Integration of Vehicle Consumer Choice Preferences in TIMES model and their Implications on Climate Policy Analysis

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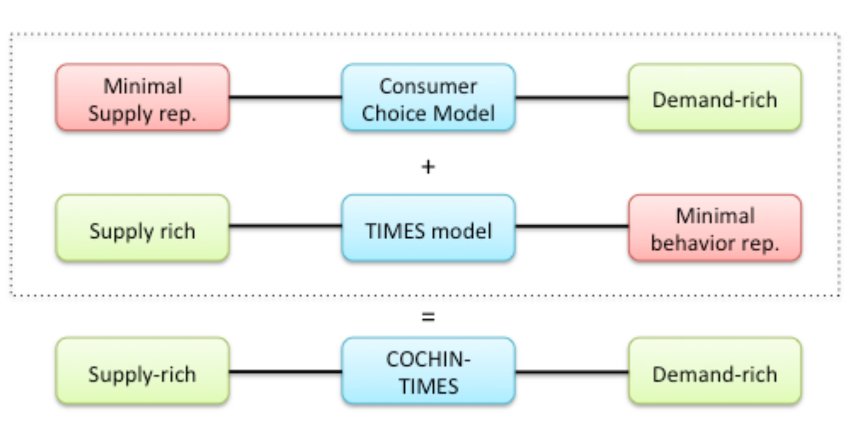
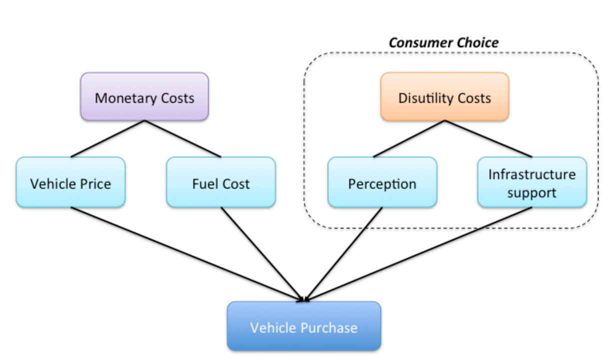
Background and Motivation

- TIMES (The Integrated MARKAL-EFOM1 System) model is an Energy–Economy–Engineering–Environment (4E) model.
- 4E models are widely used for transition scenarios for multidisciplinary subjects.
- Identifies most cost-effective pattern of resource use and technology deployment over time under various technological, behavioral, resource, and policy constraints.
- Powerful tool for policy analysis for the energy system:
  - Policy scenarios
  - 'If-Then' scenarios
  - Sensitivity analysis
- Rich in "bottom-up" technological detail – describes in detail technology operation, efficiency, availability, fuel production/ demand, retrofit, and retirement in flexible time slices.
- But represent behavioral parameters much more simply.
- The model exists at a societal level, no individual consumer behavior is captured (only ONE representative household). This ignores one of the important aspects of decision-making.
- Behavioral parameters cannot be ignored as they are one of the important aspects of decision-making.
- This is especially true for transportation sector, as 59% of energy use comes from light-duty vehicles in the US within the transportation sector.
- Typically, the consumer choice decisions are made using a non-linear simulation approach.

Optimization and Simulation models: How to bridge the gap?

- Energy systems models: Technology rich on the supply side, but lack behavioral details
- Consumer Choice models: Detail choices on the demand side, but lack supply sector details
- Objective: 'Marrying' these two types of models.



