California 2045:
Integrating 100% ZEVs with 100% Clean Energy

Noel Crisostomo, Fuels and Transportation Division
November 19, 2020
USC Schwarzenegger Institute & Stanford Energy Modeling Forum - Symposium on Climate Change Policy and Transportation
Governor Brown and legislators signing AB 2127 and SB 1000, to direct analyses of 2030 charging needs and installation gaps

Governor Newsom and agency leadership signing Executive Order N-79-20, calling for updated analyses to meet goals for 100% ZEVs, including for passenger car and truck sales by 2035, operational targets for drayage and off-road vehicles and equipment by 2035, and medium- and heavy-duty vehicles by 2045
100% zero-emission transportation powered by 100% clean electricity

GHG Emissions relative to 1990
- Equal
- 40% below
- Net zero

Electricity Grid
- Zero-carbon retail electricity sales
  - 33%
  - 50%
  - 60%
  - 100%

Charging infrastructure
- Ready for 1M EVs
- 250k
- 10k DCFC

Transportation System
- Light-duty
  - 1M
  - 1.5M
  - 5M
  - 100% new sales
- Medium- and heavy-duty
  - 100%
- Freight vehicles and equipment
  - 100k
  - 100% drayage trucks
- Off-road vehicles and equipment
  - 100%
...Consider All Necessary Charging Infrastructure, Including, but Not Limited to:

<table>
<thead>
<tr>
<th>Existing Chargers</th>
<th>Other EVs</th>
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<tbody>
<tr>
<td>Counting Chargers</td>
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<tr>
<td>Including in Low-income Communities (SB 1000)</td>
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<table>
<thead>
<tr>
<th>Future Chargers</th>
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<tbody>
<tr>
<td>Electric Vehicle Infrastructure Projections (EVI-Pro 2)</td>
<td>EVI-Pro RoadTrip</td>
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<tr>
<td>Widespread Infrastructure for Ride-hailing EV Deployment (WIRED)</td>
<td>Medium- &amp; Heavy-Duty EV Infrastructure Load, Operation, &amp; Deployment (HEVI-LOAD)</td>
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<tr>
<td>Off-Road, Port and Airport Electrification</td>
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</table>

- Charging Hardware and Software (*Equipment Components, Standards, and Interoperability*)
- Make- Ready Electrical Equipment (*Local Planning, Building Codes, & Grid Evaluation*)
- Other Programs to Accelerate the Adoption of Electric Vehicles (*Incentives, Investments, Others*)
## Multi-Pronged Effort Needed

<table>
<thead>
<tr>
<th>Assess Needs</th>
<th>Harmonize to Scale</th>
<th>Grow Partnerships</th>
<th>Electric For All</th>
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</thead>
<tbody>
<tr>
<td>Expand Electric Vehicle Infrastructure Projections</td>
<td>Interoperable: Convenient, Controllable, and Competitive</td>
<td>Lever Public and Ratepayer Investment with Private Capital</td>
<td>Robust Supplier Ecosystem &amp; Installation Workforce</td>
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</table>

**Charging Infrastructure Deployment Strategies**

- Regional Readiness Plans and Community Blueprints
- Portfolio of Solutions Best Fit for the Local Environment
- Project Finance and Innovative Economic Models
- Construction, Energization, and Sustained Operations

**Biennial & Ongoing Updates**
Support Planning Efforts

Infrastructure Demand Modeling:

- Helps CA understand what chargers are needed
- Informs stakeholders of load impacts, and potential for managing the time and location charging vehicle-grid integration (VGI)
- Enables local holistic planning to support EV adoption
Find Implementation Pathways

Harmonize to Scale
Interoperable: Convenient, Controllable, and Competitive

Infrastructure Demand Modeling:
• Prepares stakeholders to minimize grid impacts
• Quantitatively measures the benefits of standardization and interoperability
• Provides the framework for communities to find the best fit charging solutions
Spur the Market

Infrastructure Demand Modeling:

• Sends market signals for needed infrastructure
• Helps plan investments with private capital to build upon public programs, accelerating service
• Creates opportunities for business model innovation, especially with integrated solutions that are best fit for local conditions
Mobilize Construction, Enable Drivers

