions-inventory

In 2021, to ensure the health and safety of workers during the COVID-19 pandemic, the limit on the number of work gangs used at berth continued from 2020. This measure led to increased vessel times spent at berth and anchorage. In addition to vessels waiting for a berth, once at berth, vessels spent longer time at berth for most vessel calls.

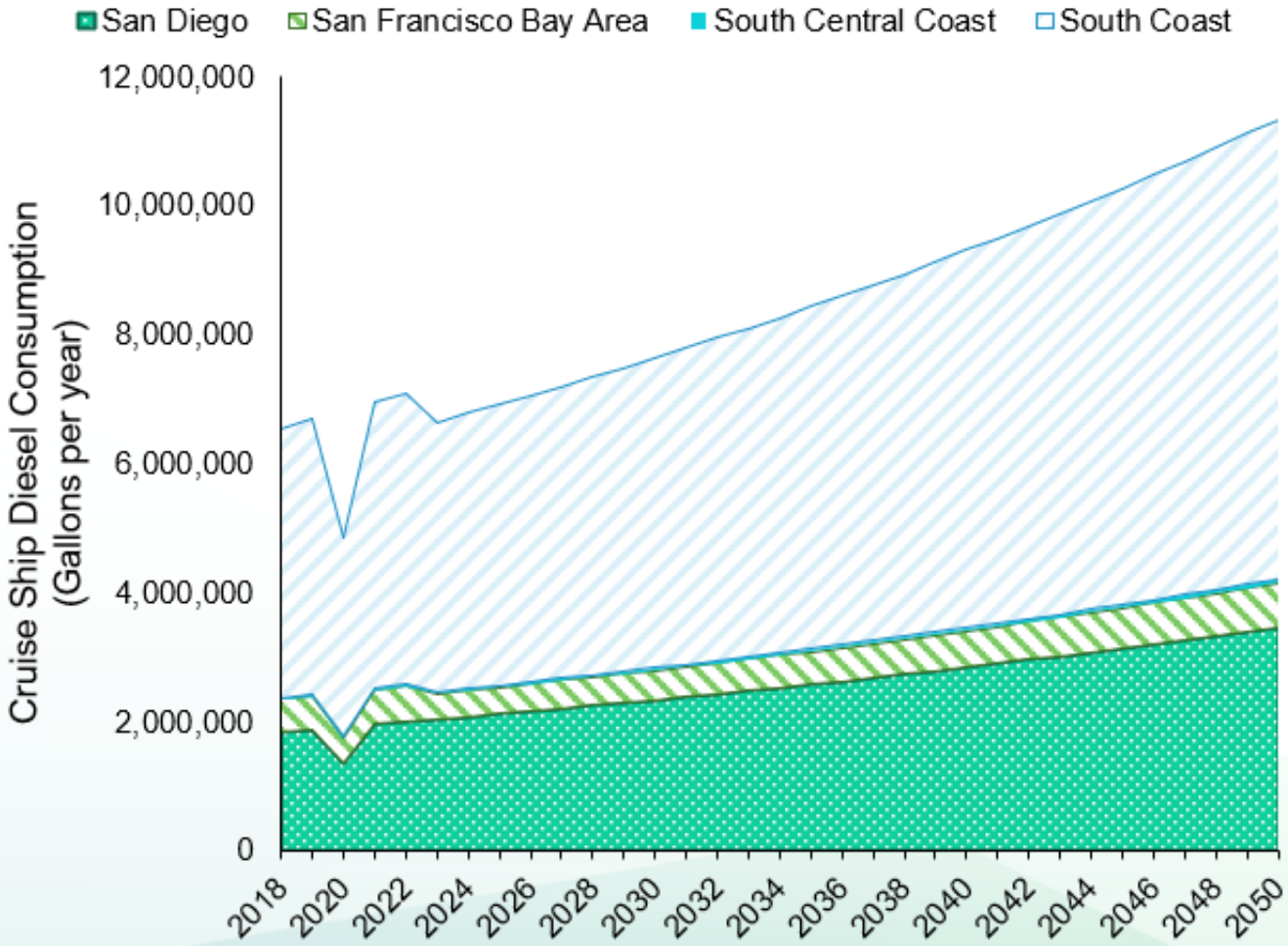
Cruise Ships – Maneuvering, Anchorage, Transit

- Utilize the fuel consumptions calculated and projected by CARB and overlay assumptions regarding clean marine fuel penetration
- There is very little information on which fuel types the industry may shift toward, but we utilized some existing programs and strategies to produce a scenario-based projection.

