India SMART UTILITY Week 2020

March 03 - 07, 2020 | The Lalit Hotel, New Delhi, India

ISGF India Smart Grid Forum

India Smart Utility Week 2020

ORGANISED BY INDIA SMART GRID FORUM

03-07 MARCH 2020, The Lalit Hotel, New Delhi, INDIA

MASTER CLASS Track 2

Technologies Enabling Energy Transition: eMobility

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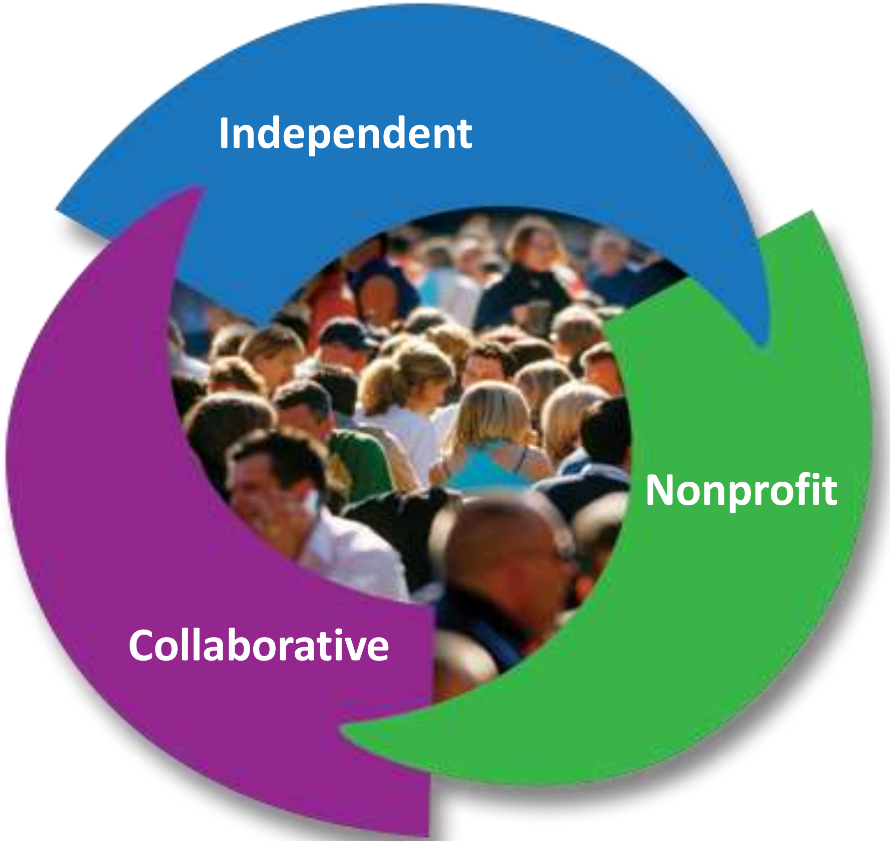
EPRI | ELECTRIC POWER RESEARCH INSTITUTE

Background: Electric Power Research Institute (EPRI)

- ***Independent, Collaborative, and Non-Profit:*** Conducts scientific research across all sectors of the power industry
  - Renewable, Nuclear and Fossil Generation
  - Transmission and Distribution
  - Energy Efficiency and Utilization
  - Environmental Studies
- ***Technology and policy agnostic:*** Supports fact-driven decision making for the benefit of members and the public
- ***Global Presence:*** International collaborations are ~27% of research, development, and demonstration portfolio



EPRI ELECTRIC POWER RESEARCH INSTITUTE

Topics Covered

1. **Introduction:** Motivation and Challenges
2. **Framework:** Electric Vehicles (EV) and Grid
3. **Vehicle-Grid Integration Services:** Market Opportunities
4. **Applications for India**
5. **Key Takeaways**

Regulatory Support Driving Technology Development and Adoption

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California

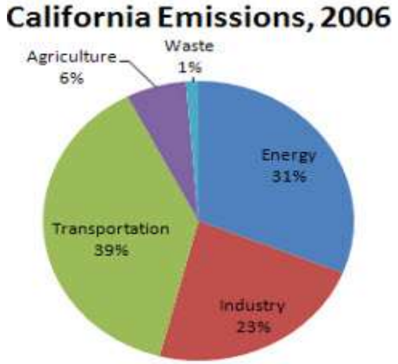
- **Renewables:** 100% zero-carbon sources by 2045 (SB 100) — currently ~30%.
- **Electric Mobility:** 5 Million EVs by 2030, EV infrastructure (2018 ZEV Action Plan)
- **GHG emissions:** 2020 = 1990 levels (AB 32); Governor's Exec. Order: 2030 = 40% below 1990 levels.

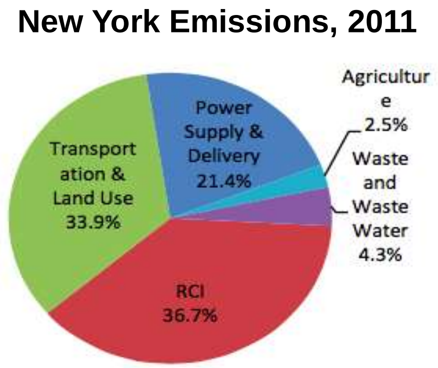
New York

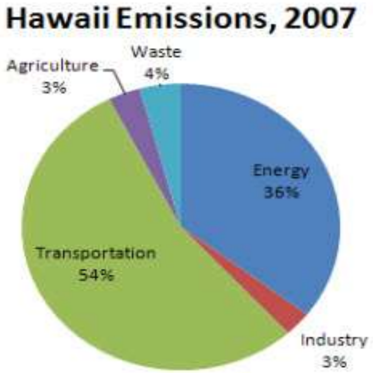
- **Renewables:** 50% by 2030.
- **Reforming Energy Vision (REV):** Forward-looking clean energy and clean transportation initiative.
- **GHG emissions:** 40% below 1990 levels by 2030.

Hawaii

- **Renewables:** 100% by 2045 (House Bill 623) – signed into law (most aggressive in the country) – currently at about 21%.
- **GHG emissions:** 2020 = 1990 levels (Act 234) – 54% of emissions from transportation.







