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Preparing the Distribution Grid to Embrace PEV

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US Frontiers Of Engineering Conference

Warren, Michigan

September 14, 2012

How Much Load is a 40 Mile Range EREV & 100 Mile Range Nissan Leaf?

PLASMA TV

Annual Energy 623 kWh

SET TOP BOX

Annual Energy 263 kWh

Annual Energy Consumption

= 865 kWh

CHEVY VOLT

Extended Range Electric Vehicle

Average Annual Energy Consumption

= 1890 kWh

Volt is approx. 11% load increase to the average Home

Nissan Leaf

All Electric Vehicle

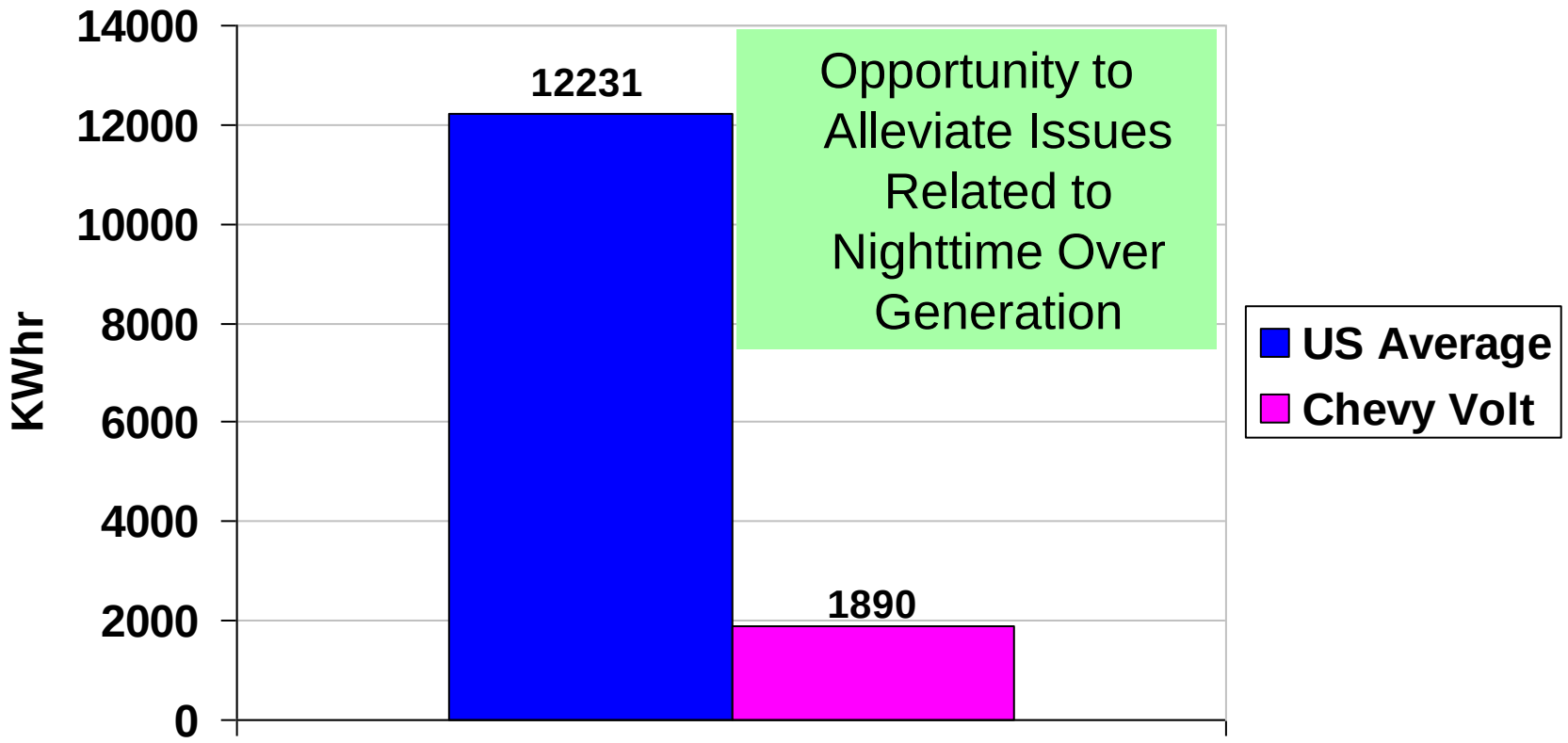
Average Annual Energy Consumption

= 2964 kWh

Volt is approx. 17% load increase to the average Home

Energy

Annual Residential Electricity Consumption



Adequate Energy Supply to Meet any Realistic Penetration

Charging Infrastructure

PEVs Generally Have Three Charging Options

120V – Level 1

Portable cordset
Use any 120V outlet

Up to 1.44 kW

DC Fast Charging

Up to ~ 50 – 60 kW

Fast, expensive

Standard not yet in place

240V – Level 2

Permanent charge station (EVSE)

Typ. 3.3 – 6.6 kW, but up to 19.2 kW

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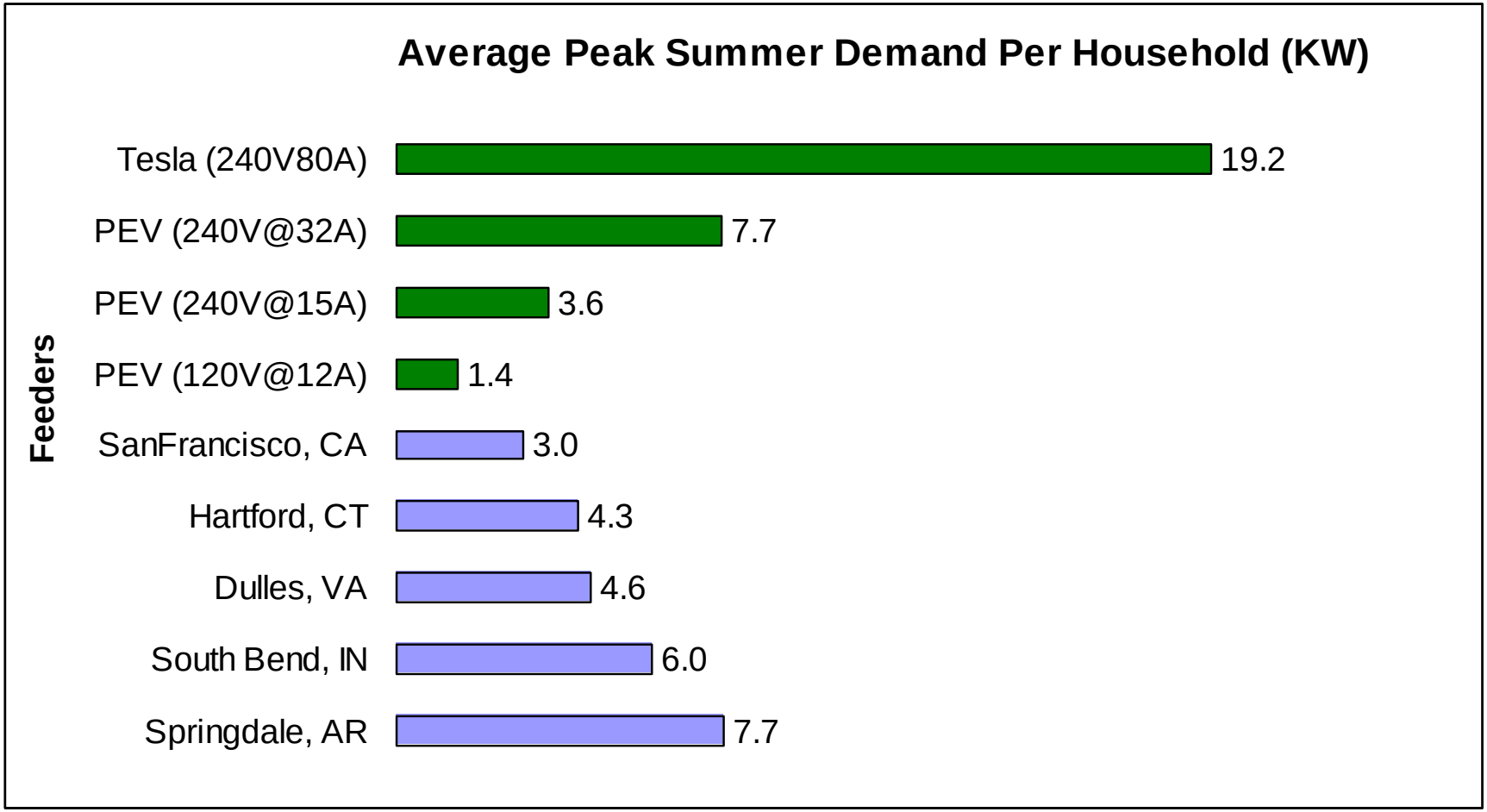
Why the Concern?

