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INTEGRATING VEHICLE CONSUMER CHOICE IN TIMES MODELS: US & CALIFORNIA

OVERVIEW OF THE PRESENTATION

- Background and Motivation
- Brief overview of COCHIN-TIMES stand-alone model
- Integration of COCHIN approach in full TIMES models (US-TIMES & CA-TIMES)
- Effect of statewide policies on the nationwide consumer preferences
- Concluding Thoughts

BACKGROUND AND MOTIVATION

- Develop improved models for analyzing the impact of policies related to climate change
- These involve alternative future energy pathways that rely on introduction of new technologies (over the long term, eg. to 2050)
- Specific target: Bottom-up energy models that use linear optimization (eg. MARKAL/TIMES)
  - They have high level of detail on technology performance and costs
  - But, fall short in producing realistic consumer response to alternative future market scenarios
- Objective: Integrate consumer choice aspects from a discrete choice model in TIMES model

DISCRETE CHOICE MODELS

- Discrete choice models have been widely used in the fields of transportation, energy, and marketing
- Choice probabilities are derived from utility maximizing behavior
- Represents demand side in detail, but supply side is poorly represented

COCHIN-TIMES MODEL

COnsumer CHoice INtegration in TIMES

BRIEF OVERVIEW OF COCHIN-TIMES MODEL

- Stand alone light-duty vehicle nationwide model (cars and trucks)
- 12 vehicle technologies (consists of conventional vehicles, hybrids, plugins, BEVs, FCV)
- Consumer preference attributes are based off of MA3T market simulation model developed by Oak Ridge National Laboratory

STEPS TO INTRODUCE CONSUMER BEHAVIOR

1 RECOGNIZE THAT PEOPLE HAVE DIFFERENT PREFERENCES AND ATTRIBUTES

- Consumer segmentation: Demand is divided into 36 groups
  - Driving profile (low, medium and high annual VMT)
  - Risk attitude (early adopter, early majority and late majority)
  - Recharging infrastructure (combinations of home and work access)

STEPS TO INTRODUCE CONSUMER BEHAVIOR

2 QUANTIFY THE DIFFERENCES

- The ‘inconveniences’ are estimated in the form of disutility costs
  - Range limitation cost (for BEVs)
  - Refueling inconvenience cost
  - Risk premium
  - Model availability cost
  - Home charger installation cost

These costs when added to vehicle and fuel costs in the model becomes a ‘cost minimization’ problem we have in MARKAL/TIMES

Utility maximization = cost minimization

STEPS TO INTRODUCE CONSUMER BEHAVIOR

3

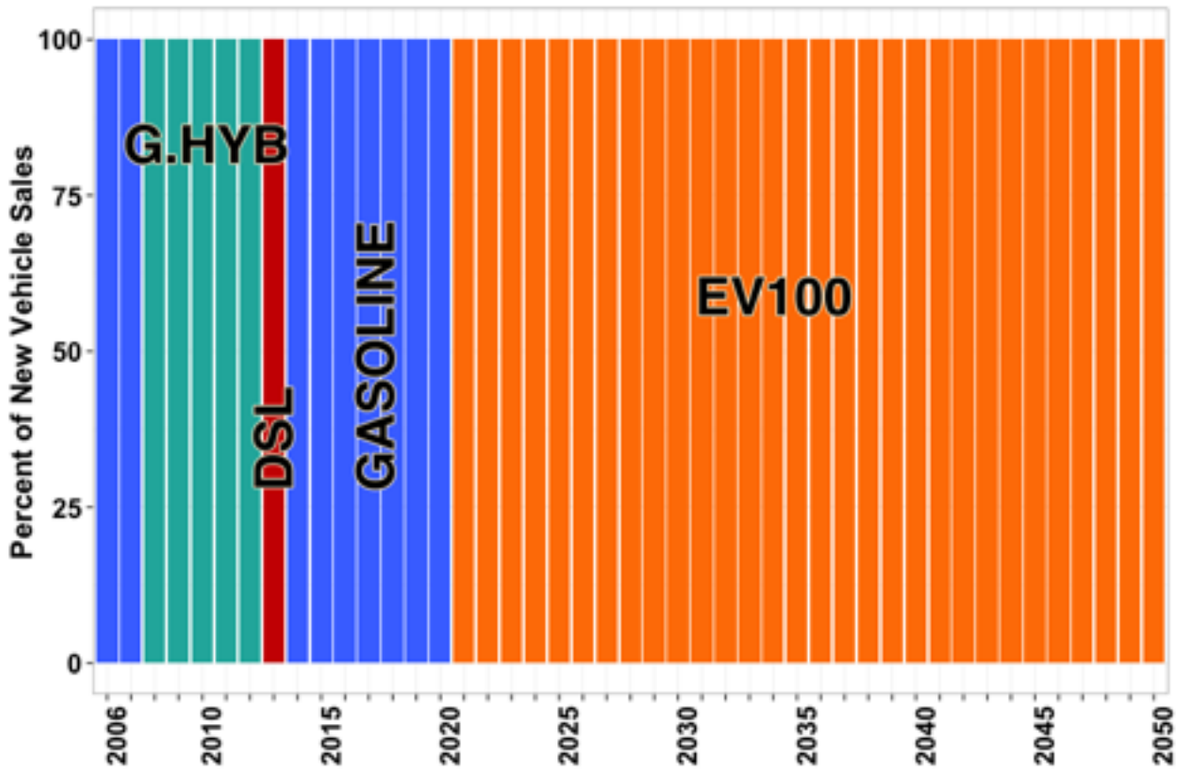
BUT THERE'S MORE!* WHAT ABOUT UNOBSERVABLE DIFFERENCES?

**If you want to be really really precise!*

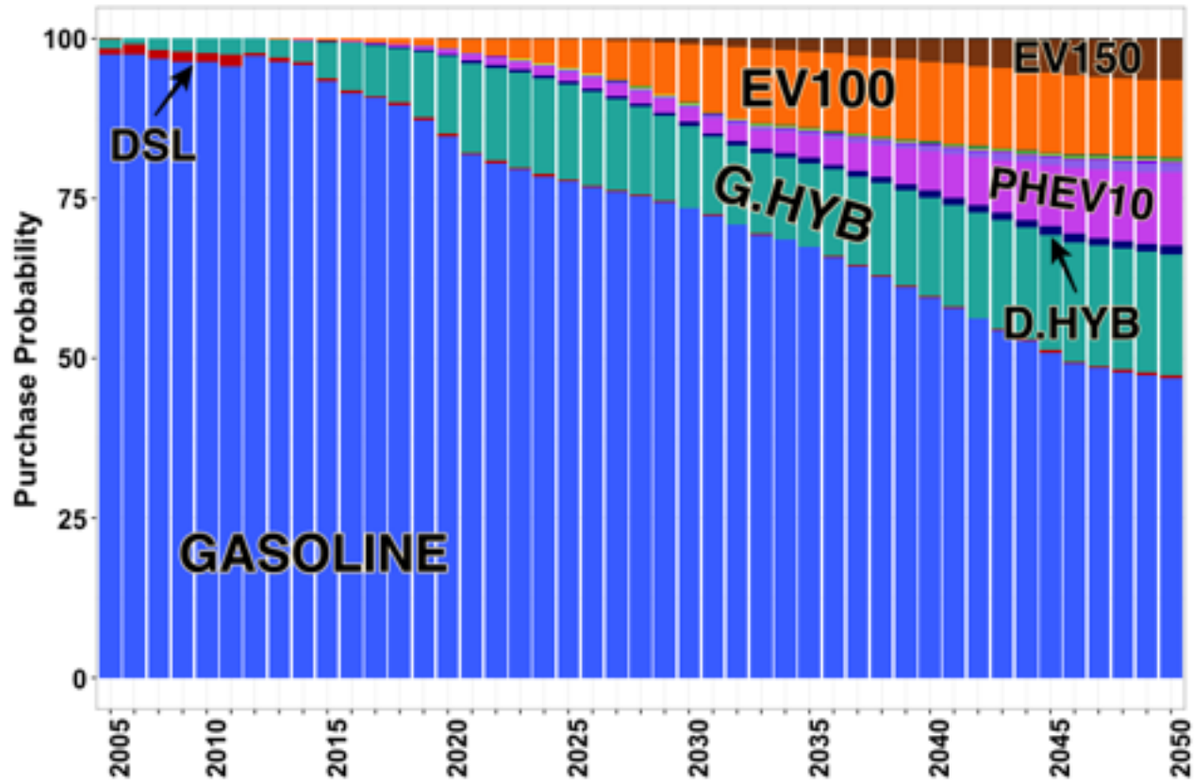
- Discrete choice model recognizes that the researcher cannot determine all the attributes of the agent who is making the decision
- Utility = Deterministic component + Unobservable differences
- Unobservable differences are error terms generated randomly from a probability distribution based on your choice of the discrete choice model (logit, nested logit, etc.)
- The consumers are further disaggregated into different clones within each group and these error terms are added as additional cost to capture the unobservable heterogeneity

COMPARISON OF NEW VEHICLE SALES SHARE RESULTS

STANDARD TIMES MODEL



COCHIN-TIMES MODEL



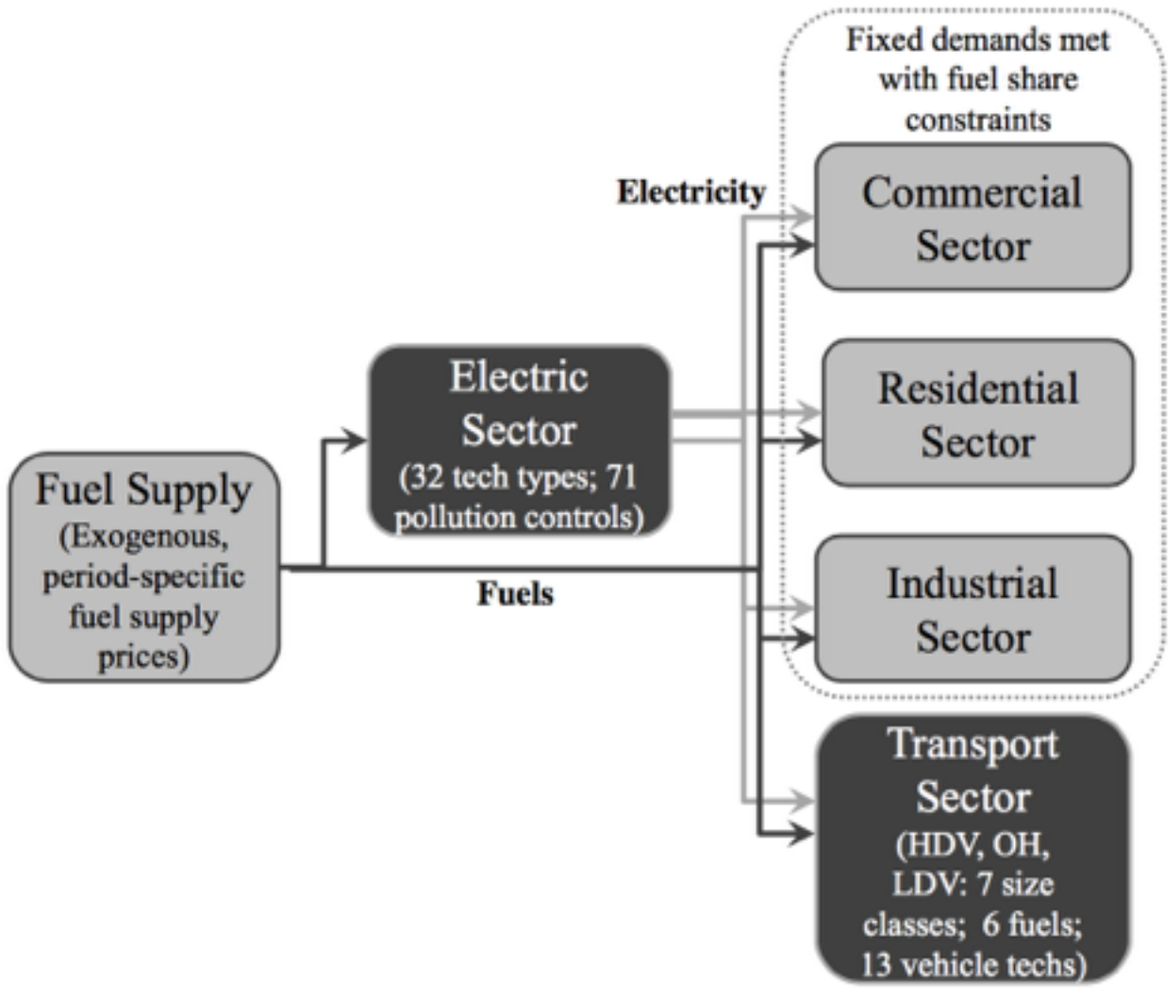
- Standard TIMES model is run “freely” – without any hurdle rates, market share or growth constraints.
- COCHIN-TIMES model reproduces MA3T model’s reference case scenario without “tweaking” the model with constraints

