Distribution Infrastructure and Electricity Transformation

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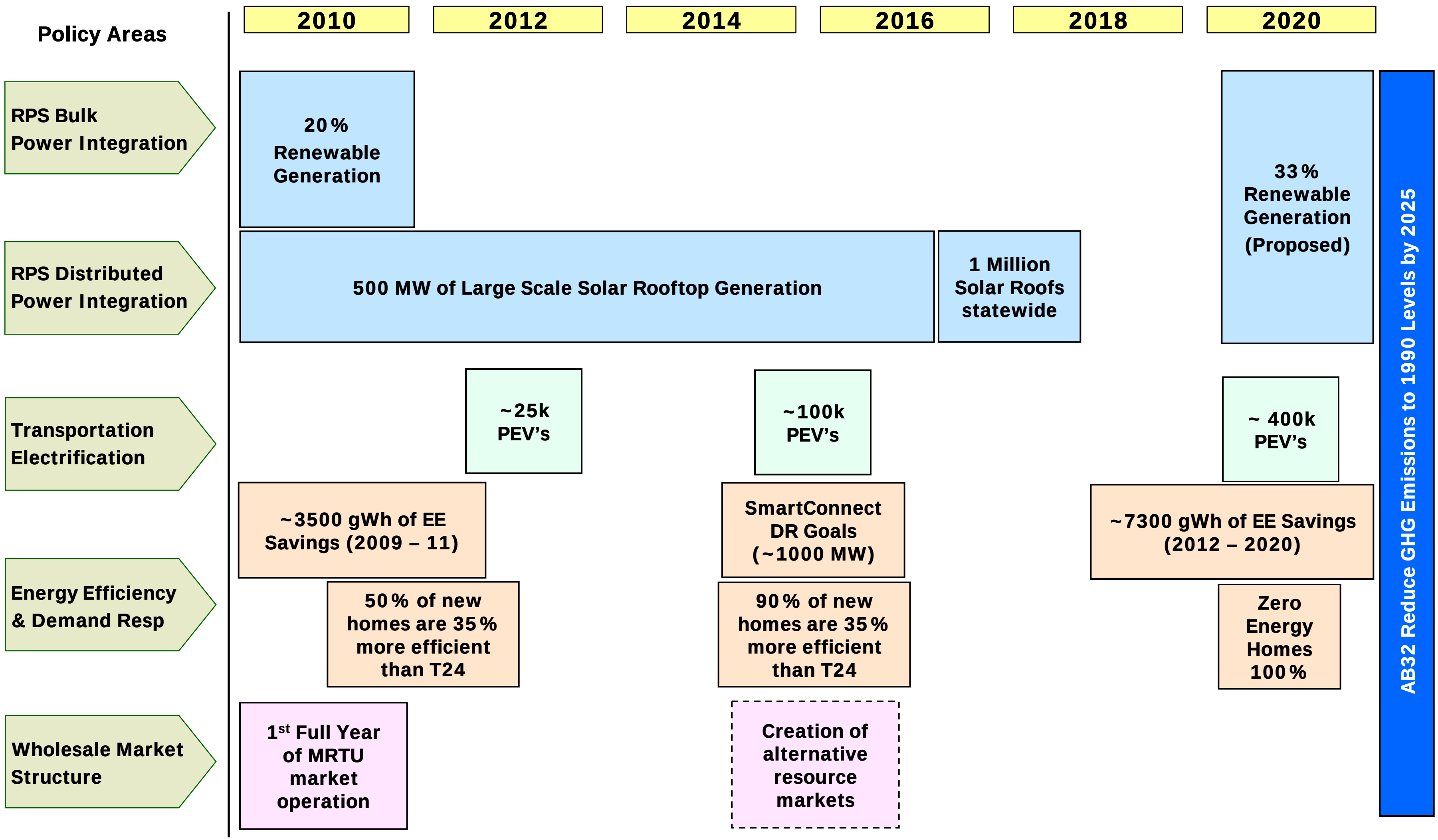
The Accepted Wisdom Five Years Ago...

