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Impacts of Distributed Generation

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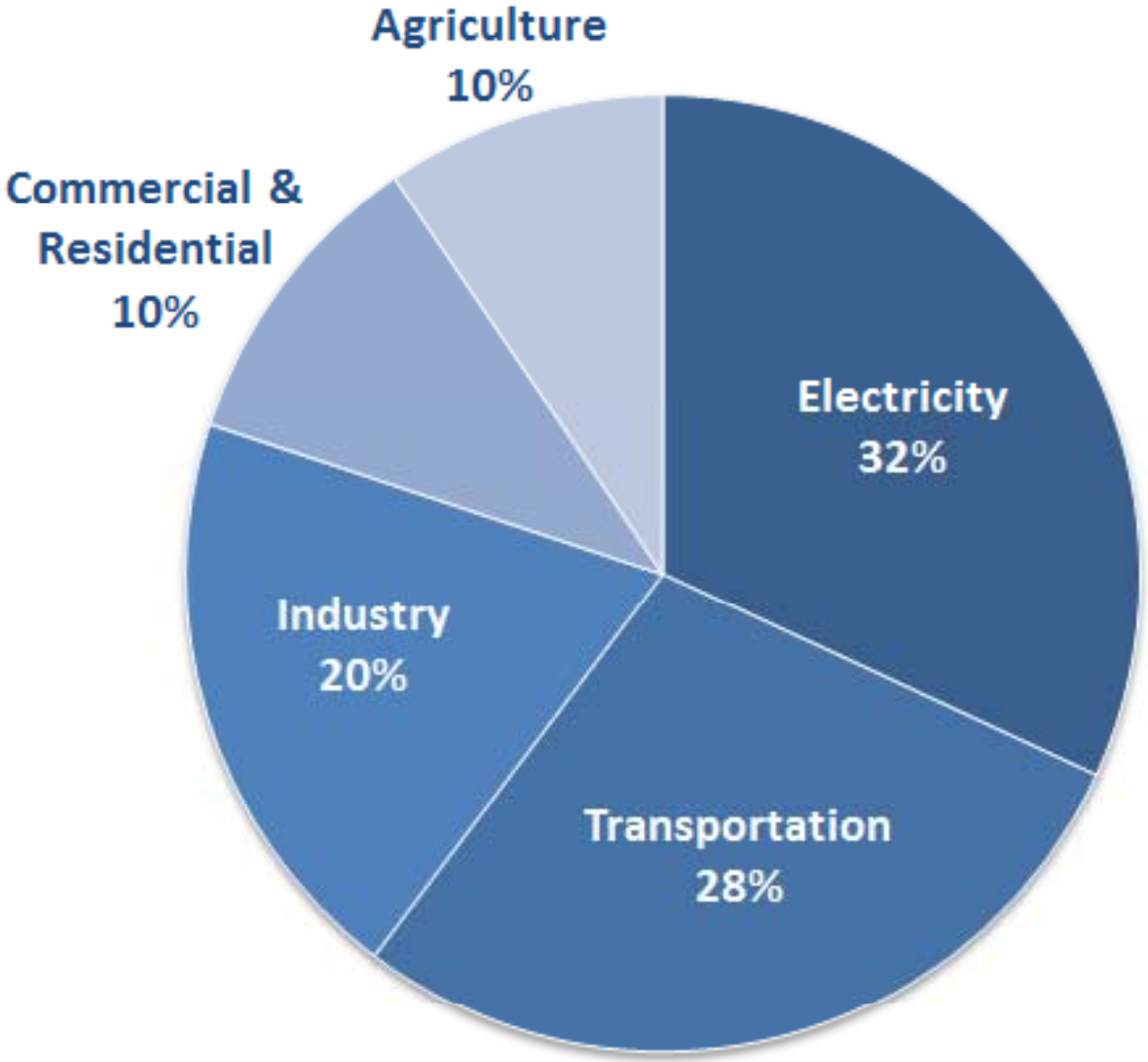
Opportunities
in Distributed Generation