Electric For All

Robust Supplier Ecosystem & Installation Workforce

Infrastructure Demand Modeling:

- Quantifies the need for an ecosystem of manufacturers, suppliers, and trained installers to close gaps
- Enables long run infrastructure and grid planning and operational analysis
- Requires additional community engagement to inform future modeling
Multi-Disciplinary and Evolving Analysis

**Scenarios and Forecasting**
- Vehicle Choice and Stock Modeling; Transportation Energy Demand Forecast
- Fleets, Travel & Charging Behavior
- Regulatory, Economic & Climate Constraints

**Charging Choice and Control Modeling**
- Vehicle Operations and Battery Charging
  - Driving simulations, charge curves
- EV/EVSE Interface
  - Conductive, Inductive, Pantograph, etc.
- Location Type
  - Home, Work, Public, Corridor, Base/Depot, En-Route, etc.

**Distribution and Transmission Grid Integration**
- DER Impact Mitigation
  - Parcel level analysis
- Distribution Utilities
  - Capacity & Load Flows
- Regional System Operations
  - Transmission assets & flow constraints, system cost analysis

**Geospatial Load Aggregation and Decomposition**
- Aggregation
  - Across Travel, Air, Grid, Equity Domains
- Decomposition
  - Forecast Zones, Utility Territories, AQMDs, etc.

**Public Education and Engagement**
- Results Viewer
  - Boundaries + Existing Infrastructure; Uncertainty Quantification; Data Downloads
- Policy Pathways Optimization
  - Benefits Analysis: Willingness To Pay for Charging; Calibrating Utilization; New Local Initiatives, etc.

**Market Evolution Feedback**
- Session Prices
  - CapEx/TOU/Dynamic/Service Model
- User Elasticity & Smart Charging
  - Multi-Location Schedule Foresight, Reserved e-Range, Cost and Load Profile

**Collaborators:**
- CEC & Other Agencies
- NREL
- LBNL
- UC Davis
- Stanford
- + Others

**Distribution Utilities**
- Capacity & Load Flows
**DRAFT Load Profiling, CA 2030**

Additional scenario analyses ongoing; network preferences and energy price optimization not shown.

NREL, LBNL, and Energy Commission analysis (see link on contact slide for updates)
Early Insights Affecting the Demand for the Charging Network

Range and Power Evolution

Calibrate to Observed Behaviors

Regional Attainment Policies

MHDV Chargers

Larger networks needed to reduce TNC driving time to charger, address market saturation, and driver effort to maximize service.

Grouping drivers may inform how heterogeneity may change with growth.

NREL, LBNL, and Energy Commission analysis (see link on contact slide for updates)
VGI can manage the rapid deployment of storage anticipated with 100% clean energy

- By 2045, 150-225 GW new capacity added, sensitive to transportation each including ~50 GW storage.
- Storage build rates in High Electrification are ~20x faster than historical maximum.
Enabling Scaled Integration

Interoperability “will provide standardized devices that are capable of functioning as intended with each other, without special effort by the user.”

Harmonized standards and regulations [will create:]
• Interoperable PEVs, EVSE, and communication networks
• Predictable investment requirements [to achieve scale]
Standards-based chargers and communication

- Improves customers’ ability to dynamically manage rates and capacity, paving the way to V2G resiliency
- Assists the business case for EVs by creating opportunities for valuable customer- and grid services

Public Utilities Code 740.12(g), AB 2127 (2018), Energy Commission analysis
Standards-based network communication interfaces

- Permits reliability monitoring, offers customers options among networks, and enables repair by technicians
- Facilitates cooperation among competing networks, while ensuring a seamless customer experience

The *Price elasticity of demand across charging locations* is challenging to characterize, but will be a key strength in shifting the time of charging and resulting distribution grid impacts.
Convenience for Customers

Standards-based connectors and communication

- Moderates network size by improving utilization among EVs
- Reduces costs to achieve EV production and use goals
- Saves equipment costs and driver search costs at stations