Central Air conditioning	3 – 20 kW
Water heater (40 gallon)	4.5 – 5.5 kW
Clothes dryer	1.8 – 5 kW
Plug-in Electric Vehicle	1.44 – 10.0 kW

Unplanned "*per capita*" load growth

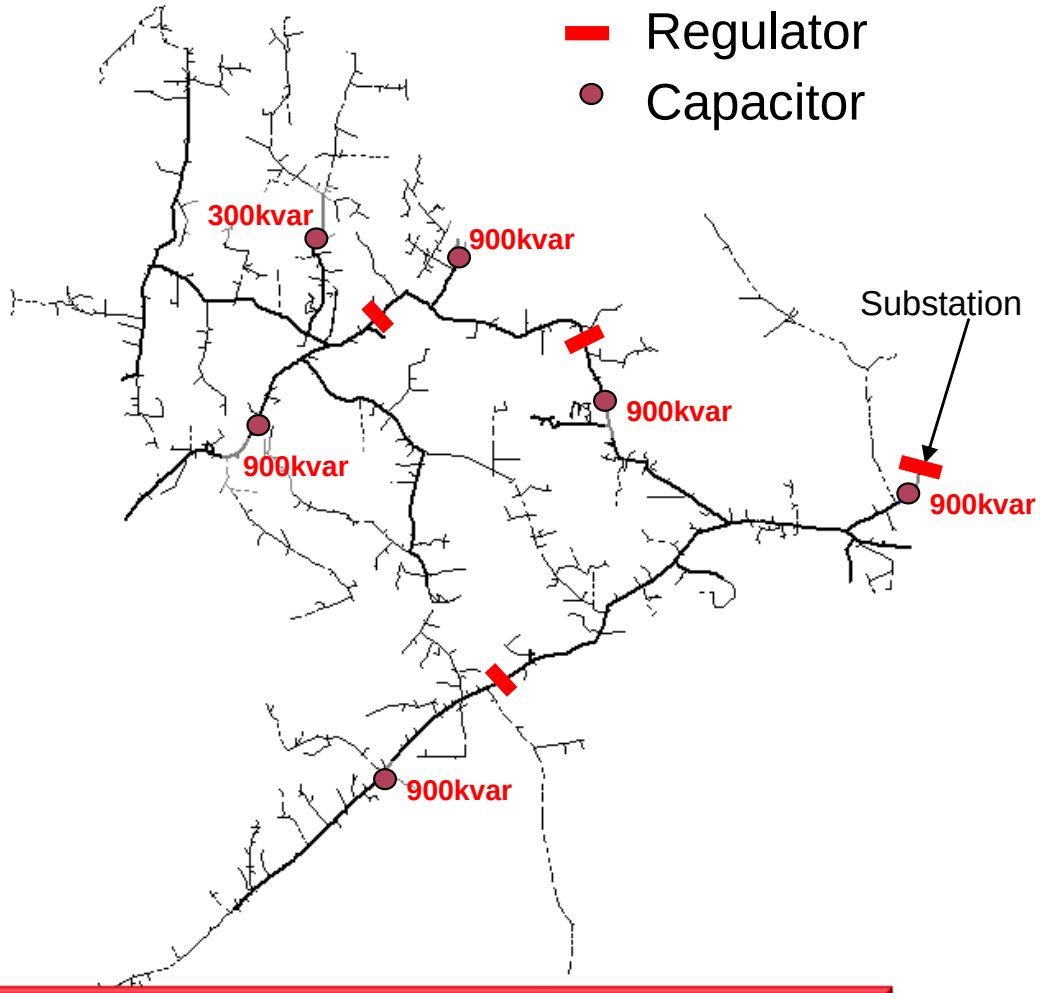
Peak Demand



PEV Peak Demand Depends on Charging Capacity (Voltage/Amperage)

Planning for PEV Peak Demand

- Unlike transmission systems most distribution system do not have full electrical model to each customer
- There is no wide spread continuous load monitoring system that can detect transformer/cable overload
- In most cases transformer failure is the first indication of overload (example, heat spells)



Challenges in Detecting Overload in Distribution System

How Will "My" System Respond?

Distribution Impacts

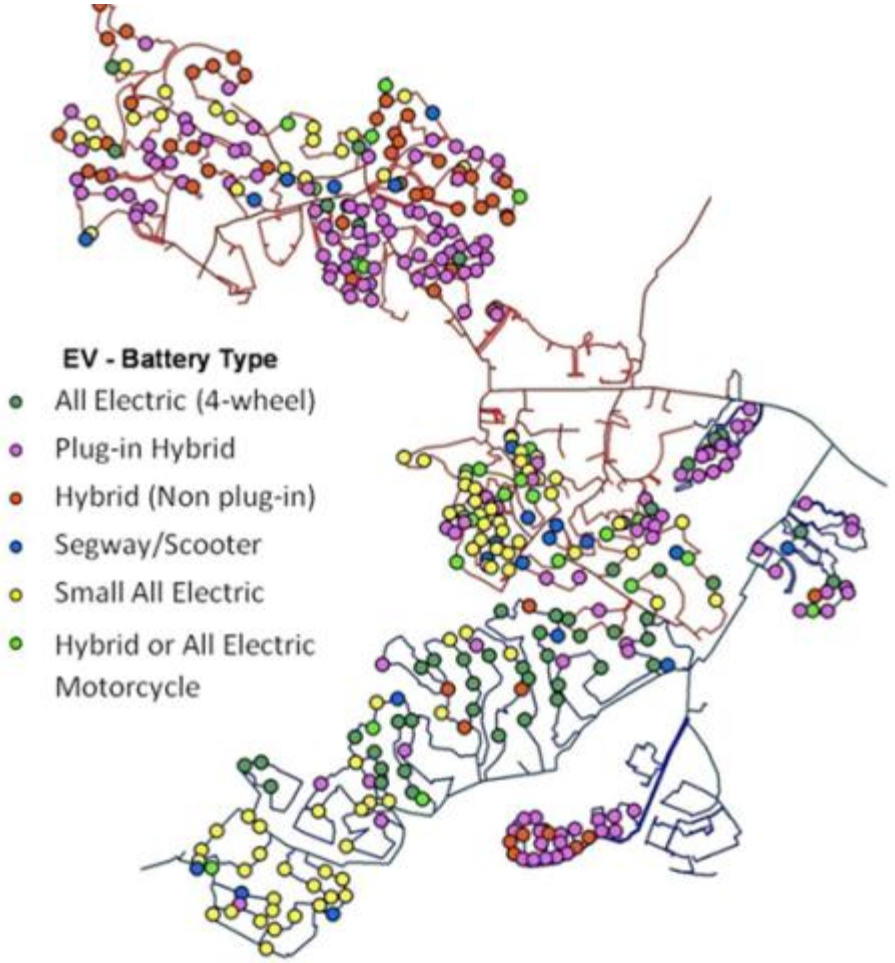
- Thermal Overloads
  - Xfmr aging
- Voltage Regulation
  - Secondary voltages
- Losses
- Imbalance
- Power quality
  - Harmonics