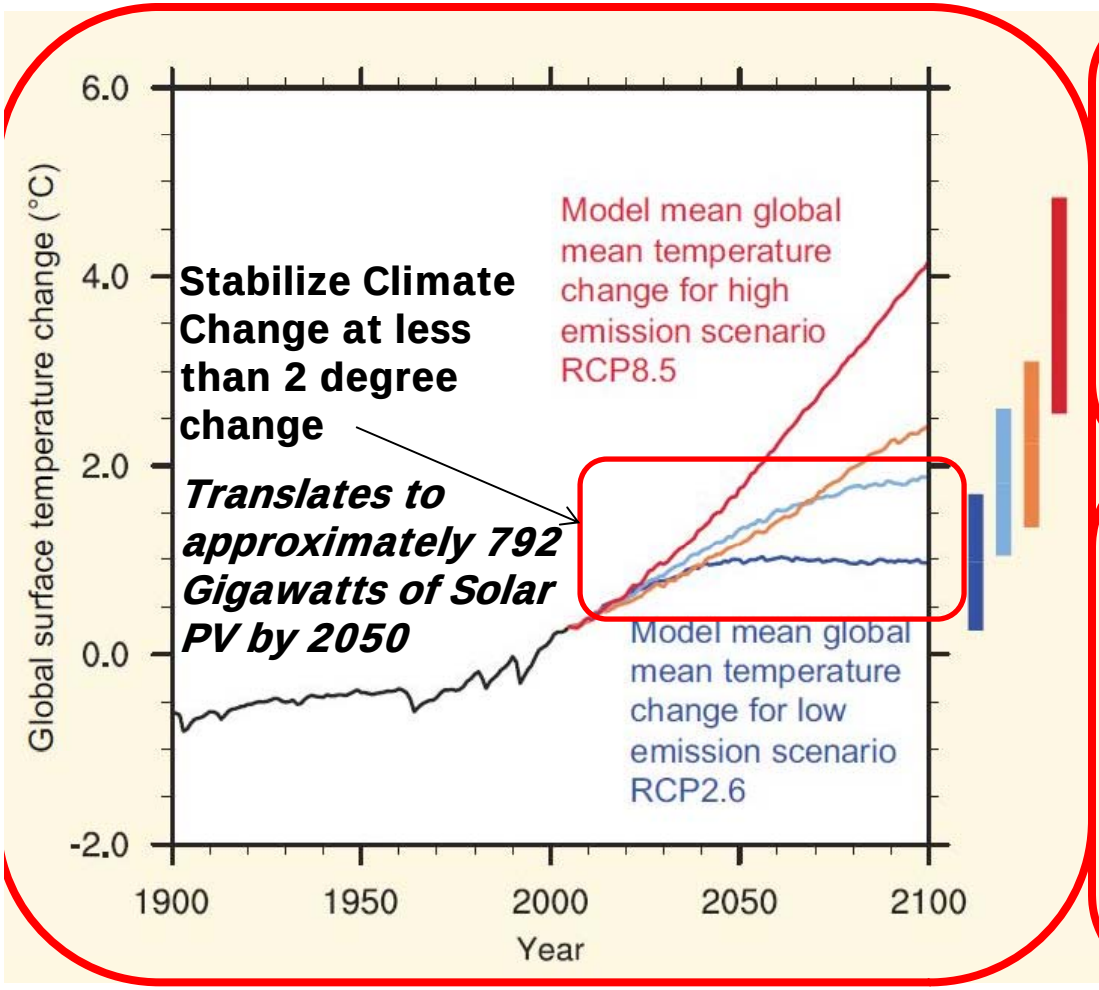
- Distributed Generation (DG) includes small-scale, on-site power sources
  - Solar Photovoltaics (Solar PVs)
  - Demand Response
  - Micro-Turbines
  - Storage
  - Fuel Cells
  - Combined Heat and Power (CHP)
- Primarily Solar Photovoltaics (Solar PVs):
  - Popular with customers and policy makers
  - Incentivized through net metering, utility subsidies, feed in tariffs, business & residential tax credits