ISO/IEC 15118
Vehicle-To-Grid Communication

Public Utilities Code 740.2 (e), Li, Jing (2019)
Smart Vehicles + Equipment Enable New Grid Integration Applications

Connectors, Transceivers, Controllers, Meters, + Protection Equipment

AC EVSE
CharIN Megawatt Charging System
DC Chargers
Plug & Charge
Vehicle-to-Vehicle
Vehicle-to-Building
Vehicle-to-Grid
Timely air quality goal attainment needs proactive grid analysis & upgrades

Multi-objective planning across disparate domains: air, travel, equity, grid

- NOx from mobile sources: 45% On-Road Vehicles, 35% Off-Road Vehicles
- Active development of methods to allocate travel energy demand to grid topology (EDGE)
- Very low-income drivers in rural areas can spend 40-50% of their income on automobiles
- Utilities est. 24-36 months to serve load for large projects; limited customer real estate

SCE Integrated Capacity Analysis Map, U.S. HUD Location Affordability Index, CEC EVSE Deployment and Grid Evaluation Tool
Innovation \(\rightarrow\) Accelerated Adoption

**55 Applicants for $7.5M total grant supporting charging for all on-road vehicle sectors:**
- Minimize Capital, Install, or Operating Costs
- Advance Customer Charging Interface
- Increase Utilization

**New Themes:**
- DER Integration
- Wireless & Robotic Charging
- Mobile & V2V Charging
- Shared MHDV Stations
- High-density garage automation

**46 Applicants Phase 2 Eligible**

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**GFO 20-605, BESTFIT Innovative Charging Solutions**

Score

0 5 10 15 20

CEC: Notice of Pre-Application of Abstract Results
Public-private partnerships are critical to maximize net benefits in the long term.

- EV charging business models are advancing beyond “reselling electricity,” using DERs to minimize grid costs and interconnection time, while leveraging new revenue opportunities: real estate value, transportation service agreements,

- Achieving goals for scale and a sustainable private market highlights the need for additional mechanisms to serve infrastructure for harder-to-reach customers.

57% of CALeVIP Investment in Disadvantaged Communities (April 2020)

<table>
<thead>
<tr>
<th>Connector</th>
<th>Public</th>
<th>Multi-Unit Dwelling</th>
<th>Workplace</th>
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<tbody>
<tr>
<td>$0</td>
<td>$3,790</td>
<td>$3,789</td>
<td>$3,625</td>
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<tr>
<td>$2,000</td>
<td>$6,397</td>
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<tr>
<td>$14,000</td>
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Average Project Costs Per Level 2 Connector By Market Segment CALeVIP

- Average Rebate Paid
- Customer's Cost Share

CEC: CALeVIP, CEC: Other Programs to Accelerate EV Adoption

- e.g. Supply
  - Grid controller (n-1) = $17/kWh

- Cheaper Storage = $9/kWh

- e.g. Demand
  - New/accelerated policy

Charging Demand by 2020, kWh

HEVI-Pro
Key Lessons

• Transportation electrification regulations and technical analysis can offer infrastructure developers and utilities insight about how to expand a robust charging network to serve customers’ mobility needs.

• Standardized, interoperable vehicles and equipment are critical to enable manufacturers’ economies of scale, to manage the size of the network, increase the use of renewable energy, and maximize the cost and functional benefits of electric driving.

• Emerging business models and new charging solutions enabled by public-private partnerships help the transition reach more customers cost-effectively.
Thank You!

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https://www.energy.ca.gov/programs-and-topics/programs/electric-vehicle-charging-infrastructure-assessment-ab-2127
Interoperable Charging Equipment

- OpenADR 2.0b or SEP 2.0b (Demand & Price Signals)
  1. Utility Direct Load Control
  2. Aggregator Managed
  3. Energy Management System
- OCPP 1.6J, 2.0 or others IEC 63110 (Equipment Management)
- OCPI or OICP (Inter-network Billing)
- ENERGY STAR (Efficiency)
- NIST Handbook 44 (Meter Accuracy)
- Open Public Payment (Access)
Bidirectional charging greatly enhances savings beyond smart charging (resiliency unquantified)