IMPLEMENTATION IN FULL TIMES MODELS

- COCHIN approach is implemented in US-TIMES and CA-TIMES models in the light-duty vehicle sector
- Two-fold objective
  - Enhance the LDV behavioral representation of these models
  - Soft-link US-TIMES-COCHIN and CA-TIMES-COCHIN models to capture change in nationwide consumer purchase preferences due to statewide policies

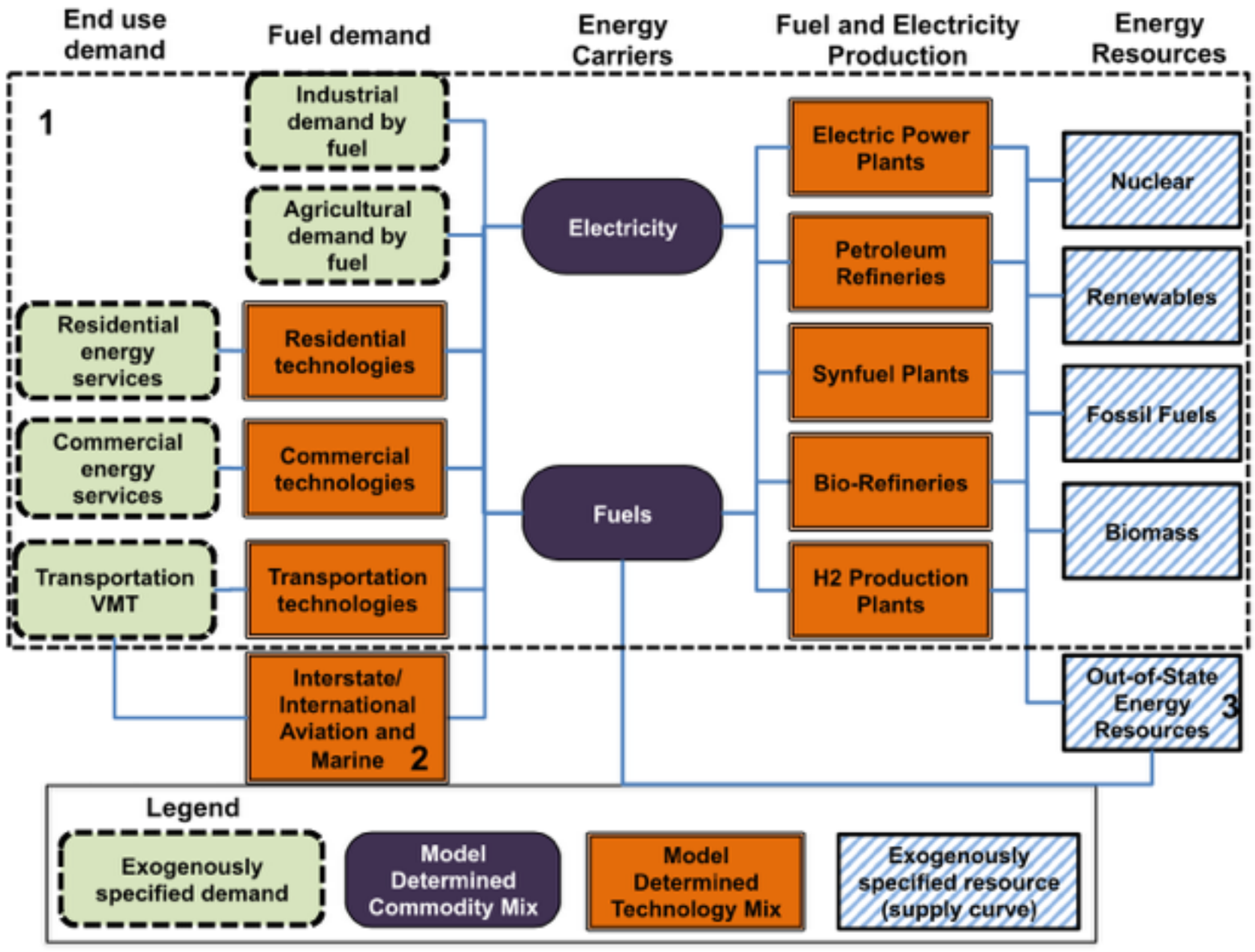
US-TIMES MODEL

SCHEMATIC OF US-TIMES



- Developed by North Carolina State University. Aggregated nationwide model, does not have subregions
- Baseline policies: Renewable portfolio standards for electricity generation, Fuel economy standards for vehicles, NOx and SOx pollution limits for electricity sector, renewable fuel standards (biofuel availability)

CA-TIMES MODEL



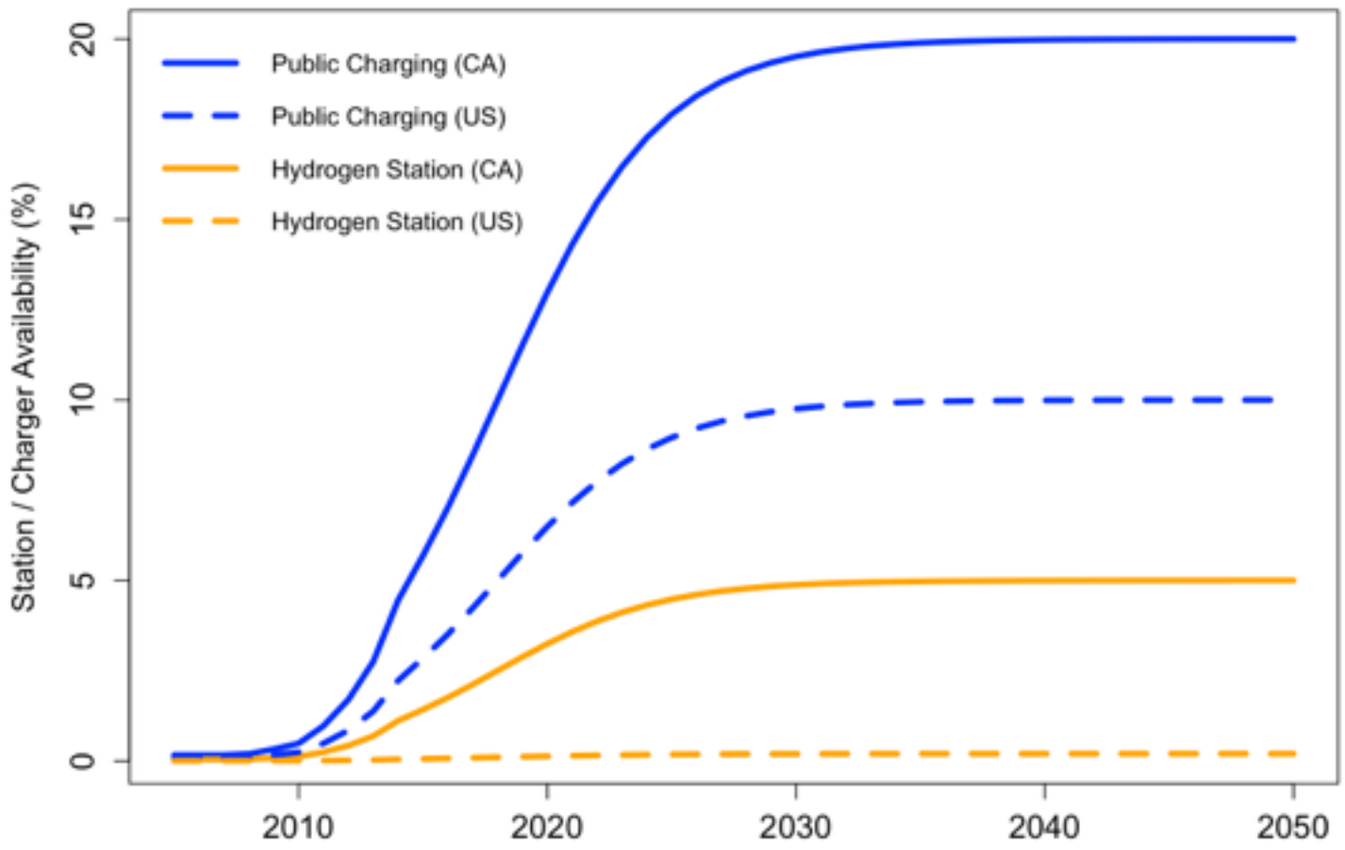
- Developed by ITS Davis. Has a more detailed supply and demand sectors than US-TIMES.

- Scenarios: BAU (fuel economy standards, renewable portfolio, low carbon fuel standards, zero emission vehicle mandates, tax credits, subsidies), and a GHG scenario (80% reduction of 1990 GHG emissions level by 2050).

ADDING COCHIN COMPONENT TO THESE MODELS

- Standardize the vehicle technologies in CA-TIMES and US-TIMES (same technologies that are used in COCHIN stand-alone model are used, E85 flex-fuel vehicles are added)—costs and efficiencies are the same

- Demand is divided into 36 consumer segments. Model is run with 10 cloner per segment

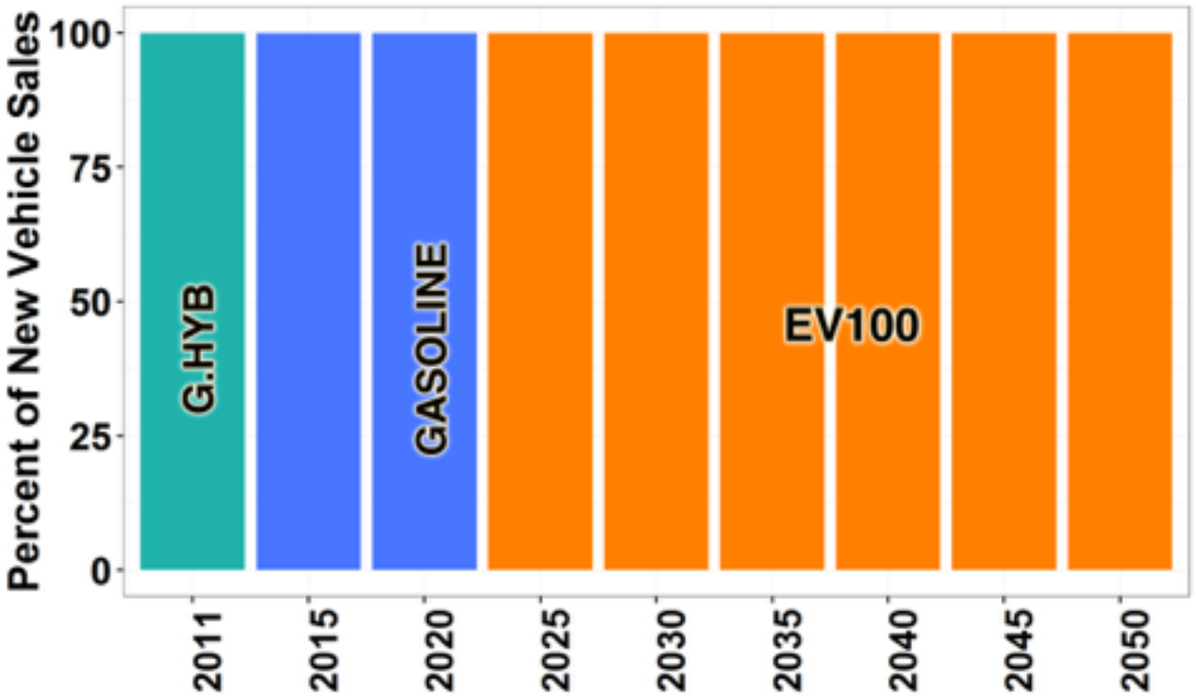


- Here, availability refers to the probability of finding a station when you need it. Typically, higher density of stations –> more availability