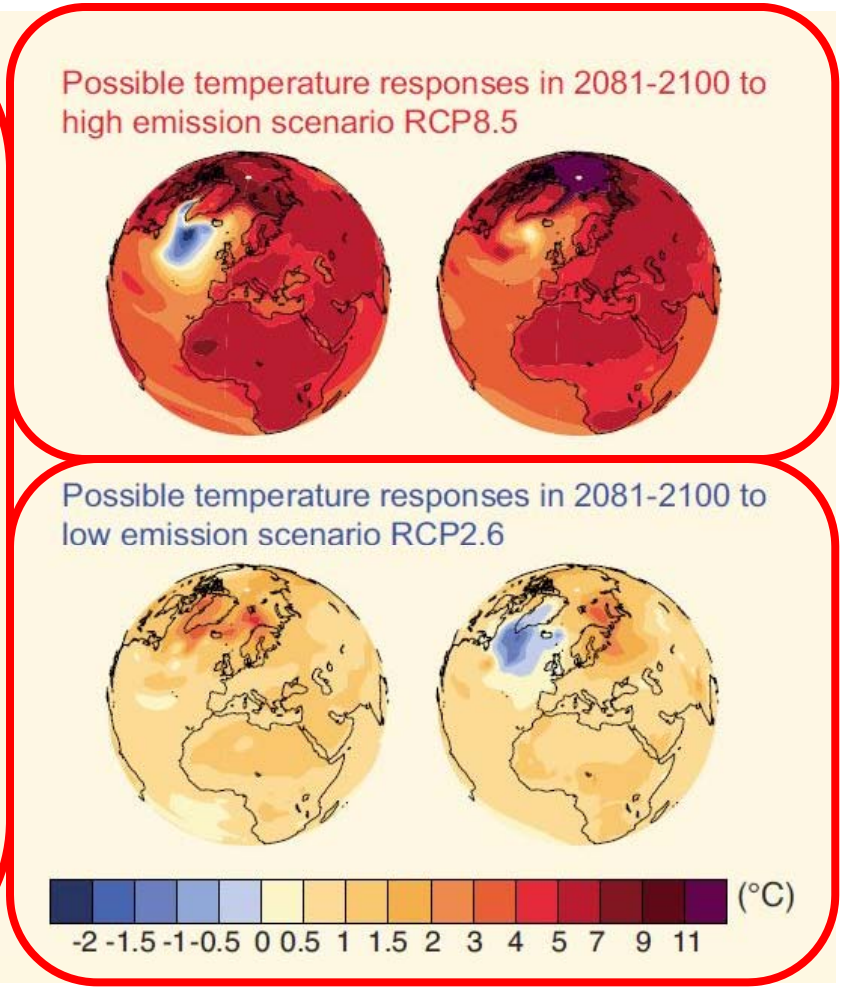
Greenhouse Gas Sources in the US



Source: Environmental Protection Agency, *available at*:
http://www.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2013-Chapter-3-Energy.pdf

Climate Change
High and Low Emissions Scenarios





Srouce: International Panel on Climate Change, *Chapter 1: Introductory Chapter*, pg. 20 of 63. In: Climate Change 2014: Mitigation of Climate Change. Working Group III Contribution to the IPCC 5th Assessment Report - Changes to the underlying Scientific/Technical Assessment.

Realizing the Opportunities

- Strong societal value in decarbonizing the power system – Solar PV could help

- But first:
  - Must fully explore the challenges and barriers
  - Work together find solutions

Challenges in Distributed Generation

- Intermittency - safety & reliability
- Fairness & equity - cost shifts to non-participants
  - Affordable Power Supply
- Shared cost recovery
- Utility investor

inextricably linked

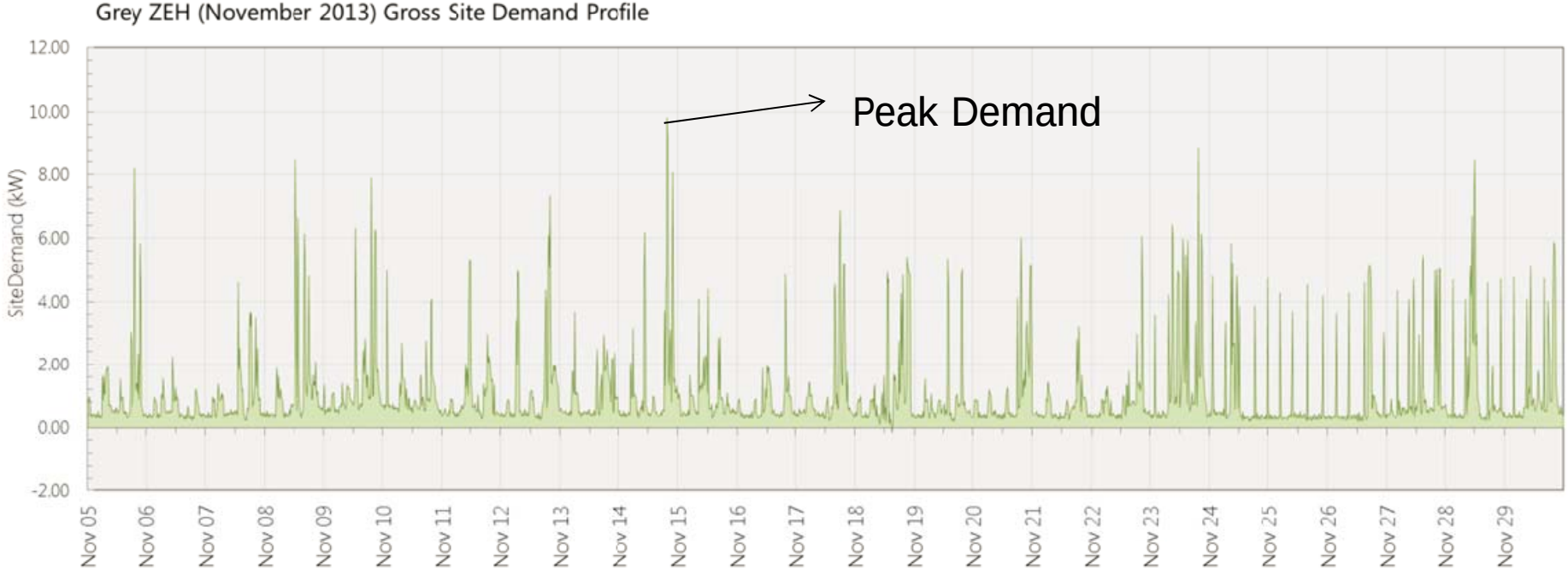
What are the options for addressing these challenges?