- Until fairly recently, the notion of the Smart Grid was focused on customer applications…
  - Smart meters
  - Smart appliances
  - Home energy control systems
  - Conservation, energy efficiency and demand response
- Then the focus shifted to transmission systems…
  - Transmission and transformation of renewable power
    - CA policy mandates
    - Significant challenges of renewables integration

But Now…

- While all of the foregoing issues continue, now we face:
  - Expectations of widespread Distributed Generation
    - To meet renewable goals
    - To reduce the need for long-lead-time transmission
  - Expectations of significant penetration of PHEVs and BEVs
    - Very difficult to forecast consumer adoption
      - Highly dependent on subsidies, gas prices, policy mandates and moral sentiment
    - Even harder to forecast clustering
    - Rate design impacts on grid effects
    - Charging protocols vary widely

CA 2020: Energy Policy Initiatives



Renewable & DER Growth

California is pushing beyond limits of current grid capabilities

CA Renewable Portfolio Standard

- **20% by 2010**
- **33% by 2020** (Governor's Exec Order)

Lg Rooftop Solar PV Program

- 500 MWs by 2015
- 250MWs by SCE & 250MWs by IPP
- ~ 350 projects at 1-2MWs each

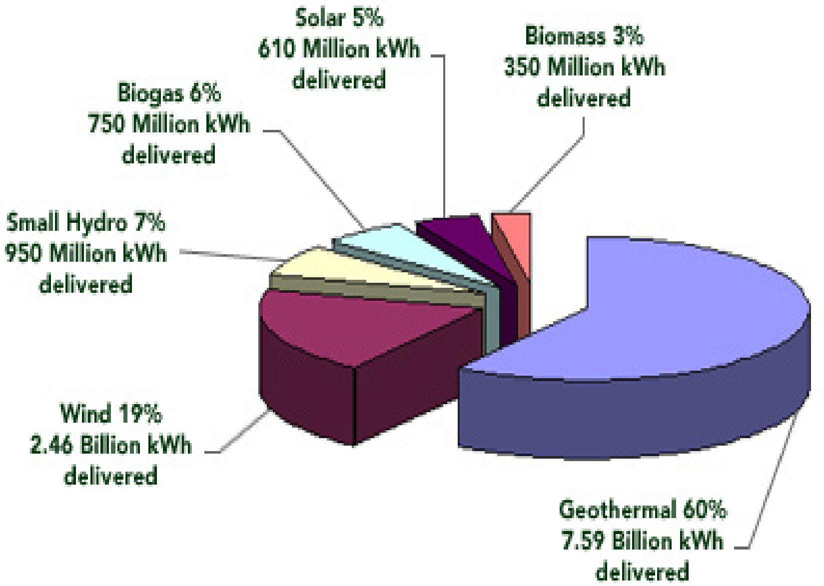
California Solar Initiative (CSI)

- Goal of install 3,000 megawatts (MW) of new, customer-side solar photovoltaic projects by 201

CA Carbon Reduction Law (AB32)

- Reduce GHG by 25% by 2025

16% Renewable Portfolio 2007



Grid Impacts

- Distribution systems were never designed for large two-way flows
  - Studies underway to determine issues
- DG power quality a significant issue
  - Maintaining voltage and frequency remains utility job
- EV charging may represent step-change in distribution design parameters
  - The Tesla example
- No imminent crisis, but prompt action is needed
  - “No regrets” design revisions
  - Broader penetration will likely be expensive - and messy

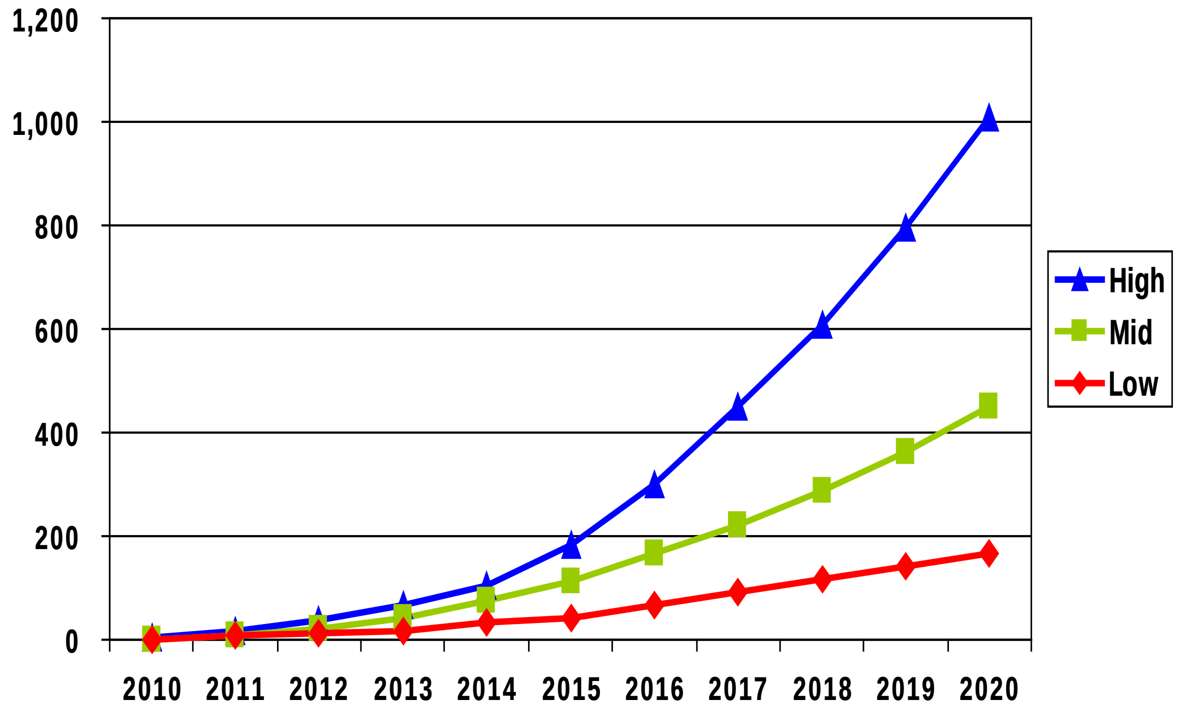
PEV Adoption Forecast for SCE Service Area