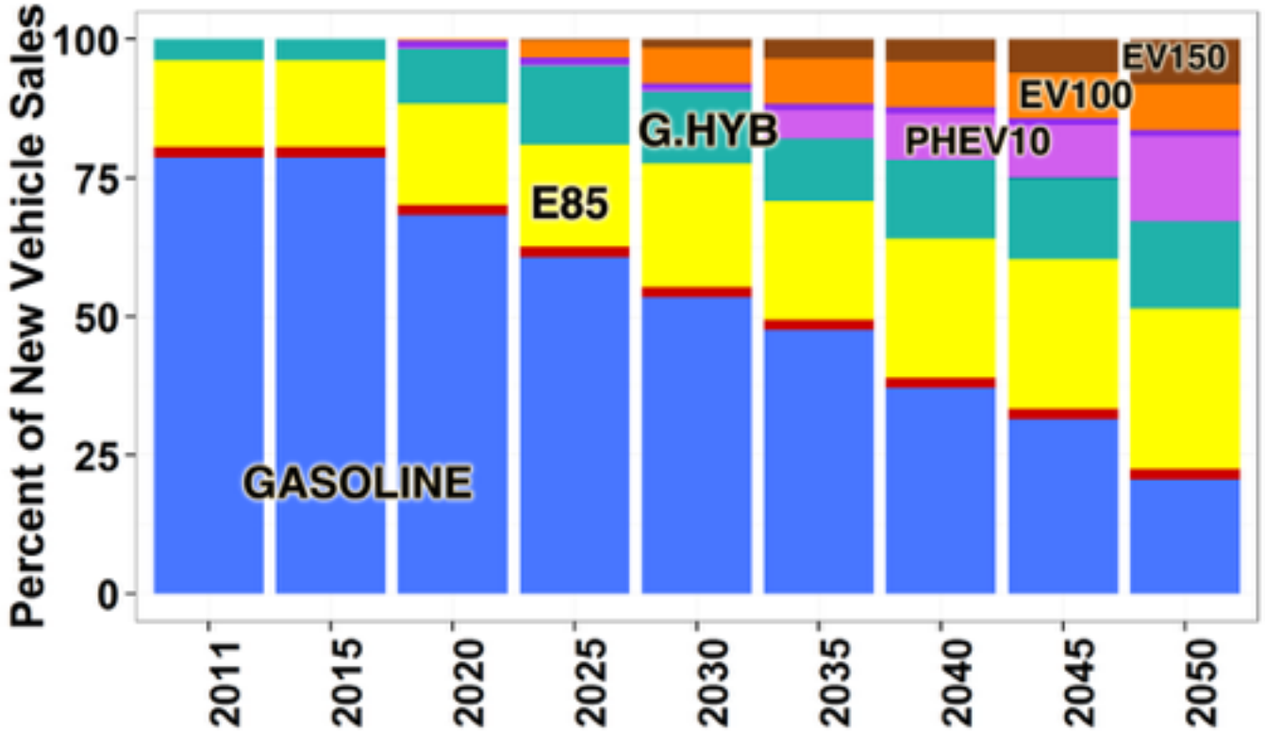
- These influence the range limitation and refueling inconvenience disutility costs

RESULTS OF BASELINE SCENARIO (NEW VEHICLE SALES SHARE)

US-TIMES



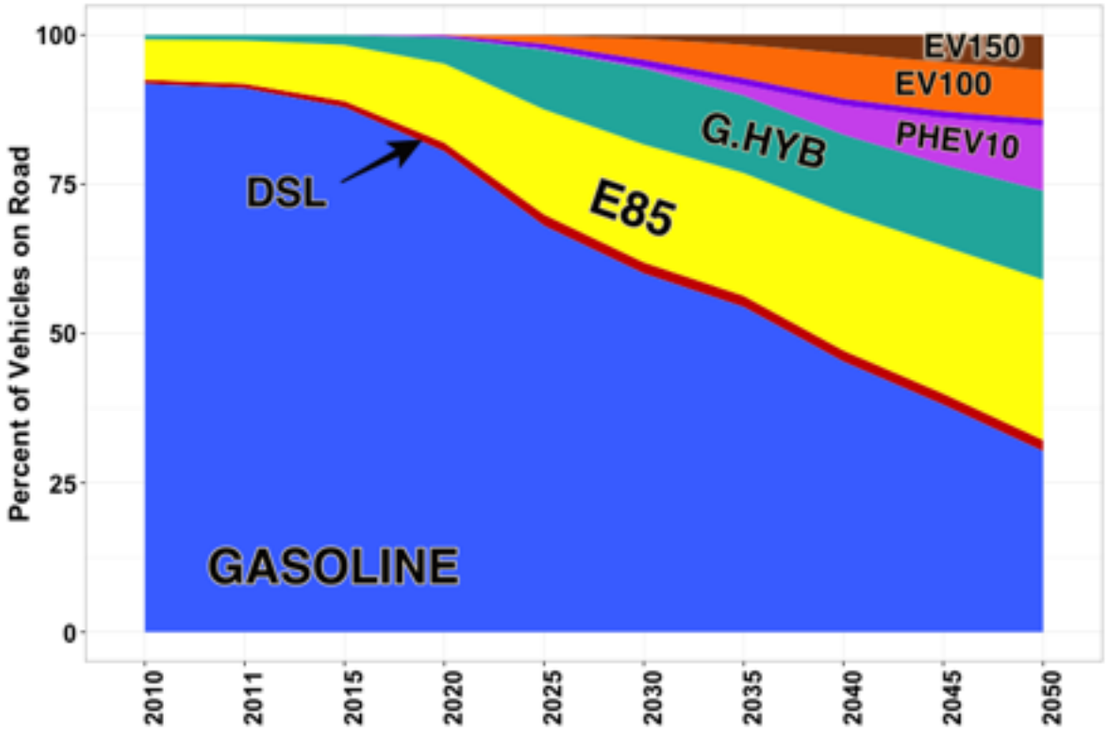
US-TIMES-COCHIN



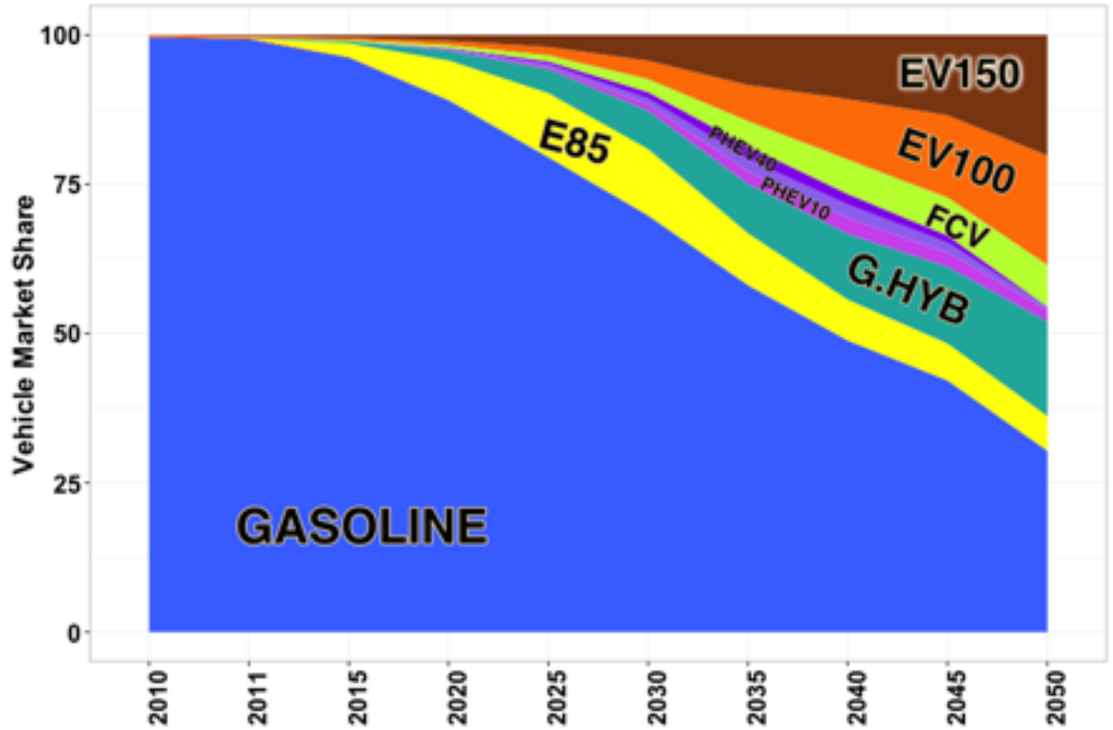
- US-TIMES model is run without market share, hurdle rates or growth constraints
- US-TIMES-COCHIN model shows more diversity of vehicles adopted (the outcome is similar to COCHIN-TIMES stand alone model)—the only additional technology being E85 flex fuel vehicles

RESULTS OF BASELINE SCENARIO (VEHICLE MARKET SHARE)