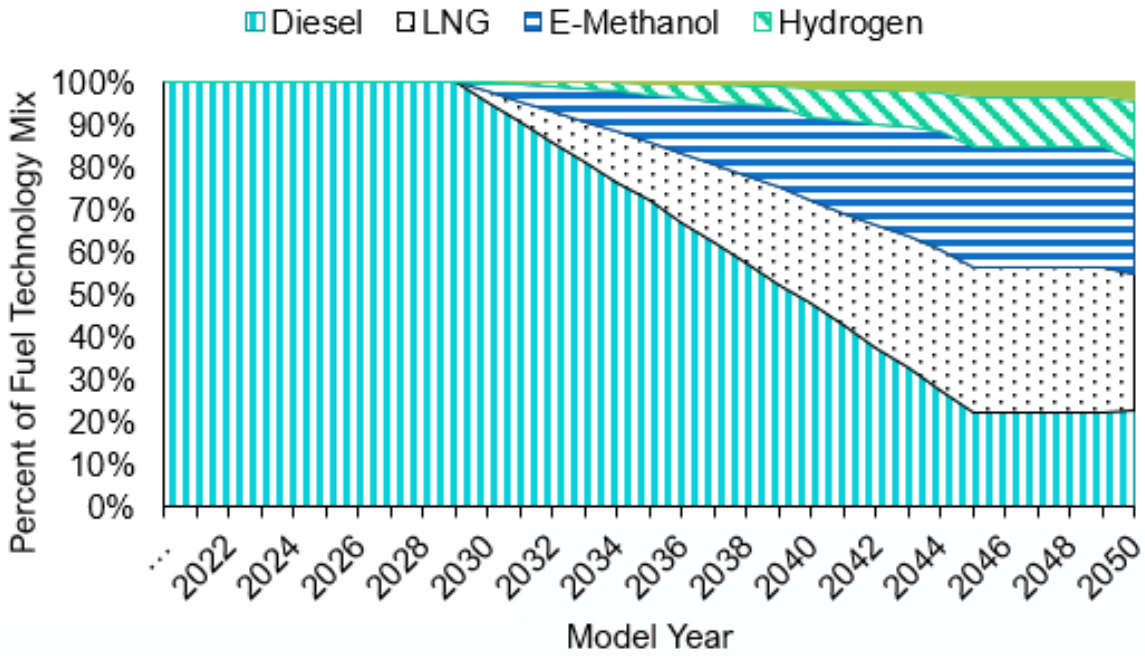


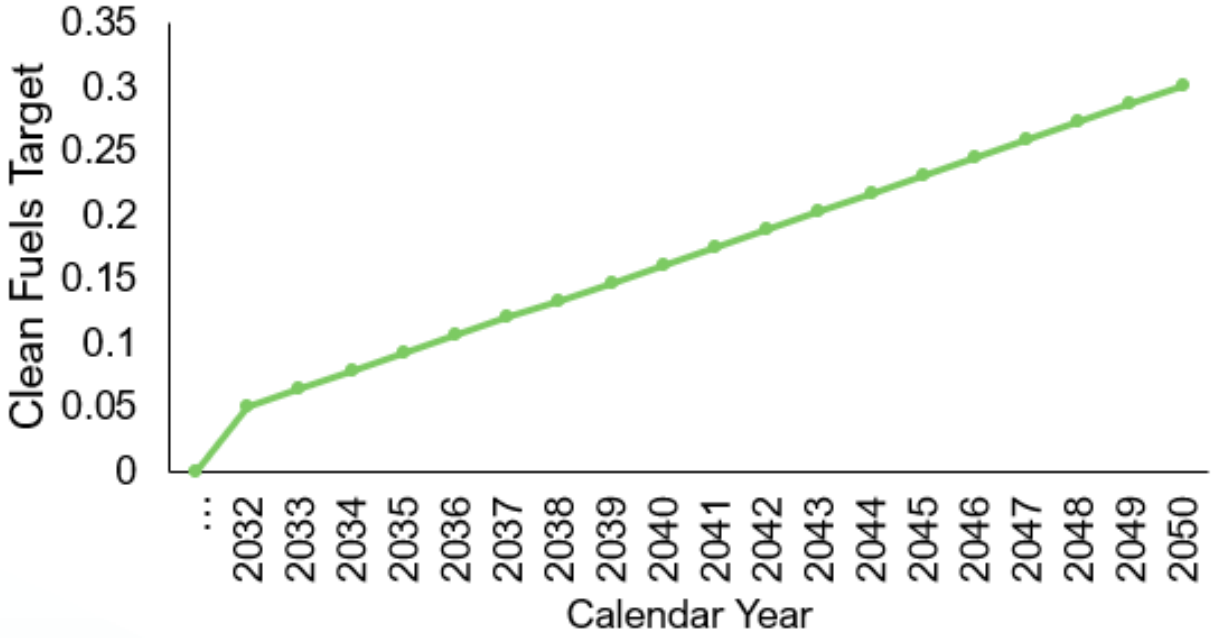
CARB Projected OGV Fuel Demand

- CARB's 2021 OGV Emission Inventory
  - Provides total annual activity and diesel fuel consumption for OGVs
- Provides air basin resolution and breakdown of cruise ship population by MY, horsepower bin
- Reflects changes in diesel fuel consumption as a result of the pandemic



Clean Marine Fuels Penetration





- CARB's Mobile Source Strategy (2020):
  - Renewable hydrogen and other hydrogen-derived fuels such as ammonia, methanol, batteries and fuel cells are being considered as potential fuel choices for zero-emission vessels. Zero-emission technologies for marine vessels are still at an early stage and technological feasibility needs to be proven.
- Maersk, the world's second largest container shipping firm, set to target net-zero emissions by 2040.
- IMO Initial GHG Strategy: roughly 30% reduction by 2050 (compared to 2008).

Aviation Module

Aviation Model

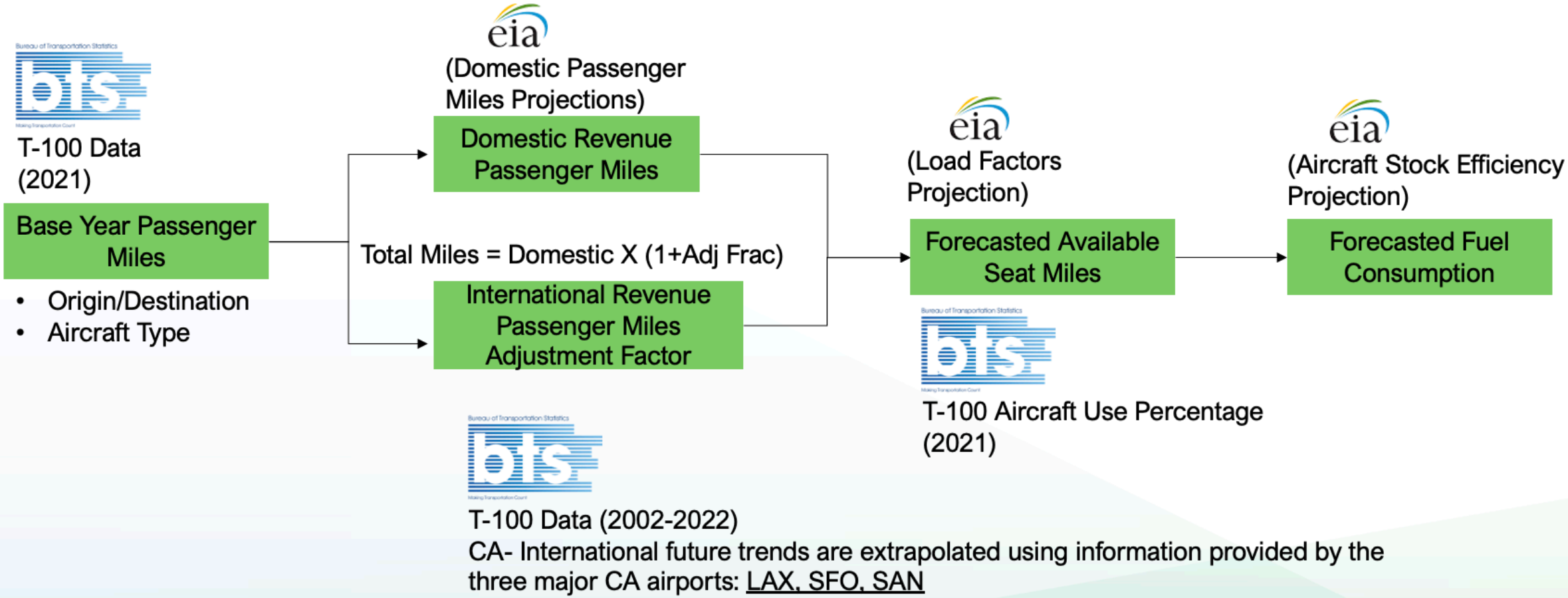
Purpose: To estimate energy demand (e.g., electricity, hydrogen, and liquid fuel consumption) associated with passenger aircraft transportation

- Leveraged CEC's existing aviation model
- Spatial resolution
  - Statewide
  - Assuming origin-destination will remain the same, the model can also provide energy demand at airport level
- Current CEC's Aviation model estimates energy demand (i.e., liquid fuel consumption) for commercial passenger
- The new model considers potential energy demand from general aviation and electric vertical take-off and landing (eVTOL) aircraft

