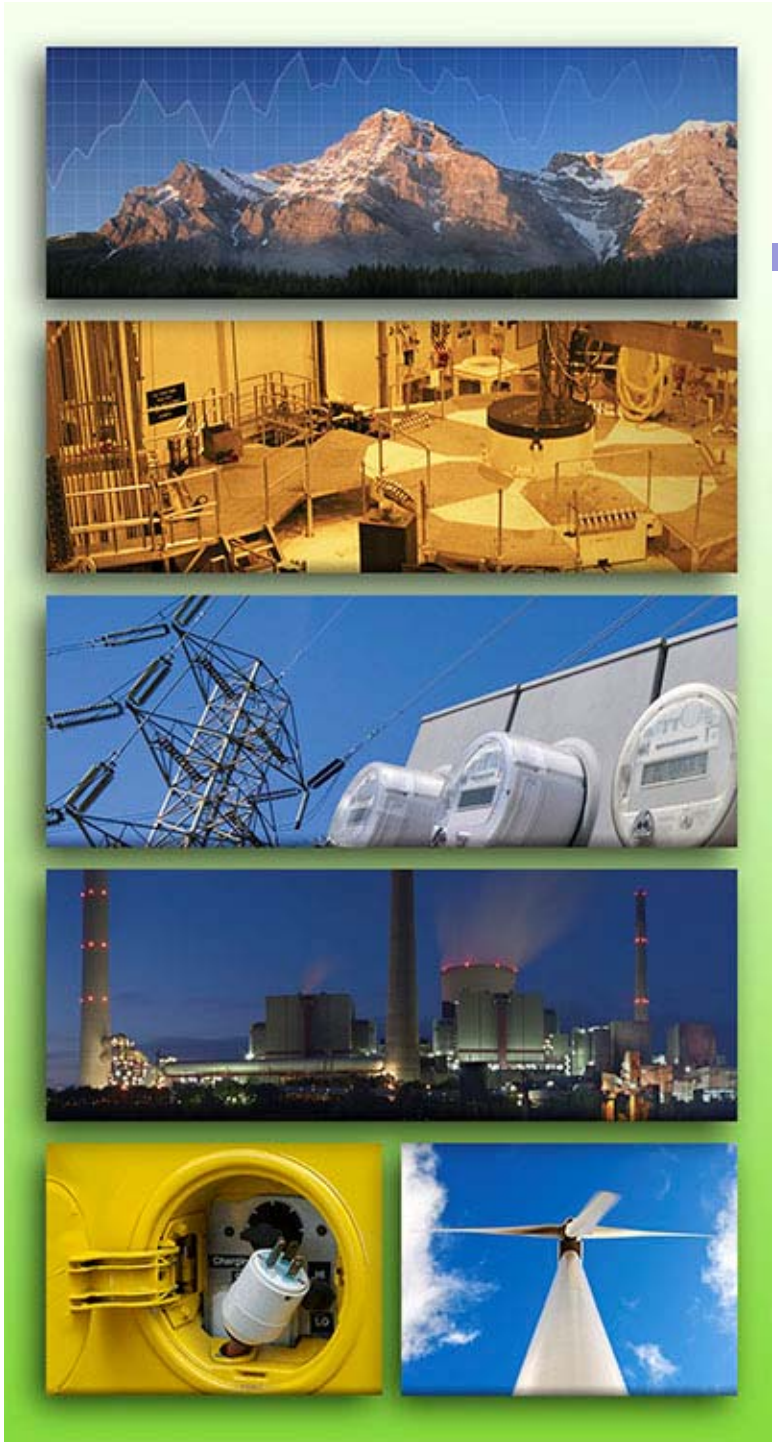


PHEV Design Impacts

Jason Taylor Ph.D.