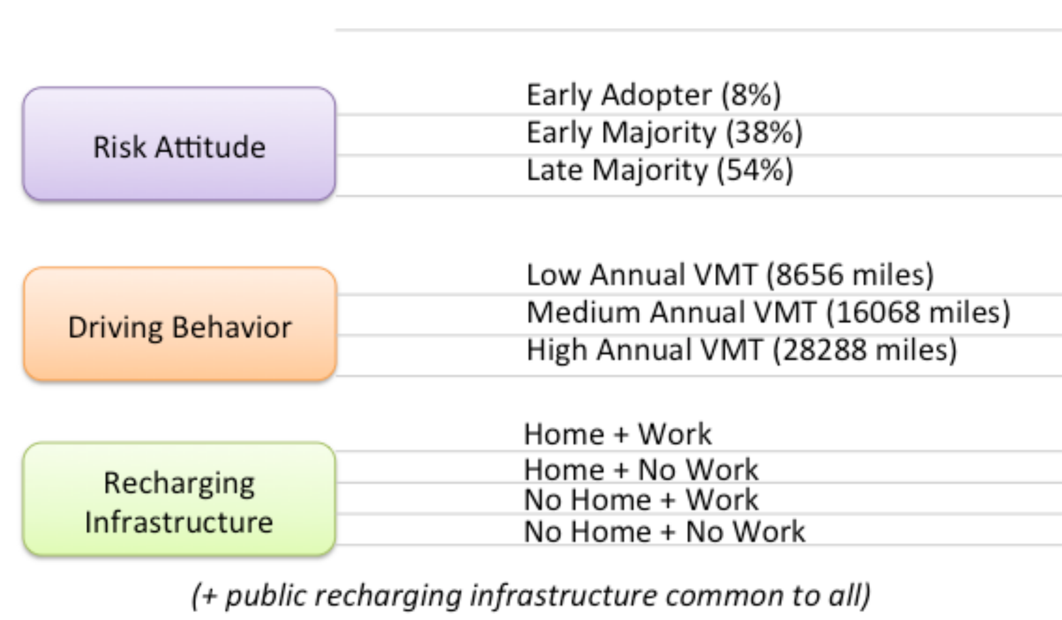


COCHIN-TIMES model

- **CO**nsumer **CH**oice **IN**tegration in TIMES
- Consumer behavior is utility driven.
- Varying consumer decisions can be captured by the perception of utility differences. The disutility can be measured as "utility cost".
- The new approach is to disaggregate the demand for different consumer groups, and give an additional cost (utility cost) for each technology in each group, that will also be used in the decision-making process.
- Each consumer group will choose the car technology that is optimal to them (addition of utility costs will make a difference in the mix).
- The utility costs are obtained from MA³T (Market Adoption of Advanced Automotive Technologies) model, a nested multinomial logit vehicle consumer choice model developed by ORNL.
- There will be 25 'clones' or instances of consumers in each consumer group. A random disturbance term (that follows a cumulative extreme value function) will be added to the utility cost. This is to capture differences WITHIN the each consumer group.

Demand-side Heterogeneity

- Thirty-six consumer groups were represented in this illustrative model.
- The groups were divided initially based on the risk attitude of drivers towards technology risk (early adopter, early majority and late majority), then each of those were divided based on annual miles driven (Low (8656 miles), Medium (16068 miles) and High (28288 miles).