US-TIMES-COCHIN



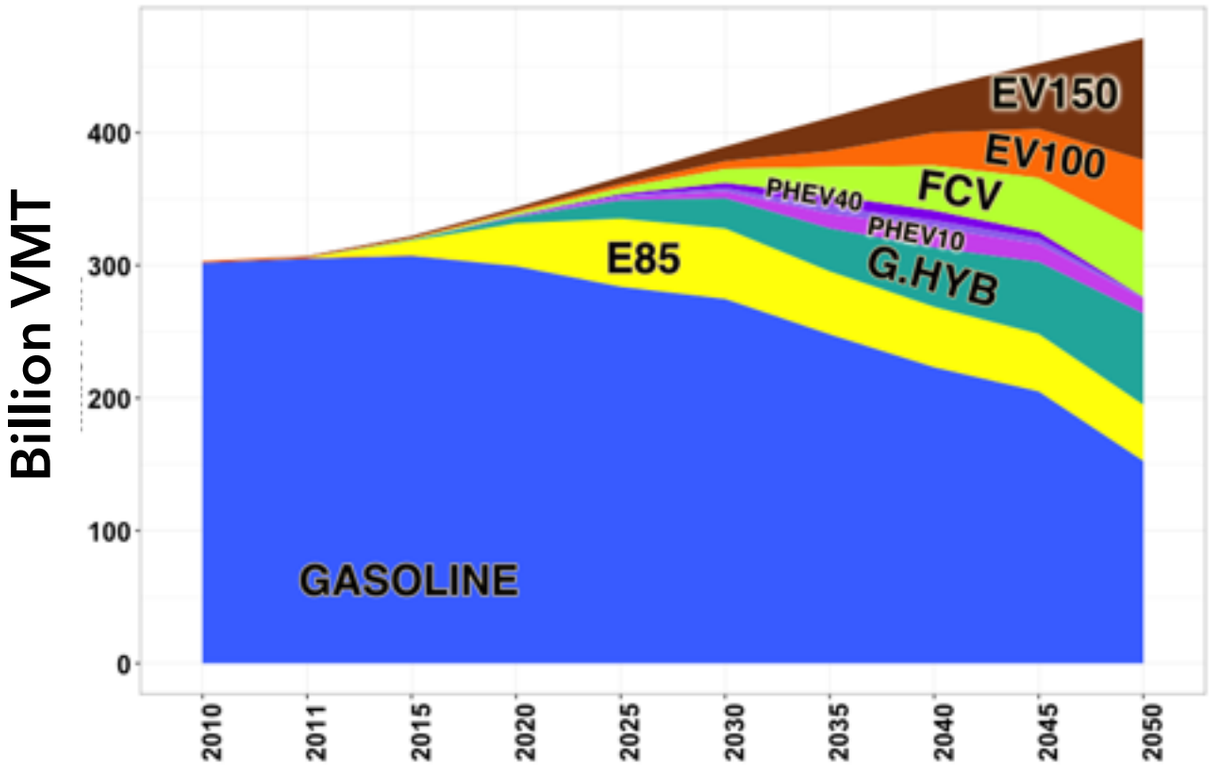
CA-TIMES-COCHIN



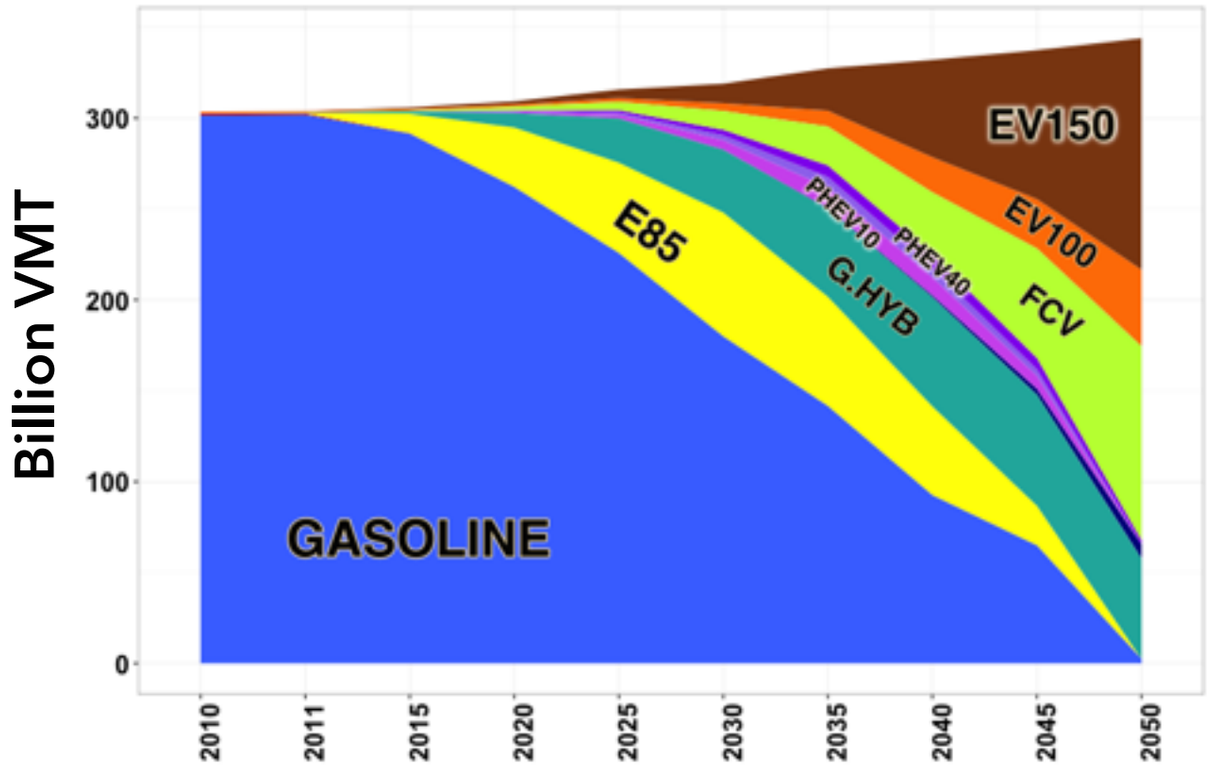
- In CA-TIMES-COCHIN model, we see more adoption of fuel cell vehicles and battery electric vehicles, mainly due to infrastructure availability (and ZEV mandates & subsidies in the early years)

RESULTS OF CA-TIMES-COCHIN (BAU VS. GHG)

CA-TIMES-COCHIN (BAU)



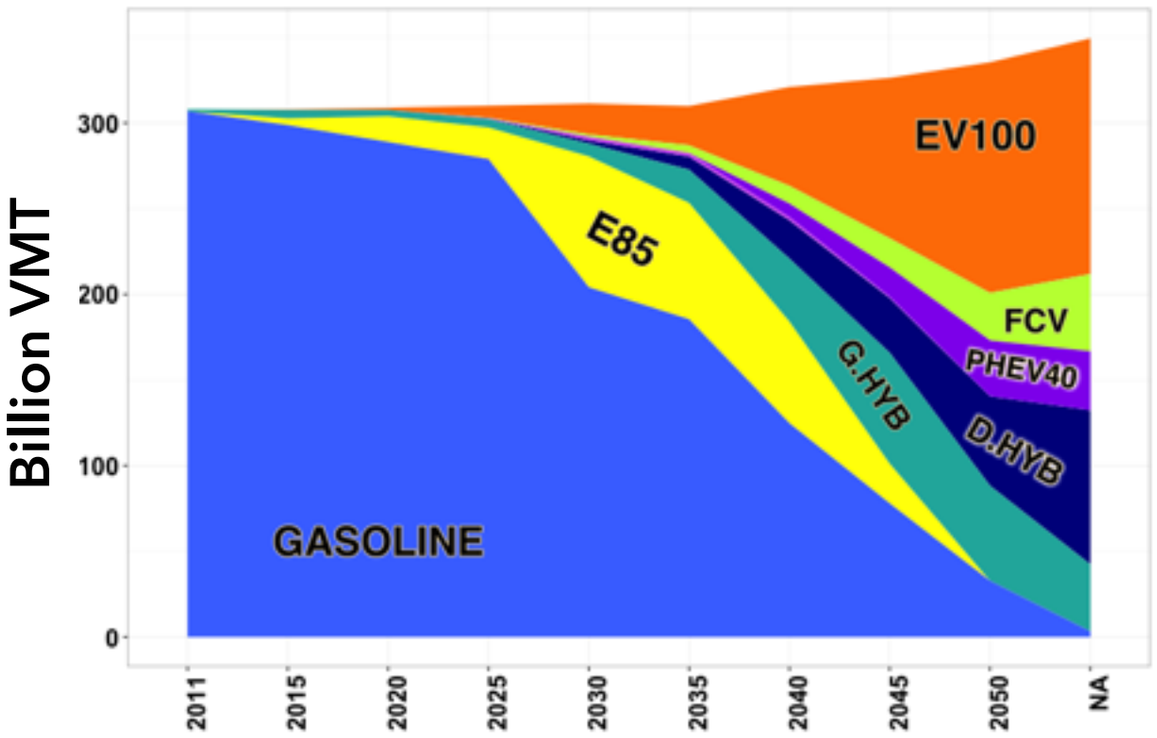
CA-TIMES-COCHIN (GHG)



- Notice GHG scenario has lower VMT demand as one of its policies.
- Under GHG scenario, there is more investment in fuel cell vehicles and battery electric vehicles, but more gasoline hybrid vehicles enter the market to meet the target.

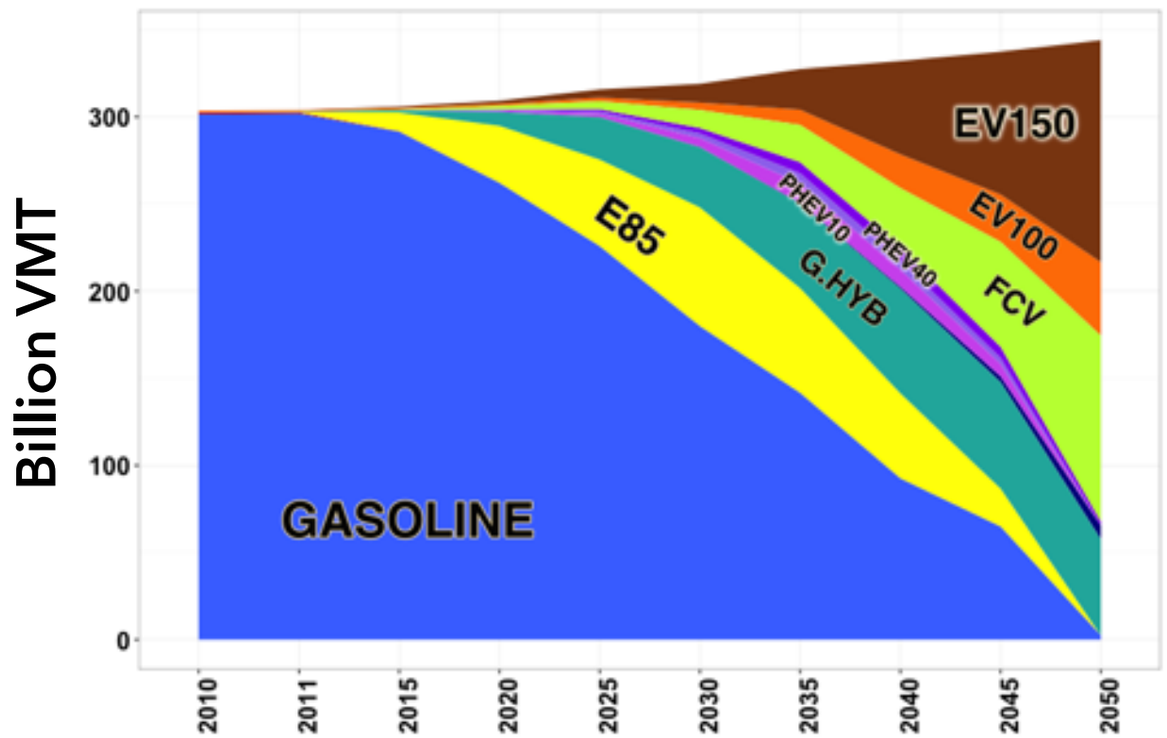
FOR COMPARISON. . . .

CA-TIMES (GHG)



No Consumer Behavior. Model run with growth rates, market share constraints and hurdle rates.

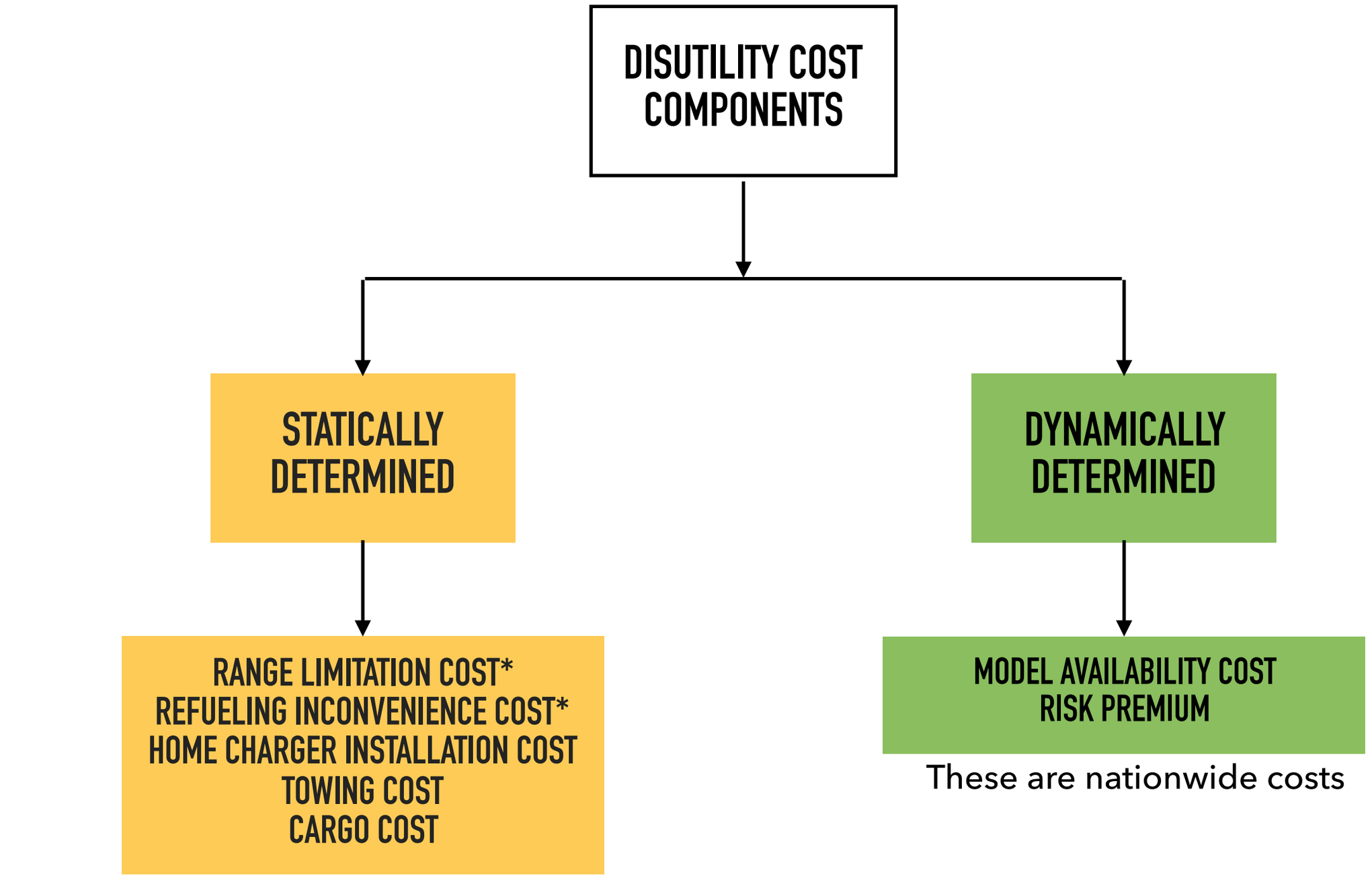
CA-TIMES-COCHIN (GHG)