South West Electric Distribution Exchange
May 6th, 2010

Annual Energy Usage – Electrical Appliances

Home Heating System	2,136 kWh
Central Air Conditioning	3,475 kWh
Refrigerator/Freezer	1,359 kWh
Water Heater	2,552 kWh
VOLT	1890 KWh
Clothes Dryer	1,079 kWh
Lighting	1839 kWh
TV + Others	4182 kWh

Volt is approx. 10% load increase to the average home

NISSAN LEAF zero Emission 2964 KWh

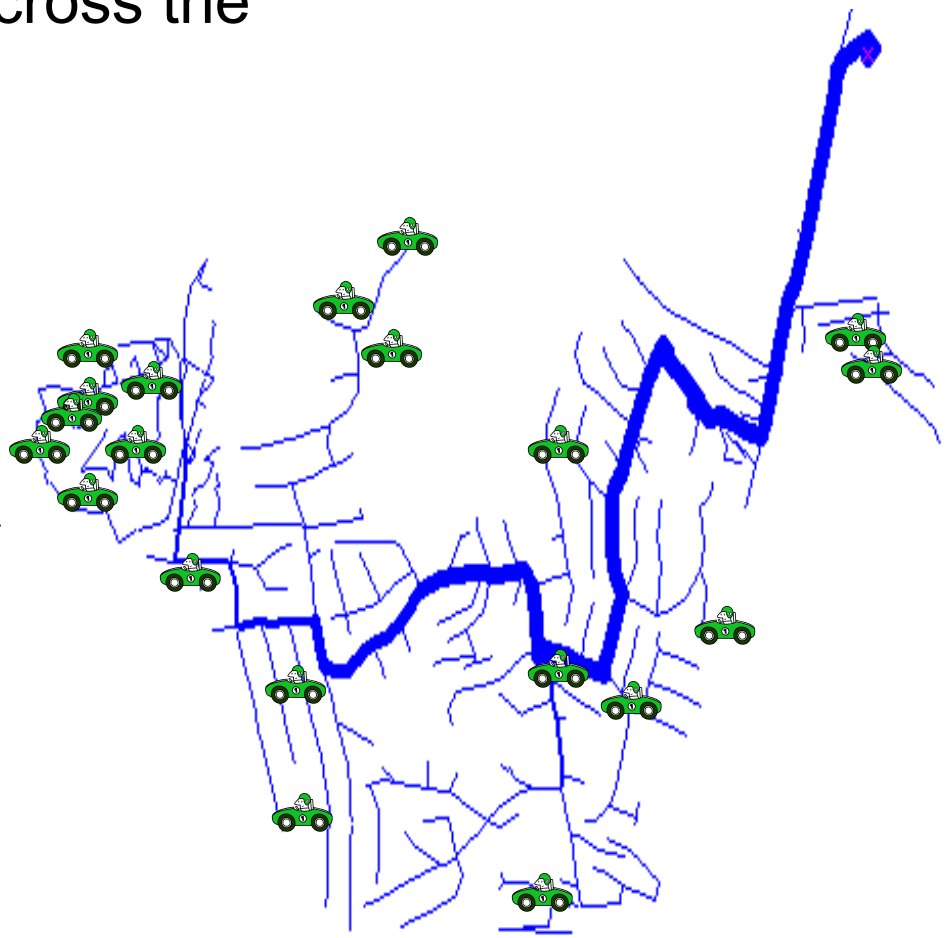
Nissan Leaf is approx. 15% load increase to the average Home

[1] 2005 Residential Energy Consumption Survey

[2] *AEO2009*, EIA, national average for 2009 data

Electrical Charging Characteristics (Load Diversity)

- Demand will vary spatially across the feeder
  - Market penetration
  - System configuration
  - Socio-economics
- Demand will vary temporally
  - Driving patterns
  - Battery size
  - Electrical connection