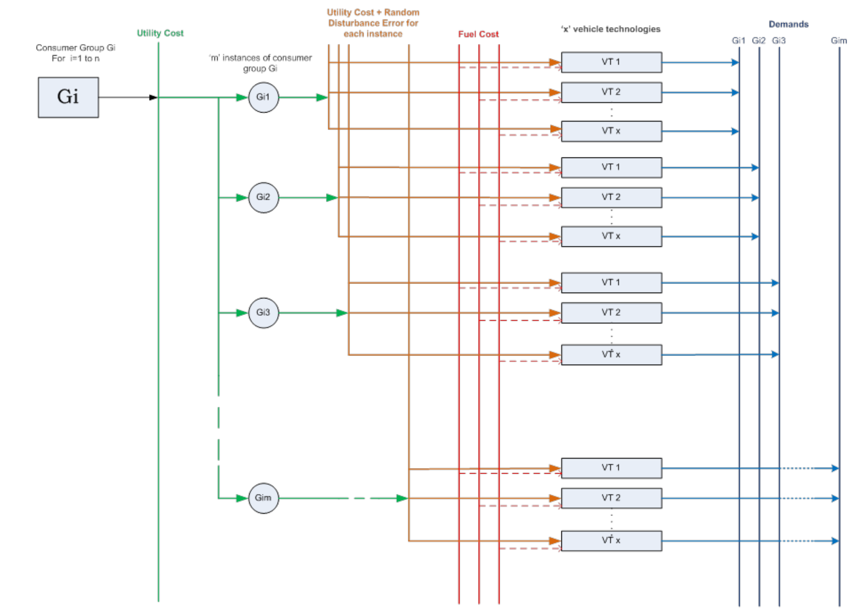


Intangible Cost Components

Intangible Cost Component	Description
Range Anxiety Cost	Cost of the consumer willing to spend on rental cars in a year based on their value of perceived anxiety due to range limitations of the owned vehicle. It is calculated based on the charge sustaining capability of the vehicle, how much or how long the consumer drives every day, and the attitude of consumer towards technology risk. This attribute monetizes the anxiety of the consumer when it comes to using limited range EVs.
Refueling Infrastructure Inconvenience Cost	Cost associated with the ease of access to recharging and refueling infrastructure. This cost captures the fuel availability and the ease at which the consumer can have access to refuel his vehicle. It depends on the fuel infrastructure itself, as well as the driving behavior of the consumer; if the consumer is prone to drive more, he or she has the need to refuel often. For example, in the year 2010, gasoline cars have an easier access to fueling stations than hydrogen cars, hence the gasoline cars have a lower cost associated with this compared to hydrogen cars.
Model Availability Cost	Cost associated with the number of vehicle models available for a given vehicle technology. It is assumed that, when the vehicle technology is new to the market and has limited sales, the models available to sell are also limited. So, if the user prefers to have a different model car in the given new vehicle technology, it may not be readily available until there is a sizeable market demand for it. This disutility is captured in this cost attribute..
New Technology Risk Premium	Cost calculated based on the willingness to accept the technology risk and the perceived riskiness of new vehicle technologies. The consumers in this model are divided into early adopters, early majority and late majority, based on their attitude towards technology risk. For example, when a certain vehicle technology is new to the market, early adopters are more willing explore them rather than the other two groups. They have a lesser "risk premium" cost compared to the other consumer groups.
Towing Capability	Cost calculated based on the towing capacity of the vehicle technology. This cost is technology specific, and not consumer group specific. A few vehicle technologies, such as gasoline cars or diesel cars have a better towing capability than electric vehicles, for example. If a consumer prefers to have a better towing capacity for his vehicle, this cost attribute captures it.