Identify

- Load Behavior
- Asset Risk
- Impact Likelihood
- Planning Factors

PEV Adoption, Types, Charge Preference, & Customer Behavior

- **Localized Adoption**
  - Initial PHEV adoption is likely to be geographically contained within residential neighborhoods
- **PEV Types**
  - Voltage connection
  - Battery size
  - Demand level
- **Charging Behavior**
  - Correlate with statistical driving patterns



Distribution Impact Phase I –
Planning for Near-Term PEV Demand

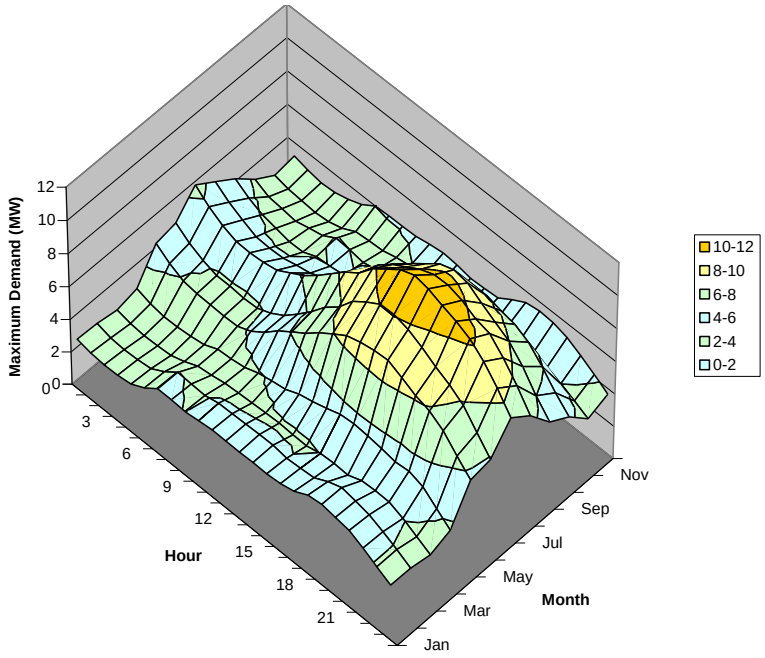
- Detail electrical model of selected feeders that includes each customer
- Assessment of different PEV charging type and penetration
- Hourly analysis using 8760 hours load profile to assess impacts
- Qualitative evaluation of distribution capacity margins and asset risk
- PEV clustering impacts

Near-term Planning Horizon
- Load only operation
- Customer behavior driven
- Market projections
- Mainly residential charging

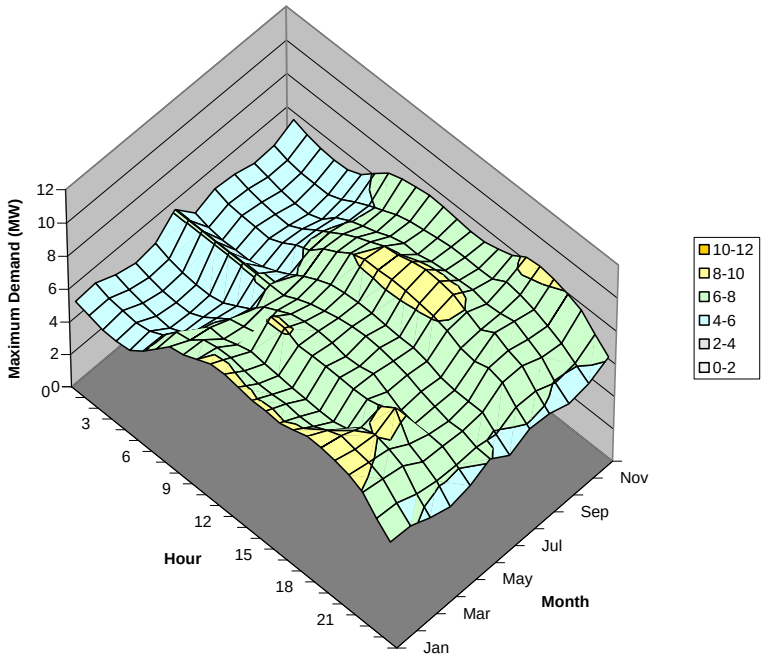
Evaluated Impacts
- Feeder demand
- Thermal overloads
- Steady-state voltage
- Losses
- Imbalance
- Power quality