- Carbon cap is still a strong factor in determining the reduction of conventional vehicles.
- In the model without consumer behavior, it invests in a significant amount of 100-mile range EVs, because there is no “range anxiety” component

SOFT-LINKING CA & US TIMES MODELS AND CAPTURING CHANGES IN CONSUMER PREFERENCES

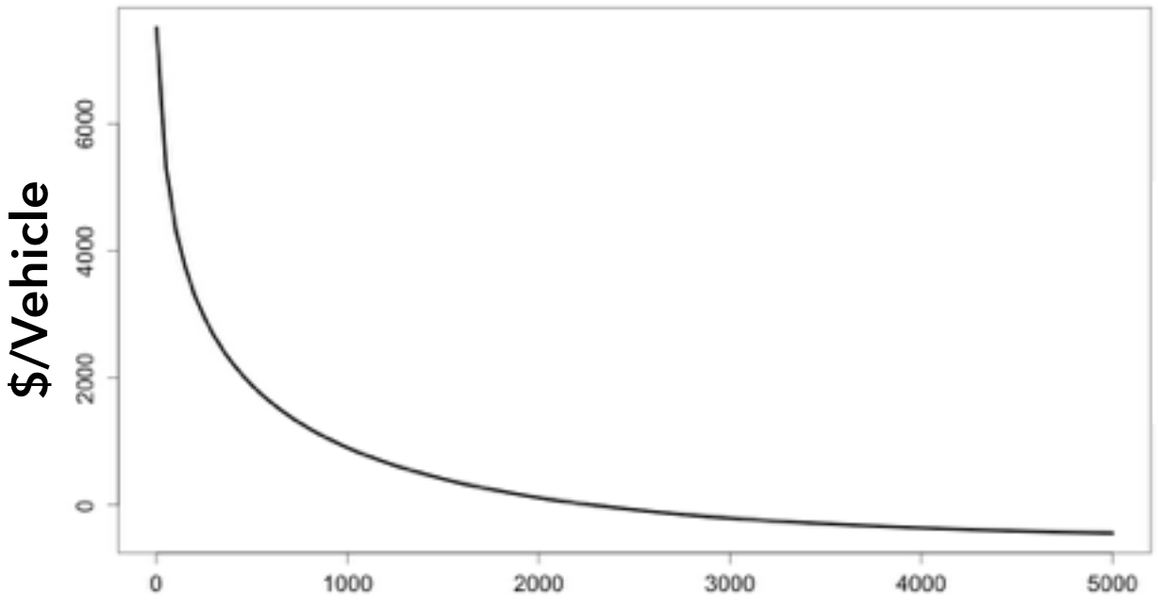
DISUTILITY COST COMPONENTS



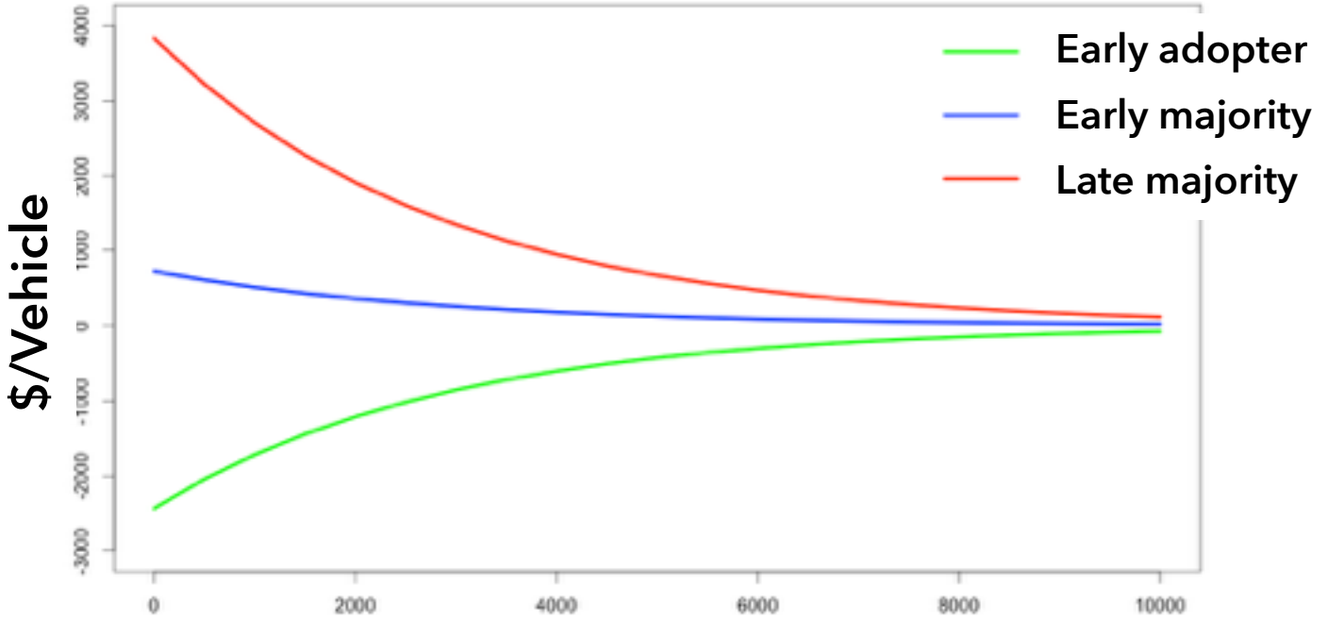
*If infrastructure availability is endogenized, these can be dynamically determined.

MODEL AVAILABILITY COST AND RISK PREMIUM

MODEL AVAILABILITY COST

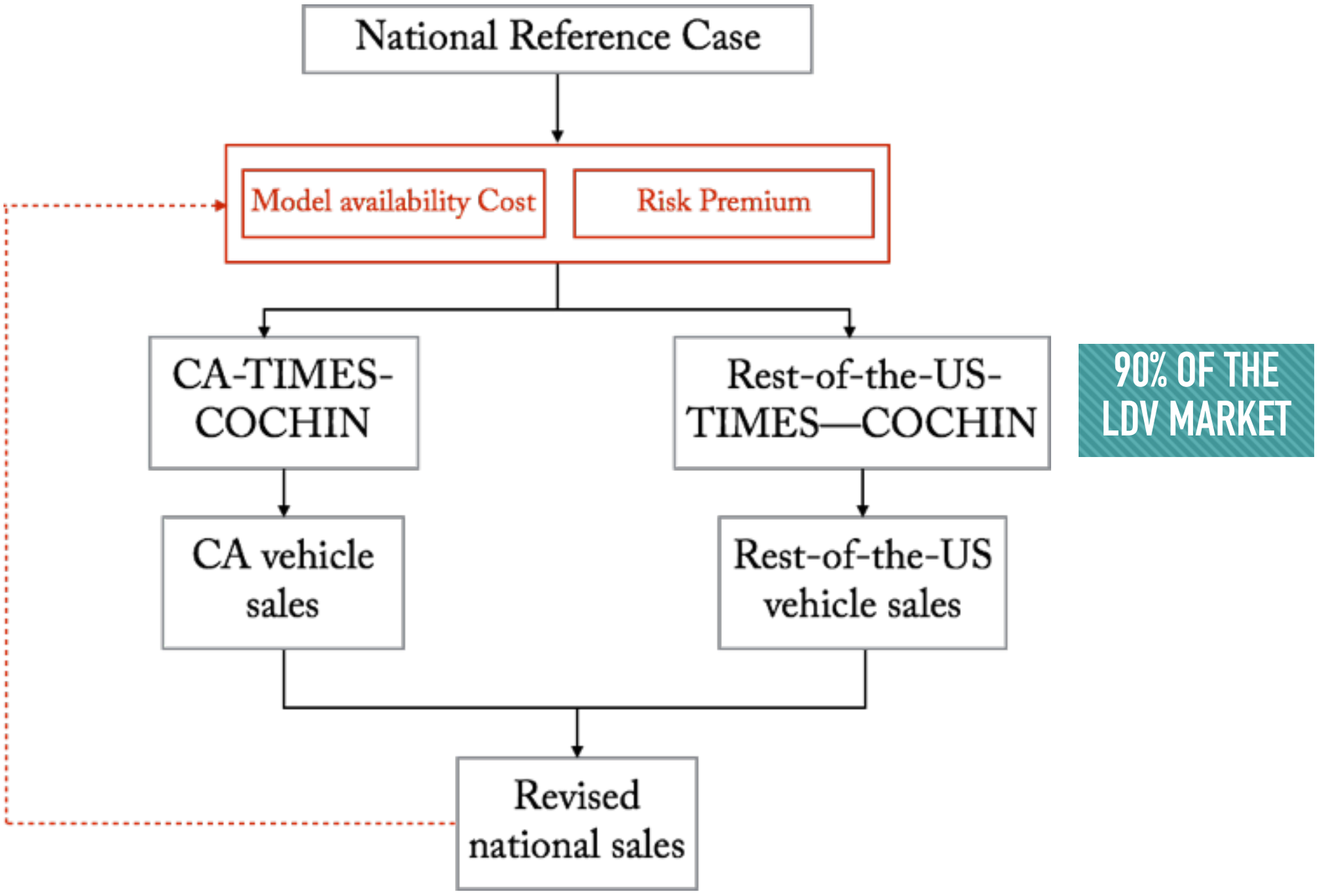


RISK PREMIUM



- Model availability quantifies the preferences based on make and model diversity of vehicle technologies
- Risk premium quantifies the ‘newness’ of the vehicles
- Both model availability and risk premium tends to become zero as more fleet enters the road. This is called the ‘legitimization point’.