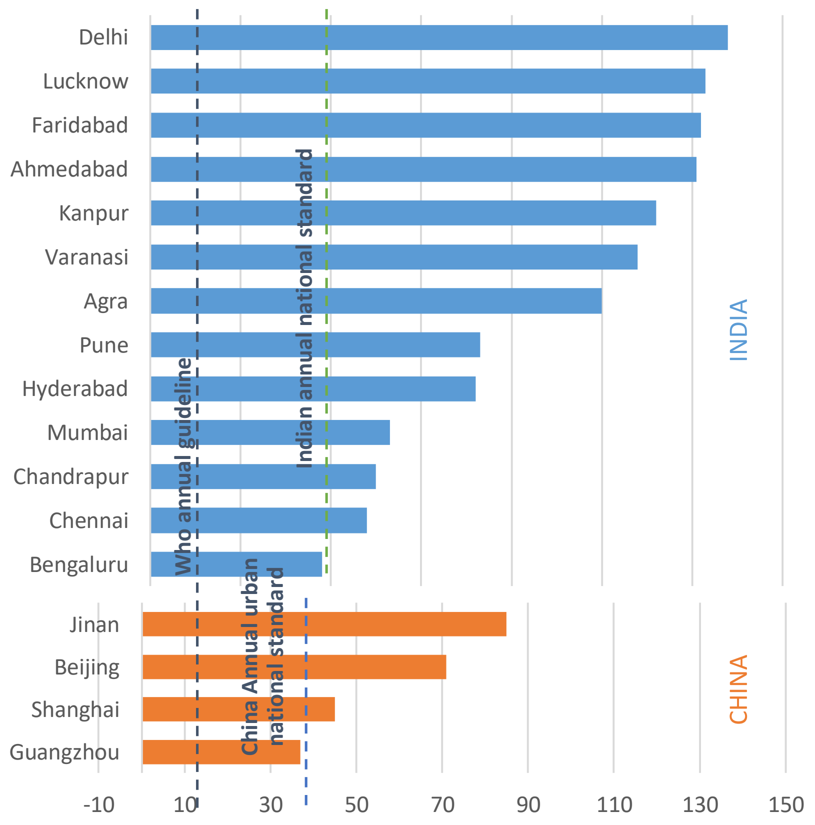
India's Motivation for Electric Mobility

Accelerated electrification of clean transportation, charging infrastructure, and the 21st century electric grid are key contributors to future-proof global energy security, environment, and clean-air objectives.

1. **National Electricity Mobility Mission (NEMM) Plan 2020**
   - **6 to 7 million electric vehicles**
   - **EV@30 campaign – 30% EV sales by 2030**
2. **Reduction in greenhouse gas emissions and improved air-quality**
   - 68% power generated from coal.
3. National Smart Grid Mission (NSGM)
   - Primary driver of grid modernization
4. Renewable generation of 175 GW by 2022
   - Includes bulk and distributed generation

India now overshadowing China

Average PM2.5 concentration, micrograms per m^2 July-November 2015



Source: Greenpeace, Economist.com

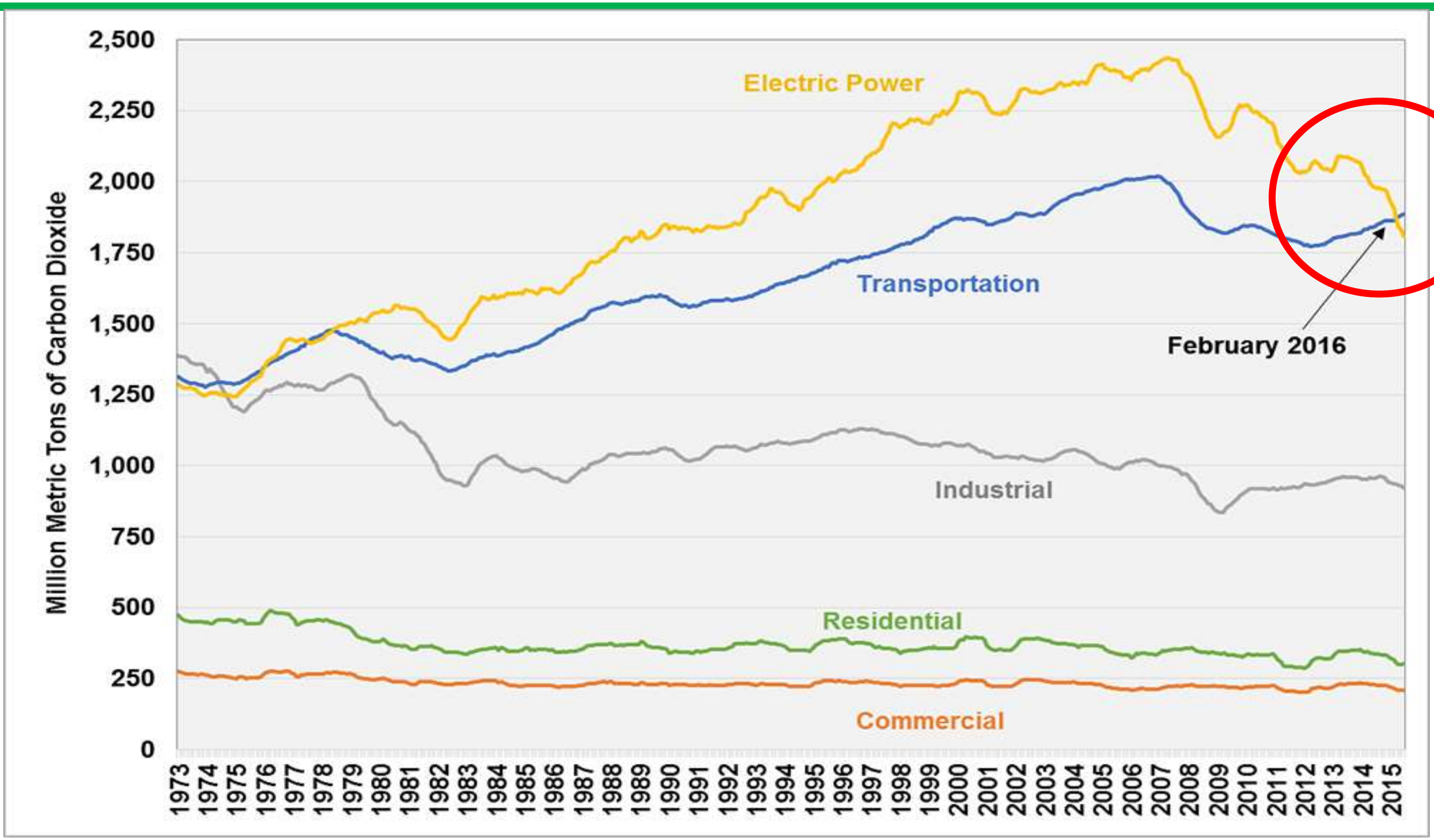
Vehicle-Grid Integration (VGI) in a nutshell

VGI encompasses the ways EVs can provide grid services. To that end, EVs must have capabilities to manage charging or support two-way interaction between vehicles and the grid.

- Two main categorizations of VGI:
  1. One-way power flow (V1G) for managed/smart/controlled charging.
  2. Bidirectional power flow (V2G) for managed/smart charging of a resource AND providing power to the grid (similar to power plants and or stationary energy storage)
- There are others sub-sets: V2H (home), V2B (building).
- VGI can include aggregated resources or one resource.

Reference: California Independent Systems Operator (CAISO), California Vehicle-Grid Integration (VGI) Roadmap: Enabling vehicle-based grid services, 2014

Carbon dioxide emissions in U.S. has a new leader— Transportation sector!