Hourly Loading Levels

Feeder #1

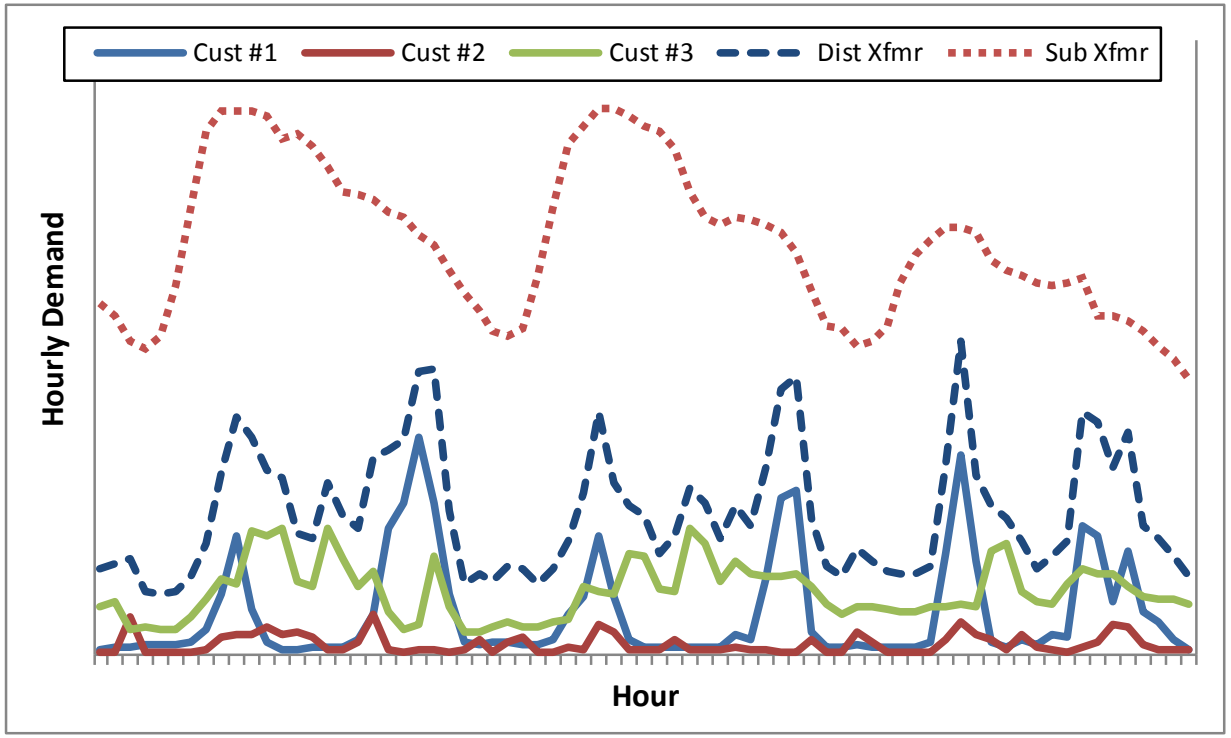


Feeder #2



Summer peaking	Winter peaking
Load Factor: 39.6%	Load Factor: 64.8%
Peak: 11.4 MW	Peak: 8.68 MW

Substation Versus Transformer Loading

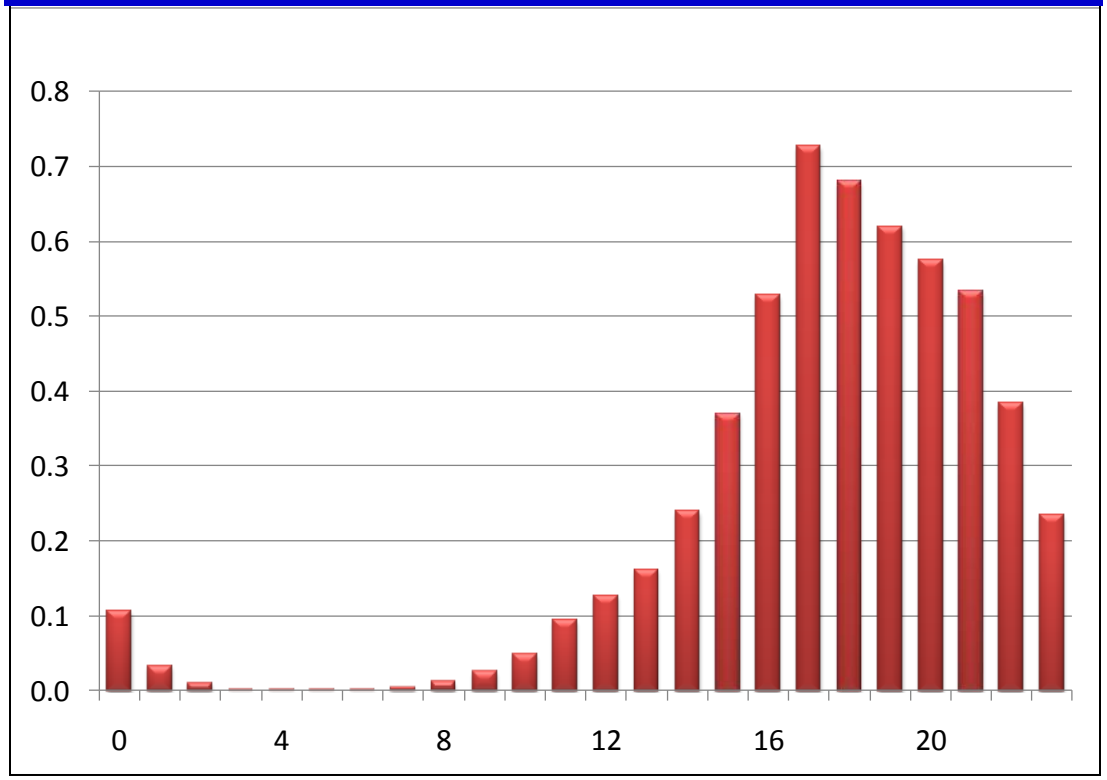


Localized peaks do not always correlate with substation demand

Controlled Charging must consider loading conditions for both substation and individual distribution transformers

Aggregate PEV Demand

Hourly Demand per PEV (kW)



Peak Demand

720 W / PEV

Average Energy Consumption

5 kWh / day

75% of charging occurs between 4 – 9 pm

Demand strongly correlates with home arrival

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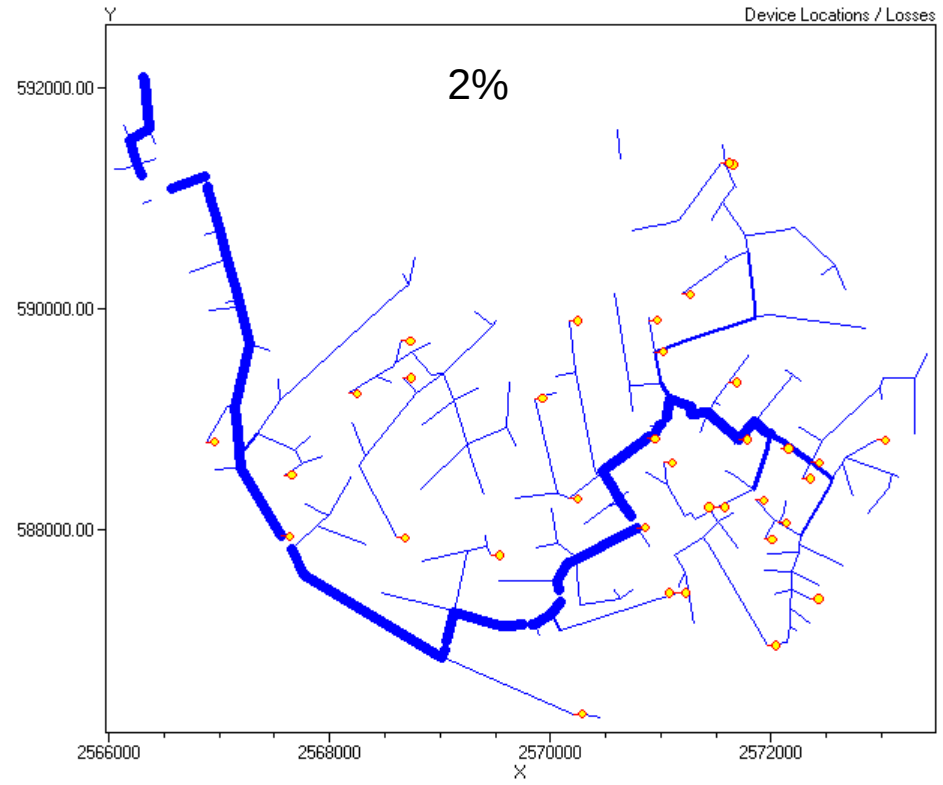
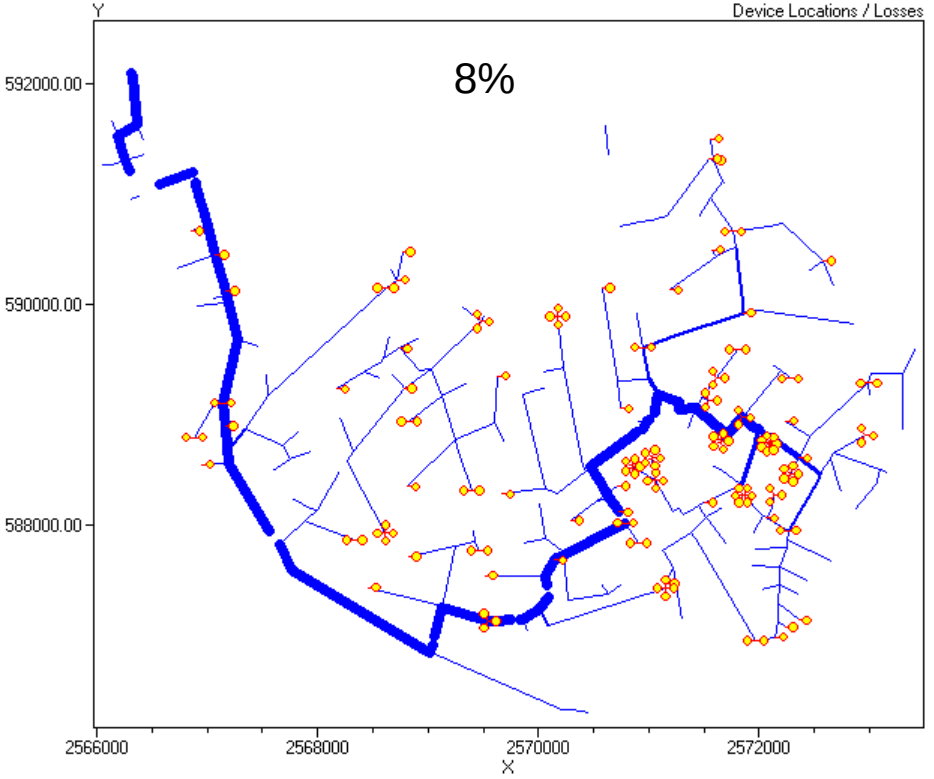
PEV Proliferation (Clustering)