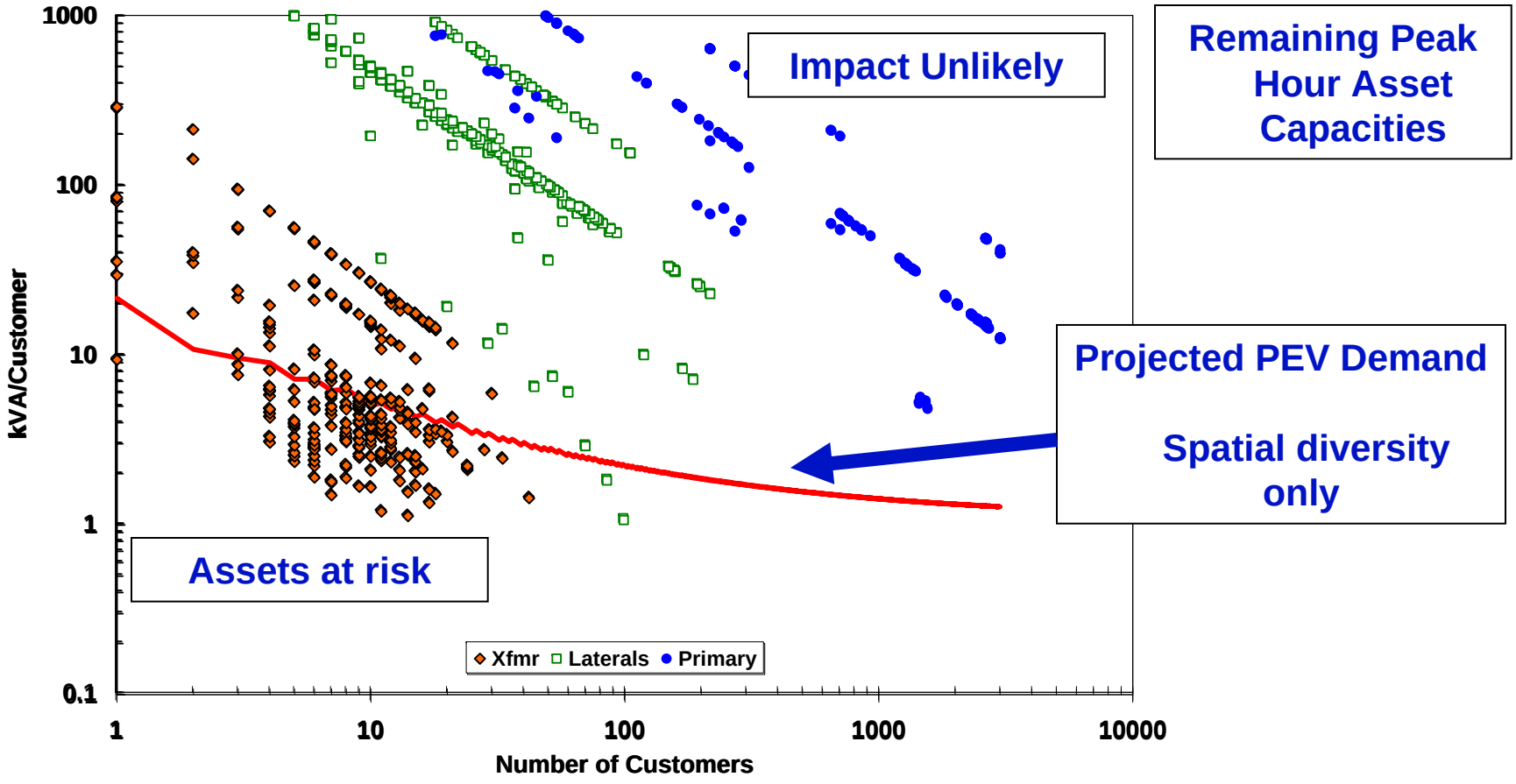
Near-term System Impacts

- Per-capita load growth
- First generation vehicles
- PEV operate only as *uncontrolled load*
- Most likely impacts from PEV clusters
  - *Thermal overload*
  - *Customer low voltage*

Evaluated Distribution Impacts

- **Thermal Overloads**
- **Steady-state Voltage**
- **Losses**
- **Imbalance**

Evaluating Thermal Overload Risk



Impact Likelihood (Thermal Overload)

Stochastic Analysis

Low Penetration Case

ckt	Case w/ Overloads	Avg Overloads per Case	# Xfmr Involved
A	95%	2.9	43
B	17%	1.0	4
C	2%	1.0	2
D	1%	1.0	1
E	30%	1.2	11
F	98%	2.5	4
G	14%	1.0	1