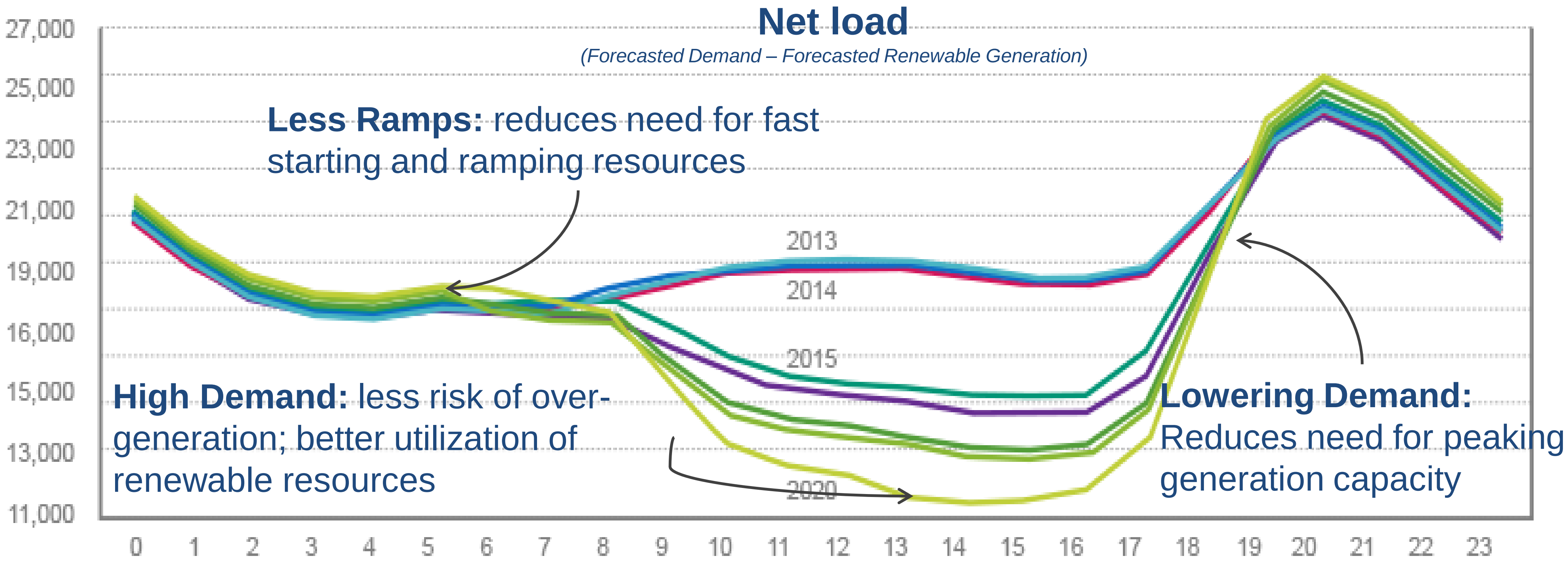


CARBON DIOXIDE EMISSIONS BY SECTOR, DECEMBER 1973 – MAY 2016

** Figure/Data Source: Energy Information Administration (EIA), August 2016 Monthly Energy Review, Tables 12.2, 12.3, 12.4, 12.5, and 12.6.*

High penetration of renewables provides grid decarbonization opportunities and localized variability

Renewable Integration



California Independent System Operator (CAISO); *Demand Response and Energy Efficiency Roadmap: Maximizing Preferred Resources*. December 2013

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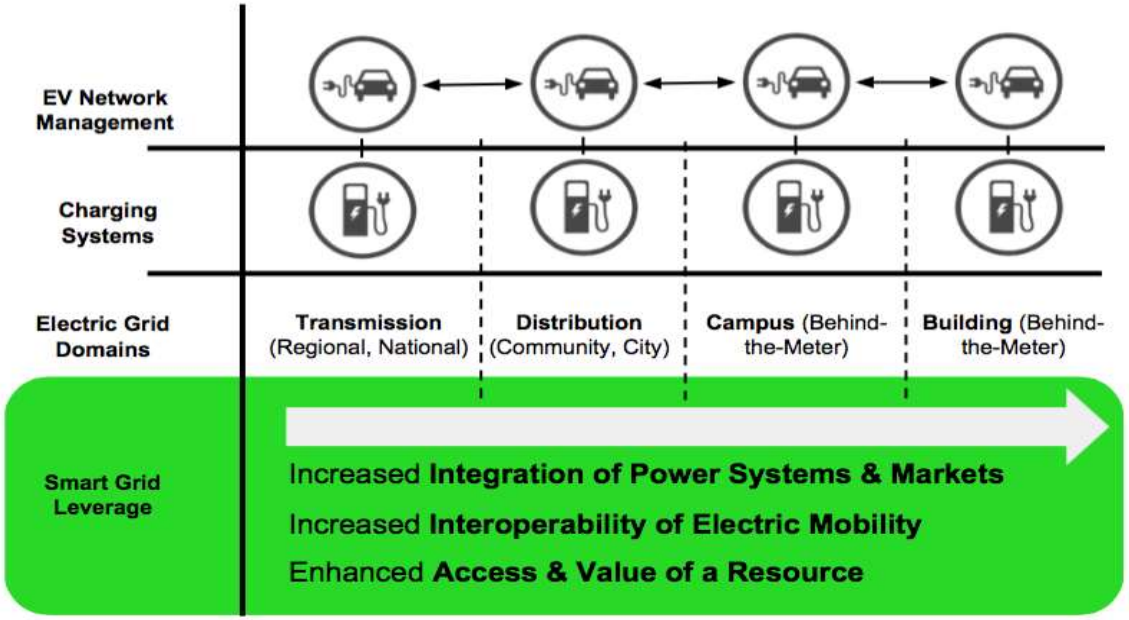
Electric Mobility Infrastructure and Grid for Vehicle Grid Integration (VGI)



Framework for Electric Mobility Infrastructure Integration and Interoperability with Electric Grid Domains, as Grid Resource[2]

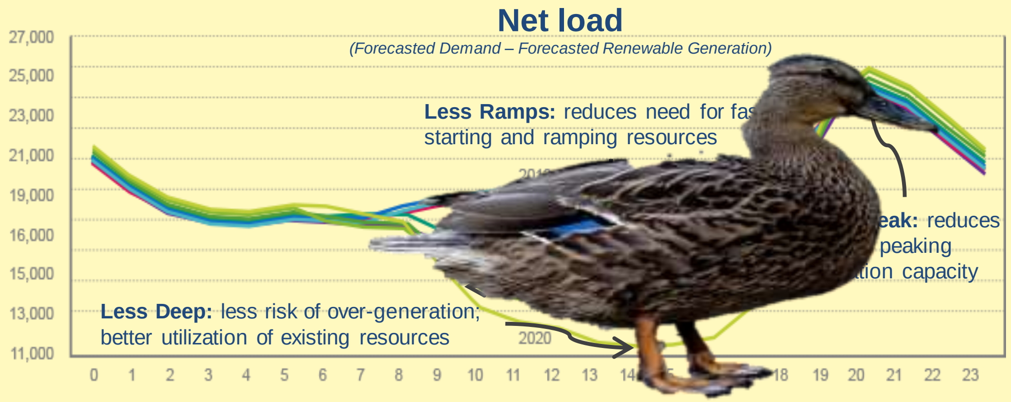
Focus on V1G or Smart Charging: V2X services such as V2G face inherent problems such as battery degradation and voided manufacturer's warranty when a BEV is used for functions external to driving needs