Challenges: Safety & Reliability
Intermittent Resources

- How much intermittent resource can the grid absorb without violating safety or reliability metrics?
  - Significant disruptions if Solar PV approaches 20% of total energy on local grid
  - Need feeder-by-feeder power system impact study to assess costs & benefits

- Analysis → impact of Solar PV on distribution system
  - Overvoltage and voltage variations
  - Solar PV masks demand on system: net zero *energy* is **not** net zero *demand*
  - Impact on equipment operation – feeder regulators, load tap changes, switched capacitor banks
  - System protection - relay desensitization, unintentional islanding
  - Each feeder has unique hosting capacity and at increasing penetration levels, violations can happen (voltage, protection, power quality, thermal)

Demand versus Energy

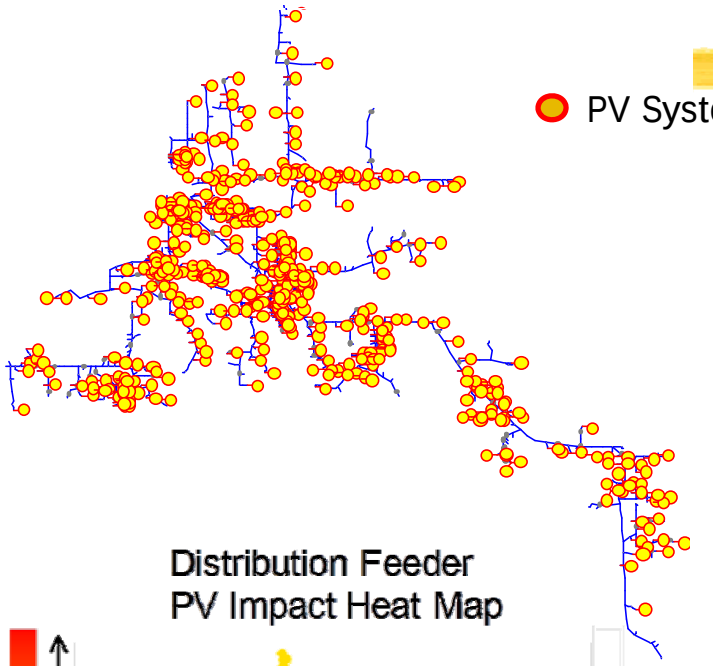


Measured Demand Profile from a *Zero Energy House*

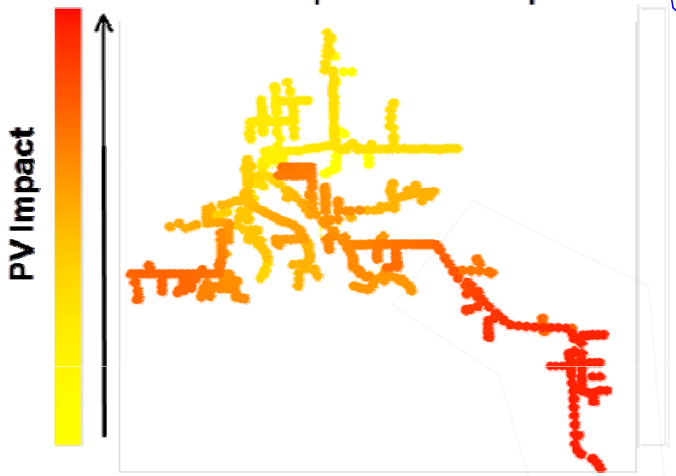
Energy Rich but Capacity/Demand Poor

Assessing Distribution System Impact

Feeder Hosting Capacity: A Brief Primer



Distribution Feeder
PV Impact Heat Map



- Baseline – No PV
- PV Penetration 1
- PV Penetration 2
- PV Penetration 3
- Beyond…

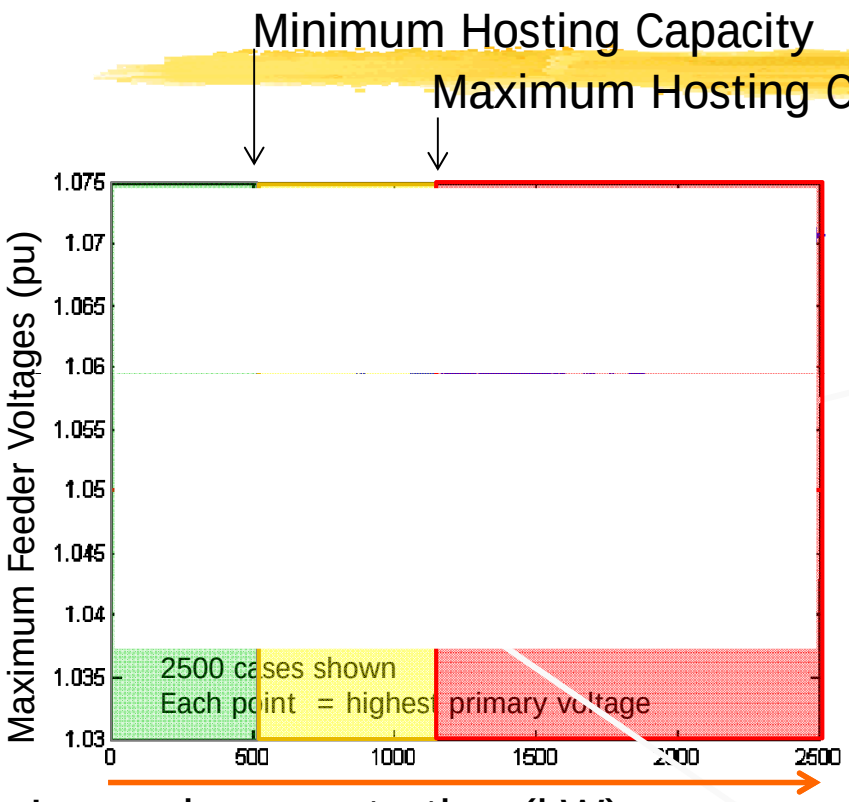
Process is repeated 100's of times to capture many possible scenarios

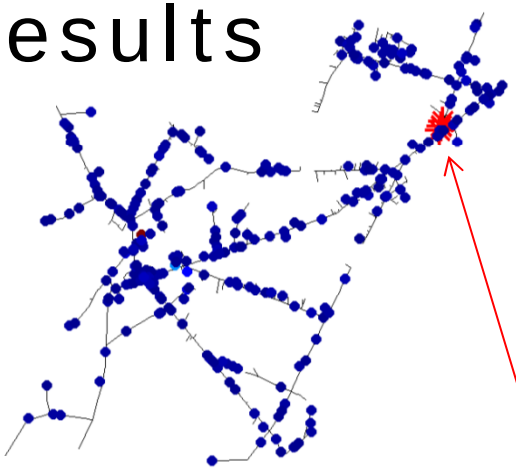
Increase Penetration Levels Until Violations Occur