Impact likelihood is system dependent

Only a small percentage are likely to be impacted

Feeder A

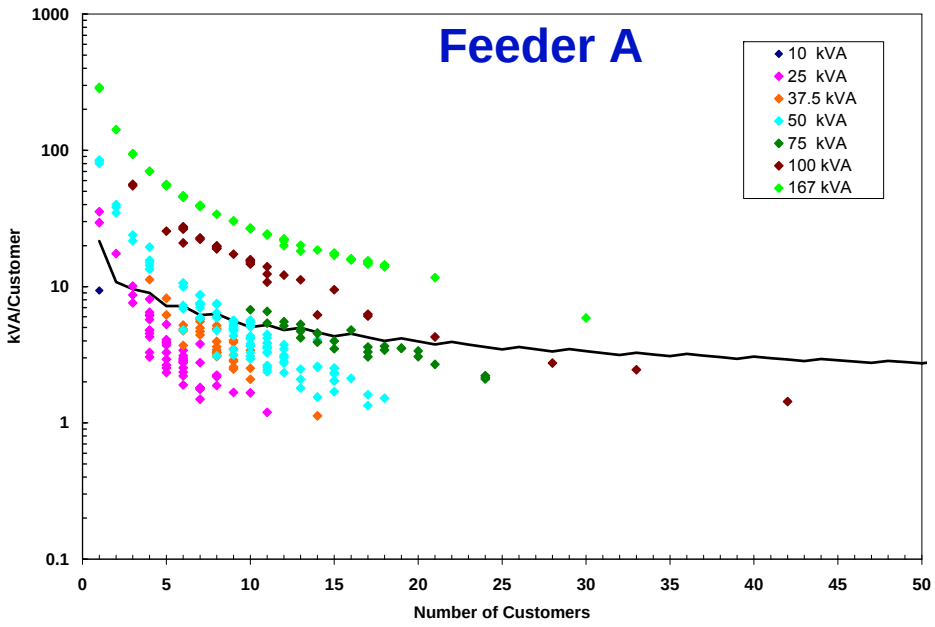
300 Transformers

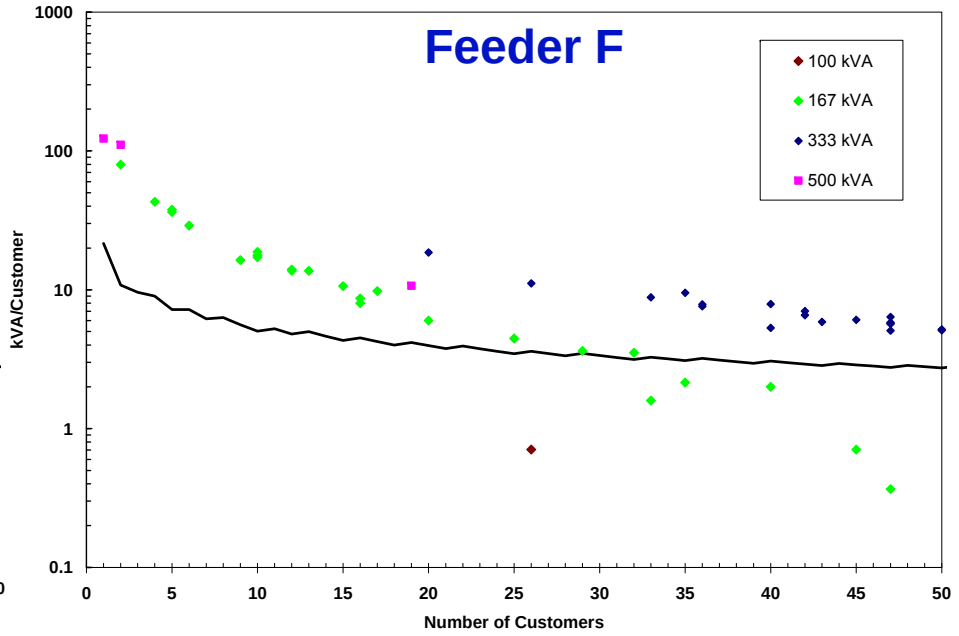
14% at risk

1% likely impacted

Likelihood Factors (System Design)