[1]*Piette M. A., S. Kiliccote, and G. Ghatikar; Linking Continuous Energy Management and Open Automated Demand Response, Gridwise Architecture Council Interoperability Forum, November 2008. LBNL-1361E. DOI 10.13140/2.1.4032.3366*
[2]*Ghatikar G.; Decoding Electric Mobility and Power Systems Interoperability for Clean Transportation and De-Carbonized Electric Grid, Proceedings of the India Smart Grid Week, March 2016*

EVs, as distributed energy resources (DER), must be designed to interoperate with the grid.

Leveraging Demand Flexibility for Grid Integration of Distributed Energy Resources (DER)

Renewable Integration



Generation & DER Integration

Sensors | Measurement | Control

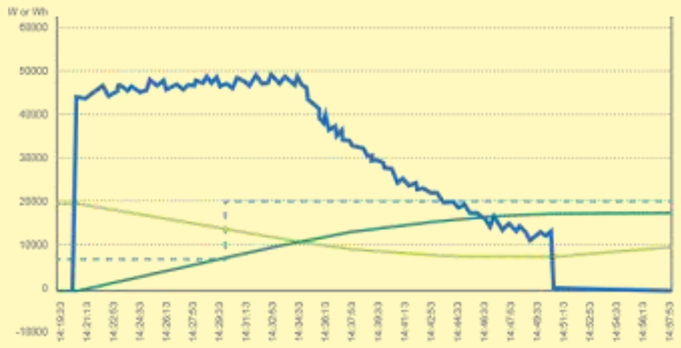
Interoperability | Systems & Devices

Tools | Decision Making & Planning

Grid | Operations and Markets

Security | Reliability | Resiliency

EV/ DER Management				
EV Charging Systems				
Electric Grid Domains	**Transmission** (regional, national)	**Distribution** (community, city)	**Campus** (behind-the-meter)	**Building** (behind-the-meter)



* Ghatikar G; *Decoding Power Systems' Integration for Clean Transportation and Decarbonized Electric Grid*, The Proceedings of the India Smart Grid Week. March 2016, New Delhi.
* California Independent System Operator (CAISO); *Demand Response and Energy Efficiency Roadmap: Maximizing Preferred Resources*. December 2013

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Challenges with enabling V2* Services.

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The Most Common Warranty for Plug-In Vehicle Batteries is 8 Years/100,000 Miles*

1. Battery Warranty
2. Battery Degradation
3. Power Systems
4. Market Value

Make and Model	Warranty Years	Warranty Miles
Model Year 2016 Electric Vehicles		
BMW i3 BEV	8	100,000
BMW X5 xDrive40e	8	100,000
Chevrolet Spark EV	8	100,000
Fiat 500e	8	100,000
Ford Focus Electric	8	100,000
Mercedes-Benz B250e	8	100,000
Mitsubishi i-MiEV	8	100,000
Nissan Leaf	8	100,000
Volkswagen e-Golf	8	100,000
Tesla Model S (60 kW-hr battery pack)	8	Unlimited
Tesla Model S (85 kW-hr battery pack)	8	Unlimited
Tesla Model S AWD - 70D	8	Unlimited
Tesla Model S AWD - 85D	8	Unlimited
Tesla Model S AWD - 90D	8	Unlimited
Tesla Model S AWD - P85D	8	Unlimited
Tesla Model S AWD - P90D	8	Unlimited
Kia Soul Electric	10	100,000
BYD e6	10	Not specified*
smart fortwo electric drive	10	Not specified*
Model Year 2016 Plug-In Hybrid Vehicles		
Audi A3 e-tron ultra	8	100,000
Mercedes-Benz S550e	15	150,000
Porsche Cayenne S e-Hybrid	6	Not specified*
Porsche 918 Spyder	7	Not specified*
Porsche Panamera S E-Hybrid	7	70,000
BMW i3REX	8	100,000
BMW i8	8	100,000
Cadillac ELR	8	100,000
Chevrolet Volt	8	100,000
Ford C-Max Energi Plug-In Hybrid	8	100,000
Ford Fusion Energi Plug-In Hybrid	8	100,000
Hyundai Sonata Plug-In Hybrid	Lifetime**	Unlimited
Volvo XC90 AWD Plug-In Hybrid	4	50,000

Source: Compiled by Oak Ridge National Laboratory from manufacturer and industry websites, February 2016.

Charging Station Options: Types and Charging Rates

	Level 1	Level 2	DC Fast Charger	Tesla Supercharger
Examples of Charging Stations				
Electrical Current Type	AC	AC	DC	DC
Range per Charge Time	2-5 miles/ 60 minutes	10-20 miles/ 60 minutes	50-70 miles/ 20 minutes	170 miles/ 30 minutes

* *Figure/Data Source: The U.S. Department of Energy, April 2016;* AC = Alternating Current. DC=Direct Current.

Electric Mobility Infrastructure and Networks

EV Supply Equipment (EVSE)/ Charging Stations

- Not all EVSEs have native communications and control
- EV to EVSE interoperability exists with Level 1 and Level 2
- EV to EVSE interoperability for direct current fast chargers (DCFC) is a challenge

Charge Levels	Volt/Current (V/A)	Power (kW)	Charging Station-to-BEV Connection	
			Power	Communication
Level 1	108-120/15-20	~1.4	NEMA 5.15	N/A
Level 2	208-240//≥30	~7.2	J1772	ISO 15118 (BEV) OCPP (Grid)
DCFC	400-800/≥120	≥50	CCS/CHAdeMO/ Supercharger	

XFC, 550-920 V / ≥375 A, ≥200kW

EV Battery Storage

- Battery Sizes determined by range and cost
- Batteries are 35% to 40% of total BEV costs
- The higher the battery capacity, faster are the customer charging needs.