- voltage
- protection
- power quality
- thermal

Hosting Capacity – Sample Results

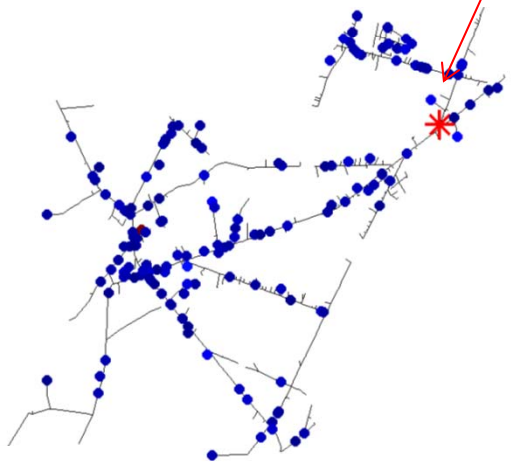
Overvoltage Results Shown for Feeder J1





Total PV:
1173 kW

Voltage violation



Total PV:
540 kW

No observable violations regardless of size / location

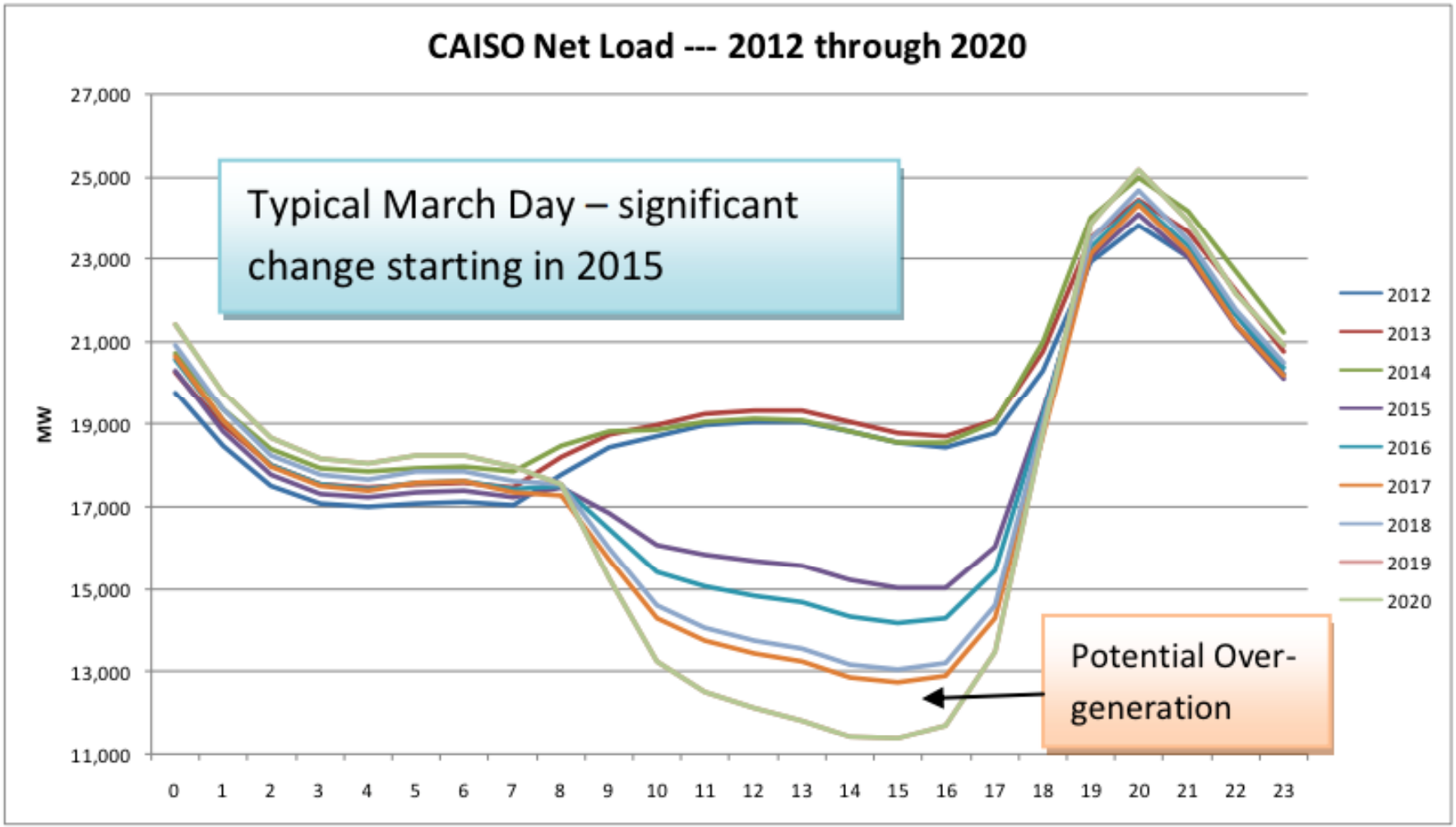
Possible violations based upon size / location