Aviation Model Diagram

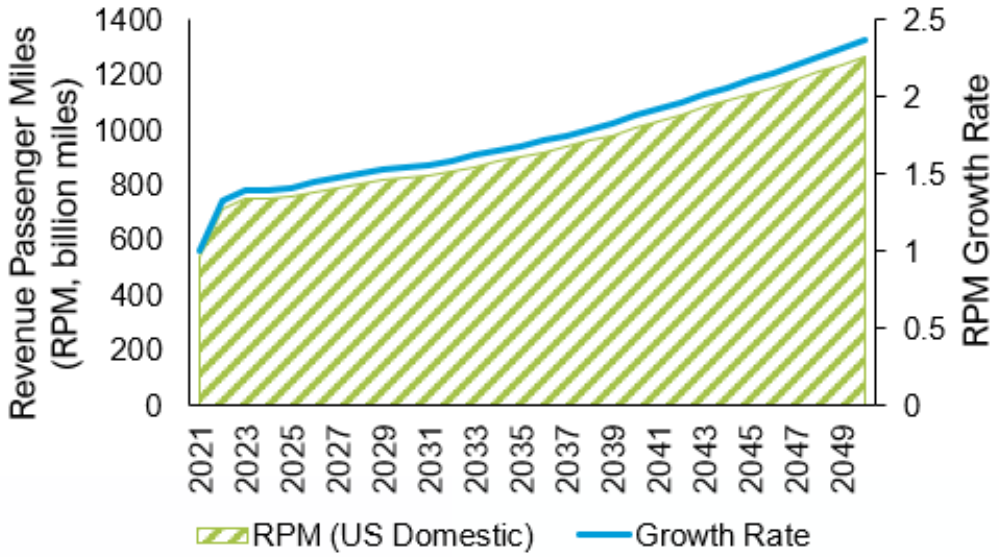
- Aviation
  - Commercial Passenger
    - Intrastate
    - Interstate
    - International
  - General Aviation
  - eVTOL

Methodology At-a-Glance – Commercial Aviation (New Approach)



https://www.transtats.bts.gov/Data_Elements.aspx?Data=3

Commercial Aviation Passenger Miles Growth

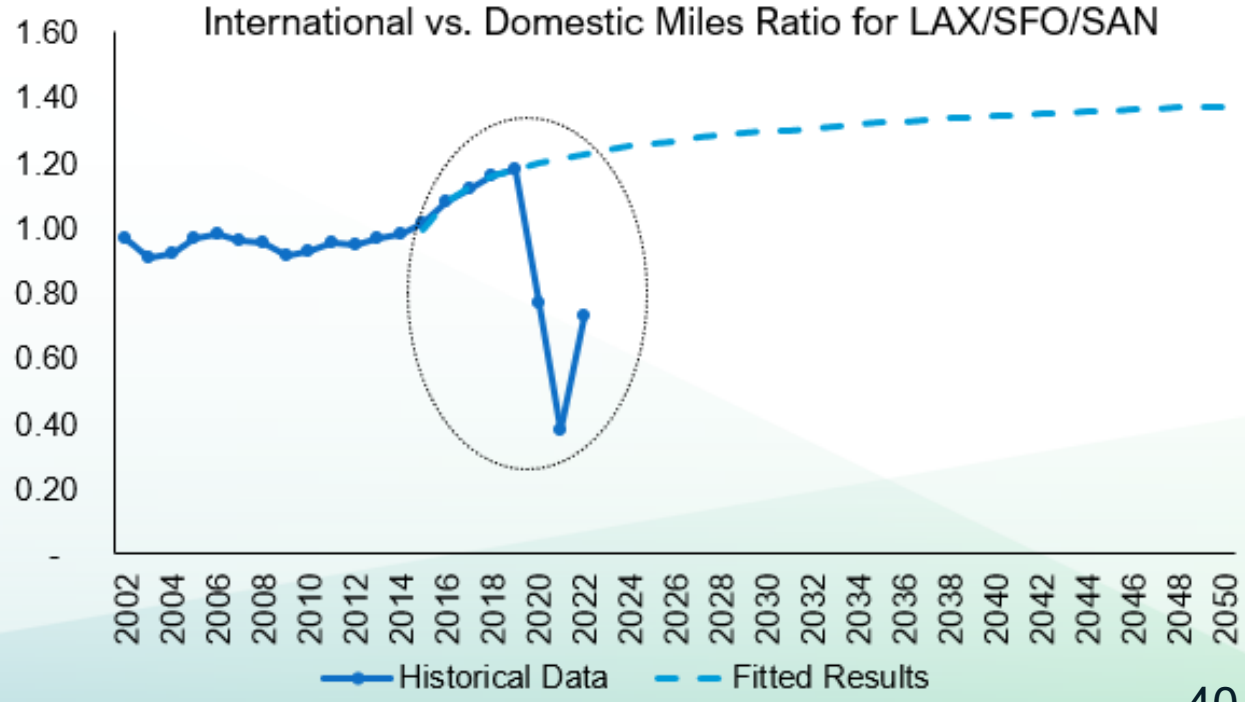


Instead of using AEO projection for international miles, we examined three major airports from CA: LAX, SFO, and SAN (94% of international miles in CA) and derived adjustment factors based on domestic miles (INTL/DMSTC ratio).

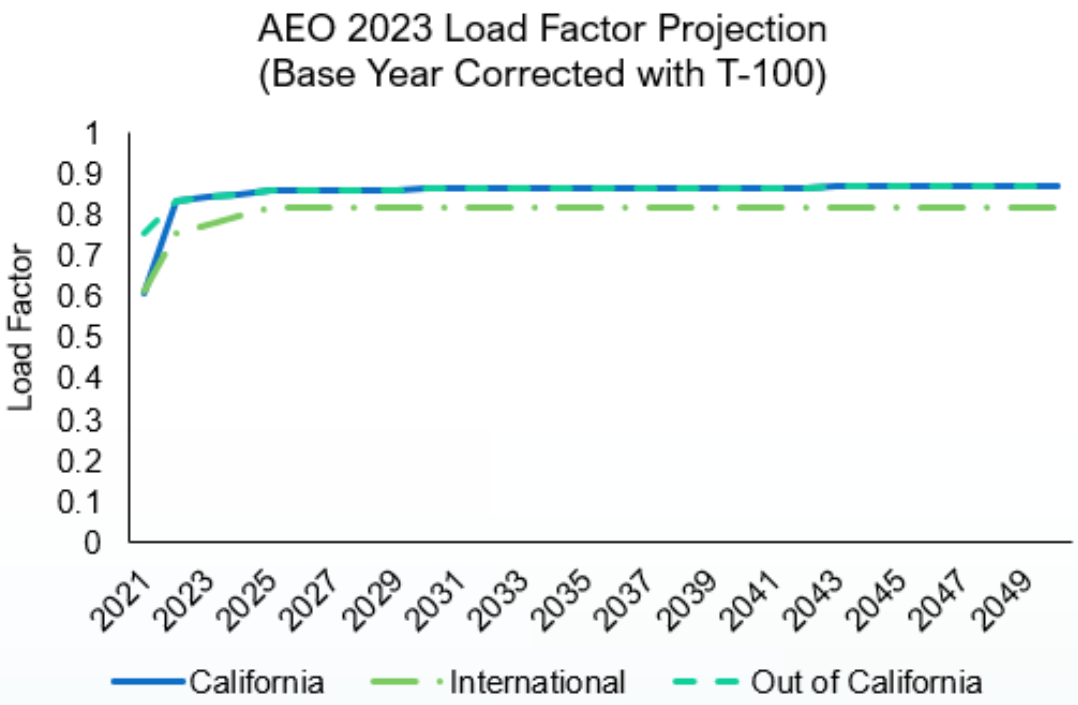
The actual impact of pandemic was considered in the final INTL/DMSTC ratio, but only 2014-2019 data were used to extrapolate the future trend.