BEV-Class and OEM Models		Rated Battery Capacity (kWh)	Range (Miles)
2-Wheelers	Zero S/SR/DS	9.4–15.3	87–125
Light-Duty	Nissan LEAF	25	80
	Chevy Volt*	18.5	55
	Tesla (Model S)	60–85	180–250
Medium-Duty	Enova ZE Van	40-120	50–150
Heavy-Duty	Proterra Bus	257	255

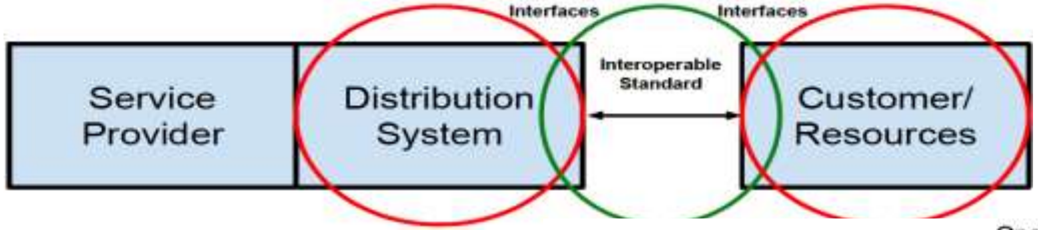
* Hybrid BEVs with ICE for extended range following full battery discharge.

Ghatikar G; *Decoding the Electric Mobility and Power Systems Interoperability for Clean Transportation and Decarbonized Electric Grid*, To be Submitted to the Proceedings of the India Smart Grid Week, March 2016, India.

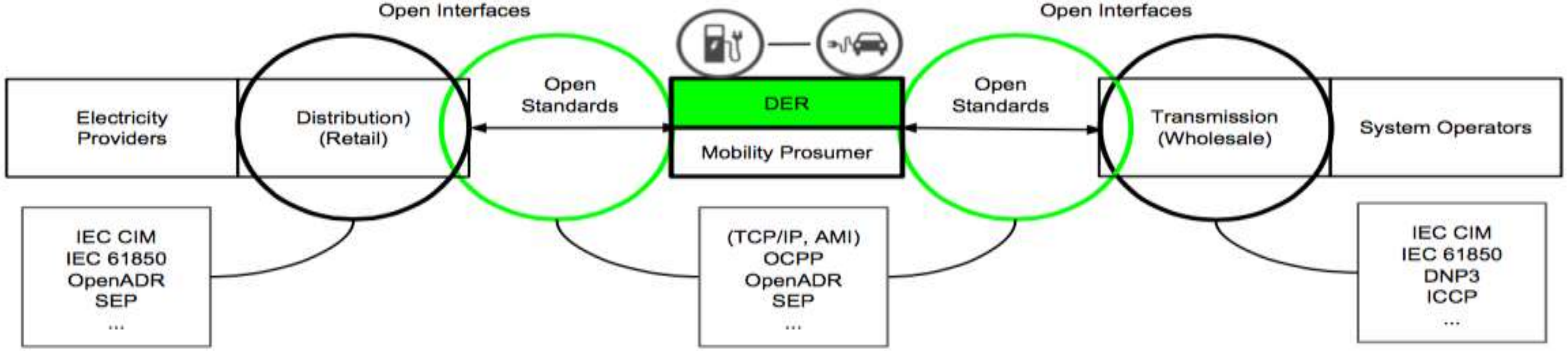
Open data standards for customer choice, innovation, and new business models*

Interoperability among disparate energy systems, markets, vendor technologies, and ownership models.
Inclusiveness and customer choice to lower adoption barriers, and improve cost-effectiveness of public funds.
Innovation in eco-system and new market-entry opportunities with innovative technologies and services.

Standard Interfaces for Smart Grid Domains – Distribution Systems and Customer/Resources*



Standard Interfaces for Smart Grid Domains – Distributed Energy Resources**

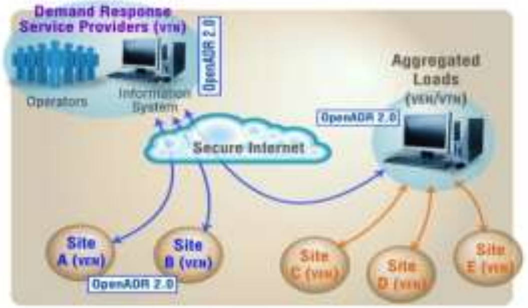


* Ghatikar G., J. Zuber, E. Koch, and R. Bienert, Smart Grid and Customer Transactions: The Unrealized Benefits of Conformance, Green Energy and Systems Conference (IGESC), 2014 IEEE, November 2014** Ghatikar G; *Decoding Power Systems' Integration for Clean Transportation and Decarbonized Electric Grid*, The Proceedings of the India Smart Grid Week. March 2016, New Delhi.

Open Interoperability Standards: Grid Services, EVs, and Battery Storage

Enables electricity providers to communicate grid-signals to customers using non-proprietary and open standardized interfaces using a common language and existing communications.

State of Affairs: Formal OASIS standard adopted by the utilities and industry for commercial demand response programs.



openADR ALLIANCE

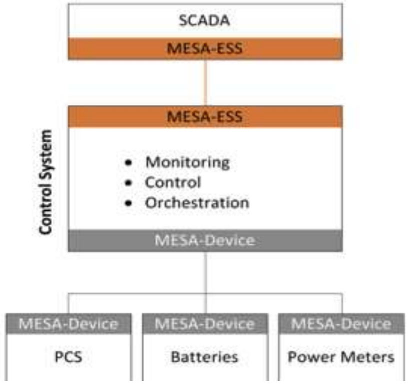
Offers a interoperable solution for the method of communication between charge station and any central system.

State of Affairs: De-facto standard adopted by utility and industry and EV community for interoperability and access to charging stations.

OPEN CHARGE ALLIANCE

Cost-effective scaling with any partners' energy storage systems with open standards (in development by organizations for utility-sited storage) for energy storage systems.

State of Affairs: In development by MESA with support from industry, utilities, and research institutions.



MESA Open Standards for Energy Storage

Open Charge Point Protocol: A Standard to Network and Manage Charging Stations

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Market opportunities – *clean transportation, energy storage, and demand flexibility*