Observable violations occur regardless of size / location

Challenges: Safety & Reliability
Bulk Power Systems Impacts

- **Resource adequacy** – ramp rate, over generation, cycling
- **System stability** – frequency, voltage
- **Transmission flow** – constraints, protection and coordination
- **Need grid support**:
  - Smart inverters, with 2-way communication, will be necessary at higher penetration levels
  - Germany is now retrofitting more than 300,000 Solar PVs with smart inverters
  - California is beginning a smart inverters rulemaking process

Challenges: Safety & Reliability
California "duck" chart Example



Source: CAISO, Flexible Resource Adequacy Criteria and Must-Offer Obligation, December 13 , 2012, *available at* http://www.caiso.com/Documents/StrawProposal%E2%80%93FlexibleResourceAdequacyCriteriaMustOfferObligation.pdf

Challenges: Fairness & Equity
Net Metering & Cost Shifts

- Net metering policies vary by jurisdiction, but *generally* –
  - Rooftop Solar PV customers credited for any electricity sold via power grid
  - Electric companies must buy electricity at full retail rate- includes fixed costs
- Net metering credits generally allow Solar PV customers to avoid paying fixed costs – and those costs are shifted to non-participating customers through higher utility bills
- In the U.S., Solar PV participants tend to have wealth
  - Even with subsidies, less well off don't have capital or credit ratings to participate
- California cost shift to non-participants estimated to be between $370 million and $1 billion by 2020*
- Cost shifting & net metering may result in overall increases in costs, making power less affordable

Should policymakers should re-examine Solar PV incentives?

* California Public Utilities Commission Energy Division, *California Net Metering (NEM) Draft Cost-Effectiveness Evaluation*, p. 7, Table 2 – Net Cost of all NEM generation in 2020, September 26, 2013.

Challenges: Shared Cost

DG Needs the Grid

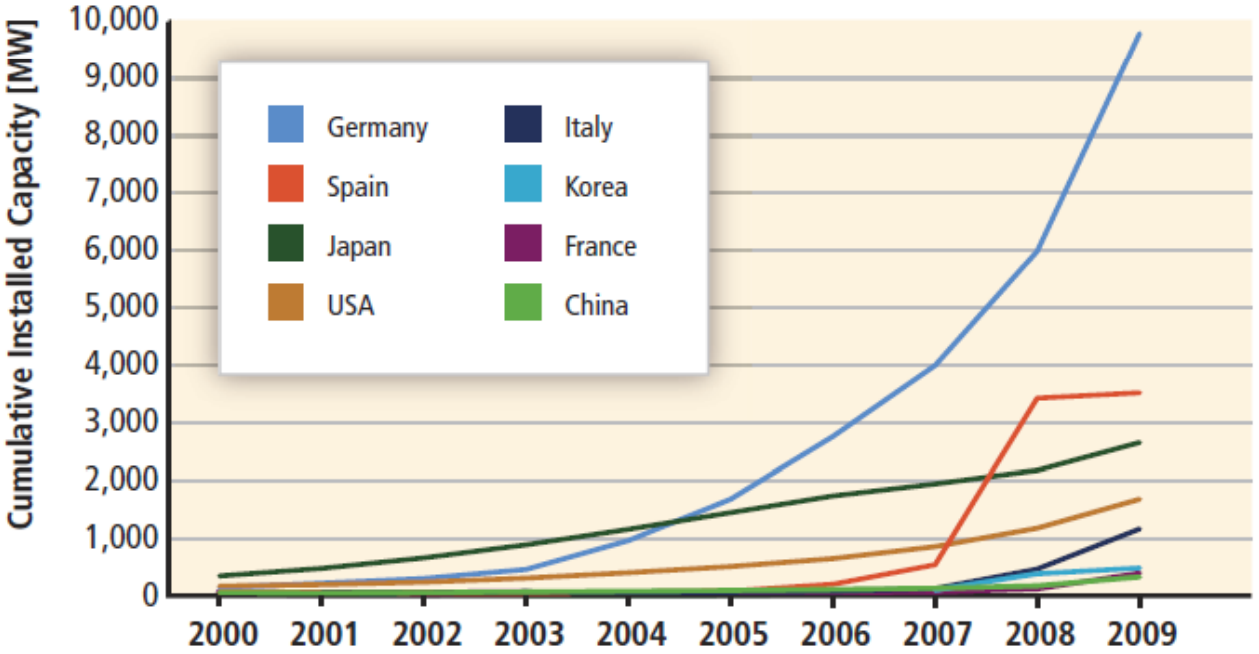
- DG needs the grid to thrive
  - A “grid-less” future not likely
  - Remember the example of “net zero home” – still places demand on the system
- Net metering and FIT rules are unlikely to require Solar PV hosts to pay equivalently for fixed costs
- Most rate designs do not require Solar PV hosts to pay for grid costs like non-participants