Early Market (2010-2014)

- Modest number of PEVs;
- Early adopters with high expectations;
- Uncertainty around market development; and
- New policies and standards developed & implemented.

Growing Market (2015 +)

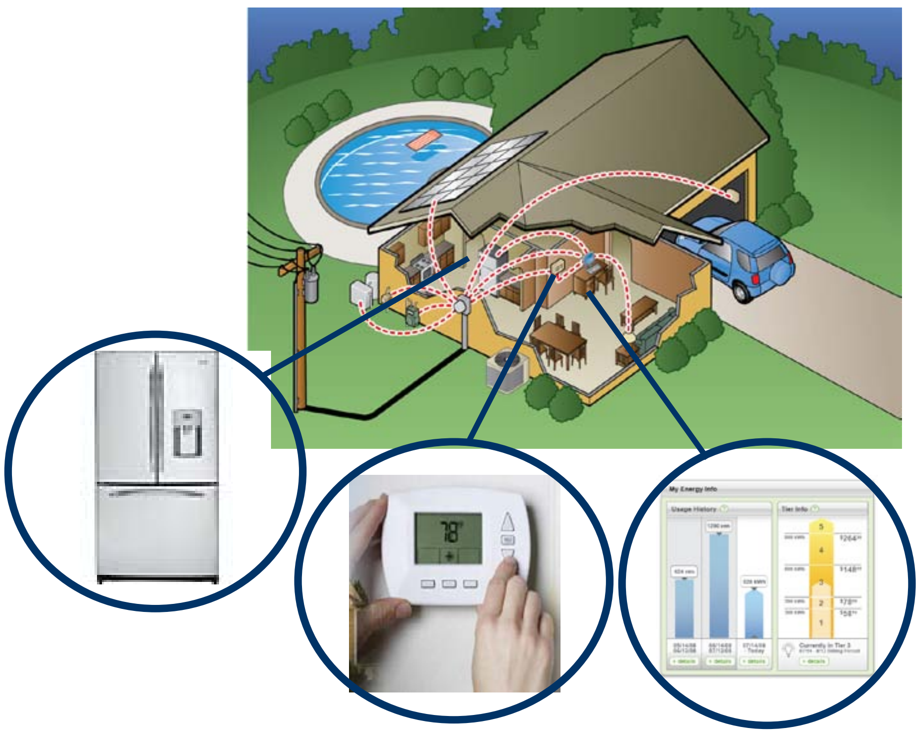
- Growing number of PEVs;
- Some clarity around customer charging behavior and impacts to electric grid; and
- Growing significance of load management.



We are in the early days. All of us – policy makers, auto manufacturers, auto dealers, utilities – need to figure it out together.

Engaging Customers in the Supply Chain

By 2020, in SCE's service area there may be as many as 10 million intelligent devices[1] linked to the grid providing sensing information and automatically responding to prices / event signals



1. Includes smart meters, energy smart appliances and customer devices, electric vehicles, DR, inverters and storage technologies

What is Needed to Realize a Smarter Grid?