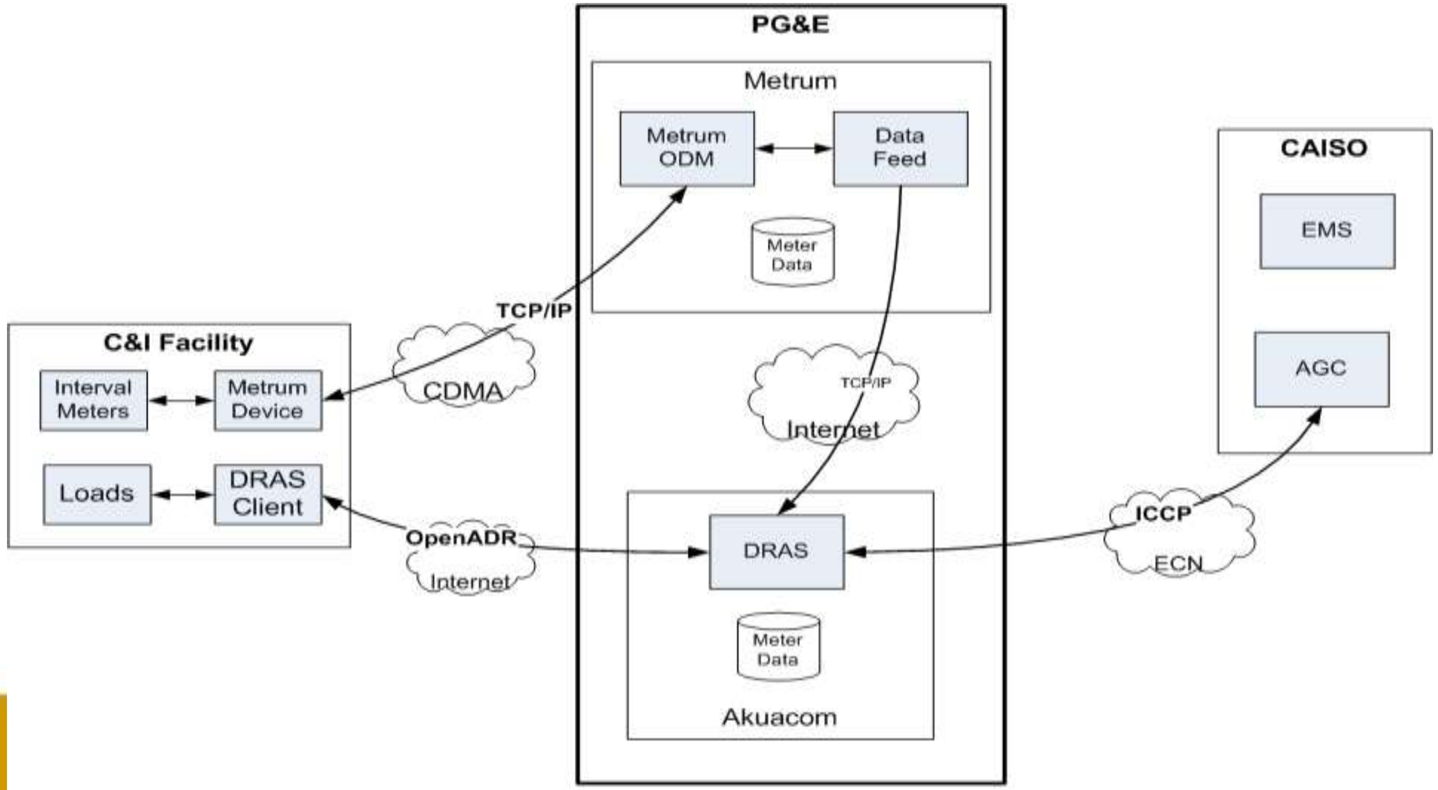
ELECTRIC VEHICLE INFRASTUCTURE MARKET - 2023	STATIONARY ENERGY STORAGE - 2020	DEMAND RESPONSE 2020
$2.9 BILLION	**$24.5** BILLION	**$5.27** BILLION

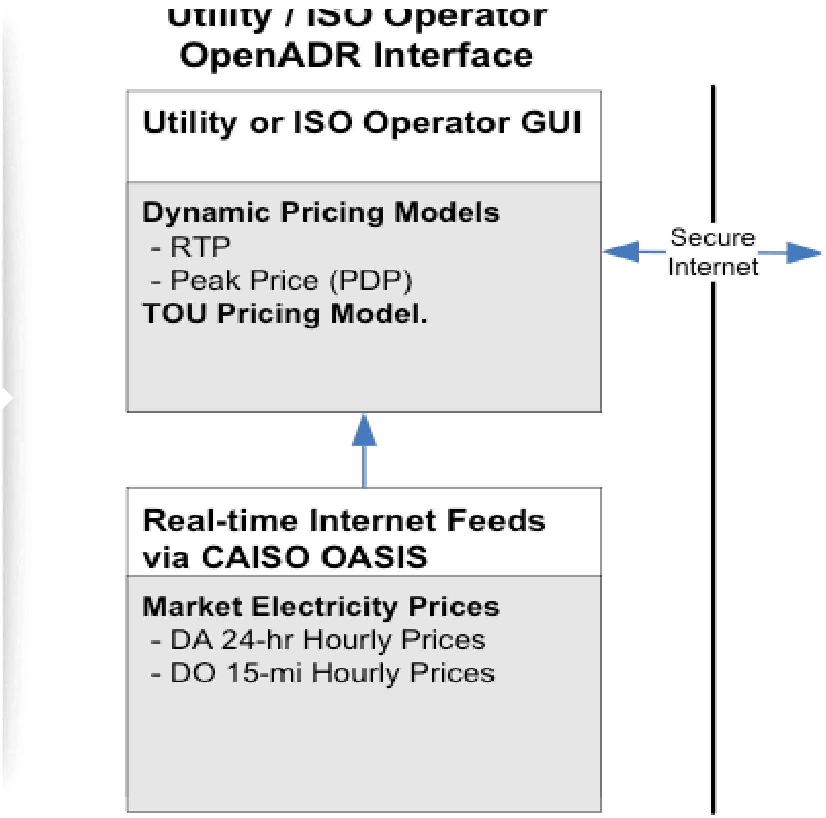
The Indian DISCOMs are on a cusp of new annual revenue opportunity of $36 billion (INR 231,705 Crores).

Ghatikar, G., N. Parchure, and R. Bhatnagar; Macro-Level Methodologies to Assess Grid Impacts and Flexibility from Battery Electric Vehicles: Opportunities to Reform India’s Energy Sector, Proceedings for the India Smart Grid Week, New Delhi. March 2018.

A Precedent: End-to-end data and communication integration.

Open standard(s) are key for EV ecosystem interoperability, as empirically evidenced by similar experiences for automated demand response (DR) systems.*





Ghatikar G, J.L. Mathieu, M.A. Piette, E. Koch, D. Hennage; Open Automated Demand Response Dynamic Pricing Technologies and Demonstration. August 2010. LBNL-3921E.