- Existing asset loading
- Customers served
- Number of assets
- Asset ratings





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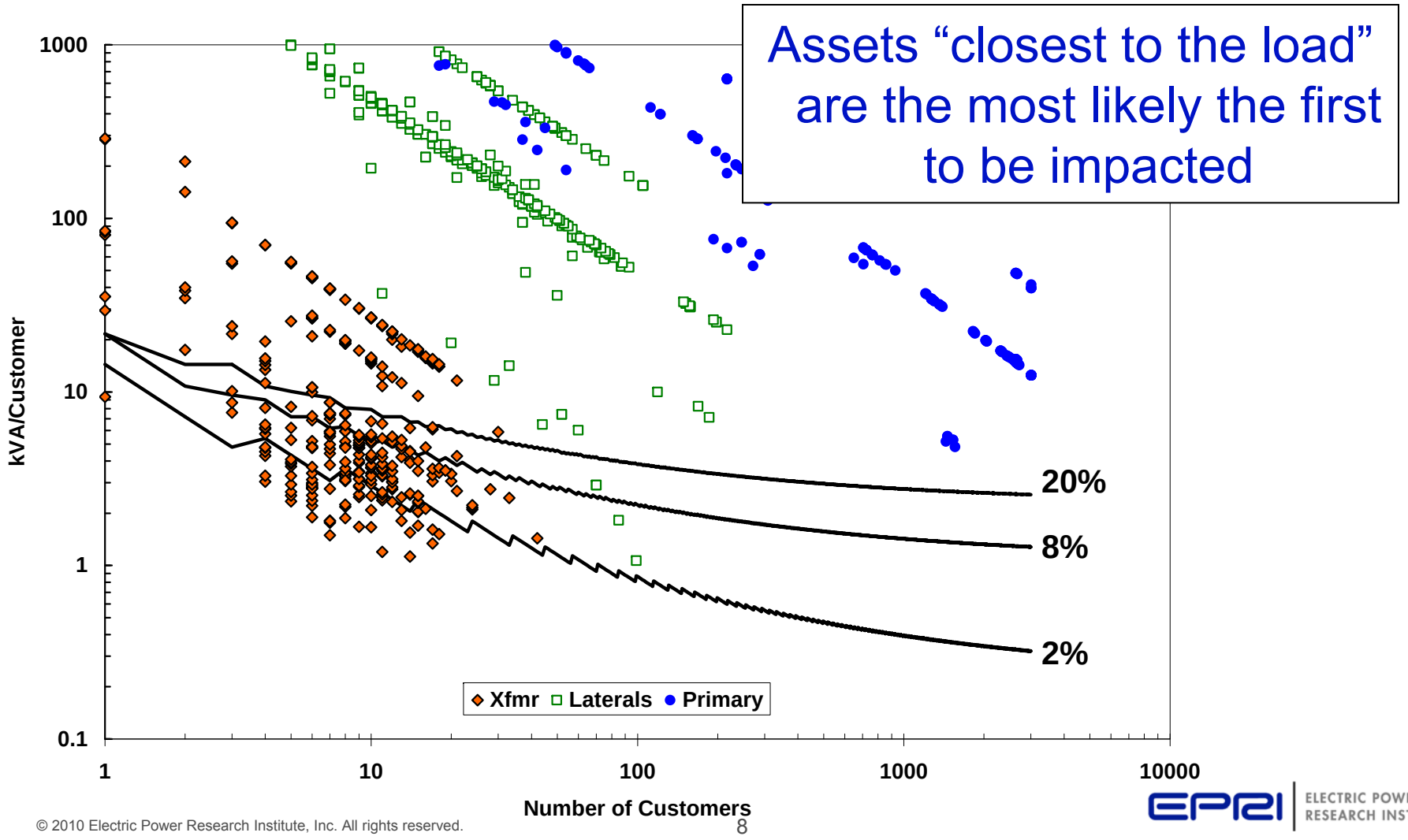
Likelihood Factors (Market Penetration)



Near-Term Steady-State Impacts

- PEV clustering impacts most likely on assets:
  - Close to the customer
  - Low capacity per customer

- Few clusters at low penetration levels

- Possible planning standards adjustments
  - Transformer sizing
  - Asset/Customer allocations
  - Transformer thermal ratings

