RAP®

August 26, 2020

Vehicle-to-Grid: Right at Your Doorstep

Webinar

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Chris King, Siemens

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Our Panelists

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Chief Architect for Electric Grid Transformation, Pacific Northwest National Laboratory

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Professor, University of Delaware

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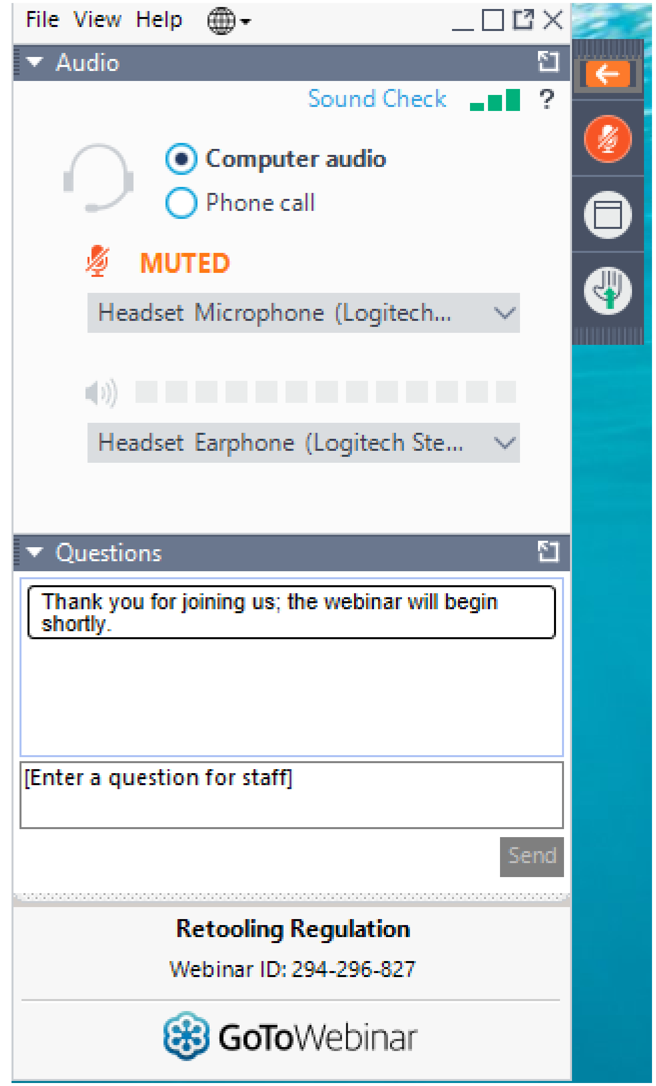
Energy Policy Analyst, University of Delaware

Moderator:
David Farnsworth,
Principal, RAP

Questions?

Please send questions through the Questions pane



Grid Architecture
and
Vehicle-to-Grid

26 August 2020

Jeffrey D. Taft, PhD
Chief Architect for Electric Grid Transformation
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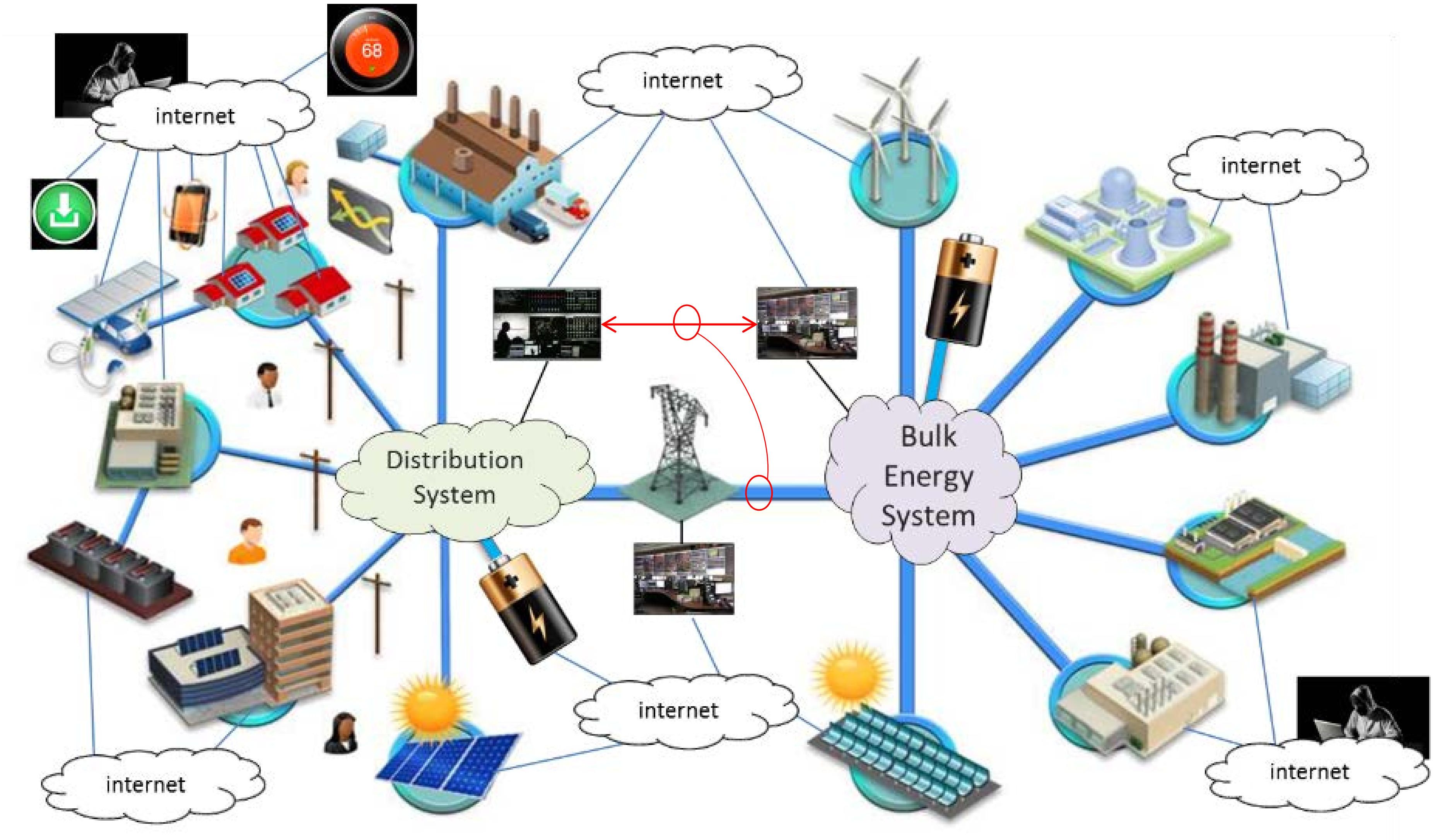
NATIONAL LABORATORY

DER & Connectivity Are Changing Grid Structure

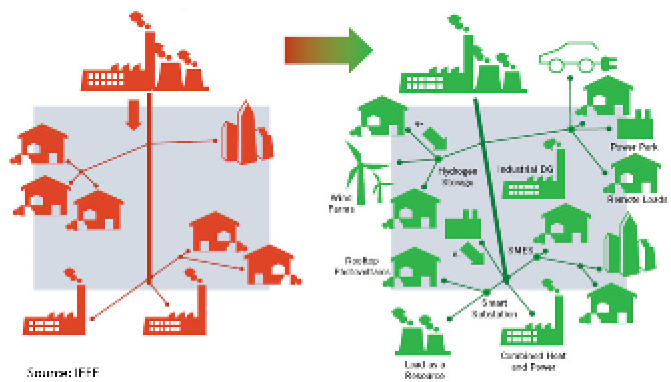


Underlying diagram source: EPRI

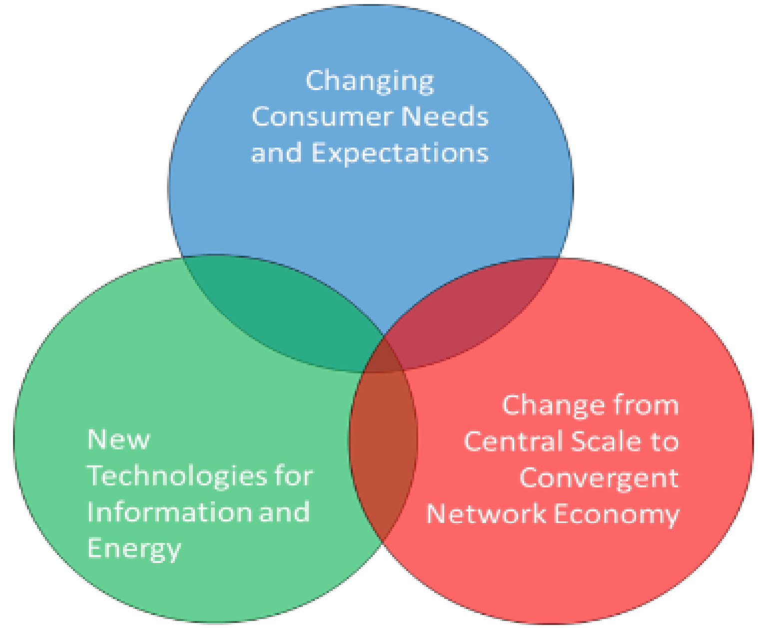
Re-Shaping of the Grid Affects Grid Value

