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Tom Turrentine, Scott Hardman & Gil Tal
Plug-in Hybrid & Electric Research Center
University of California, Davis
& the International EV Policy Council
Definitions

**HEV** = hybrid electric vehicle (Prius)

**BEV** = (pure) Battery Electric Vehicle (Nissan Leaf, BMW i3, Tesla Model S & X, Chevy Bolt)

**ZEV** = Zero Emission Vehicle = BEV + hydrogen fuel cell vehicle (HFCV) Toyota Murai, Honda Clarity FCV

**PHEV** = Plug-in Hybrid Electric = PHEV 10 - 80 = Volt (PHEV 40), Toyota Prius Prime (PHEV 30), BMW i3 REX (PHEV 80)

**PEV** = Plug-in Electric Vehicle = PHEV + BEV

**VMT** = Vehicle Miles Traveled

**eVMT** = electric vehicle miles traveled = % of VMT for a PHEV that is powered by electricity
The total number of PEVs in the world at end of 2018 will likely exceed 5 million (out of 1 billion vehicles) & 1.9 million in sales out of 88 million (about 160,000 per month)
Global PEV sales are concentrated in a few upscale markets with a variety of policies to support sales.
Forecasts are increasingly optimistic about PEV sales

- 10% of world market in 2020 (100 million LDVs)
- 600 million LDVs might be 40% of world market in 2040 (150 million LDVs?)

Source: Bloomberg New Energy Finance
The California ZEV program: carrots & sticks

1st generation policy, vehicles, “innovators” & infrastructure
200,000 PEVs 20-30 models

2nd generation
200 mile batteries, “followers”
4-500,000 PEVs 30-100 models

3rd generation: vehicles, “core market”
6-800,000 PEVS

California 2025 ZEV goal
= 15% / 1.2-5 million BEVS, FCV & PHEVs

4th generation
3 - 4 million???

Main market 15-25%

Current California market at about 6%

$700 per kWh $300 $200 $150 Lithium pack prices
We developed an International EV Policy Council to evaluate policy successes & failures

- 25 researchers, at 15 Institutions, in 13 Beachhead markets
  - Australia, Belgium, Canada, China, France, Germany, Netherlands, Norway, Portugal, South Korea, Sweden, UK, & USA
Policy evaluation done through council member consumer research, workshops & collective review of published research

- Sweden - April 2016
- Montreal - June 2016
- Shanghai - August 2016
- Washington DC - January 2017
- London - June 2017
- Stuttgart - October 2017
- Washington D.C - January 2018
- Oslo - May 2018

Future workshops:
- Kobe - October 2018
- Washington D.C - January 2018
- Lyon - May 2018
- California - October 2018
The council has completed review of Five Policy Intervention topics & published five briefs

- Consumer Engagement
- Purchase Incentives
- Reoccurring and Indirect Incentives
- Infrastructure
- Regulatory Mechanisms (NEV and ZEV)

**Scope of Interventions:**
Plug-in Electric Vehicles (PEVs), including:
- Battery Electric Vehicles (BEVs)
- Plug-in Hybrid Electric Vehicles (PHEVs)
- Not Hybrid Electric Vehicles
“Can you name a BEV that is being sold in the US?”

Consumer Engagement is Lagging Behind the Market
Surveys in 2014-2017 California Car Buyers (n=1600)
Source:, K.Kurani UC Davis
Educating Consumers is essential to policy success

Consumers won’t buy EVs if they are not knowledgeable about the benefits of the technology, incentives & infrastructure

- **Awareness**: consumers know PEVs, incentives, charging stations etc. exist
- **Knowledge**: consumers know what an EV is and the pros and cons
- **Decision**: consumers consider if they would purchase the vehicle

Awareness → Knowledge → Decision → Purchase
Different types of financial incentives are being used in different “beach-head” markets

**Tax Credit (e.g USA)**
- Incentive amount: $7,500
- You pay: $32,687 out of pocket

**Grant (e.g UK)**
- Incentive amount: $6,000
- You pay: $26,675 out of pocket

**Rebate (e.g California)**
- Incentive amount: $2,500
- You pay: $32,687 out of pocket

**Grant (e.g UK)**
- Incentive amount: $6,000
- You pay: $26,675 out of pocket

**Tax Waiver (e.g Norway)**
- Incentive amount: 6.5% MSRP ($1995)
- You pay: $30,680 out of pocket

**Fee-bate (e.g. France, Sweden)**

MSRP: $30,680 + $1995 tax
Incentives are Increasing in importance as sellers move to more risk averse buyers

- **Q:** *If the federal tax credit were not available how would this impact your decision to buy your PEV?*
- "No change" means they will still buy their PEV.
Financial Purchase Incentives - Recommendations

- Incentives more important for later buyers.
- Closer incentives are received to the time & location of purchase the more effective.
- Incentives should be lower for PHEVs with short driving ranges (higher for BEVs & PHEVs with long ranges).
- Incentives are less important for buyers of high-end/luxury PEVs or for persons of high income.
Reoccurring/non-financial incentives are important to both purchase and use of vehicles