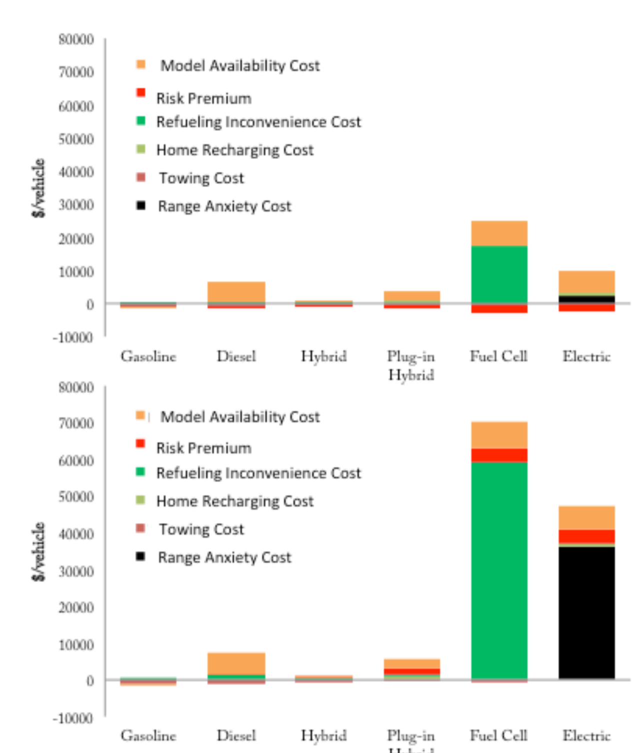
Schematic of the COCHIN-TIMES model

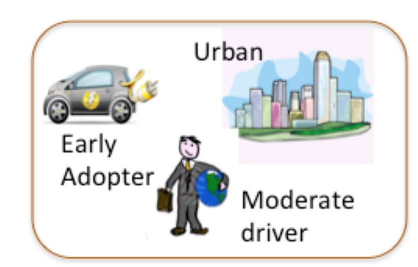
- The TIMES model typically takes in fuel cost, vehicle cost and other O&M costs associated with the technology to make decisions.
- In this approach, the demand is disaggregated for different consumer group instances, and utility cost (+ random disturbance term) are included as an additional cost for each technology in each consumer group instance.

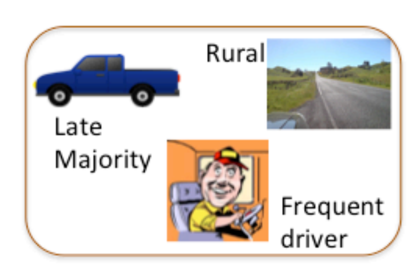


Total cost profiles of vehicle technologies

- The total cost differs across vehicle technologies as well as across consumer groups. For example, early adopters have a lower cost for electric vehicles than the late majority groups, due to their willingness to invest in new technologies.

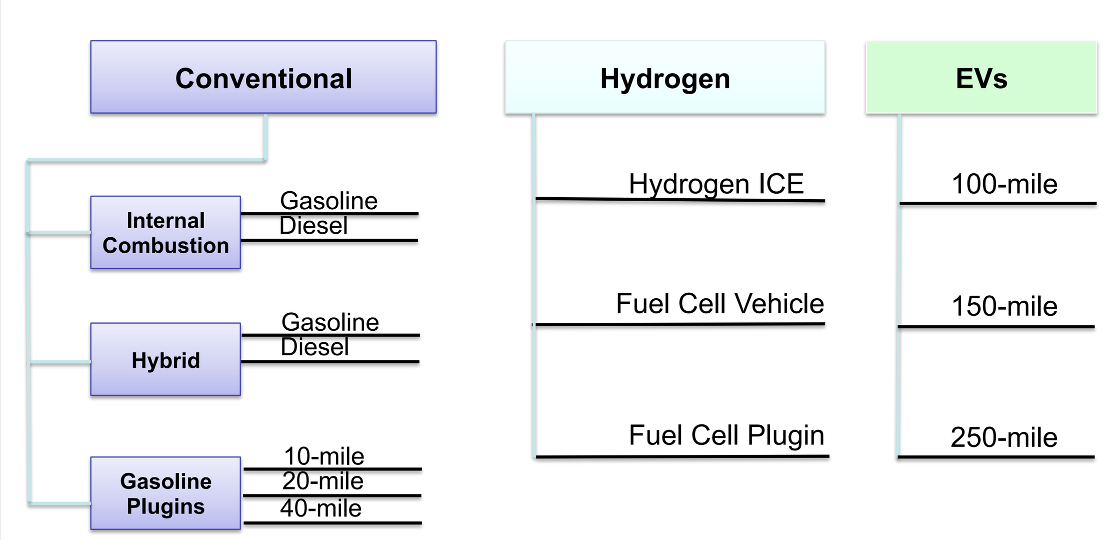






Vehicle Technologies in COCHIN model

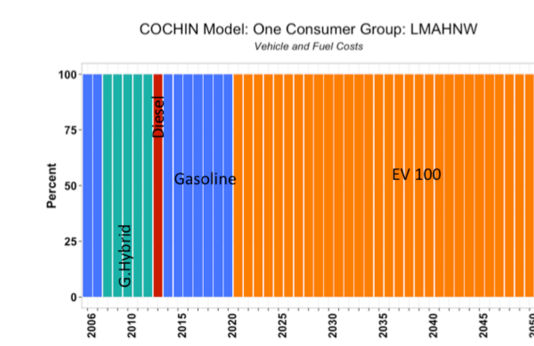
- COCHIN model has both light-duty cars and light-duty trucks. For each class the following vehicle technologies are represented.