Grid Evolution: One-way Road to Grid of Things

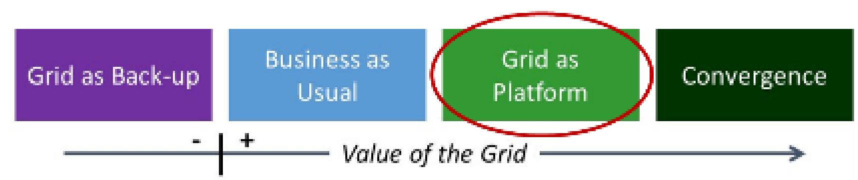
Distribution grid becoming a multi-directional network integrating millions of intelligent devices, DER and back-up generation



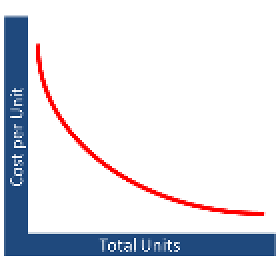
Operating such a system requires greater situational visibility and collaboration with customers and their services providers



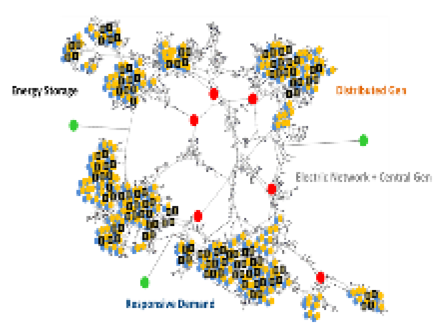
Grid Economics Are Evolving



Economies of Scale



Network Economics

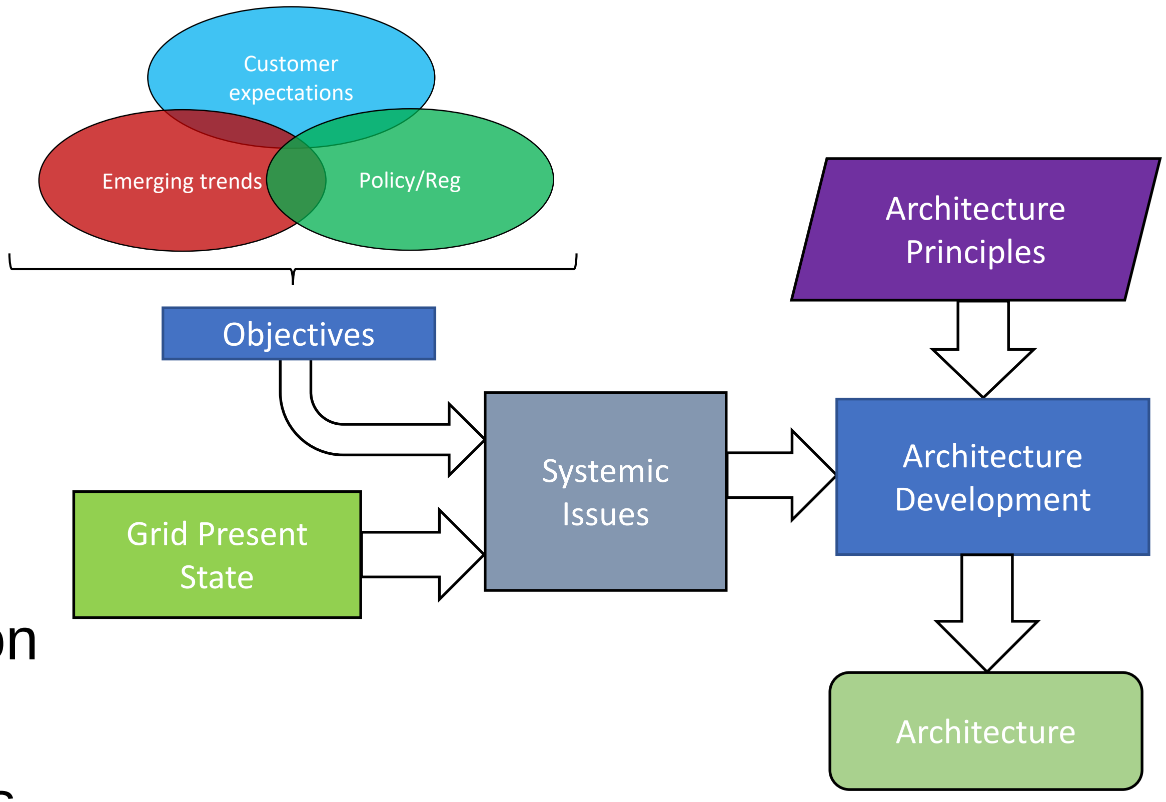


- Grid as Back-up to customer self-sufficiency erodes grid value
- Business as usual enhances value through aging infrastructure replacement and operational efficiencies
- **Grid as Platform expands value through enabling DER integration at scale and utilization as a system and grid resource**
- Convergence model extends value through synergies between electric service and other essential networks such as water and transportation, often pursued in smart city initiatives

source: P De Martini

Grid Architecture Methods

- Clarity of definitions
- Focus on structure
- Uses foundational principles
- Driven by:
  - User requirements
  - Emerging trends
  - Public policy/regulation
- Agnostic to:
  - Products and services
  - Business plans and models
  - Hype cycles
- Driven by systemic issues, not individual use cases



➢ Manage Complexity
➢ Produce Insight

The Overwhelming Importance of Structure

Structure sets the essential limits on what complex systems can and cannot do.

- Get the structure right and all the pieces fit into place neatly, all the downstream decisions are simplified, and investments are future-proofed
- Get the structure wrong and integration is costly and inefficient, investments are stranded, and benefits realization is limited

We have inherited much legacy structure and therefore structural constraints from the 20th Century grid. These constraints limit the ability to fully realize the benefits of V2G (and DER in general).

Core Problem of Grid Modernization

Determine the appropriate structures or minimal structural changes to the grid that:

- Relieve crucial constraints on new capabilities
- Limit propagation of undesired change effects*
- Strengthen desirable grid characteristics
- Simplify design and implementation decisions

We need these changes to be:

- ➢ As small as possible
- ➢ Implementable incrementally (proportional roll-out)
- ➢ Future-proofed to the maximum degree possible

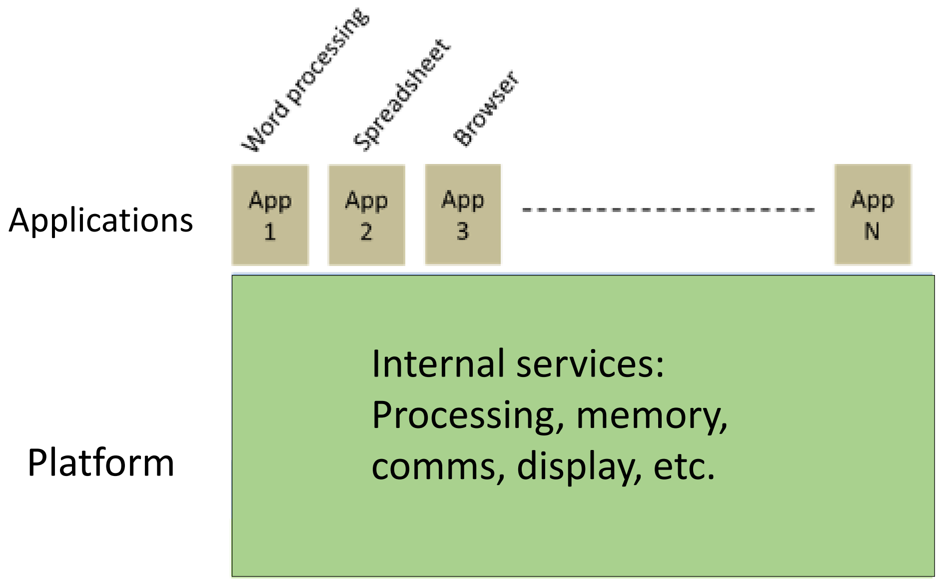
* Including design and technology changes as well as externalities and inimical events

Platform is an Architectural Concept

- Distinguish common support capabilities ("foundation" or "core") from uses or applications

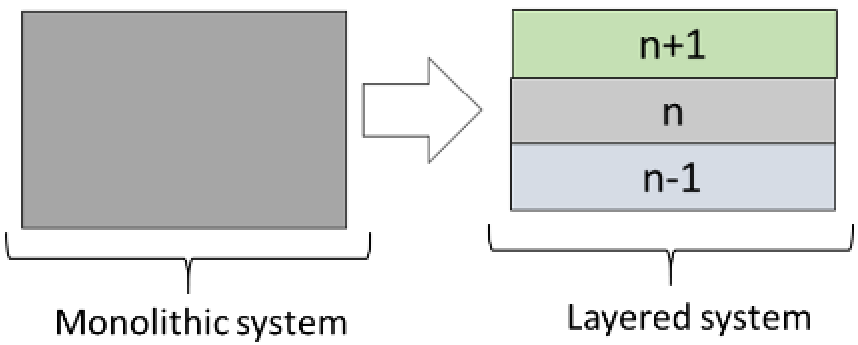
A platform is a stable collection of components that provide fundamental or commonly-needed capabilities and services to a variable set of uses or applications through well-defined interoperable interfaces.