- HOV, bus, or transit lane access
- Parking incentives (free, discounted, preferential locations)
- Toll waivers/discounts
- Restricted zone fee waivers/discounts
- Annual vehicle tax/fee exemptions
Reoccurring incentive impact differs between regions

**California**
HOV lane access is a primary motivation for 25-40% of buyers in San Francisco & Los Angeles

**Norway**
Free tolls have large impact on 50% of PEV buyers
Reoccurring/ Non-financial Incentives- Recommendations

• Any intervention that makes PEV ownership easier, cheaper, or more convenient can be effective
• Incentives used should depend on location, market saturation rate, consumer preferences, regulatory power
• Incentives should differentiate between BEVs, long range PHEVs, & short range PHEVs
• Can be easier to implement compared to purchase incentives
Charging infrastructure development must keep pace with technology change & market growth

Charging locations
- Home (while at home)
- Work (while at work)
- Public
- Corridor

Charging levels (North America)
- Level 1
- Level 2
- DC Fast
Charging Infrastructure Development
Recommendations

• Home location chargers most important followed by work, then public

• Charge level needs to be optimized for specific use.
  • Level 1 is fine for short trips & locations with long parking times.

• Charging should not be free as this can increase congestion & reduce dependability

• Charging should be managed by pricing, location, charging speeds, and smart charging.
Regulatory mechanisms ensure market develops, but have to be reworked as technology & market mature

### California ZEV Program

<table>
<thead>
<tr>
<th>Regulated OEMs</th>
<th>OEMs that sell more than 20,000 vehicles per year</th>
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</thead>
<tbody>
<tr>
<td>Credits¹</td>
<td>7% in 2019&lt;br&gt;9.5% in 2020&lt;br&gt;7-12% by 2025</td>
</tr>
<tr>
<td>Can credits be saved for future years?</td>
<td>Yes</td>
</tr>
<tr>
<td>Technological specificity</td>
<td>Certain portion of requirement must be pure ZEV (BEV or HFCV)</td>
</tr>
<tr>
<td>Credits per vehicle sold</td>
<td>0.4 to 4</td>
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</tbody>
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- ZEV works as part of an systematic approach together with purchase incentives & infrastructure development.
- Requires OEMs to sell “ZEVs” which includes PHEVs, BEVs, FCVs
- OEMs must obtain a certain number of credits by selling ZEVs
Council briefs & background publications at:

phev.ucdavis.edu/international-ev-policy-council-policy-briefs

Contact: Scott Hardman shardman@ucdavis.edu
Plug-in Hybrid & Electric Vehicle Research Center

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Contributing Authors

Scott Hardman, Tom Turrentine, Jonn Axsen, George Beard, Nicolo Daina, Erik Figenbaum, Dahlia Garas, Suzanne Goldberg, Auke Hoekstra, Niklas Jakobsson, Alan Jenn, Patrick Jochem, Sten Karlsson, Neale Kinnear, Ken Kurani, Denis Naberezhnykh, Mike Nicholas, Patrick Plötz, Jose Pontes, Nazir Refa, Benjamin Sovacool, Daniel Sperling, Francis Sprei, Bert Witkamp, and Gil Tal
Additional slides
Challenges & Opportunities

Policy:
• durable policy systems (till market reaches 15% / battery prices hit $100 kWh)

Battery prices:
• Expensive, but price dropping faster than expected leading to bigger batteries

PEV rollout:
• Automakers are developing a wider range of vehicle designs & bigger batteries
• > 40 “Makes & models” per market (but main market has hundreds of designs)

Charging:
• Complex system: home, work, corridors, destinations including low to very high powered “plugs” (3 – 350 kWh)
• Difficult to make money (especially with “free” charging), need to engage public utilities

Renewable energy: consistent progress in last decade

Early market: Most buyers uninformed
• First buyers “motivated” to inform rest of market
• Public fleets and taxis can inform

Need to motivate “retail” sector (dealers, sales staff)
China has over 2 million PEVs & 50% of world PEV sales (Total vehicle sales around 23 million)
Sales of PEVs in ZEV & non ZEV States

- The ZEV mandate creates supply and sales in ZEV and non ZEV states.
USA Sales could hit 2% by end of year;
Multiple studies point to pack prices under $200 per kWh early next decade. A 60 kWh pack (Bolt or Tesla 3) would be around $10,000.

- Tesla says cells $190 kWh in 2016 & $100 in 2020.
- GM said it paid $145 per kWh "cell" for 2017 Bolt.

Bloomberg - "cells" & "packs"  McKinsey - "pack price"
California almost 5% in this quarter, 8 states are at 1-2%, the rest of US at about .5%
Public Charging enables more eVMT but is not a prerequisite for EV adoption in the USA.