SOFT-LINKING US-TIMES-COCHIN AND CA-TIMES-COCHIN

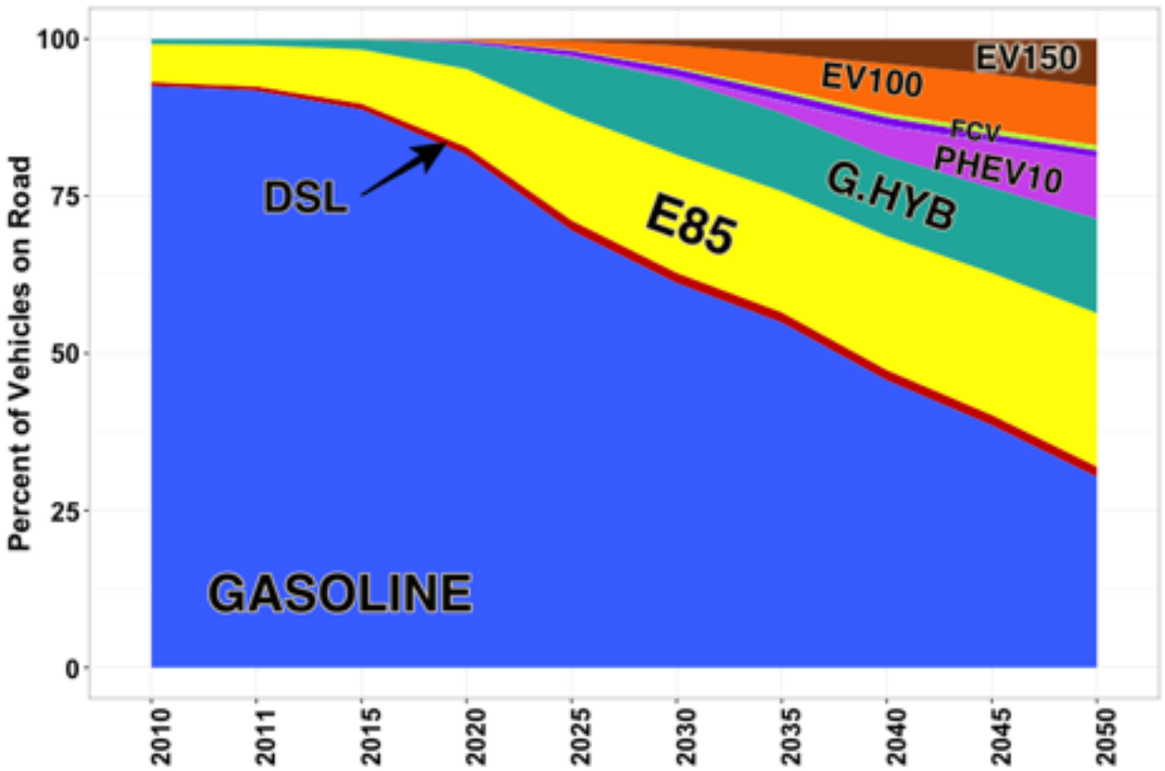


90% OF THE LDV MARKET

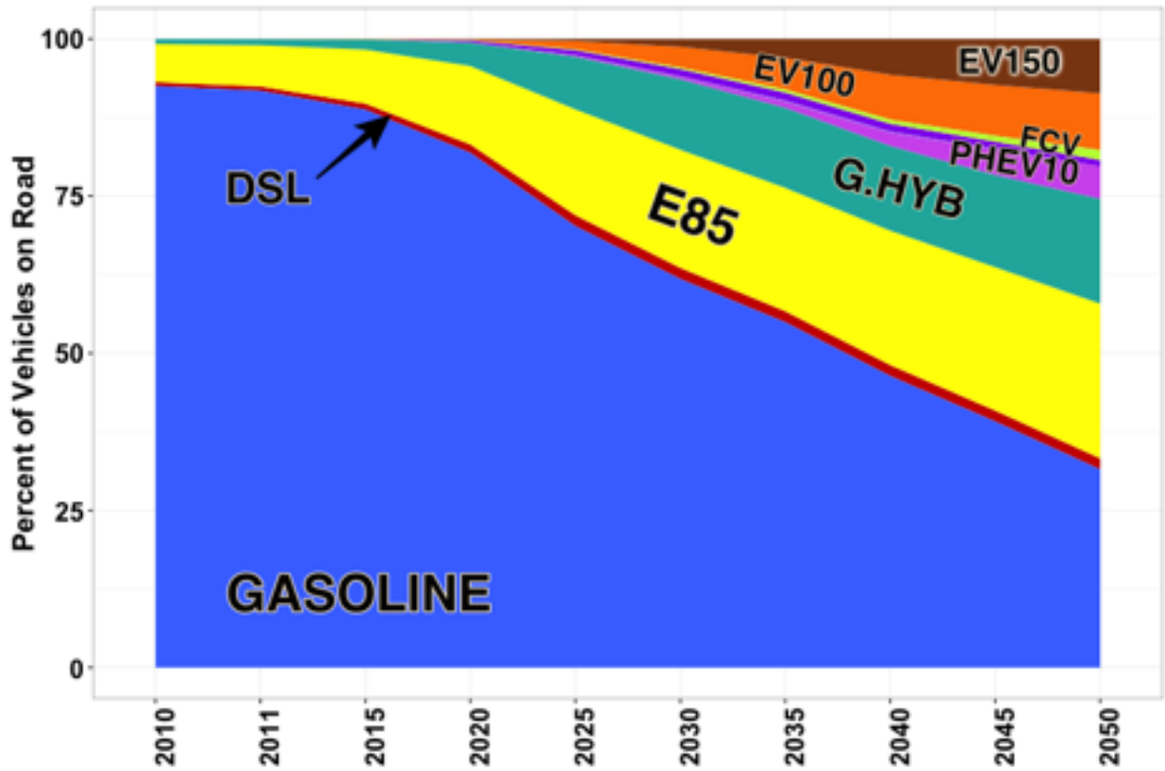
- To capture changes in consumer preference due to statewide sales of vehicle technologies
- Assumption: CA market is about 10% of the national LDV market

US-TIMES-COCHIN (INITIAL ITERATION VS. FINAL ITERATION)—CA BAU CASE

INITIAL RUN



FINAL ITERATION

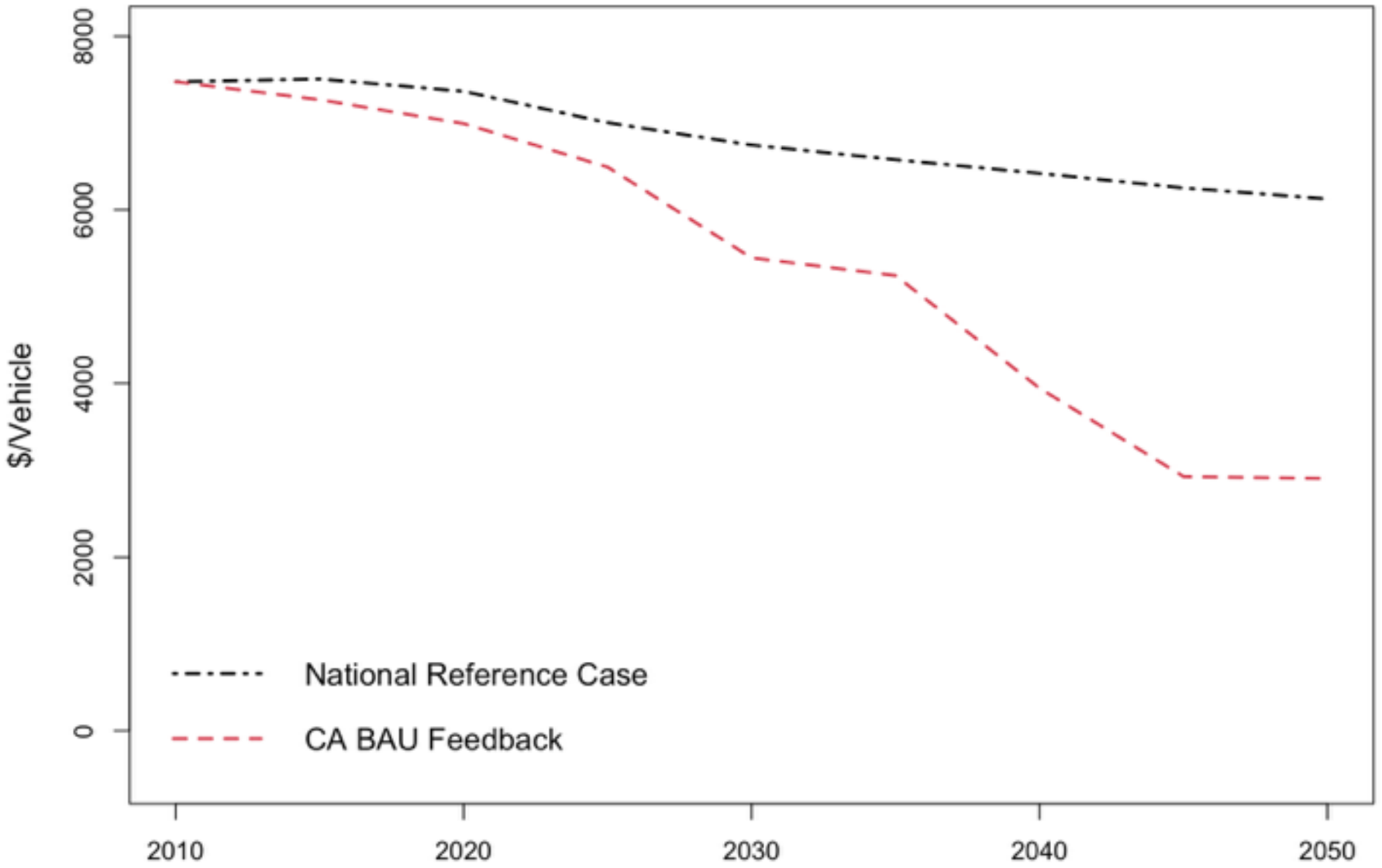


FCV ↑ BEV ↑ PHEV ↓

- This is because of the chain reaction:

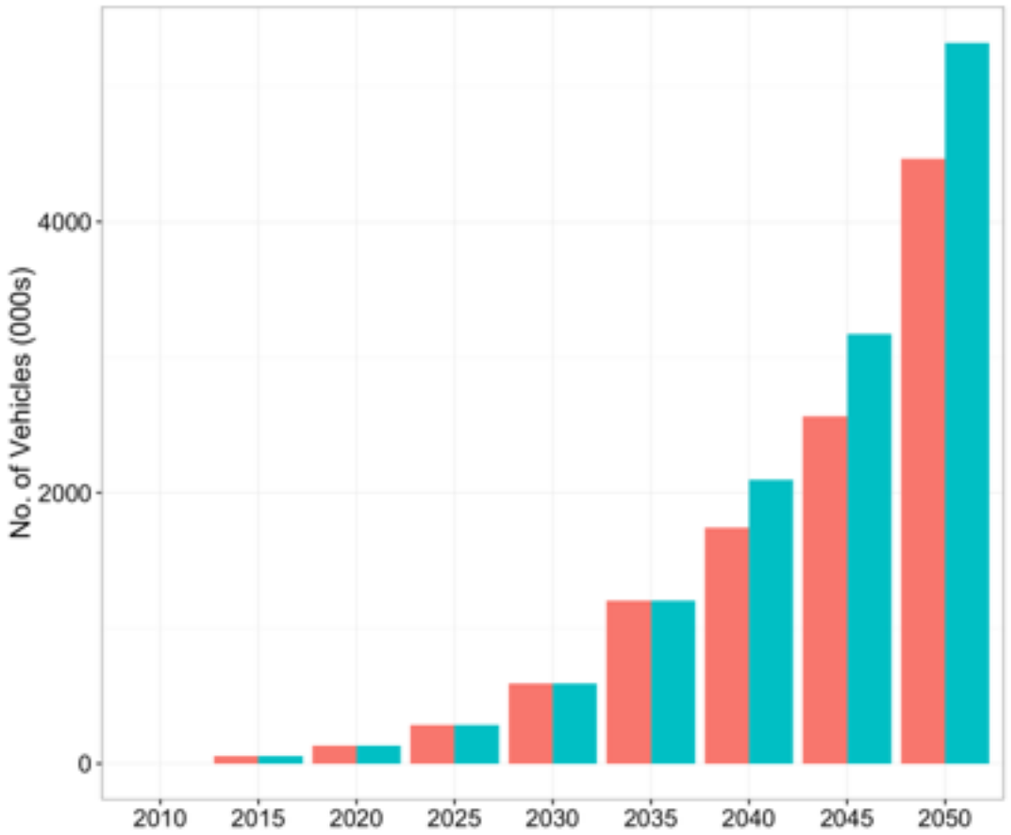
Increased Presence of FCV & BEV in US Market → Reduction in disutility costs → Increase in CA FCV sales → (back to Increased Presence of FCV & BEV in US Market)

MODEL AVAILABILITY COST TRAJECTORY (FCV)

