

#### **The CA-TIMES Model**

- 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.

#### Motivation

- The underlying assumption of a technology-forcing policy, where a regulator specifies a standard that cannot be met with the existing technology without switching to more expensive options, is that technology costs will eventually come down with more investments in R&D and/or deployment of technologies due to so-called "endogenous technological learning"
- Many of the climate policies adopted in California are considered technology-forcing policies. Examples such as the Zero Emission Vehicle (ZEV) program, the Low Carbon Fuel Standard (LCFS), and the energy storage were intended to elicit advancements in technology and/or technology costs reductions by forcing firms to commit resources to R&D or technology deployment
- In the electricity grid with a high penetration of renewable energy, demand management could also maximize the capacity factor of the electricity network and save a lot of investments in infrastructure
- Marginal abatement cost (MAC) curves have become a very popular tool in the policy world to answer this question, since they can represent the complex issue of cost-effective emissions reduction in a simple manner

#### **Research Questions**

- What is the role of technology forcing policies of California in promoting uptake and cost reduction of alternative fuel vehicles?
- What is the impact of technology-forcing policies in the transportation sector on the entire economy and other sectors?
- What are the possible global implications of different countries' attempts to promote uptake of alternative fuel vehicles?
- What are the implications of various global learning and deployment scenarios for California?
- What is the role of electricity and hydrogen in scenarios in which the benefit for learning are share between different cars?
- How can we account for the seasonal and daily variability of supply and demand in order to develop expansion plans of the electricity system with a high penetration of renewables and taking into account the existence of energy storage systems and Evs?
- How can the shift to electric vehicles help reduce GHG emissions and what is the impact of EVs on the electricity system?
- What is the impact of flexible charging on the transportation sector and on the adoption of EVs (given the learning effect)?
- What is the contribution of different measures (sectors, enduses, technologies) in reducing GHG emissions up to 2050?
- What influences abatement cost curves and to what extent? (e.g. technology availability, cost assumptions)

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291-313, 1997.

• LR: Learning rate

• In linear optimization models, the cost reduction of technology based on experience requires the use of technology as a trigger that contradicts with the original paradigm of TIMES (selecting least-cost technology)

• Methods have been developed to implement endogenous learning in linear models using MLIP, which is computationally burdensome

• In the proposed methodology –the same as in the real world– technology-forcing policies play a very crucial role in imposing the learning process and consequently cost reduction of emerging technologies.

## Understanding the role of transportation in meeting California's greenhouse gas emissions reduction target: a focus on technology forcing policies, interactions with the electric sector and mitigation costs

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### Learning



#### Learning Implementation



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- learning.
- technologies



Learning Rate	7%	10%
Exogenous cost reduction	1.5%/yr	2.3%/y
Initial Cumulative Capacity	6.5 GWh	250 GV



- are defined
- TIMES.

### **Cluster Learning**

• In the cluster approach, a group of technologies share a common component – "key technology" – which is subject to

• Only the investment costs undergo the learning process. Therefore, we only attribute capital cost to key component

#### Learning Results



• With learning adoption of hybrid vehicles as well as fuel cell

• In 2050 alternative fuel vehicles become competitive with the



• Load profile of commercial and residential service demands

• We can implement *Load shifting* and *Peak shaving* in CA-





- decarbonize (i.e. biofuels).

- energy system model of California
- plants and related emissions
- sector can benefit the grid and utility companies.
- future





#### **Future Work**

• In the future work, we increase the spatial and temporal resolution of the CA-TIMES model electricity sector in order to include a representation of the Western US electricity grid into the long-term

• The spatial modeling addition (inclusion of the entire WECC) will enable the CA-TIMES model to accurately represent electricity imports/exports, reduction in the variability of renewable energy due to geographic aggregation, and track spatial locations of power

• we can model benefits of the electric grid with high penetration of renewables to optimally charge electric vehicles. On the top of these transportation sector related results, we also study how the implementation of smart grid and flexible demand in the building

• we investigate how cost reduction in fuel production (hydrogen and electricity) and storage technologies can facilitate the adoption of alternative fuel vehicles and pave the road for low-carbon energy