- Common examples:
  - Personal computers
  - Smart phones

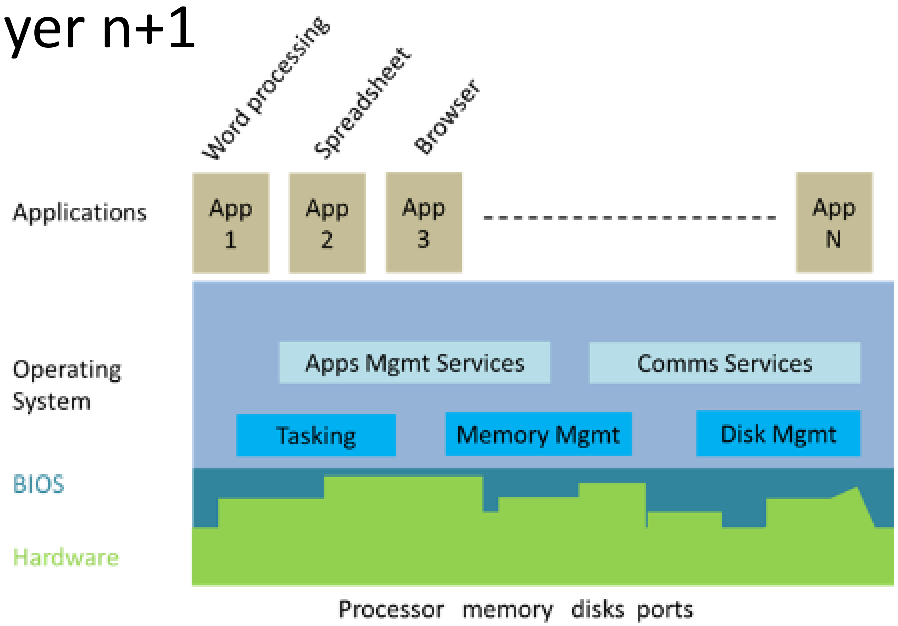


Layering is an Architectural Concept

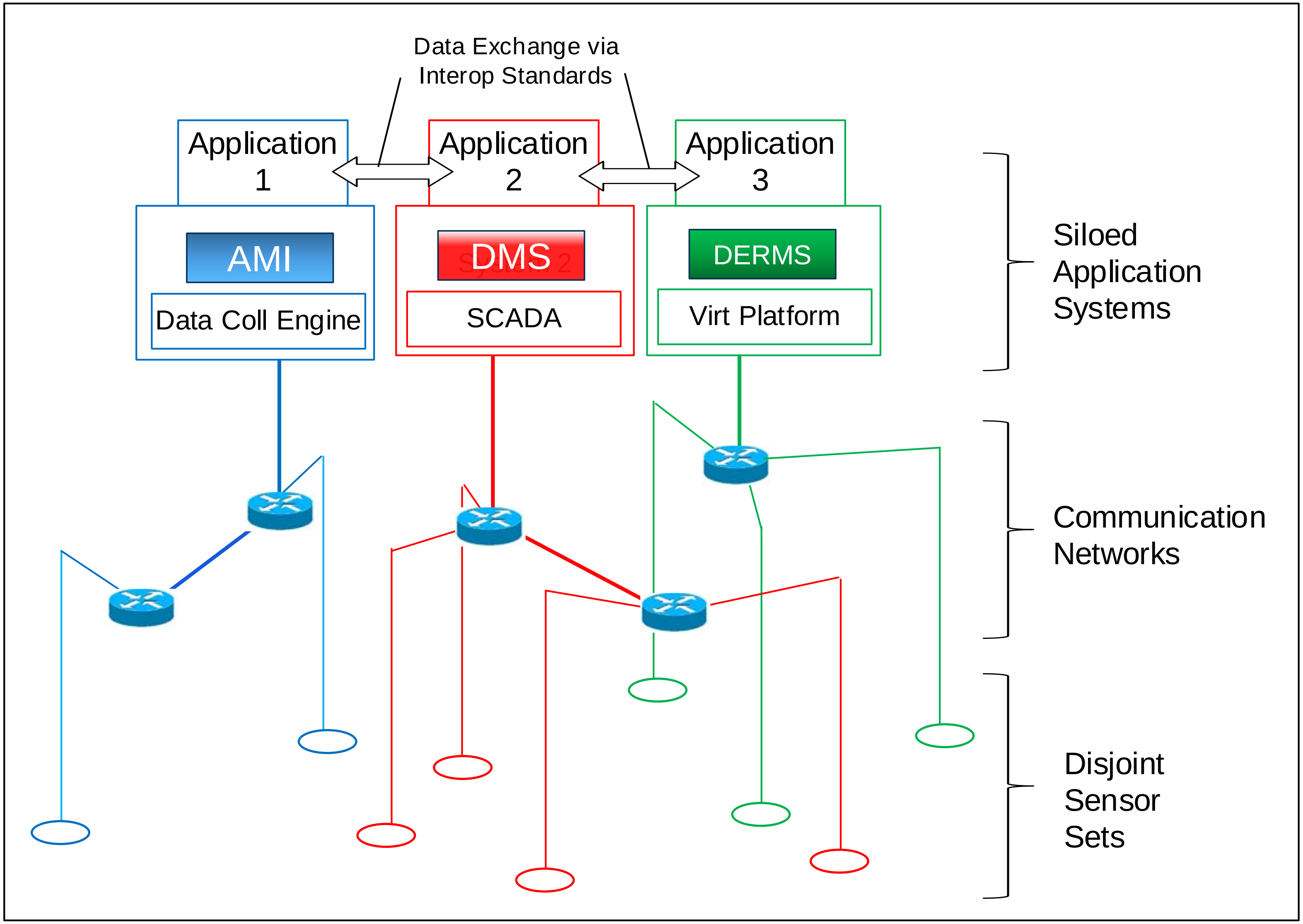
- Partition structure into stacked layers
  - May be three or more layers in a system or subsystem:



- Layer n isolates layer n-1 from layer n+1
  - o Future-proofing
  - o Resilience
- Platforms are often layered