Cluster $\dfrac{\#\mathrm{PEV}}{\mathrm{Total\,Customer}} > \mathrm{avg}$

Clustering cannot result in widespread system impacts

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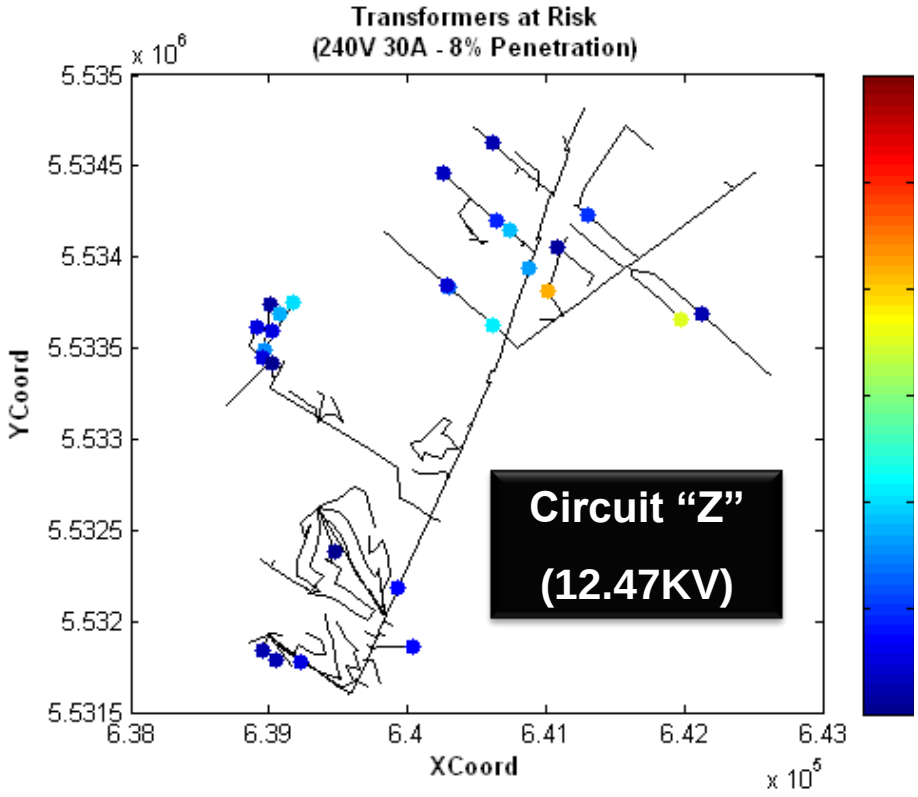
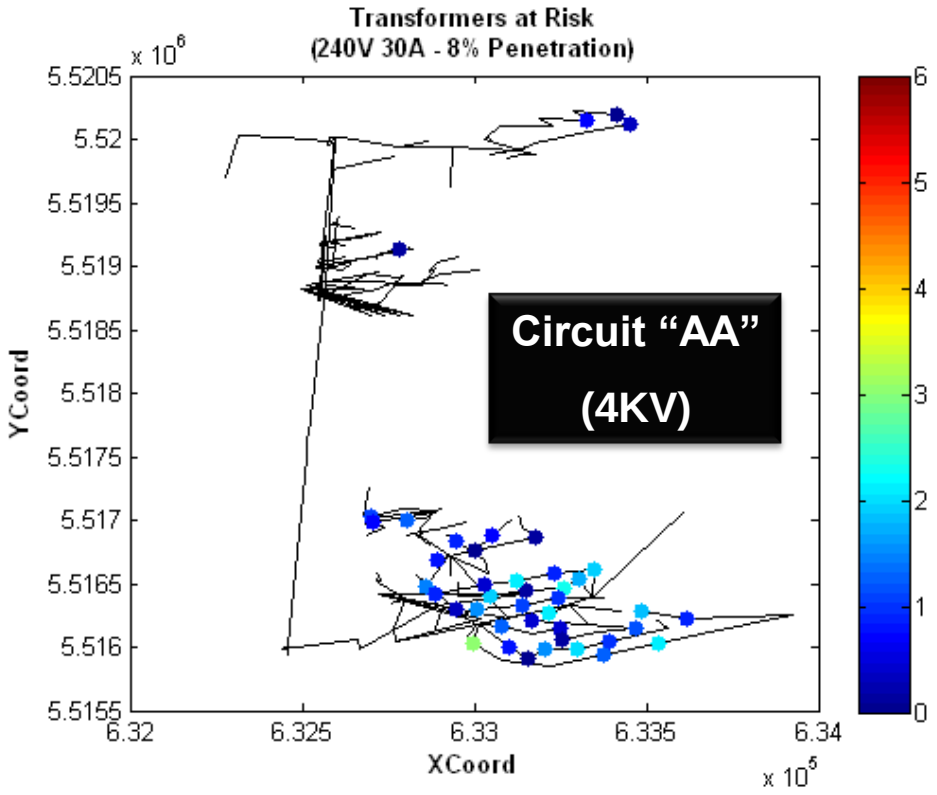
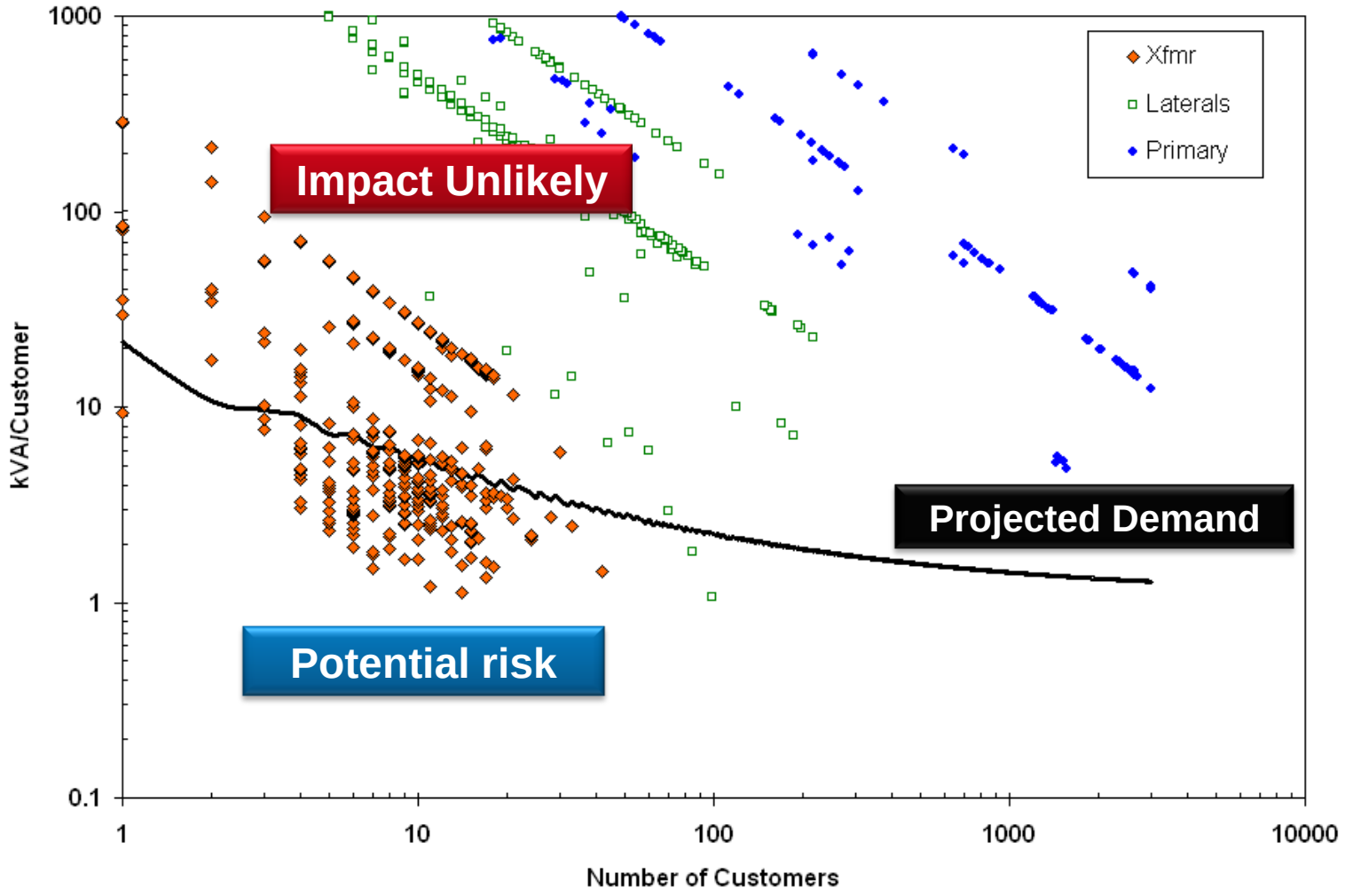
Circuit Characteristics and Design – 4KV Versus 13KV Systems