The growth trend of domestic (California – California and California – Out-of-California) passenger miles will follow the same trend as AEO 2023.

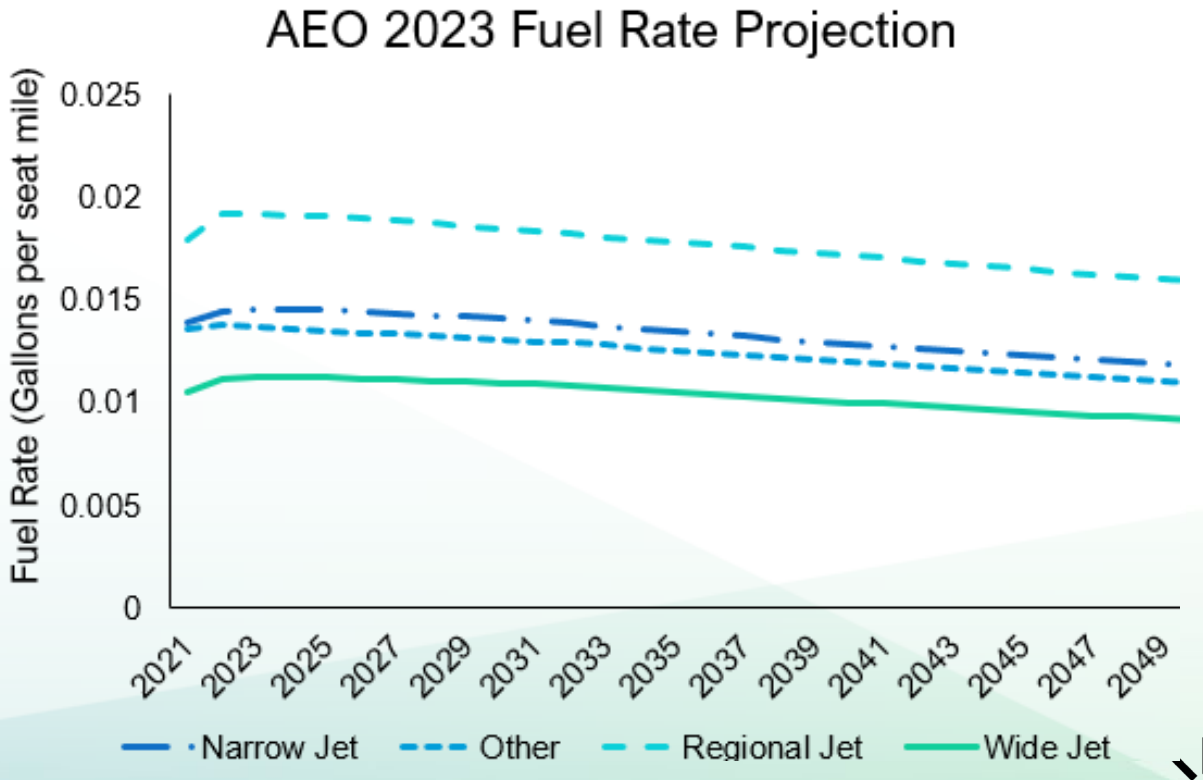
Although AEO 2023 also includes international projection, California will likely have different trends than the rest of the country.



Load Factor and Fuel Efficiency



AEO2023 load factors for both domestic (California to California and California to Out-of-California) and international were used as input. 2021 data were adjusted based on T-100 base year.



Current fuel rate was taken directly from AEO 2023. Will also consider the dependence of fuel rate on aviation load factor.

General Aviation Model

Source: https://www.faa.gov/sites/faa.gov/files/FY%202023-2043%20Full%20Forecast%20Document%20and%20Tables_0.pdf

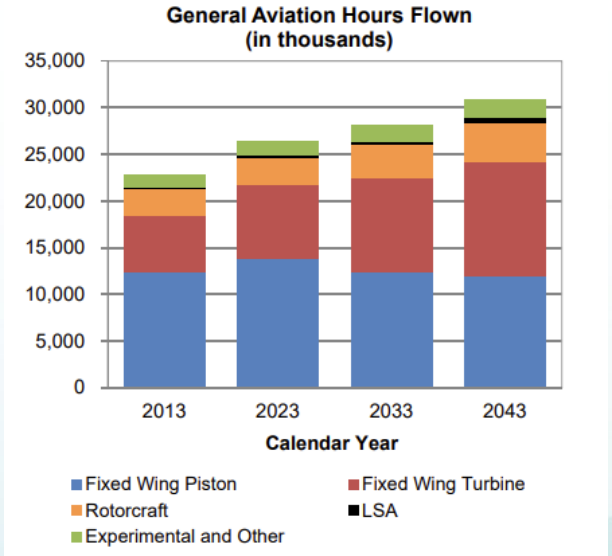
General Aviation Fuel Efficiency Improvement