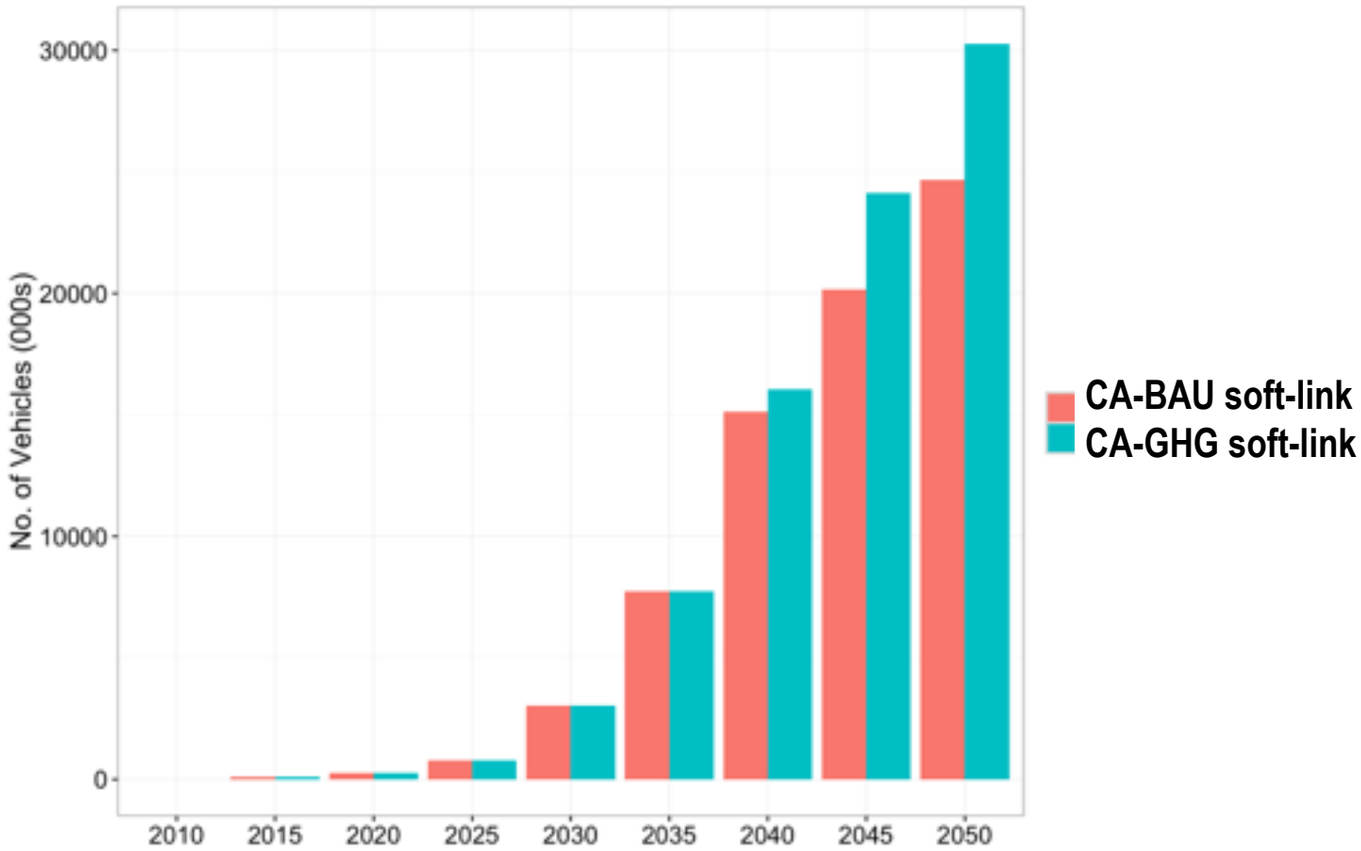


NATIONWIDE RESULTS OF SOFT-LINK BETWEEN CA-TIMES-COCHIN (GHG) AND US-TIMES-COCHIN

CUMULATIVE SALES IN THE US: FCV

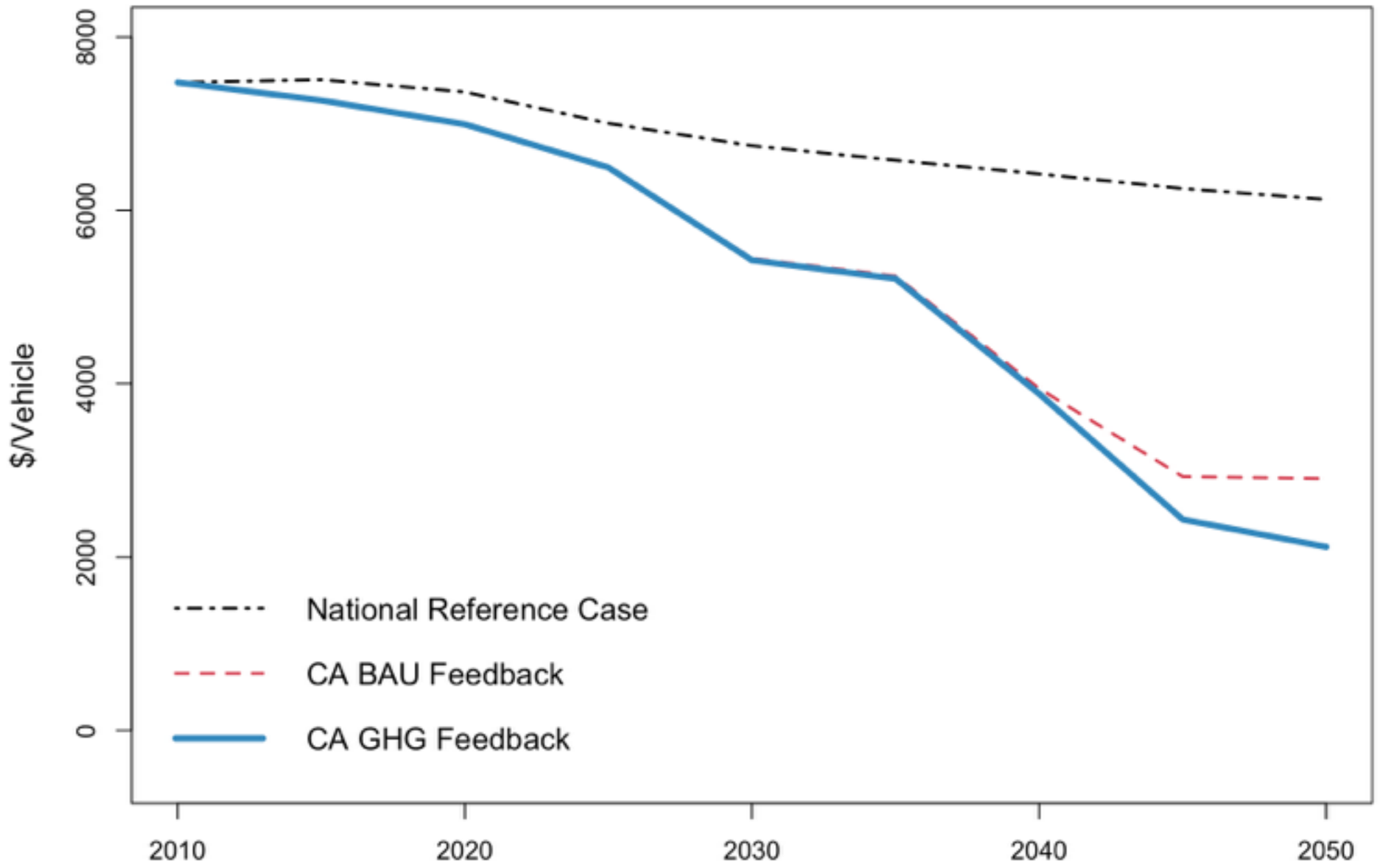


CUMULATIVE SALES IN THE US: BEV-150

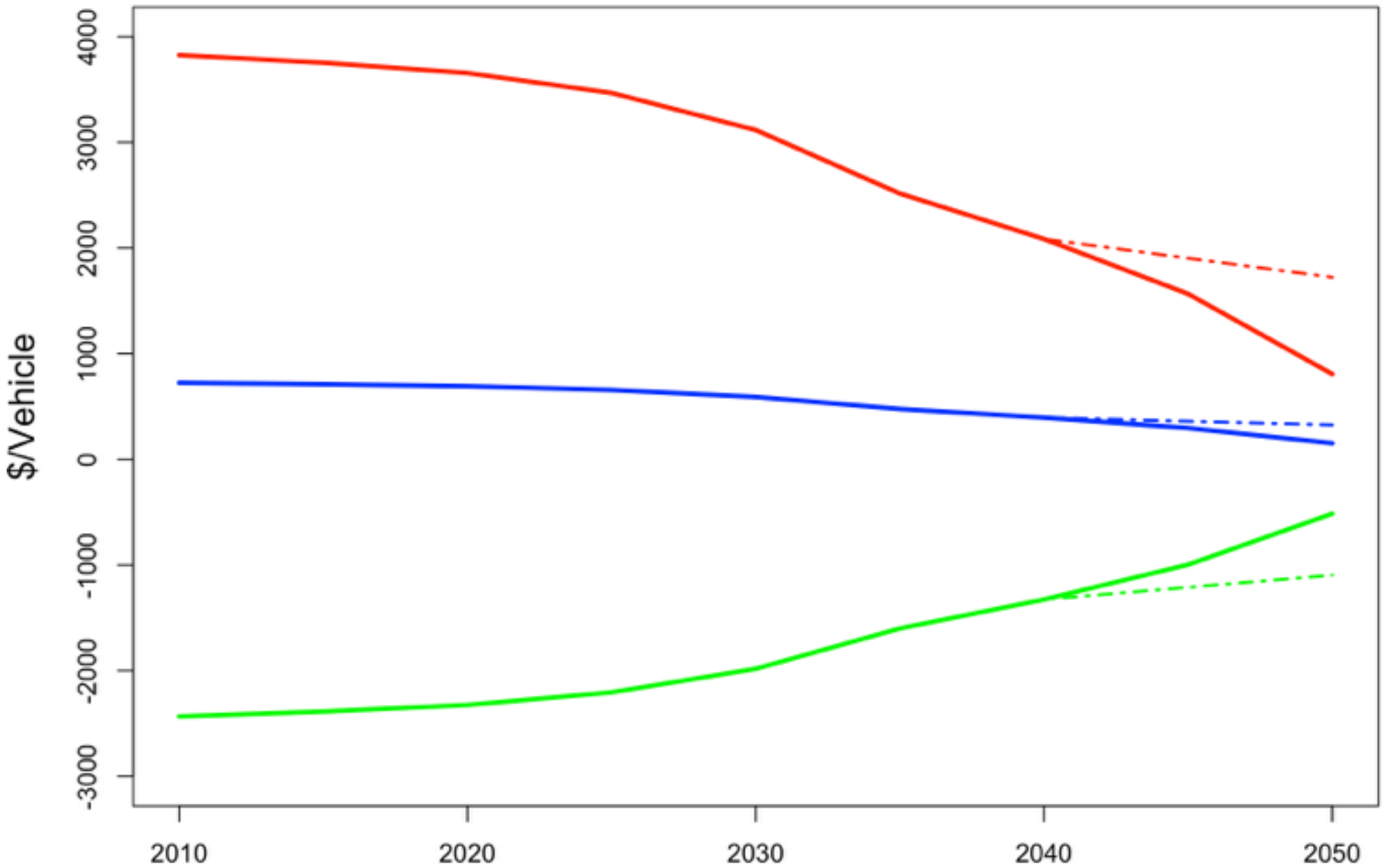


- Similar runs are performed for the soft-link between CA-GHG scenario and US-TIMES-COCHIN model.
- There is increase in FCV and BEV sales in the nationwide model due to CA's stringent carbon cap in 2050.