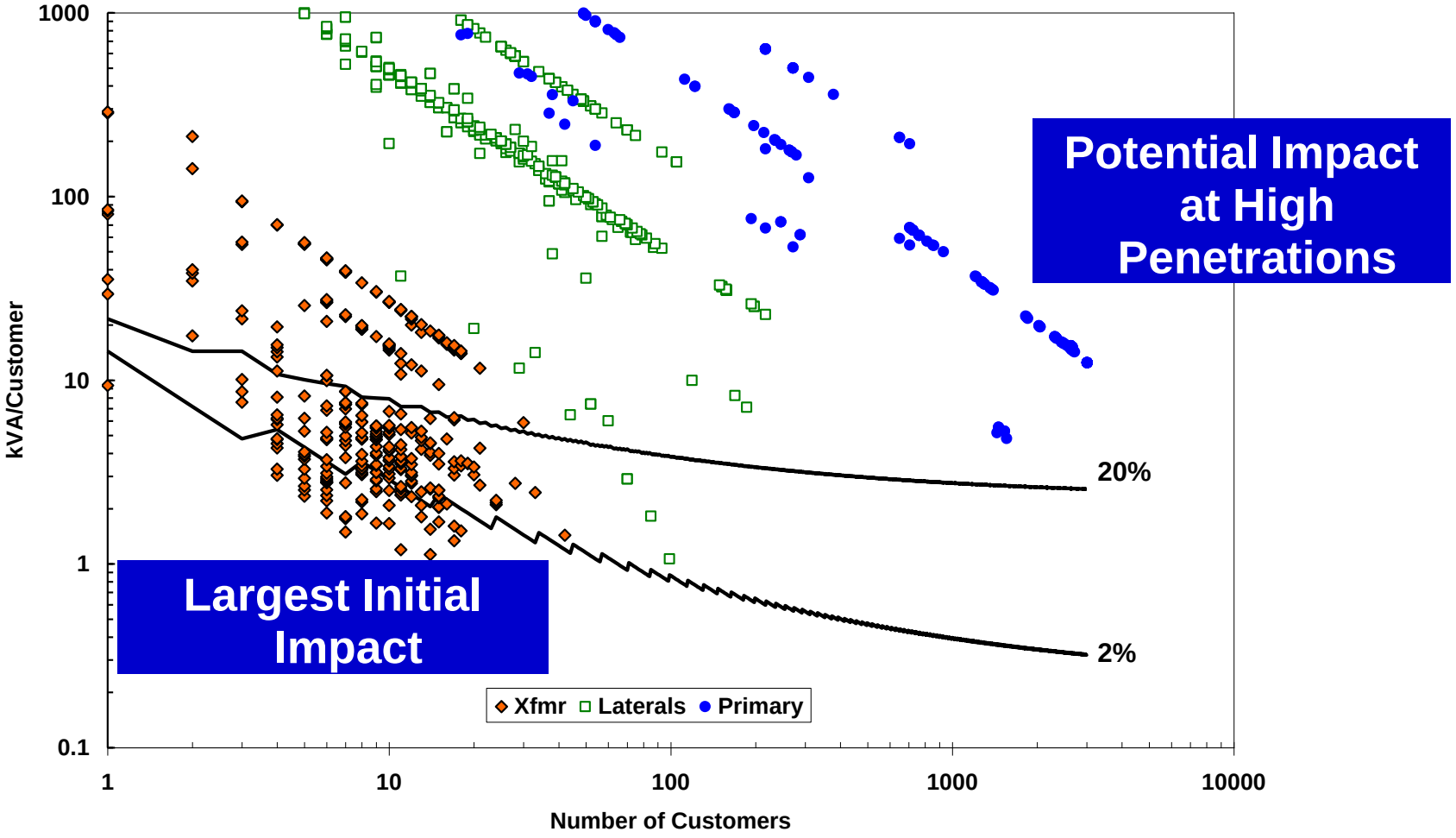
Clustering cannot result in widespread system impacts