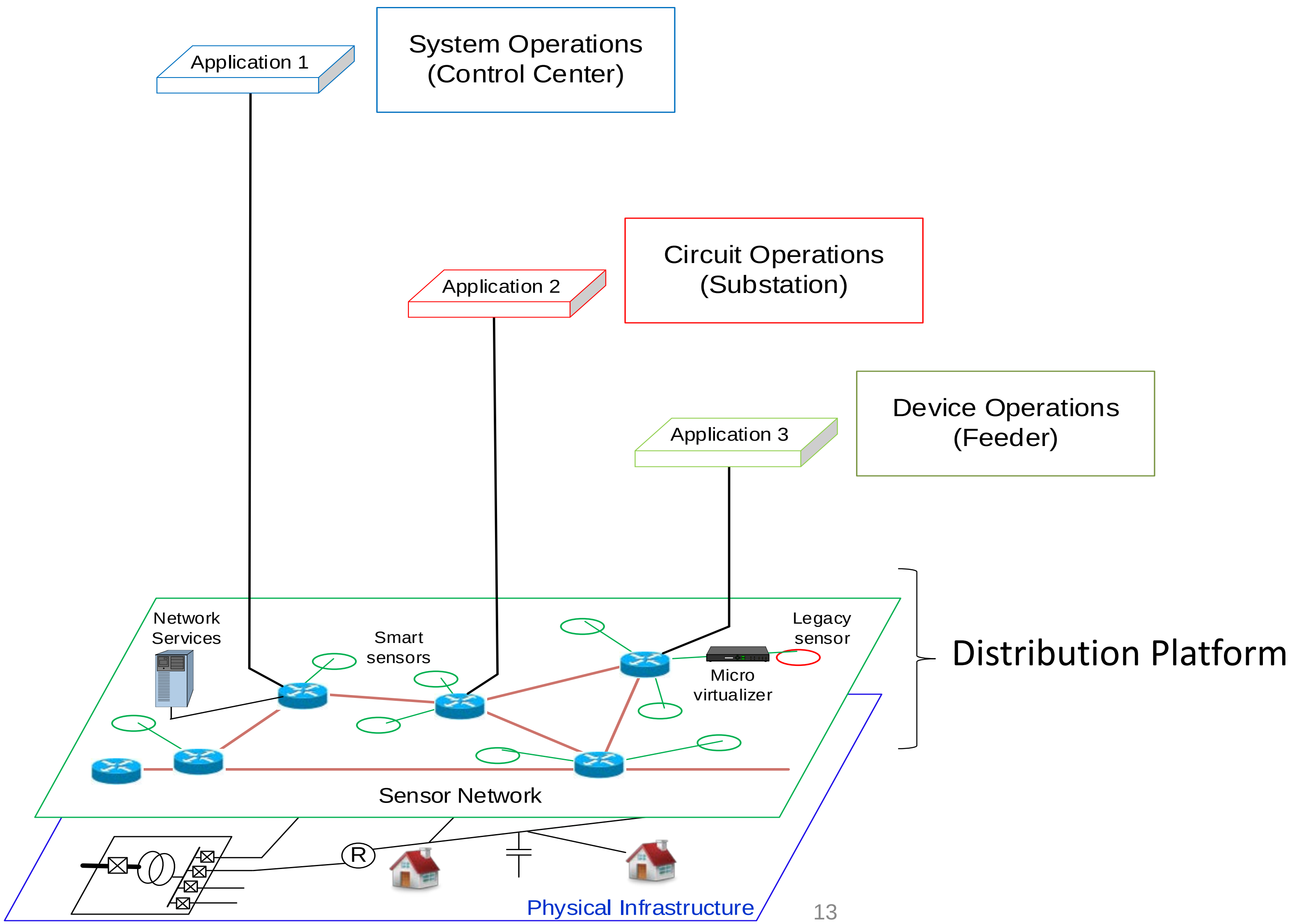


20th Century Distribution System Structure



Brittle & Expensive

Distribution Platform Structure



Definition: The Grid Coordination Problem

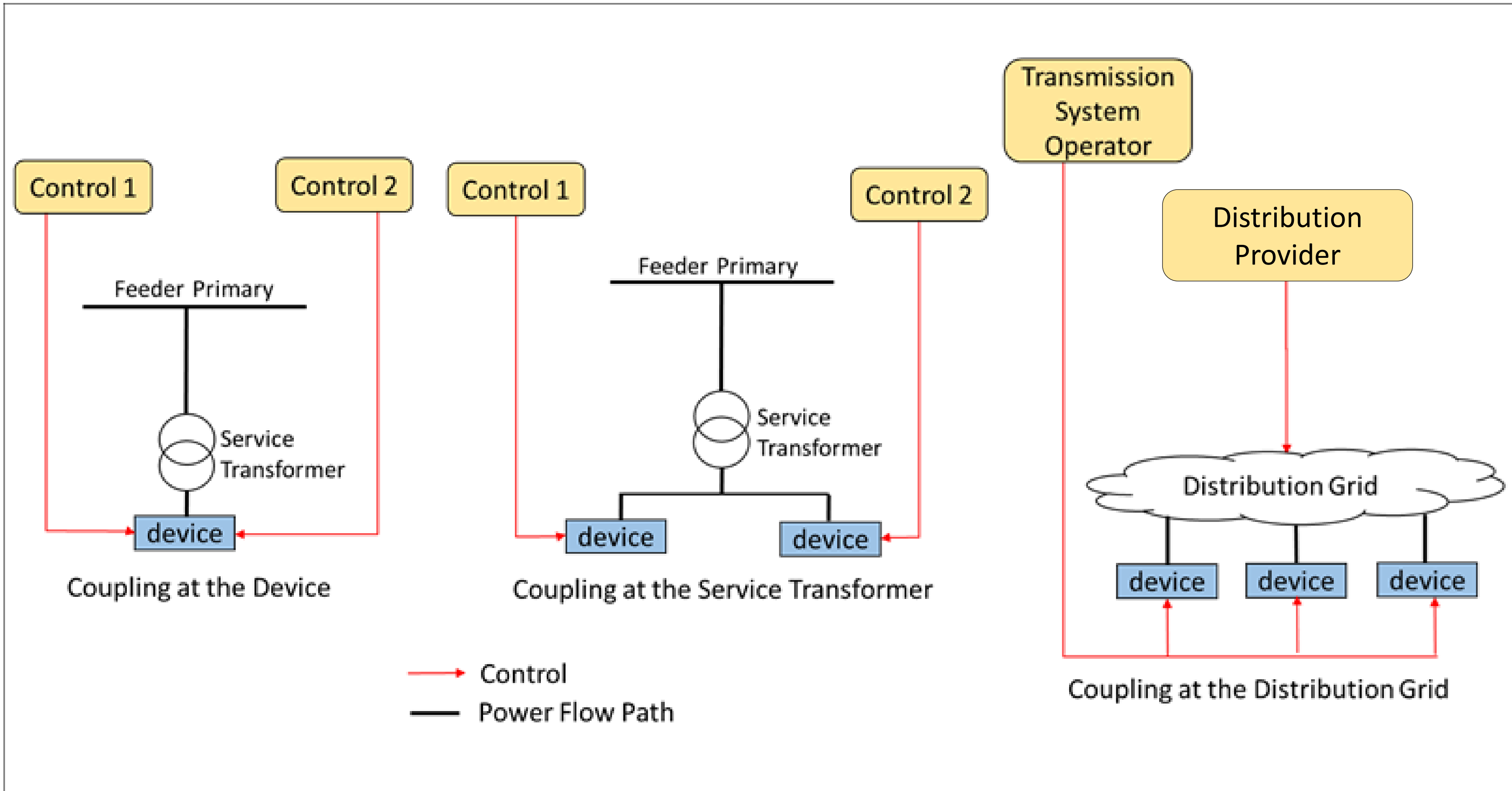
- Grid coordination is the systematic operational alignment of utility and non-utility assets to provide electricity delivery
- Coordination was not a well recognized issue for electric distribution until fairly recently
  - Some forms have been around a long time
    - C&I DR
    - Bulk gen in deregulated industry segments

- The motivation for the present level of interest comes from two emerging trends:
  - Distribution-connected energy resources
  - Electrification of transportation (V2G)

This is an issue because many of these resources are not owned by the utility and often cannot be controlled directly.

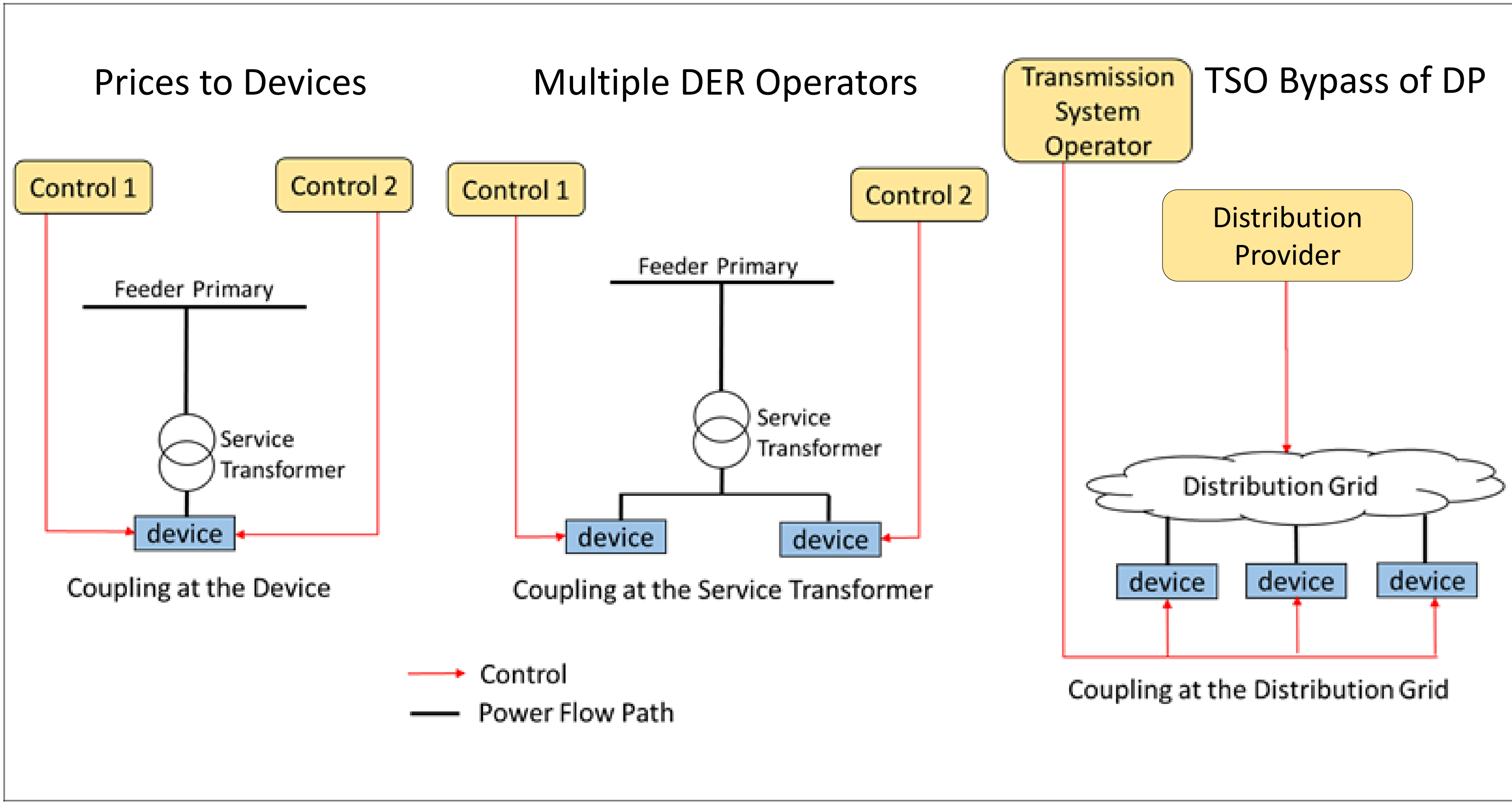
Hidden Coupling

- Having multiple parties trying to operate coupled systems independently leads to conflicting controls
- Hidden coupling can occur many ways and can be hard to recognize