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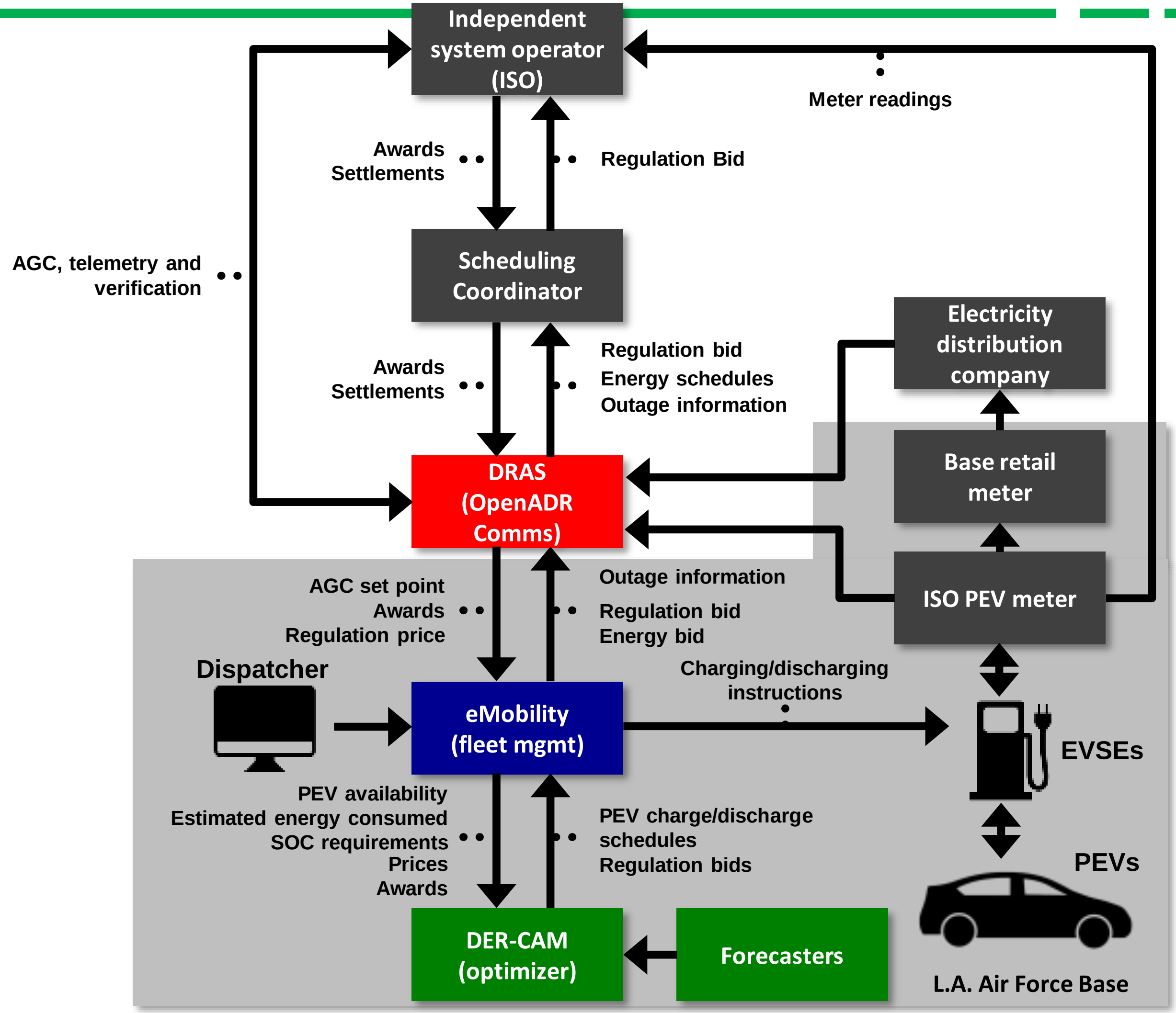
Piette M. A, G. Ghatikar, S. Kiliccote, D. Watson, E. Koch, D. Hennage, Design and Operation of an Open Interoperable Automated Demand Response Infrastructure for Commercial Buildings, JCISE, June 2009. LBNL-2340E.

Ghatikar G. and E. Koch, Deploying Systems Interoperability and Customer Choice within Smart Grid, Grid-Interop, December 2012. LBNL-6016E..

Role of electric vehicles and simulations for microgrid-based grid services

A microgrid is a **group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid.** A microgrid can **connect and disconnect from the grid** to enable it to operate in both grid-connected or island-mode*



* U.S. Department of Energy Microgrid Exchange Group. Figure Courtesy: Nicholas DeForest, Lawrence Berkeley National Laboratory

In U.S., California leads electric mobility innovation, driven by policy objectives and >$1 Billion investment

EV Infrastructure Pilots by Investor-Owned Utilities

PG&E (pending)	SCE	SDG&E
7,500 L-2 and 100 DCFC	1,500 L-1 and L-2	3,500 L-1 and L-2
$160 million	$22 million	$45 million
Public, Workplace, MUD	Public, Workplace, MUD	Workplace, MUD
Own and Operate	Hosts Own and Operate (SCE can manage VGI)	Own and Operate
TOU Rate to Driver or Host	TOU Rate to Host	VGI Rate to Driver or Host

PG&E: Pacific Gas and Electric Company; **SCE**: Southern California Edison; **SDG&E**: San Diego Gas and Electric
L-1: Level-1 chargers (~1.4 kW); **L-2:** Level-2 chargers (~7.2 kW); **DCFC:** Direct Current Fast Chargers (>=50 kW)
MUD: Multi-Unit (Residential) Dwelling
TOU: Time of Use Electricity Rate Tariff
VGI: Vehicle-Grid Integration (e.g., Demand Response)

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Applications for India: Demand Response (DR)

- In 2013-14, India had an average peak power deficit of 9% and an average energy deficit of 8.7%, resulting in rolling blackouts.
- India has aggressive plans for renewable energy generation (e.g., 175 GW by 2022).

With support from the U.S. DOE, we evaluated customer performance and technology effectiveness for an automated demand response (AutoDR) project by TATA Power Delhi Distribution Limited (TPDDL).

- Analysis from real data and field deployments.

References:
G. Ghatikar, R. Yin, R. Deshmukh, and A. H. Khan, "**Characterization and effectiveness of technologies for India's Electric Grid Reliability and Energy Security**," *Lawrence Berkeley National Laboratory*
R. Yin, G. Ghatikar, R. Deshmukh, and G. Das, "**Findings from an advanced demand response smart grid project to improve electricity reliability in India**," *Lawrence Berkeley National Laboratory*
R. Deshmukh, G. Ghatikar, R. Yin, G. Das, and S.K.Saha, "**Estimation of potential and value of demand response for industrial and commercial consumers in Delhi**," *Lawrence Berkeley National Laboratory*

Conclusions from Assessment of DR Potential in Delhi's C&I Customers

1. Significant DR potential from commercial and industrial (C&I) customers, enough to reduce 8% to 10% of peak demand.

2. DR can result in short run economic benefits to the utility and consumers

1. DR can also result in long run benefits such as capital investment deferral, by not needing to invest in additional generation capacity

1. OR using the same capacity to serve more loads and avoid uncompensated load shedding

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Key Takeaways: VGI

1. Grid operators/service-providers and vendors are challenged to develop an interoperable EV eco-system.
2. Open standards encourage customer choice, innovation, and new business models.
3. Government unavoidably plays an important role to accelerate EV/DER and demand-flexibility innovation.

Future: Addressing EV Adoption and Grid Connectivity Challenges

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    - Third level
      - Fourth level
        - Fifth level

Technical/Economical

Regulatory/Market Products

THANK YOU!