MODEL AVAILABILITY COST TRAJECTORY (FCV)



RISK PREMIUM (FCV)



CONCLUDING THOUGHTS

- COCHIN approach demonstrates a novel approach to replicate consumer choice outcomes in bottom-up energy systems models
- This approach can be implemented for any sector (transportation, residential or commercial), given the comparable discrete choice model to capture preferences
- US-TIMES-COCHIN and CA-TIMES-COCHIN models show vehicle technology adoption over time based on consumer preferences– implications on other sector and sectorwide emissions
- Soft-linking both model indicates that the statewide policies can have a significant change in the national consumer preference, hence they cannot be ignored
- There are several caveats: one-car household, exogenous infrastructure trajectory, consumer preferences do not stay constant over time

REFERENCES

- Bunch, David S, Kalai Ramea, Sonia Yeh, and Christopher Yang. 2015. Incorporating Behavioral Effects from Vehicle Choice Models into Bottom-Up Energy Sector Models. Research Report – UCD-ITS-RR-15-13. Institute of Transportation Studies, University of California, Davis.
- Bunch, David S. 2015. "Simulating Random Disturbance Terms for Nested Logit Models for Use in Large Scale Energy Systems Models." Working Paper.
- Ramea, Kalai, David Bunch, Christopher Yang, Sonia Yeh, and Joan Ogden. 2016. COCHIN-TIMES: Integration of Vehicle Consumer Choice in Energy Systems Models. Manuscript in preparation
- Ramea, Kalai, David Bunch, Christopher Yang, Sonia Yeh, and Joan Ogden. 2016. Endogenizing Behavioral Effects and Infrastructure Investments in COCHIN-TIMES model and their Implications for Climate Policy Analysis. Manuscript in preparation
- Ramea, Kalai, David Bunch, Christopher Yang, Sonia Yeh, and Joan Ogden. 2016. Integrating Vehicle Consumer Choice and Soft-Linking US and California TIMES models. Manuscript in preparation

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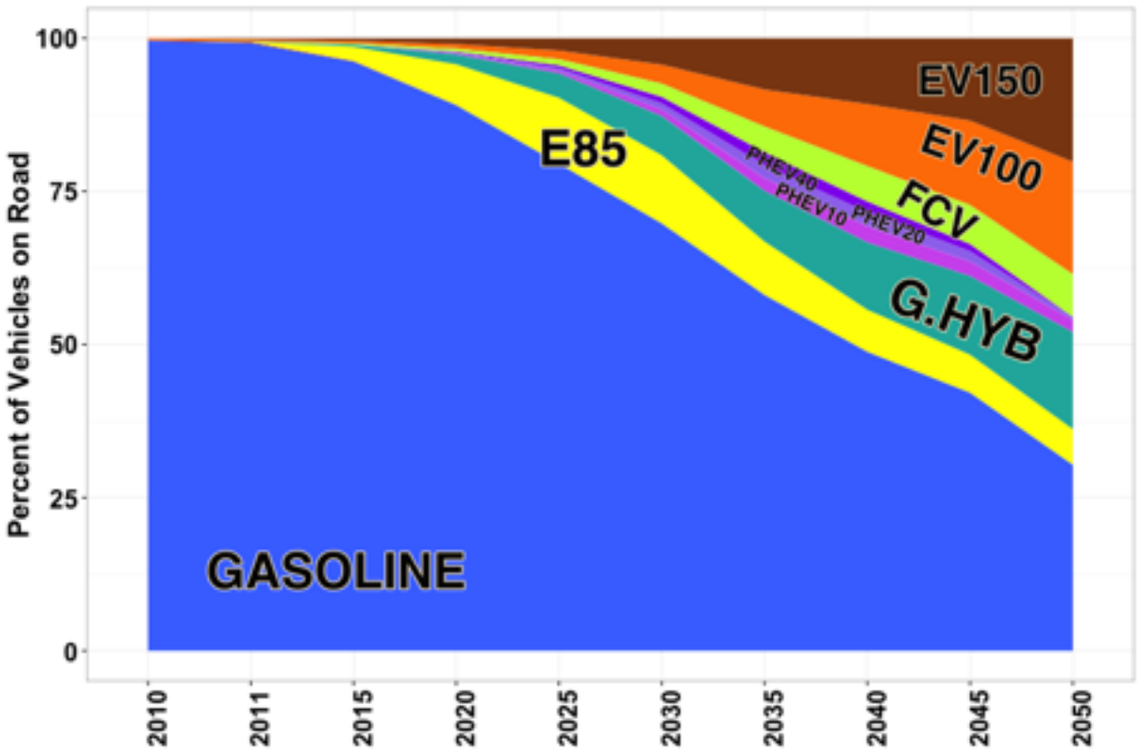
THANK YOU

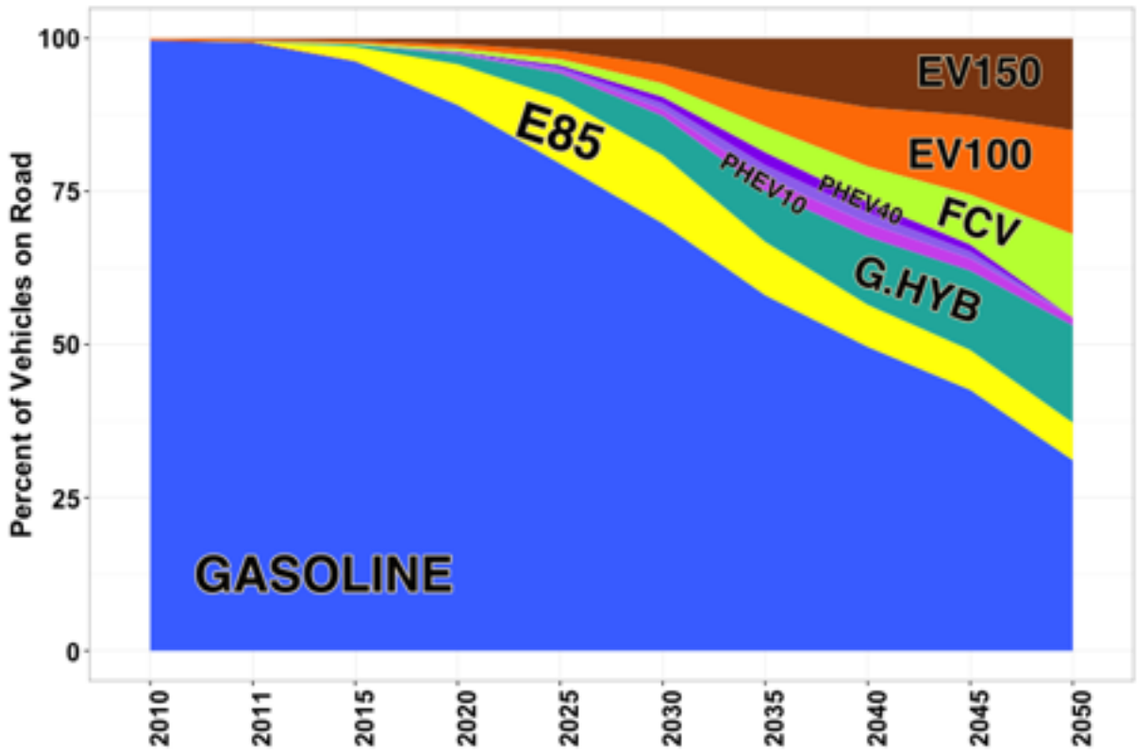
ADDITIONAL SLIDES

CA-TIMES-COCHIN (INITIAL ITERATION VS. FINAL ITERATION)—BAU CASE

INITIAL RUN



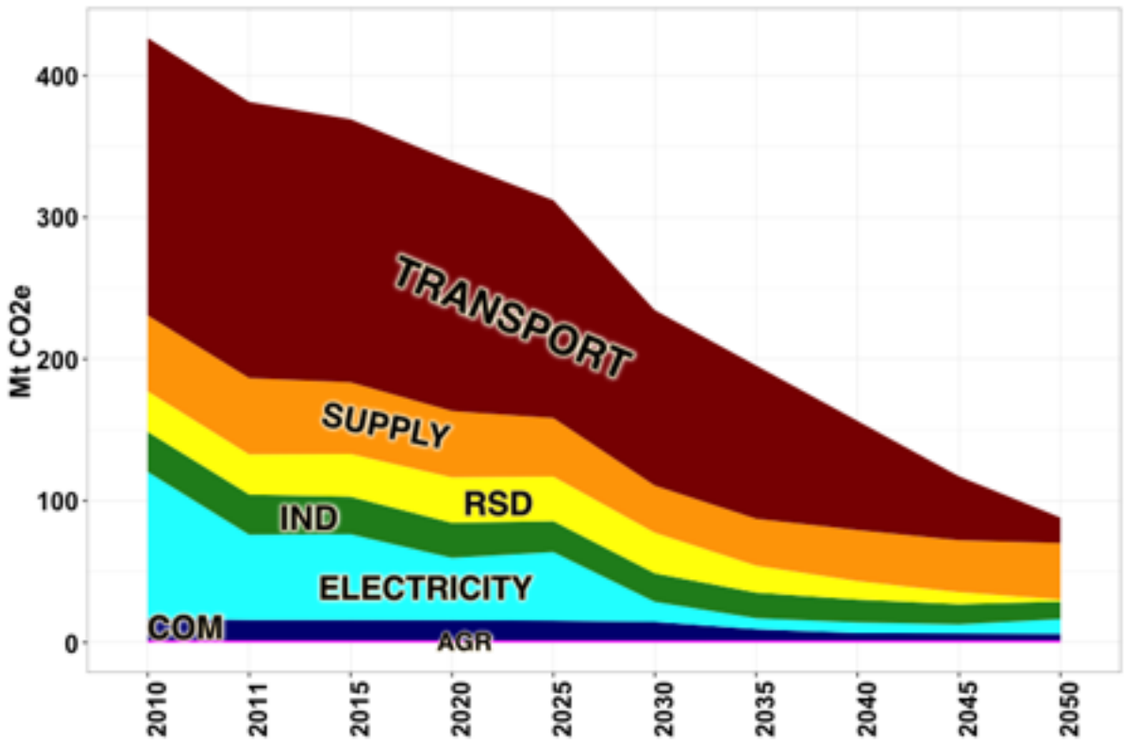
FINAL ITERATION



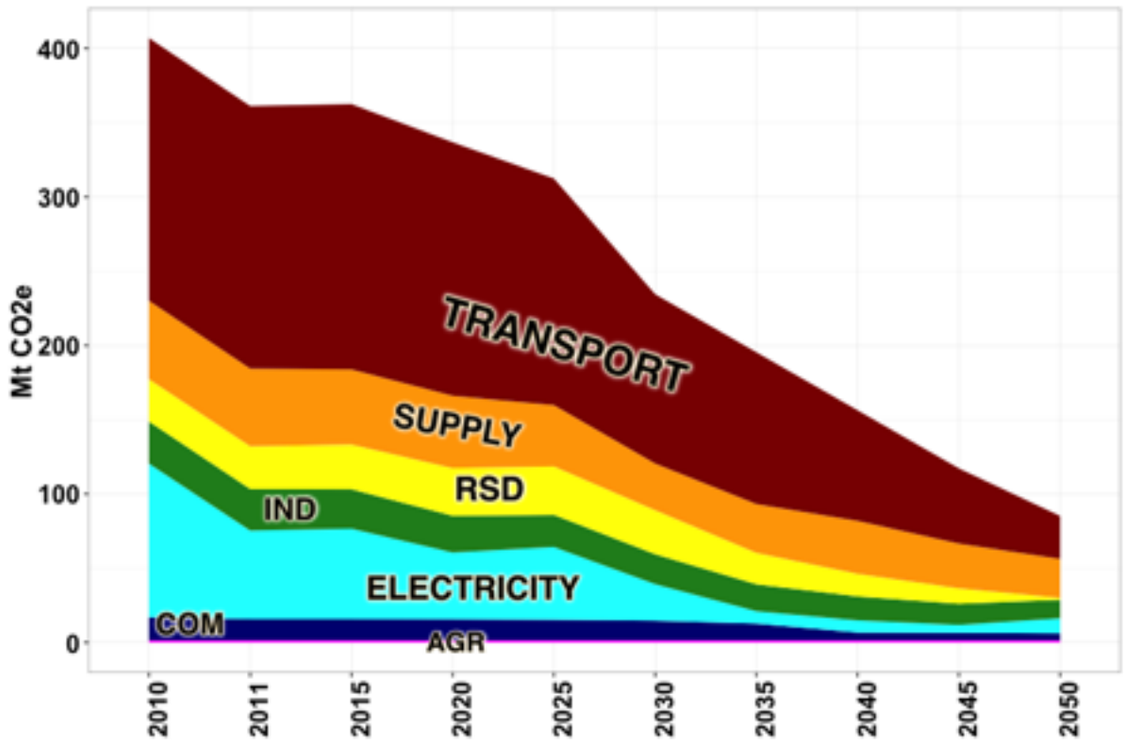
- FCV share increases towards the end of model year as the model availability cost reduces nationwide.

IMPLICATIONS ON SECTORWISE EMISSIONS

CA-TIMES-COCHIN (GHG)



CA-TIMES (GHG)



- Overall, the pattern is similar.
- There are slight differences in the transportation sector and supply sector emissions in 2050.
- Since CA-TIMES-COCHIN invests in more AFVs (alternative fueled vehicles) compared to CA-TIMES, the end-use emissions are lower in transport sector, and this allows supply sector to be flexible in reduction.