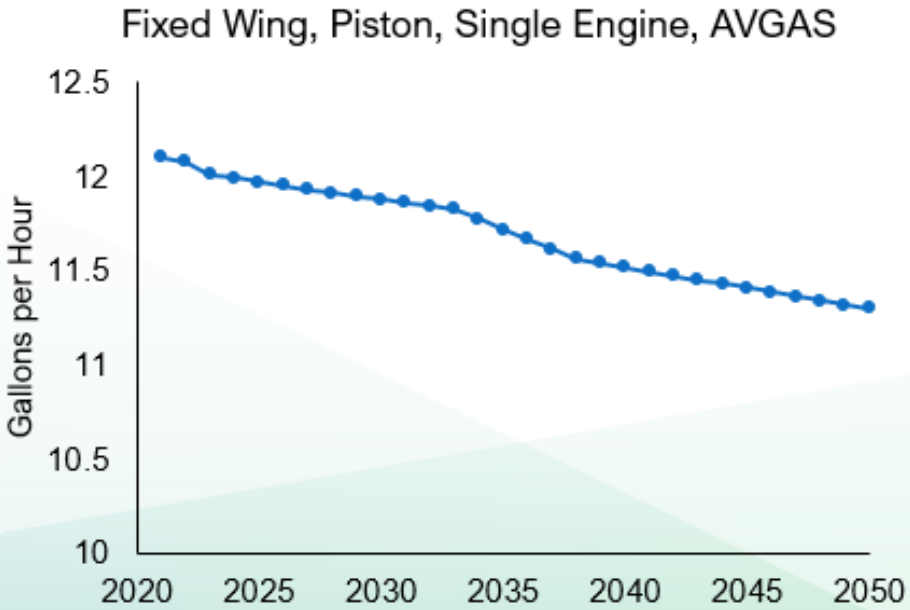
Forecasted General Aviation Hours Flown

Forecasted GA Fuel Demand and Activity

California Adjustment Factor

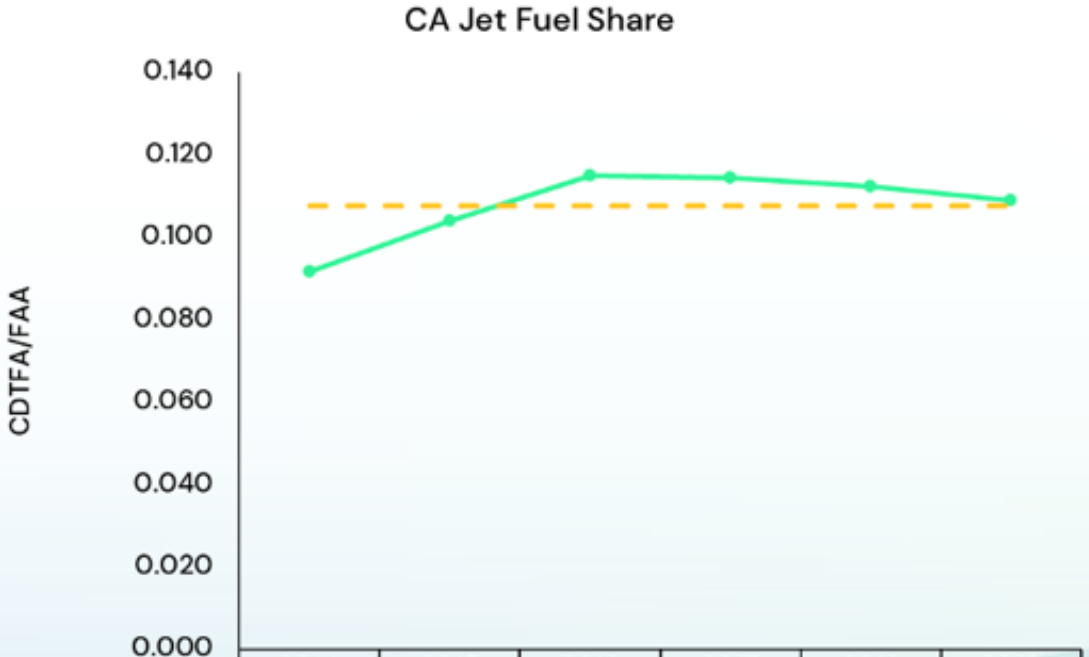
California GA Fuel Demand and Activity



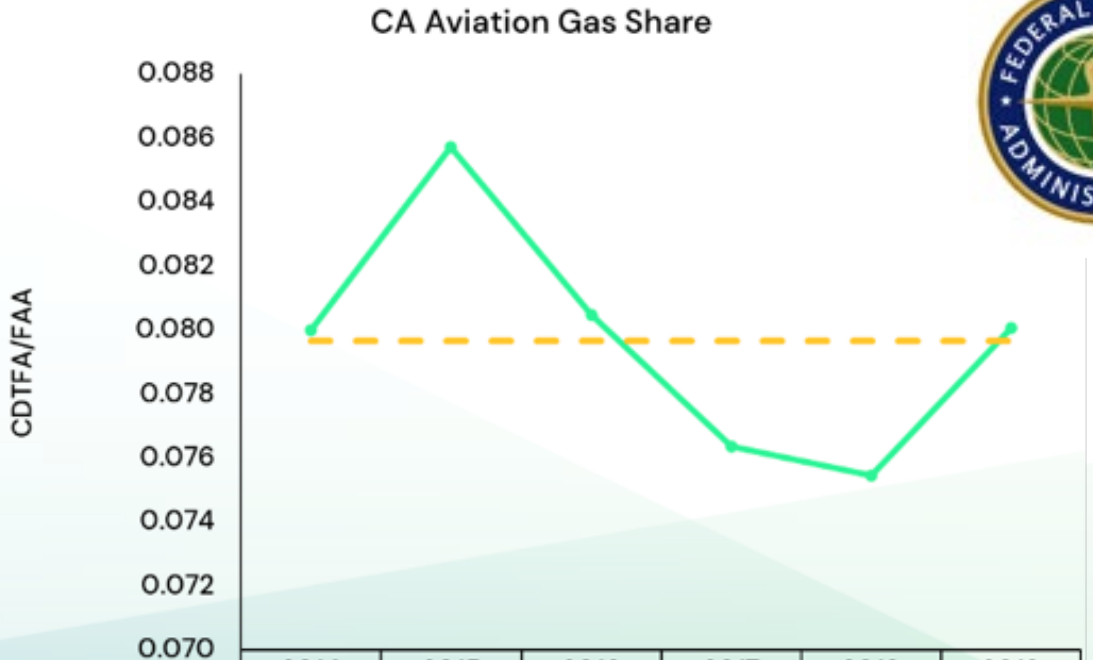


Data and Methodology – CA Fuel Share

- Model is set up to reflect California's share of general aviation fuel consumption
  - Average CA fuel share calculated using 2014-2019 historical data
  - Input file keeps average CA



	2014	2015	2016	2017	2018	2019
CDTFA/FAA	0.092	0.104	0.115	0.114	0.112	0.109
Avg	0.108	0.108	0.108	0.108	0.108	0.108



	2014	2015	2016	2017	2018	2019
CDTFA/FAA	0.080	0.086	0.080	0.076	0.075	0.080
Avg	0.080	0.080	0.080	0.080	0.080	0.080

Electric Vertical Take-off and Landing Aircrafts (eVTOL)

- Advanced Air Mobility (AAM) technology has the potential for significant economic growth worldwide.
- AAM services, including drones and air taxis, show vast promise.
- Safety, infrastructure, public acceptance, and technology changes could slow AAM's market entry.