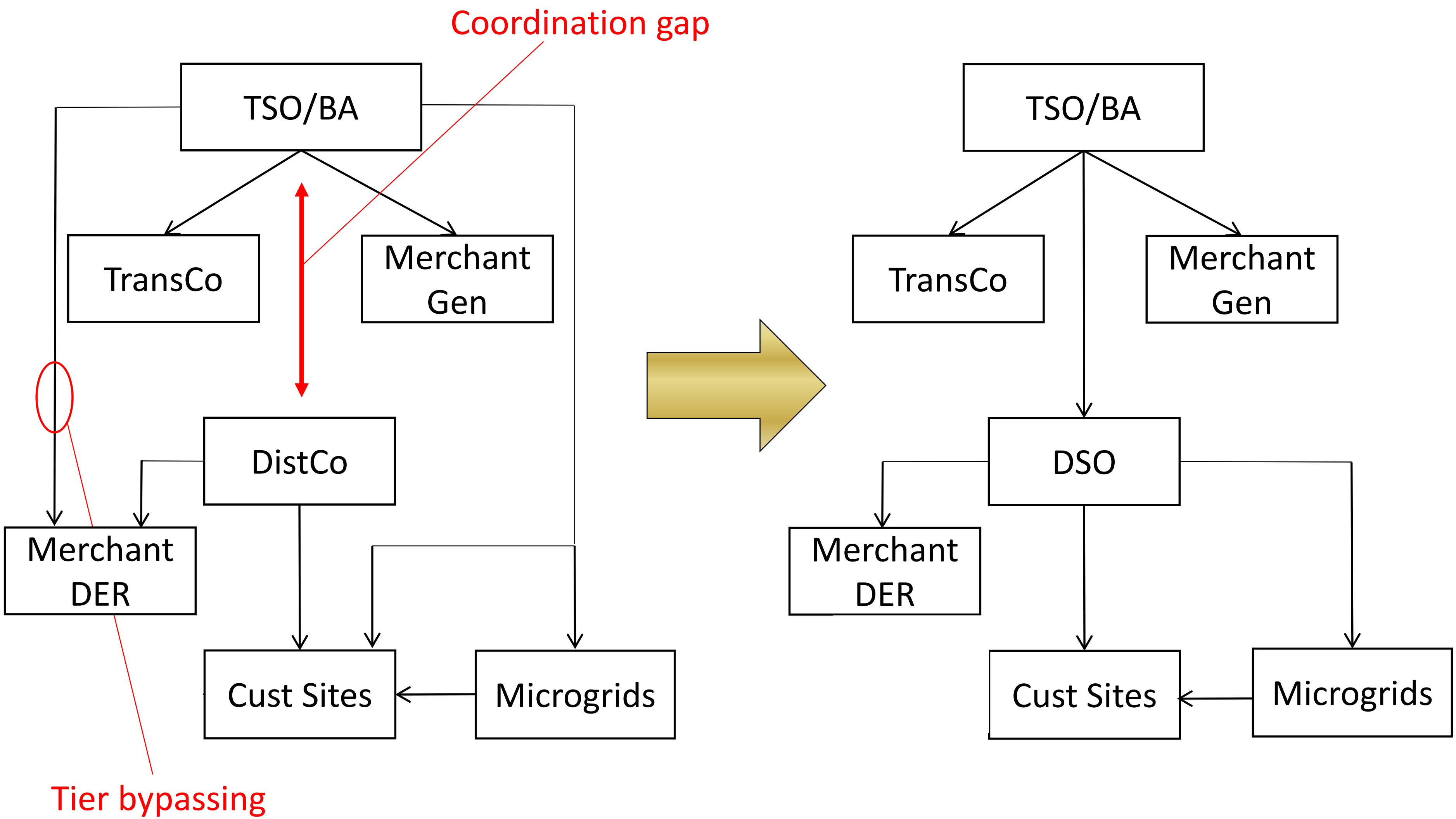


Hidden Coupling Consequences

- Results can be mis-operation, lost benefits, and reliability issues
- We have seen examples of these



Proper T/D/C Coordination Structure Can Eliminate Hidden Coupling



Final Comments

- In order to maximize the value of V2G (and other DER) some legacy grid constraints must be relieved
- Good architectural principles and structures provide needed improvements by:
  - Extending operation flexibility
  - Providing future-proofing
  - Improving resilience
- Layering, platforming, and proper T/D/C coordination structure are three keys to making the grid V2G friendly – look for these in modernization efforts

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http://gridarchitecture.pnnl.gov/

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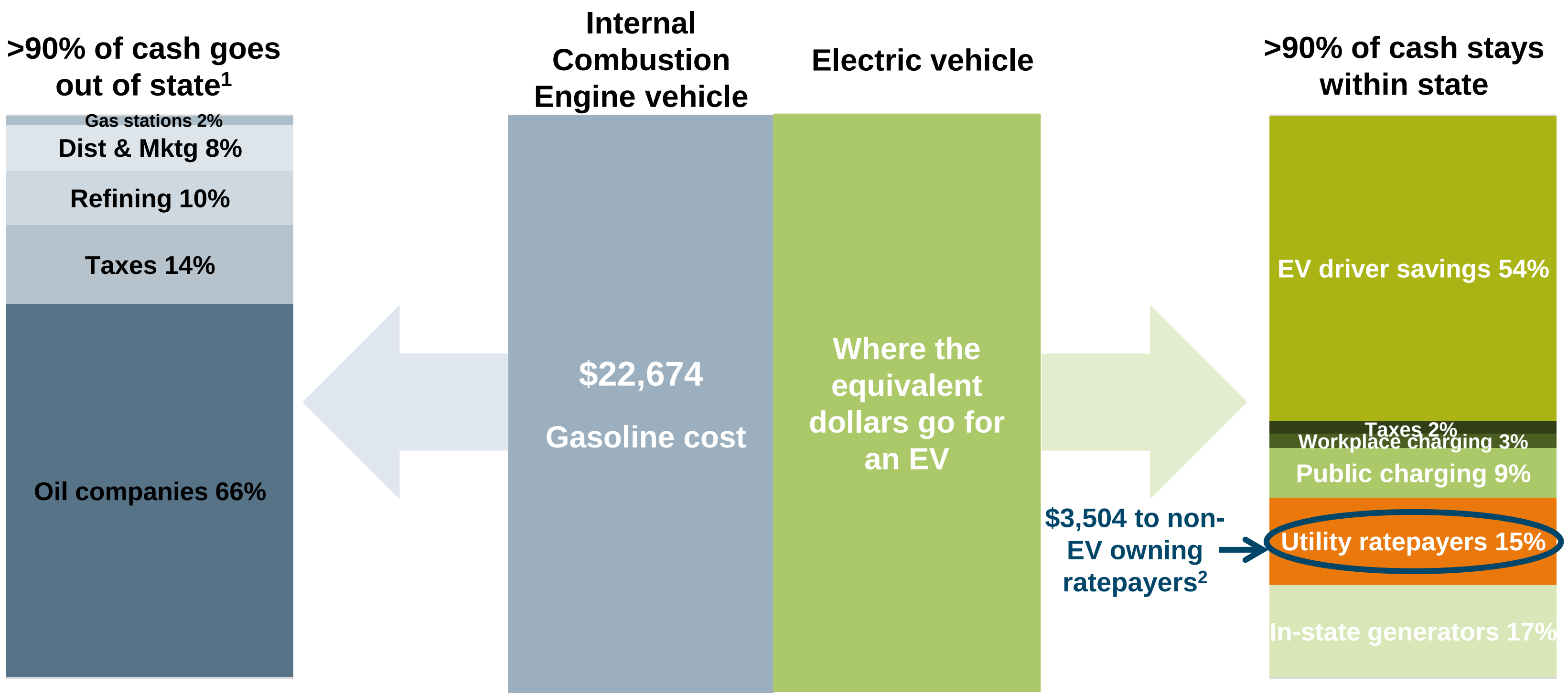
Vehicle Grid Integration (VGI), Standards, and Interoperability

Chris King, SVP – Siemens eMobility

usa.siemens.com/digitalgrid

Benefits of EV charging to non-EV owning ratepayers – if you avoid the peak



[1] – percentage is lower for oil-producing states

[2] – EV charging revenue paid for T&D portion of electricity rates; assumes 90% of charging is off-peak and, therefore, minimal T&D investment is required

Sources: Energy Information Administration, Union of Concerned Scientists, Siemens

Grid Simulation: High Penetration

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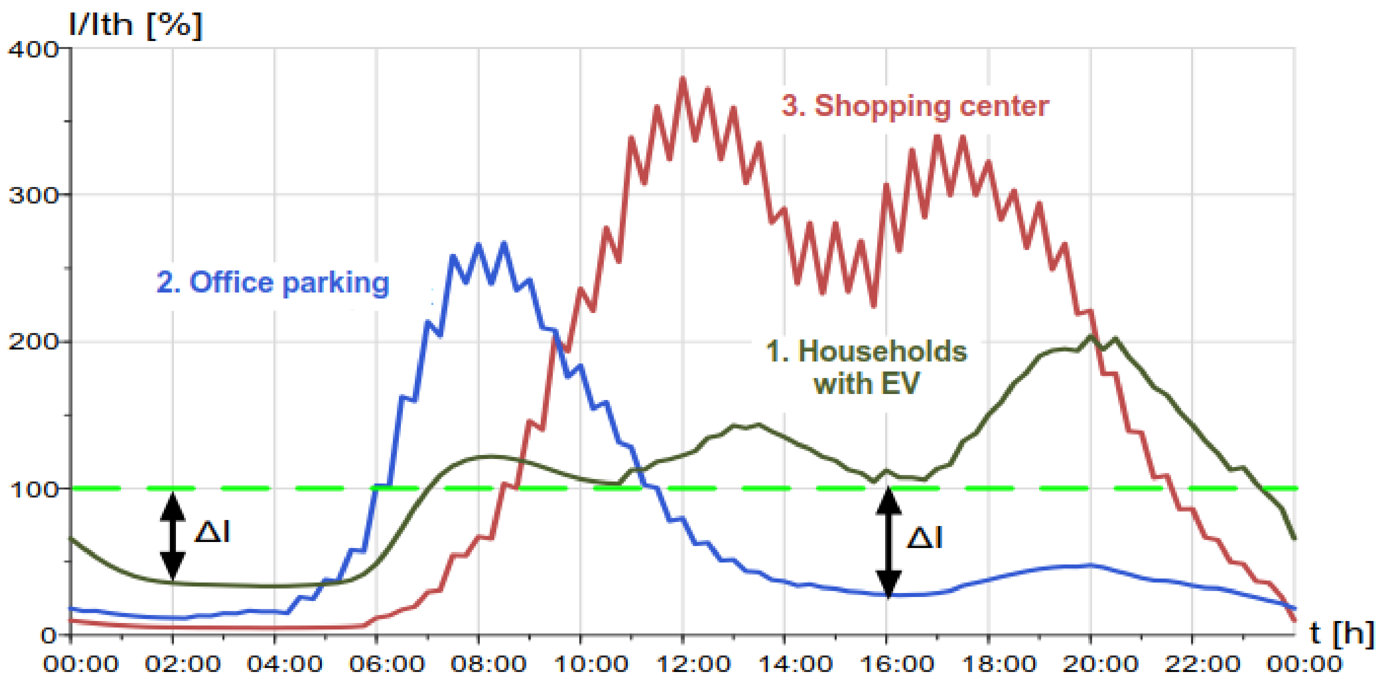
- Study of EV impact
- 50% of a small city, ~20.000 inhabitants in scope, one car per household, 50% EV rate
- 11kw charging
- Real driver behaviour / statistics
- Simulated in a real distribution grid