Evaluating Distributed Demand Impacts

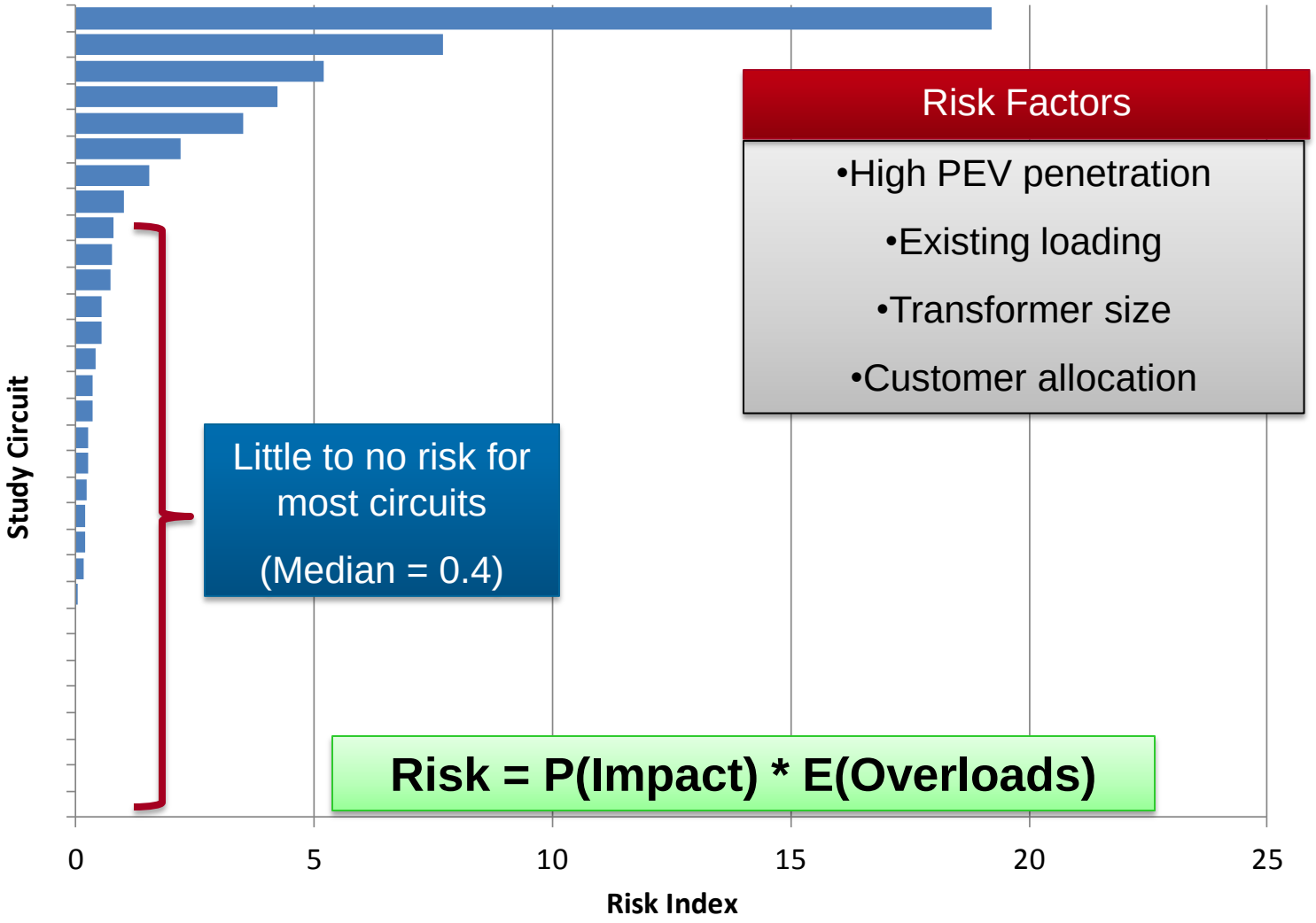


Assets close to the customer most at risk

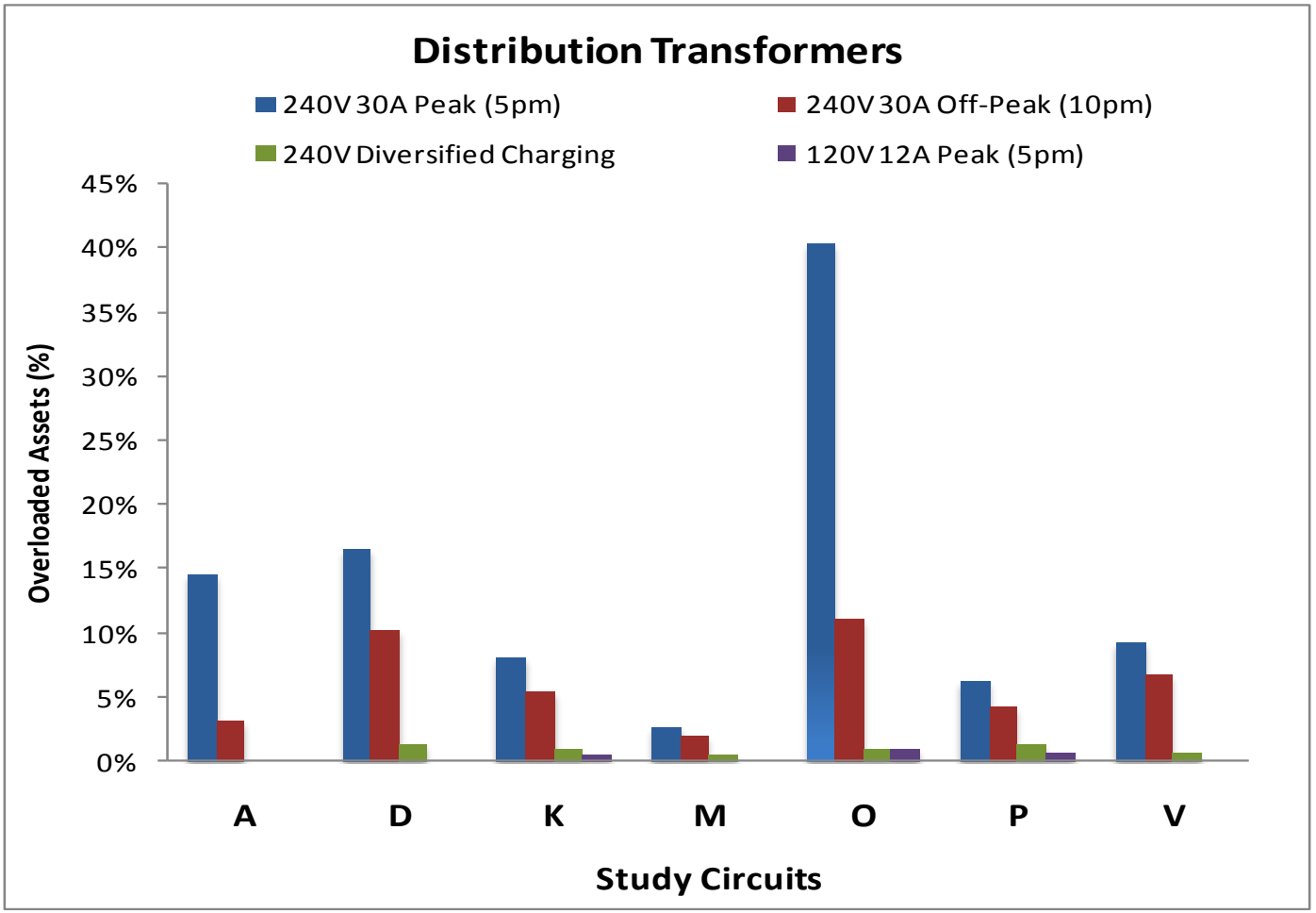
Uncontrolled PEV Demand vs. Asset Capacity