Challenges: Shared Cost "Death Spiral"

- Closely related issue: utility's ability to recover existing system costs
- Is there a "death spiral"?
  - Some customers eventually may be able to fully disconnect from grid, like cell phone users have disconnected from landlines
- CREPC study: not a serious revenue threat until 10% of generation is Solar PV
- These developments beg a question of timing & location – it will develop differently depending on the jurisdiction's current system and drivers

Potential Solutions
Options for Regulators

- Solar PV Penetration differs by jurisdiction-
  - Germany: 20%
  - US: 1% now, but ramping up
  - California: nearing 5% limit for net metering



Source: International Panel on Climate Change, *Chapter 3: Direct Solar Energy,* pg. 361, Fig. 3-9 installed PV capacity in eight markets. In: *IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation*.

Where possible, we must address:

- ❑ Safety & reliability
- ❑ Fairness & equity
- ❑ Shared costs/Impact on the utility

Potential Solutions
Safety & Reliability

- Examine interconnection standards & refresh
- Ability to require smart inverters with 2-way communication
  - Smart inverters enable grid supportive Solar PV and permit more Solar PV
- Let utility “throttle” amount of Solar PV on feeders
  - Distribution planning
  - Ability to say “no” (or, “not on this feeder but on this other feeder”)

Potential Solutions
Fairness & Equity

- Fairness & equity
  - Addressing shared cost recovery may also address fairness & equity issues
  - Third party leasing may bring in more participants that are not as wealthy
  - Lawmakers incentivize Solar PV- lawmakers could authorize bill payment assistance
  - Can be a difficult and frustrating issue in US

Potential Solutions
Shared Costs

- Contributor to “fairness & equity” challenge
- Even net-zero buildings use the grid *and* the utility’s central station generation
  - Exception: generation with batteries/storage and complete disconnection from the grid
- Predominantly a rate design issue
  - “Price per kWh sold” rate designs shift shared fixed costs to others (non-participants)

Potential Solutions: Shared Costs Alternatives to per kWh sold pricing

Three Example Alternatives:

- **Straight fixed-variable rate design**
  - Imposes a fixed charge to customers, designed to recover all of a utility's fixed costs
- **Customer demand charge**
  - May include fixed charges and a volumetric rate for each kilowatt-hour of consumption, but may also include a variable charge based on the individual customer's peak demand
  - May accurately allocate non-energy costs of serving customers because utility must design its system and plan for the ability to meet customers' peak needs
- **Performance Based Ratemaking**
  - Utility's revenues adjusted based on performance and incentives set for utilities to meet or exceed benchmarks determined for certain operations
  - If a benchmark is not met, the utility must absorb the extra costs.
  - If benchmark met or slightly better, utility keeps the profits and shares them with shareholders;
  - If benchmark exceeded by determined margins, money is returned to customers

Utility Business Models

- New business opportunities for utilities
  - customer demand aggregation
  - utility turnkey operations
  - utility-led community solar projects
  - partnership and investment in third-party leasing
  - value-added consulting services
  - as a virtual power plant operator
- Key considerations for regulators:
  - regulatory changes necessary to enable new business models
  - potential implications on competition, reliability, and market access
  - Challenges to fundamental regulatory concepts like nondiscrimination

Conclusions

- Opportunities in DG and Solar PV deployment
- Consumer & policy interest likely to continue due to climate change
- Increased Solar PV penetration heightens challenges related to (1) safety & reliability, (2) fairness & equity, and (3) shared costs/utility impact
- Challenges differ by jurisdiction – For example, compare Germany, California, and Oregon
- Potential solutions to shared cost/utility impact issues may increase average rates for all customers
- Fairness & equity issue, through impacts of Solar PV on non-participants, is an intractable issue
- Impact on stakeholder return – can be addressed through rate design

Questions?