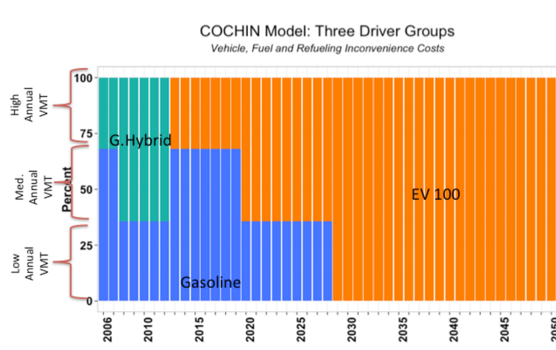
Comparison between Investment Decisions

- The reference case scenario of percentage sales of light duty vehicles is compared between the COCHIN model of different clone instances.
- TIMES model investments exhibit the 'winner-takes-all' phenomenon.
- It is observed that the COCHIN-TIMES model diversifies the investment decisions much more than the usual TIMES model approach, especially when the model includes more clones.

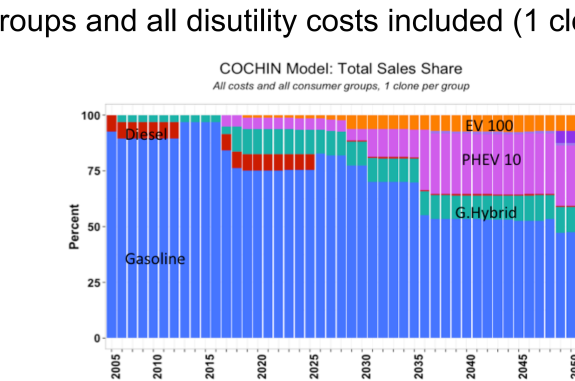
Standard TIMES model output



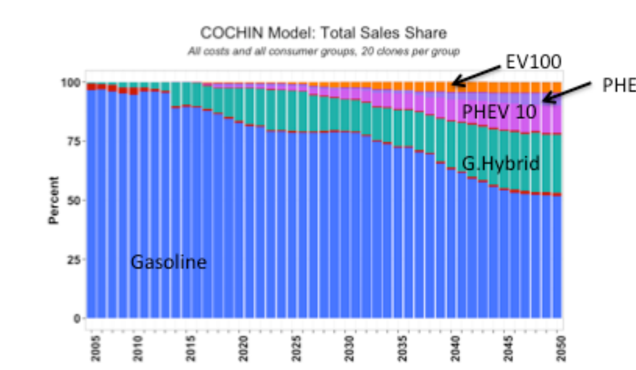
With three driver groups on the demand side



36 groups and all disutility costs included (1 clone per group)



36 groups and all disutility costs included (20 clones per group)



Conclusion and Next Steps

- COCHIN-TIMES is a significant improvement from the existing modeling methodology of energy models where decisions are made by a single social planner.
- This methodology can help us understand the different barriers in vehicle technology adoption and how policy instruments can be designed accordingly.
- On-going work includes
  a) performing policy scenarios that are relevant to consumer behavior decisions, such as vehicle subsidies, feebates, HOV fees etc;
  b) endogenizing disutility cost components; and
  c) integrating the COCHIN concept in the full CA-TIMES model.

SUSTAINABLE TRANSPORTATION ENERGY PATHWAYS

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