Preserving Non-participating Ratepayer Benefits via VGI, including V1G and V2G

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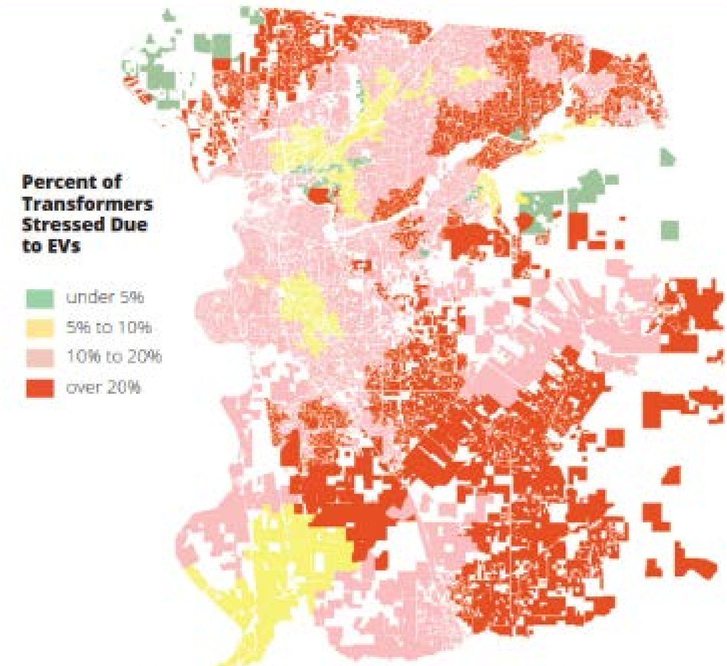
VGI can:

- Improve grid economics by achieving higher utilization rates
- Reduce emissions by aligning charging with surplus renewable generation
- Reduce grid stress and maintain grid stability by minimizing charging ramp rates and reducing the strain on distribution transformers
- Reduce the need for new peak generation and distribution capacity resulting from EVs charging during peak hours

In sum: preserve the benefits of increased revenue from increased kWh throughput through the T&D grid

Effects of unmanaged charging:

FIGURE 3: EV IMPACT ON TRANSFORMERS IN THE SACRAMENTO MUNICIPAL UTILITY DISTRICT SERVICE TERRITORY THROUGH 2030



Source: Smart Electric Power Alliance, Black & Veatch, and SMUD, 2017

The Market Opportunity – NY

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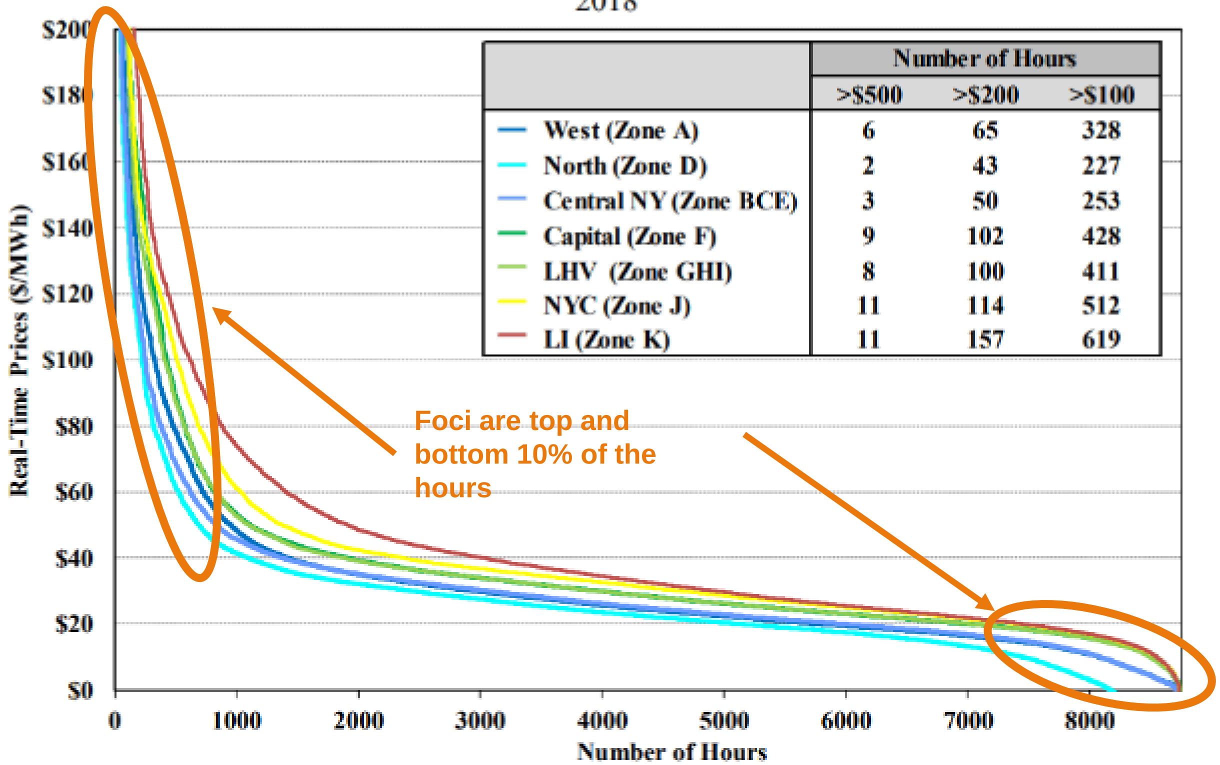
Key enablers:

- Price signals – coordinating mechanism
- Market access – allows monetization
- Interconnection – prerequisite for operations

Figure A-4: Real-Time Price Duration Curves by Region
2018



	Number of Hours		
	>$500	>$200	>$100
West (Zone A)	6	65	328
North (Zone D)	2	43	227
Central NY (Zone BCE)	3	50	253
Capital (Zone F)	9	102	428
LHV (Zone GHI)	8	100	411
NYC (Zone J)	11	114	512
LI (Zone K)	11	157	619

Source: 2018 State of the Market Report for the New York ISO Markets

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Who Benefits from VGI?

EV Drivers

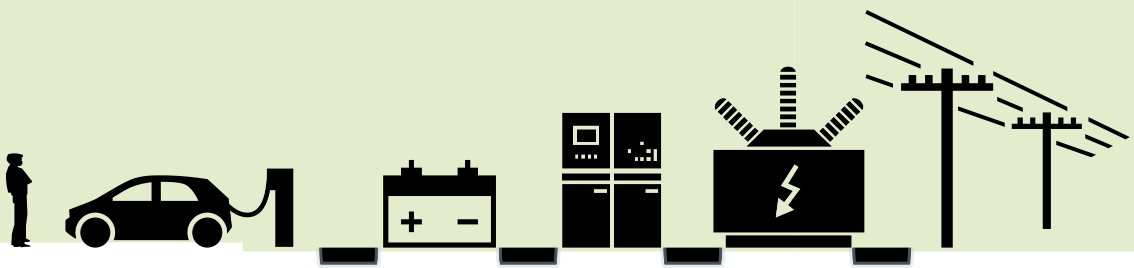
- Lower fuel costs
- Information
  - ✓ Cost to charge
  - ✓ kWh quantity
- Convenience
- Seamless payment

Site Hosts

- Improved utilization
- Demand charge optimization
- Management tools
- Equipment monitoring

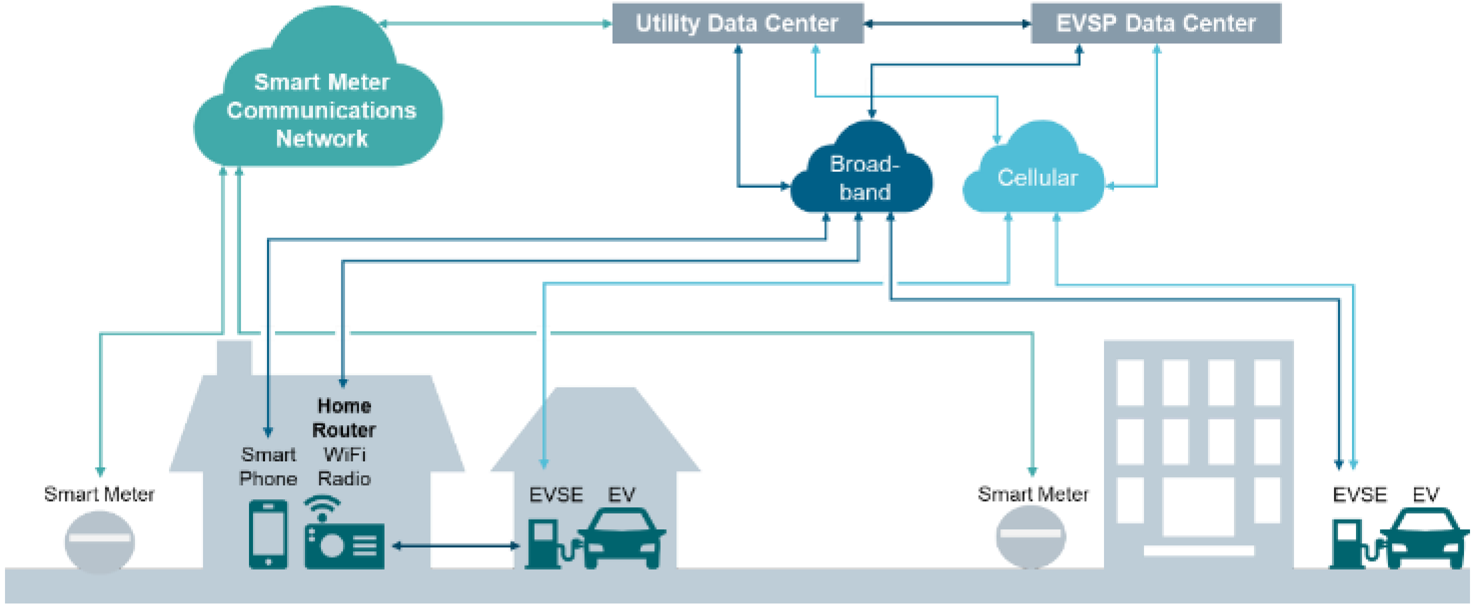
Utilities

- Promote EV adoption
- Load visibility
- Peak demand management
- Grid and market integration