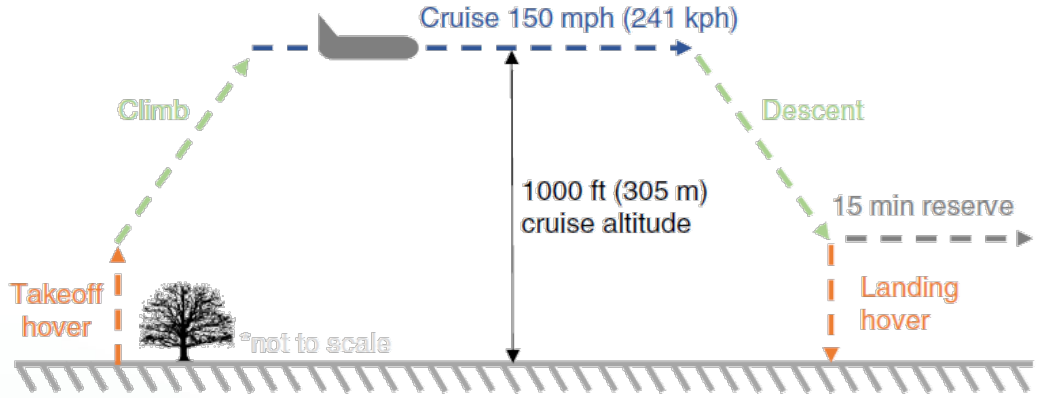


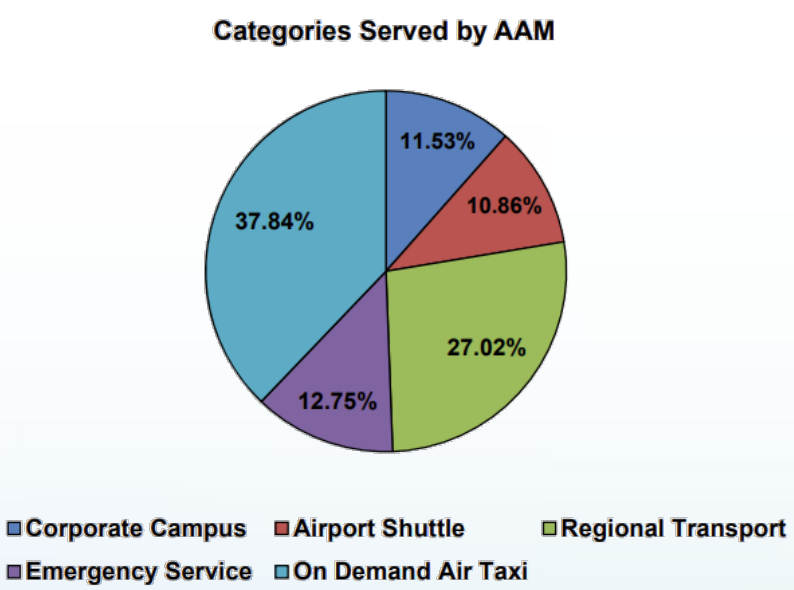
Fig. 1 VTOL flight profile. The five phases of VTOL travel are takeoff hover, climb, cruise, descent, and landing hover. Each phase will have a different travel time, velocity, and power consumption

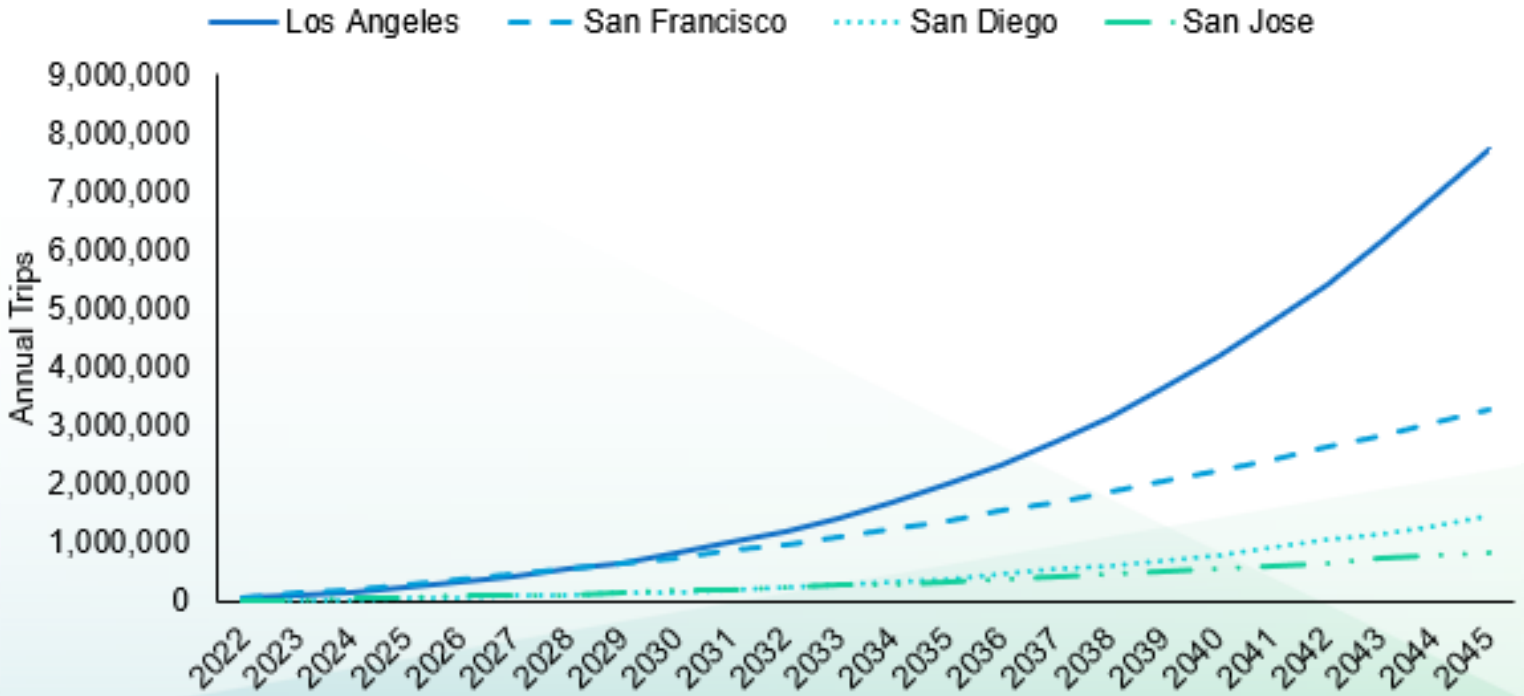
Source: https://www.nature.com/articles/s41467-019-09426-0