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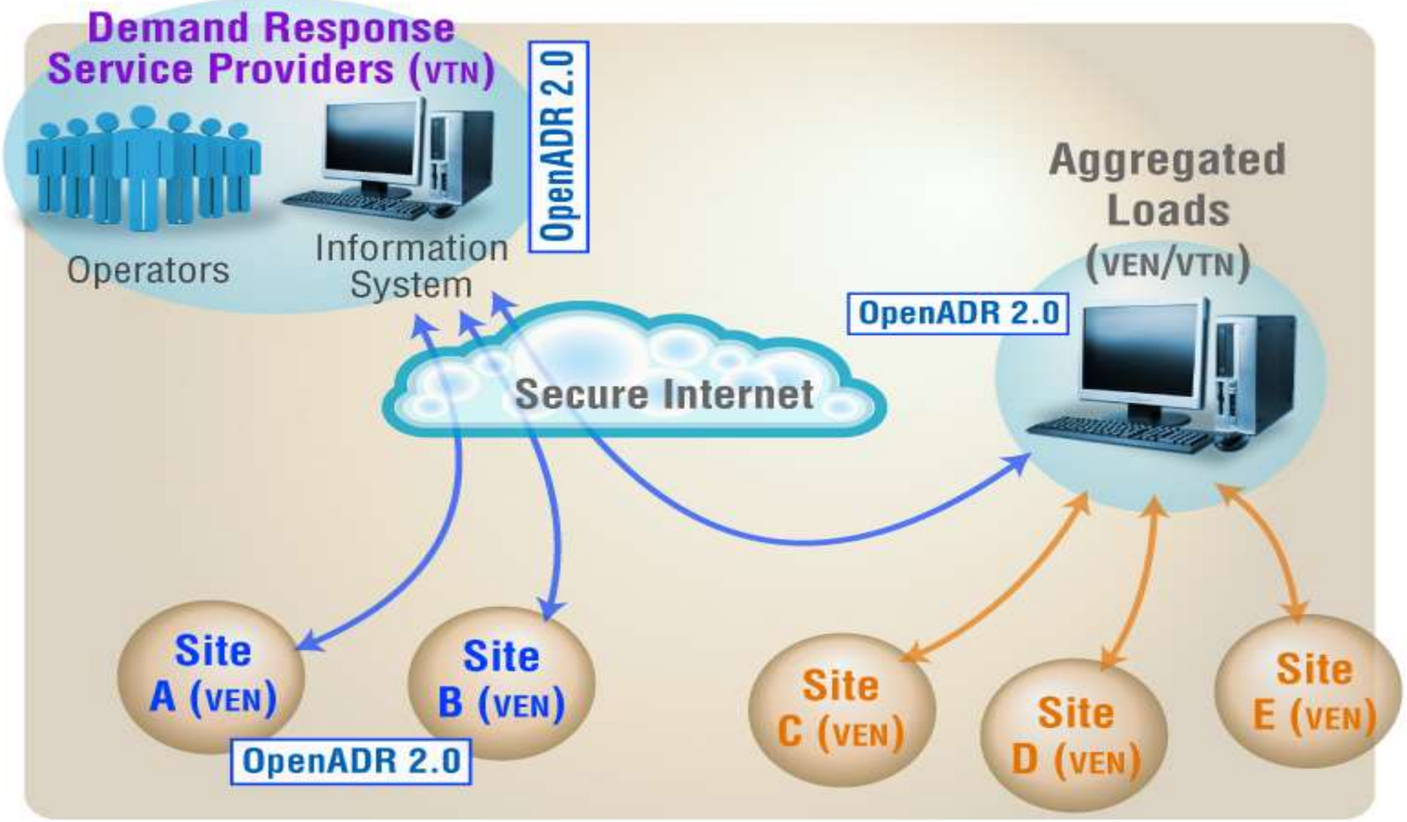
Distributed Energy Resource Interconnections and Standards

Girish Ghatikar

Open Automated Demand Response Standards (OpenADR): Demand Response and Price Transactions

Developed to meet DR automation goals: Low cost automation, technology for two-way secure communications, and controls integration

Enables electricity providers to communicate targeted grid-services to customers using non-proprietary and open standardized interfaces using a common language and existing communications (e.g., Internet).



openADR ALLIANCE

Open Charge Point Protocol (OCPP): Integration of Charging Station Network

Offers a interoperable solution for the method of communication between charge station and any central system.

1 Charging station owners (utilities, municipalities, private companies) can migrate from any third-party charging-infrastructure operators whilst not stranding them.

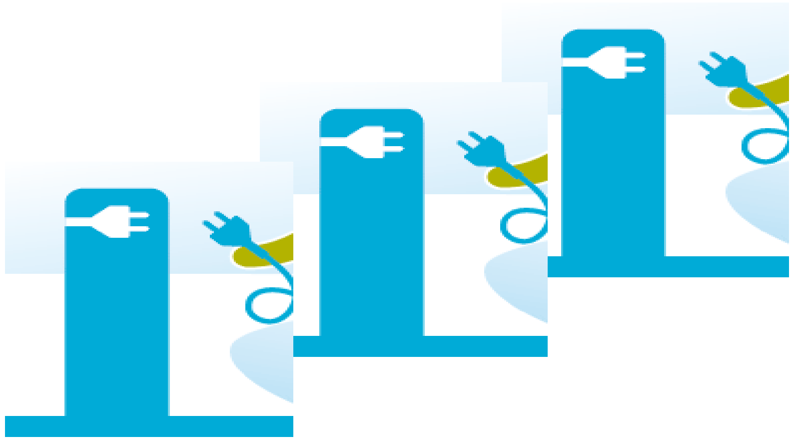
Asset Owner / Site Hosts

Charging Infrastructure Operator

Charging Infrastructure Operator

Charging Infrastructure Operator

Interoperability



OPEN CHARGE ALLIANCE

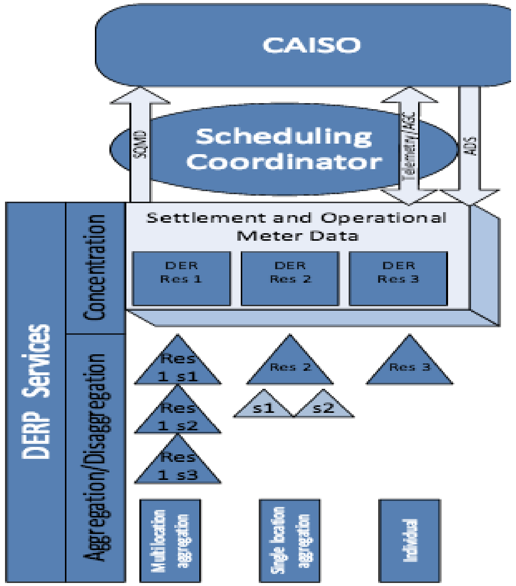
2 Charging infrastructure operators can cost-effectively integrate charging station assets

3 Charging station manufacturers can integrate more easily with multiple operators

New California Market to Firm Supply-Side Resources

Distributed energy resources participation in grid services

- Second level
  - Third level
    - Fourth level
      - Fifth level



- Distributed Energy Resource Provider (DERP) – *In progress*
  - Aggregated solar, storage, EV, and demand response in electricity markets
  - New York (Reforming Energy Vision or REV) and Texas have similar plans

Figure Source: CAISO, Expanded Metering and Telemetry Options Phase 2, DERP Draft Final Proposal