Core Elements of VGI

1. Two-way data communications
2. Remote control
3. Submeter in EVSE



Interoperability

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The need for standards

To **drive down costs and, consequently, prices to customers** by having manufacturers compete to deliver products to the same specification

(Note: Standards are for minimum functionality, manufacturers can always add more features)

To **lower the risk of stranded assets**

by ensuring that different EVSPs can interface to chargers in a vendor-neutral manner (critical in case of business failure/exit of an EVSP)

To **protect customer choice and avoid vendor lock-in**

- by enabling EV drivers to easily pay for charging at any public site, and
- by enabling charger owners to easily switch EVSPs or EVSE suppliers (for new units) if desired

Technical (Metering and Communications) Standards

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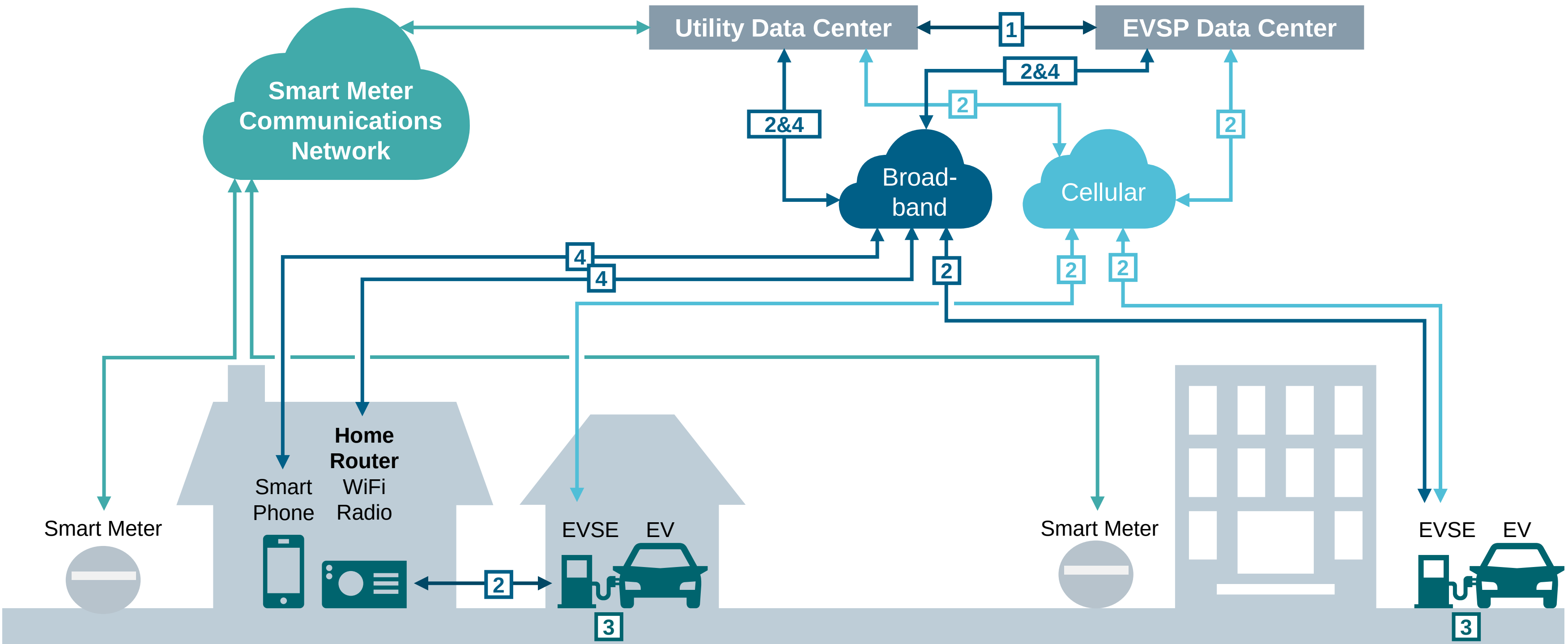

[1] OpenADR and OCPI [2] OCPP, OpenADR, IEEE 2030.5 [3] SAE J1772 (plug),ISO/IEC15118 (EV to EVSE) [4] IP

Policy recommendations

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Publicly-funded chargers – whether by taxpayers or ratepayers – should be **"smart"**

A smart charger is one that has a **sub-meter, is networked, and is integrated to back-end IT systems**

Policymakers should **require** that chargers utilize open standards where available

Policymakers should **not mandate** the use of specific standards and should allow the market to determine which standards to use

Examples of states that have adopted policies promoting or requiring open standards and interoperability are New York, Minnesota, Nevada, Arizona, Washington, and California

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Questions?

ENABLING GIV SYSTEMS

OVERVIEW OF TECHNOLOGY AND POLICY IMPLICATIONS

FOR

The Regulatory Assistance Project's

V2G WEBINAR

BY

WILLETT KEMPTON AND SARA PARKISON

EV RESEARCH & DEVELOPMENT GROUP
UNIVERSITY OF DELAWARE
AUGUST 26, 2020

Grid-Integrated Vehicle (GIV) System Concept

- EVs already have both the battery and power conversion equipment (charger and motor drive) for grid storage
- The average light vehicle is parked 95% of the time, typically near a plug
- To provide grid services, existing components may need minor adjustments, e.g.:
  - Change charger to bidirectional charge and discharge (vehicle-to-grid, V2G)
  - Add controls and signaling to respond to grid, not just by time of day
- Aggregation means we can meet trip needs of any individual and, also, meet aggregate need for balancing or reserves by RTO

How GIV Systems Operate

1 PLUG IN YOUR CAR
to any charger

Courtesy NUVVE

2 CHARGE BATTERY
safely and efficiently in V2G Mode

Courtesy NUVVE

3 **MAKE MONEY**
by providing power capacity and sending energy back and forth to regulate the Grid

OR SAVE COSTS
by using stored energy from EV batteries to reduce building energy peak consumption

Courtesy NUVVE

4 YOU'RE READY TO DRIVE

with the charge you set for the day with advance trip planning using a mobile fleet management app

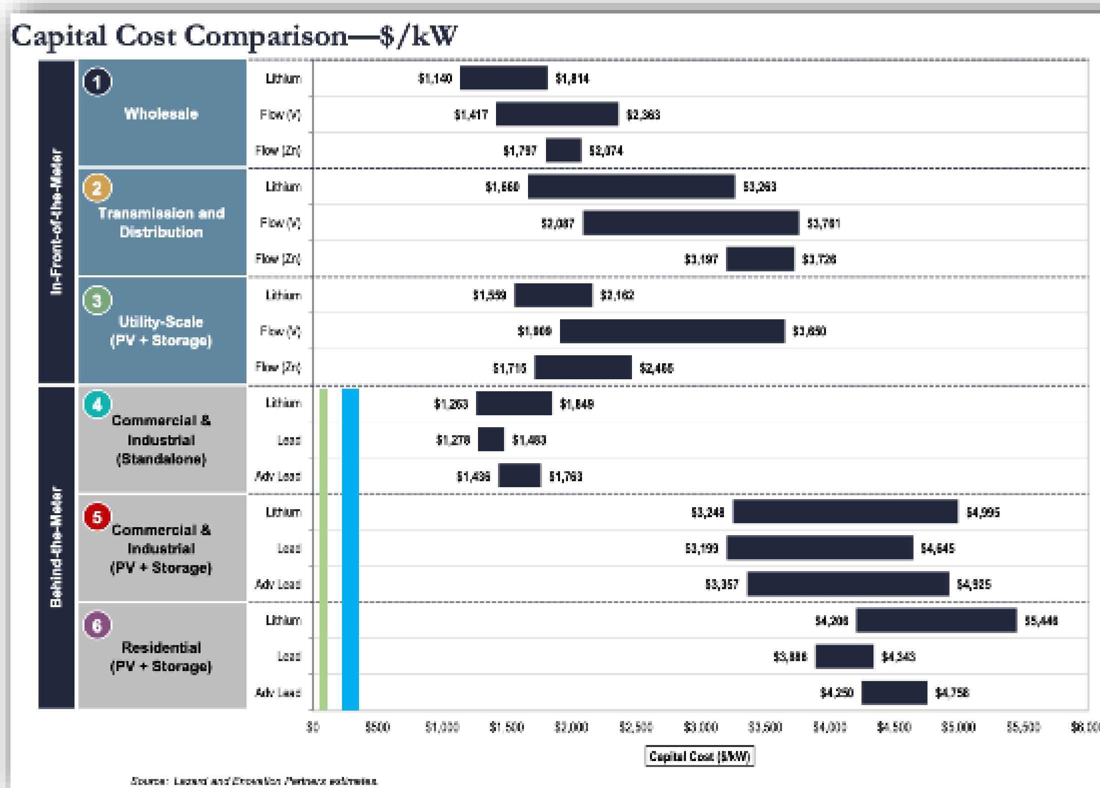
Courtesy NUVVE

Purpose-built Storage is expensive

- Lazard: Capital Cost is $1K - $5K/KW

EV Storage is not expensive

- Demo $ 227/KW
- OEM Production $45/KW



Black bars are non-EV, from Lazard LCOS v4.0, 2018

How to further improve the economics

- On-board (AC) charger, **lower capital cost**
  - AC charging 1/3 to 1/2 cost of DC charging equipment
- Bidirectional (V2G), **higher revenue**
  - 13x revenue of controlled charging, but more complex.
- Higher power per car, **higher revenue**
  - Charging power is key (more kW in/out), may not need bigger kWh battery
- Consistency of driver plug-in when parked, **higher revenue**
- Policy amendments for **market access** (end slides)