Data and Methodology – Simplified Approach

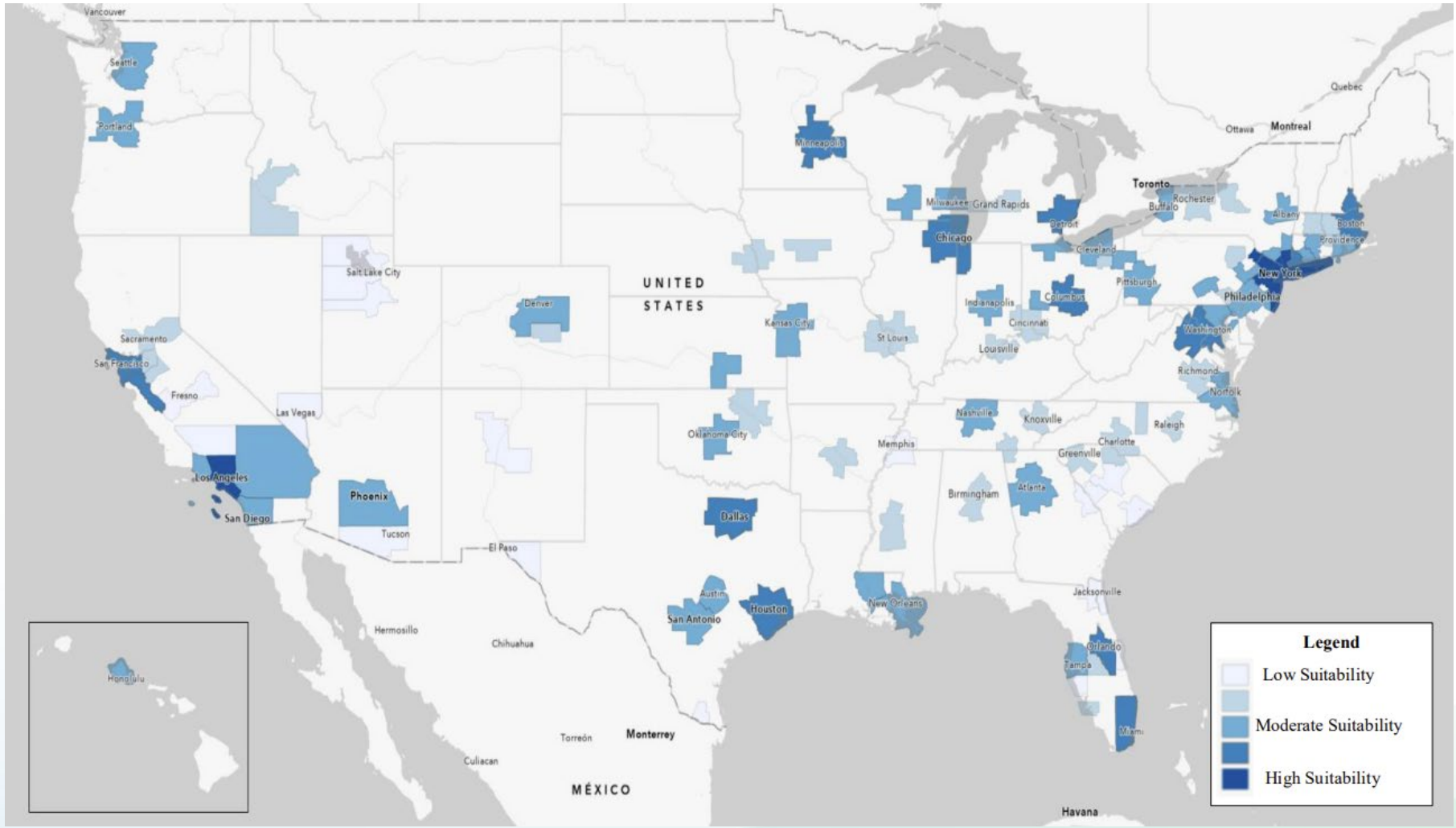
ASSURE
Alliance for System Safety of UAS through Research Excellence

- The latest FAA Aerospace Forecast explores Advanced Air Mobility (AAM) – namely eVTOL
- The AAM evaluation is informed by ASSURE projections
- FAA cites ASSURE's Urban Air Mobility Study: Safety Standards, Aircraft Certification, and Impact on Market Feasibility and Growth Potentials (2022)

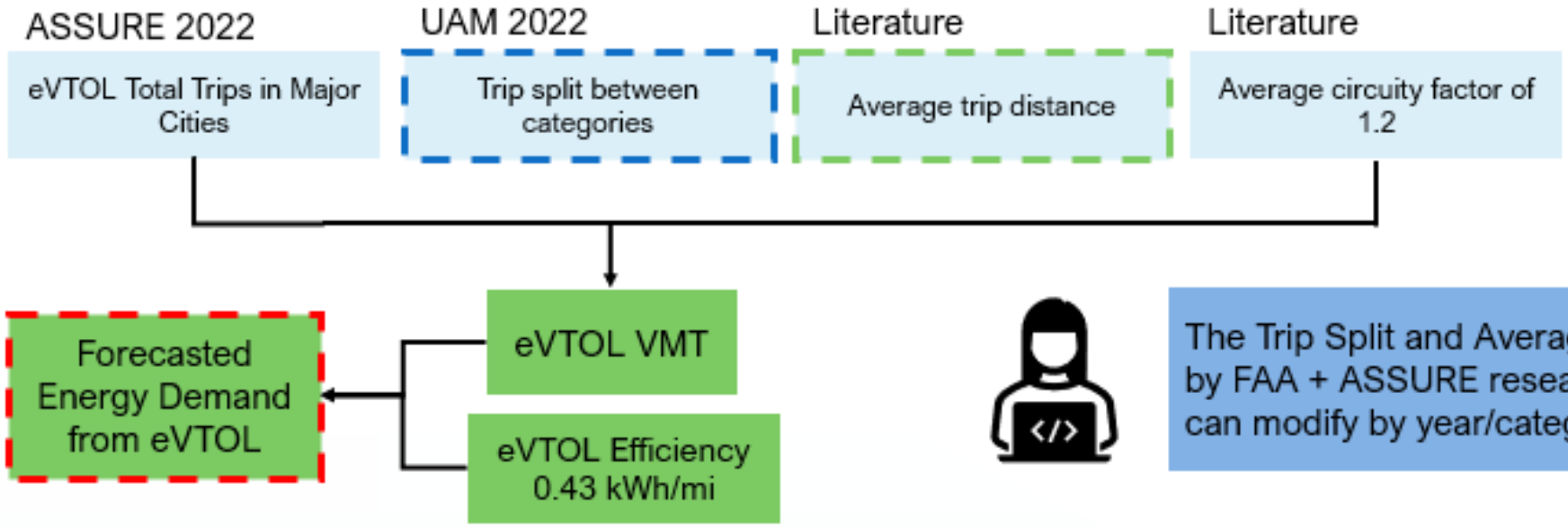




ASSURE's Regional Annual Trips Projection



eVTOL VMT and Energy Demand – Simplified Approach



The Trip Split and Average Trip Distance are informed by FAA + ASSURE research but user can modify by year/category.