Chevrolet Volt
Extended Range EV
40-mile EV range
16kWh Li-Ion
Intro: 2010 CY

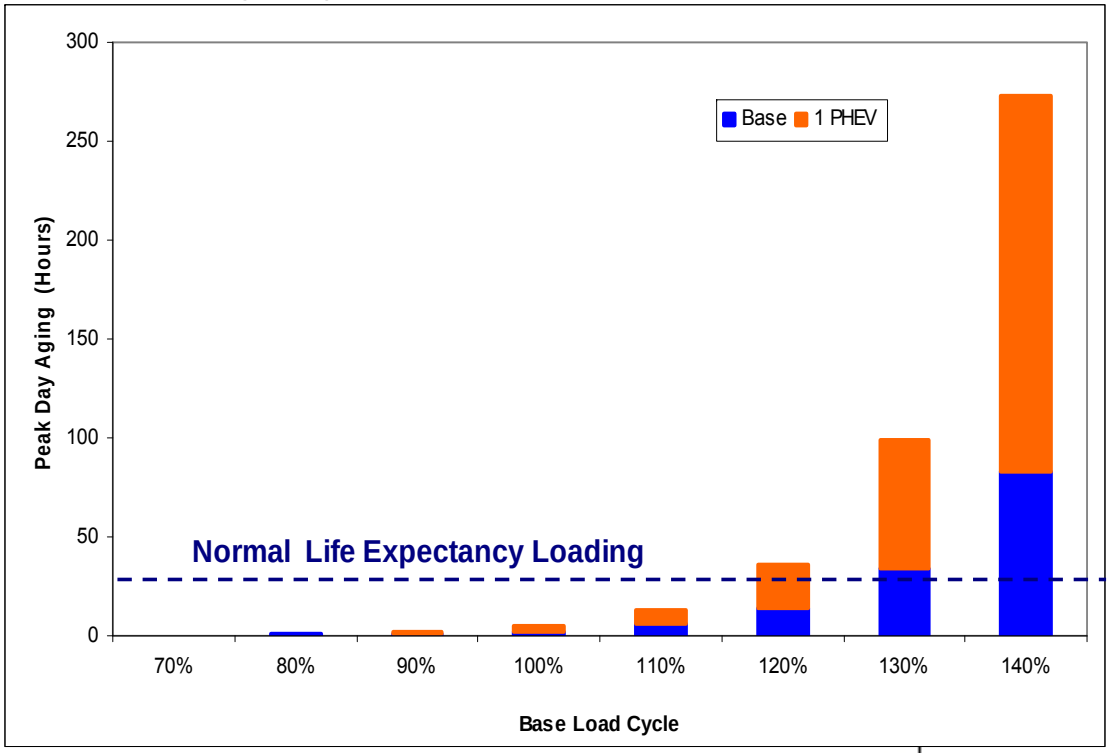
Transformer Loss of Insulation Life

- Thermal aging is system and *condition* specific

~~What impact will PEVs have on aging?~~

What impacts can I expect on my system?