Revealing the full stacked value

Group	Service	Gross Annual Revenue Range (Per 100 kW bid)	Gross Annual Revenue Range (Per 10 kW Car)	Hours per year needed or standby
BTM	Arbitrage	$500 - $3,000	$50 - $300	2,200
BTM	Customer Peak Reduction	$0 to $2,500	$0 to $250	100
DSO	Deferral of Distribution Upgrades	?	?	70
TSO	Capacity	$3,000 - $7,000	$300 - $700	?
TSO	A/S Regulation	$5,000 - $18,000	$500 - $1,800	8760 (or bid 24*n)
TSO	A/S Spinning Reserves	$2,500 - $4,000	$250 - $400	8760 (or subset)

Approximate Numbers

GIV Systems
Now Operating Commercially

UD PJM DSR PILOT PROJECT

US PJM regulation: $1,200 per EV per year

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DENMARK V2G installations

Energinet.dk Primary reserves market, earning €1,600/EV/year

AFA JCDECAUX fleet in Copenhagen

Energinet.dk Primary reserves market, earning €1,600/EV/year

UK's first V2G installation in Nissan Technical Center in Cranfield + Newcastle University

National grid, pre-market testing

Nuvve Confidential

US projects underway in California and PJM

V2G School Busses in California

Controlled charging and V2G EVs on same EVSEs at U Del

Stationary storage in PJM

US PJM regulation: $1,200 per EV per year

AC, three-phase charging + V2G

Tested to charging standards at National Renewable Energy Lab, Golden, CO

NREL standards testing

Participating OEMs

(= Original Equipment Manufacturer,
i.e. Automotive Manufacturers)

"V2G AC Resources represent a potentially lower-cost form of mobile storage that supports renewable integration and improves vehicle-grid integration for the purposes of distribution planning."
– *Auto Alliance in submission to CA PUC.*

- BMW (demonstrations)
- Honda (Pre-production EVs with AC V2G built-in)
- Nissan Europe (selling Leafs & eNV200s warrantied for V2G via DC)
- The Lion Electric (selling AC V2G busses)
- BYD (40 kW AC V2G demonstration, 28 transit buses)
- Bluebird (DC V2G buses, pre-production)
- Thomas Bus (DC V2G buses, pre-production)
- Renault (mass produced AC V2G capable vehicle)

Most of the above have done detailed studies of effect on warranty & battery life & decided that is not a problem.

Auto Alliance indicates need for 5-year lead time from design to mass production.
Regulators must demonstrate markets will be accessible.

Enabling further commercialization requires regulatory certainty for interconnection, and market access to reveal the full value of storage technology.

How?

FOUR KEY POLICY ACTIONS TO ENABLE GIVS

1. Clarify storage technology definitions to recognize both stationary and **mobile storage systems** (i.e. GIVS). This ensures DC GIVS can interconnect.

2. Address interconnection barriers by reviewing and possibly increasing kW thresholds for **expedited interconnection**, to enable low-cost study when appropriate.

3. Address inappropriate **interconnection certification** requirements by adopting the technology-appropriate and safer SAE J3072 standard for the interconnection of AC GIVS.

4. Allow for equal **credit-for export** revenue to reduce transaction costs.

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EXPEDITED INTERCONNECTION

- Following FERC Order 792, storage (thus GIVs) should be included in fast track interconnection categories.
- Raising the upper capacity limit of Level I interconnection limit to at least 25 kW, following IREC's 2019 report recommendation.
- Some States already adopted this measure (OR, UT)
  - Others adopted higher limits (CA with 30 kW, MT with 50 kW)
- Facilitates some fast charging station GIV interconnection.

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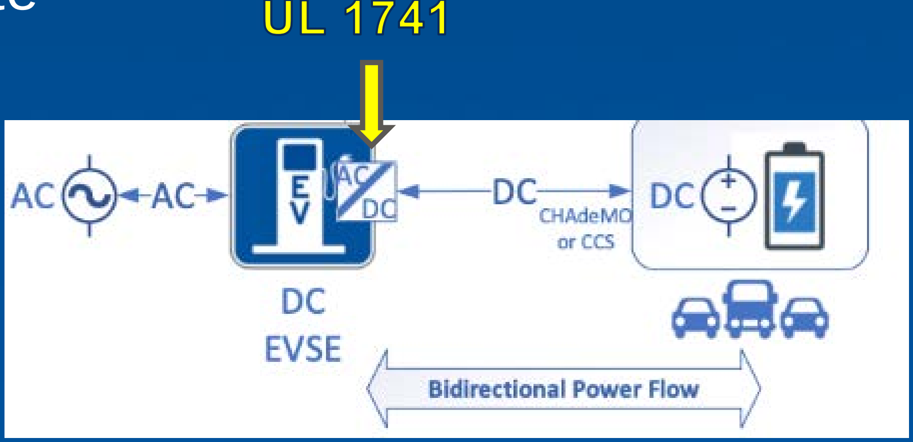
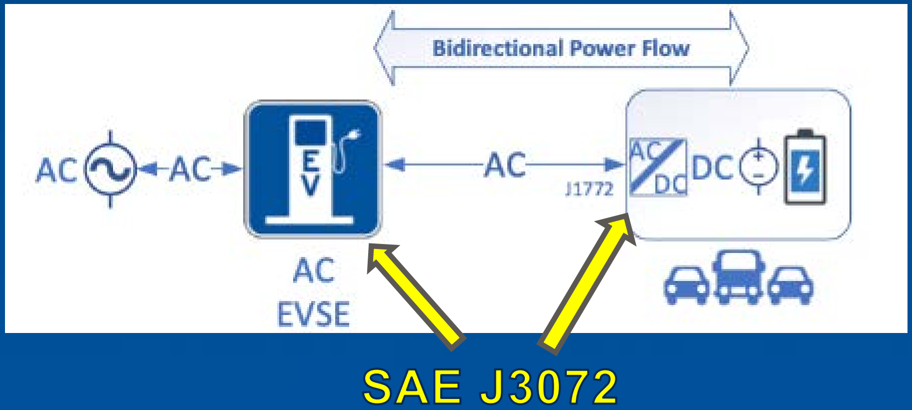
INTERCONNECTION CERTIFICATION – DC SYSTEMS

- Certification norms for interconnection equipment: IEEE, UL, NEC
  - IEEE 1547
  - UL 1741 (assumes equipment inverter is fixed onsite, not mobile)
- Components certified by OSHA-approved NRTL
- Appropriate for DC GIV systems, where the inverter is located onsite



INTERCONNECTION CERTIFICATION – AC SYSTEMS

- SAE J3072 is appropriate safety certification for AC systems
  - Requires compliance with IEEE 1547 and NEC
  - Charging station becomes "gatekeeper," only allow compliant cars to backfeed
  - Fixed components tested and approved by OSHA lab to meet UL 2594
  - Certification of mobile inverter with standard is determined by OEMs



Already codified in DE law through SB12 (June 2019)

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CREDIT-FOR-EXPORT

- To provide grid services, GIV systems must compete with transmission integrated storage systems.
- Create a tariff that enables fair competition.
  - Customer receives credit/kWh exported at full retail rate in effect at the time of export.
  - Ensures GIV systems won’t be charged more than non-GIV systems
  - Mitigates penalties imposed by bidirectional retail transactions
- Already in use (since 2009) in Delaware (Title 26, Chapter 10, Amend §1014 of Delaware Code)

SUMMARY – CURRENT STATUS

GIV systems can provide an array of benefits to consumers, ratepayers, and the grid.

- Bring down TCO of EVs
- Turn an uncontrolled influx of demand (EVs) into a controlled load
- Mitigate the variability of high integration of renewables
- Provide a cheaper, readily-available storage resource for grid services
- Full value of stacked benefits to the grid can include capacity, deferral of distribution upgrades, ancillary services, frequency regulation, spinning reserves, arbitrage, and peak shaving.

Technology is proven and maturing, with OEMs producing V2G-enabled vehicles and aggregators realizing market value

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SUMMARY– RECOMMENDED REGULATORY ACTIONS

To reveal full value of the technology, regulators must act to remove barriers to market access.

1. Modify storage definitions and protocols to include mobile storage
2. Review and potentially raise fast-track interconnection pathways
3. Modify inappropriate safety standards to include SAE J3072
4. Ensure technology not penalized at retail level through mechanism such as credit-for-export
5. Work with utilities to design and implement phase 0 implementations of the technology

THANK YOU

Final Takeaways

- Our 20th century power system is a legacy system that needs our attention to accommodate the innovations we want to see today – including vehicle-to-grid.
- Interoperability is one of the keys to lowering costs and barriers to scaling EV integration.
- Regulators need to take steps to remove market-access barriers so that the full value of grid-integrated vehicle technology is revealed.

About RAP

The Regulatory Assistance Project (RAP)® is an independent, non-partisan, non-governmental organization dedicated to accelerating the transition to a clean, reliable, and efficient energy future.

Learn more about our work at raponline.org