Category	Trip Split
Airport Shuttle	11%
Regional Transport	27%
Corporate Campus	11%
On Demand Taxi	38%
Emergency Service	13%

Category	Average Trip Distance (miles)
Airport Shuttle	15
Regional Transport	65
Corporate Campus	10
On Demand Taxi	20
Emergency Service	8

Microtransit Module

Microtransit Model

Purpose: To create a microtransit model which estimates and projects energy demand of micro mobility in unit of MW-hr

- **Categories** of mictrotransit will be modeled:
  - Electric scooters
  - Electric bikes
- **Regional resolutions**
  - Statewide

Note: This model focuses on electric scooters and bikes owned by rental sharing providers. Private owned ones are not considered in this model, due to small number and insignificant contribution of electricity consumption

Electric Scooter and Bike Rental Sharing Providers in California

- Founded in 2017
- E-bikes and e-scooters

Bird

- Founded in 2017
- Electric bikes, scooters, mopeds, pedal bikes, and car sharing

Lime

- Founded in 2016
- Electric bikes and scooters
- Owned by Ford

Spin

- In 2019, Lyft acquired *Bay Wheels*
- Both electric and traditional bikes

Lyft

- Founded in 2018
- E-bikes and e-scooters

Wheel

- Created in 2020
- E-bikes and e-scooters

Link

- A public bicycle sharing company
- Named Metro Bike Share in LA and gRide in SF

BCycle

- E-bikes and e-scooters at Fremont, CA

Hopr

Bikeshare and e-scooters locations in CA

Source: https://data-usdot.opendata.arcgis.com/datasets/usdot::bikeshare-scooter-systems/about

Microtransit: Method and Data

General Bikeshare Feed Specification

MDS

- **GBFS/MDS** or trip-level data from individual providers is not accessible

- Aggregated trip miles (or estimated from total number of trips) from major cities
  - Ride report
  - LA metro bike sharing
  - LA DOT annual report (2021)
- Attempted to contact individual cities, only San Diego provided a screenshot

Trip miles (by MPO/city) (miles)

Avg. Vehicle Efficiency (mile/kWh)

Base Year (MW-hr)

- **Publications**: a McKinsey report shows 5%-10% increase post- COVID by 2030

Planning (by MPOs; placeholder) (growth)

Future Year (MW-hr or fuel demand)

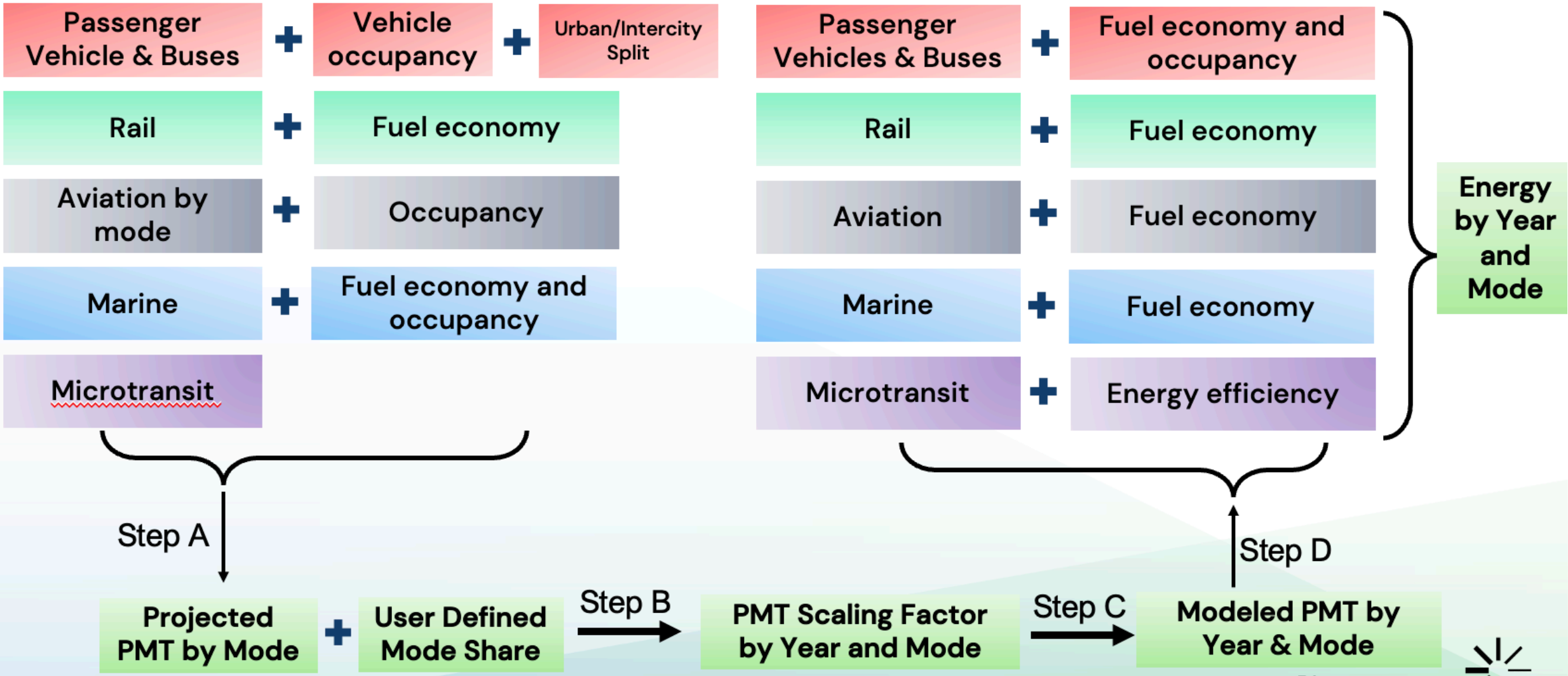
- **Publications or e-bike/e-scooter specs**: overall range (miles) and battery size (kWh)

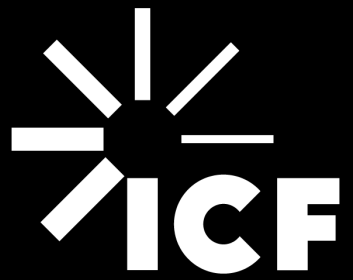
Model Integration

Model Integration and Mode Share

- To allow scenario modeling and evaluating potential impact of mode shift on transportation energy demand, the improved modeling platform allows users to use customized mode share
- Mode shares will be assigned for various modes in this modeling platform: passenger vehicles (intercity, intracity), buses, intercity rail, intracity rail, high-speed rail, commercial aviation (intrastate - business vs. leisure), eVTOL, marine, and microtransit.
- Default mode shares will be determined based on the Business-As-Usual (BAU) modeling.
- Users can input their own custom mode shares, which will influence the energy and VMT outputs for each mode.
- Mode shares will be provided as pairwise inputs (x% of Passenger Miles Traveled (PMT) is transferred from mode A to mode B). It is up to the user's discretion to modify these values; there won't be a mode choice model to determine the mode shares.

Model Integration and User-Defined Mode Share





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