- Assets at risk
- Likelihood of impact
- PEV conditions
- Severity



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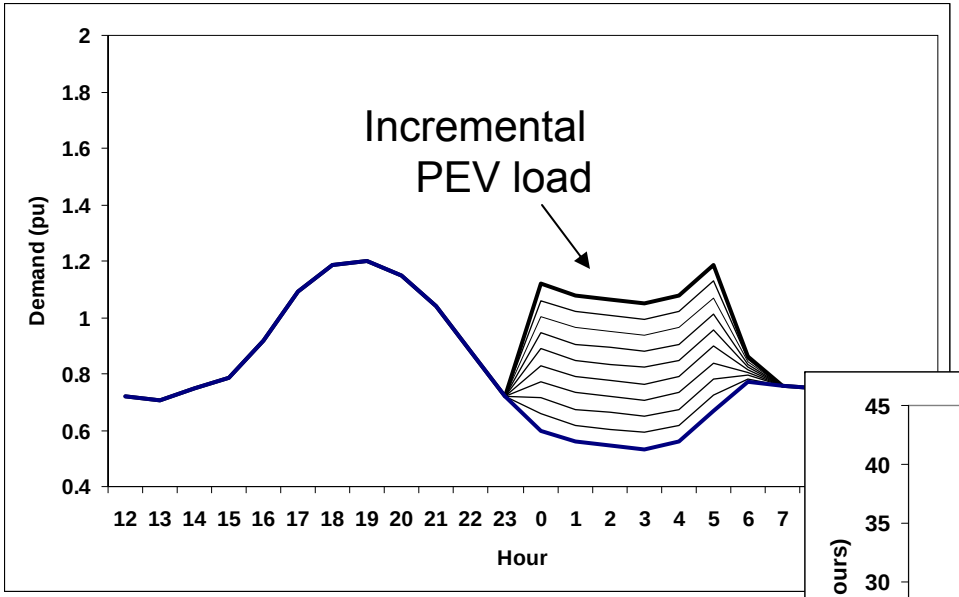
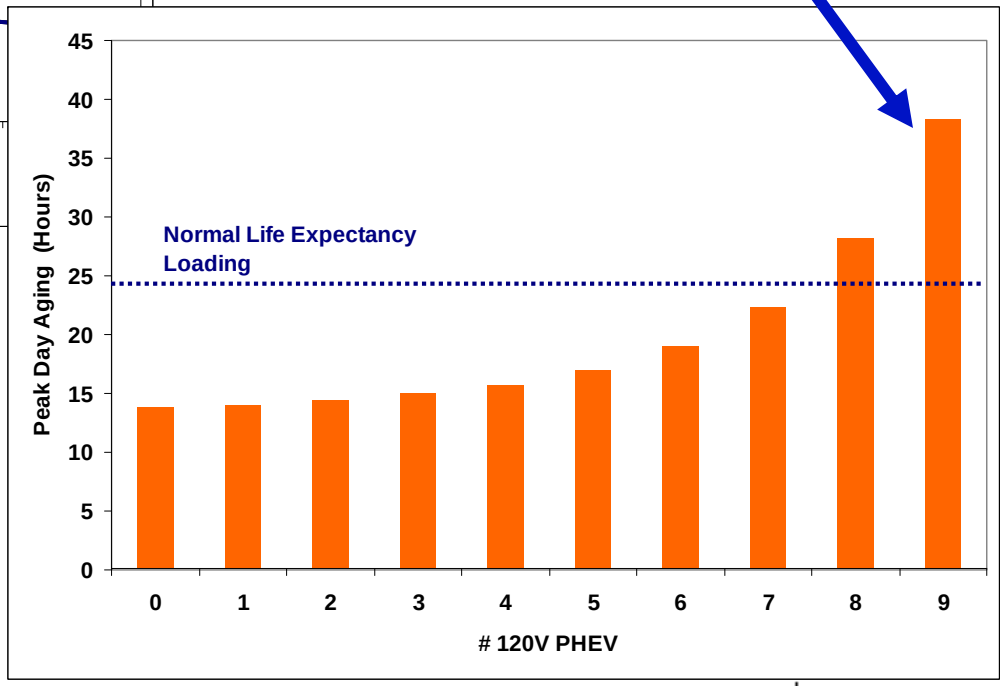
Impact Mitigation



Equivalent aging as one 240V/30A peak hour charge



Controlled charging can minimize impact as adoption increases

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Power Quality Concerns

- **EPRI current performing laboratory testing**

- **Infrastructure Working Council (IWC) Recommendations**

  - Total power factor < 95%
  - Total harmonic current distortion (THD) ≤ 20% at full rated power
  - Current distortion at each harmonic
    - IEC 1000-3-2

Harmonics

Power Quality Concerns

- Limit in-rush current to 28/56 A peak for 120/240 V
- Random start over 10 minute period after outage

Flicker & In-Rush

- 90% to110% of nominal
- 180% of nominal for 2 cycles
- 6kV surge (ANSI C62.41-1991)
- 80% sag for 2 seconds

Voltage Tolerances

Phase II Efforts

- A well integrated AMI infrastructure or a more comprehensive distribution transformer load management program will help address many distribution issues

- **Phase II Effort –**
  - **Utility PHEV Charging Demo studies**
    - Validate models and customer behavior data
    - Validate planning criteria based on real-time data
  - **Collect real-time data from transformers and AMI system**
    - Conduct utility specific loss-of-life and thermal ratings evaluation of assets