- Intelligent and communicating PEVs that integrate gracefully with the grid
- Cost effective energy storage at bulk transmission and distribution
- Re-architecting distribution circuit designs to enable distributed intermittent resources and customer participation in markets
- Commercial products based on open, non-proprietary standards that are secure
- Seemless and secure telecommunications infrastructure that integrates millions of intelligent devices to produce actionable information that is used to control the electric system
- Workforce with the skills and knowledge to engineer, build, operate and maintain an electric grid with pervasive information technology embedded

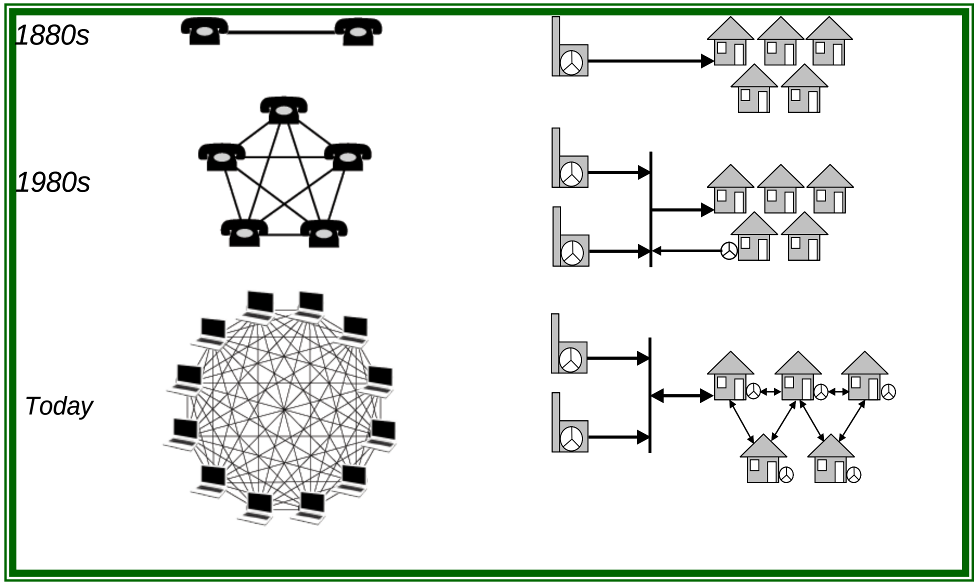
Distribution System Transformation

Distribution circuit design will evolve to resemble attributes of the bulk transmission system in terms of protection and control systems as well as the internet.

However, the number of potential interconnection points on a distribution circuit will exceed the design capabilities of today's transmission system. New engineering designs and technologies will be required to safely manage the power flows.

Also, the information system overlay to link customer market participation to grid operations will require a multi-agent based dynamically integrated micro-transaction and grid operations system.

Policy vision is that significant value can be achieved through bi-directional flow of information and energy over a smart grid to enable customer participation in markets.



Policy & Technology Research Issues

1. Engineering-economics of smarter grid development – Who pays and what are the priority technology investments?
   - Regulatory allocation of Smart Grid enabled benefits and systems & infrastructure costs
   - Should we build a solid electrical and computing system infrastructure foundation before creating broader market participation policies?
2. Electric grid as an increasingly complex network of networks
   - Grid network research and design to manage the increasing complexity for both transmission, distribution and customer systems and their integration
   - Defining the limits of optimization at an acceptable level of instability risk
   - Redesign of the distribution system
   - Understanding potential system inertia deficiencies and solutions
3. Converting the electric grid to support a trillion micro-transactions market dynamically driving grid operations
   - Multi-agent systems dynamics with 20 million potential agents (incl. people & devices) on SCE’s system by 2020
   - Cost-effectiveness of microcommerce related to engaging residential customers in wholesale market operations or intra-microgrid transactions

So Who Pays?

- Energy, like much of the American economy, is predicated on a network of policy-driven cross-subsidies
- CA decoupling removed significant barrier to DG
- Thresholds for shared cost model vs. individual cost responsibility?
  - Past game-changers: Rural electrification, widespread AC, flat screen TVs, ‘mansionization’…
  - Scale may be very different this time

Observations

- The Smart Grid is a journey that will be 20+ years in the making
  - Personal computing was introduced 30 years ago
  - Portable cell phones were introduced 25 years ago
  - Public Internet was launched 20 years ago
- Pace of technology adoption will need to consider policy, customer impact, utility operations and asset obsolesce
- Rate making considerations are critical to appropriately allocating not only benefits but also associated costs to market participants
- A smarter electric grid will become more interactive with our customers' lives thru the home, transportation and workplace