Service Transformer Overload Risk

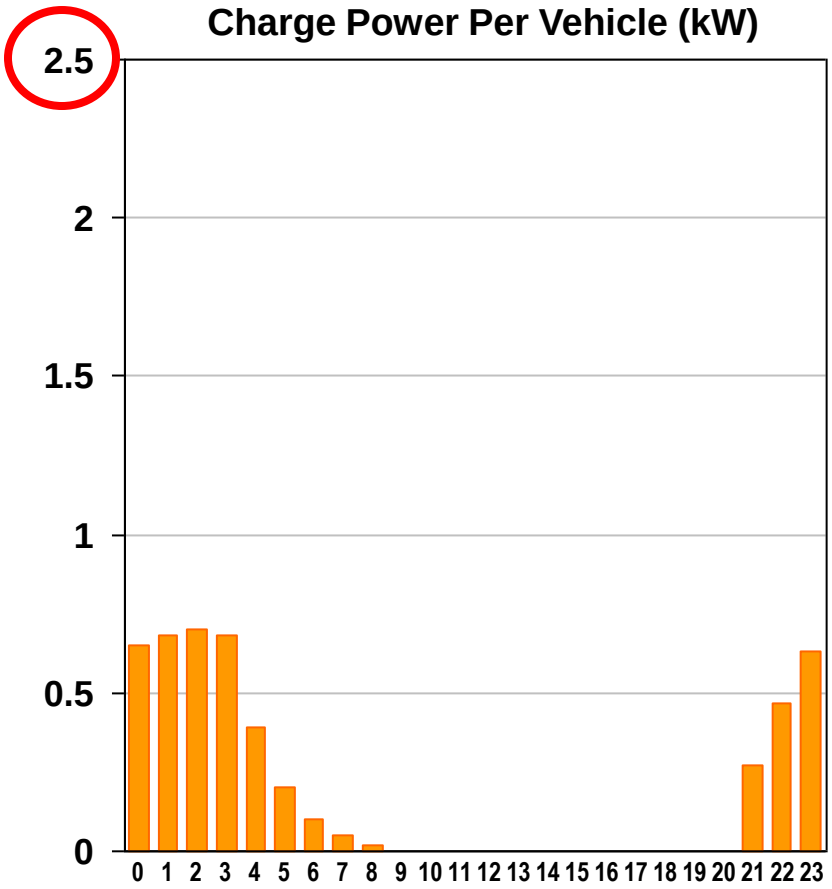


PEV Load Type and Charge Time Sensitivities – Transformer Capacity Evaluation

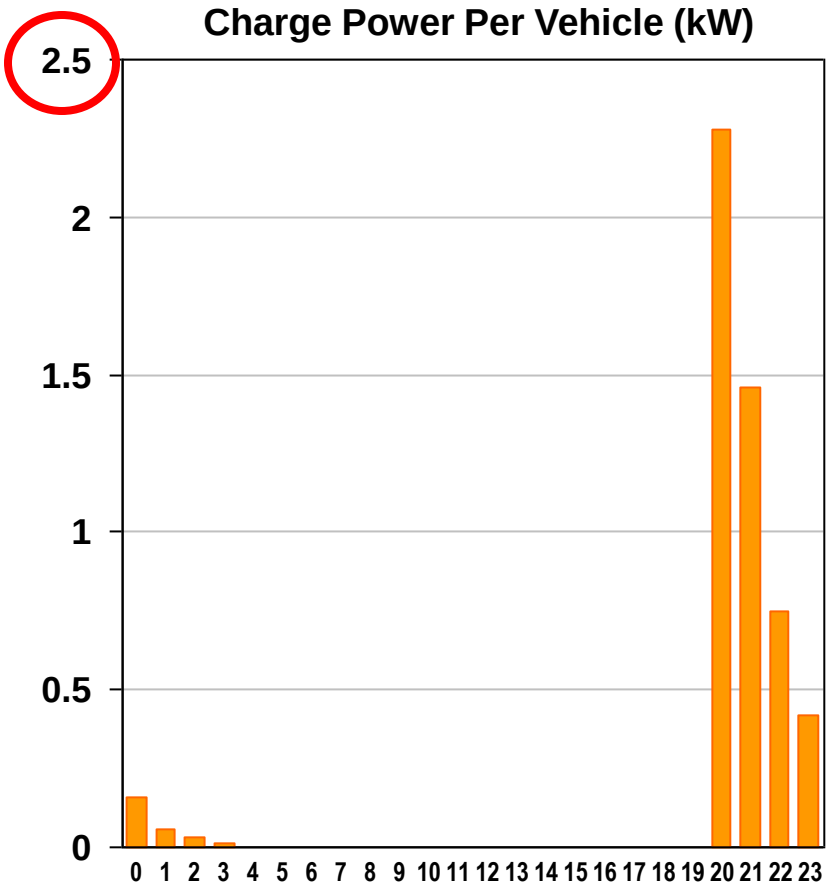


PEV charging level is a dominant driver compared to PEV charge time

Smart Charging Helps – If Done Right

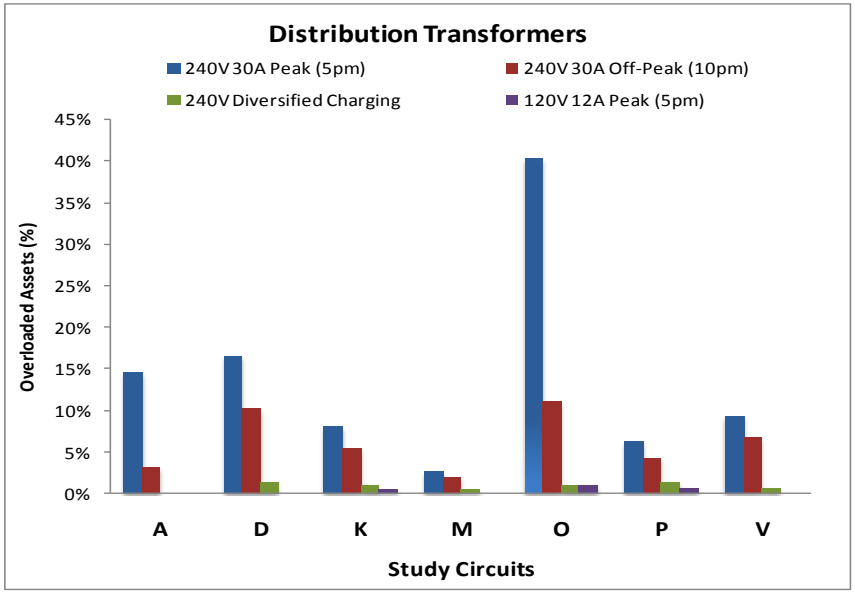


Shifts the charge load to nighttime, but spreads it out relatively evenly over 6 hours



Only shifting the time without evening out the profile can make the situation worse

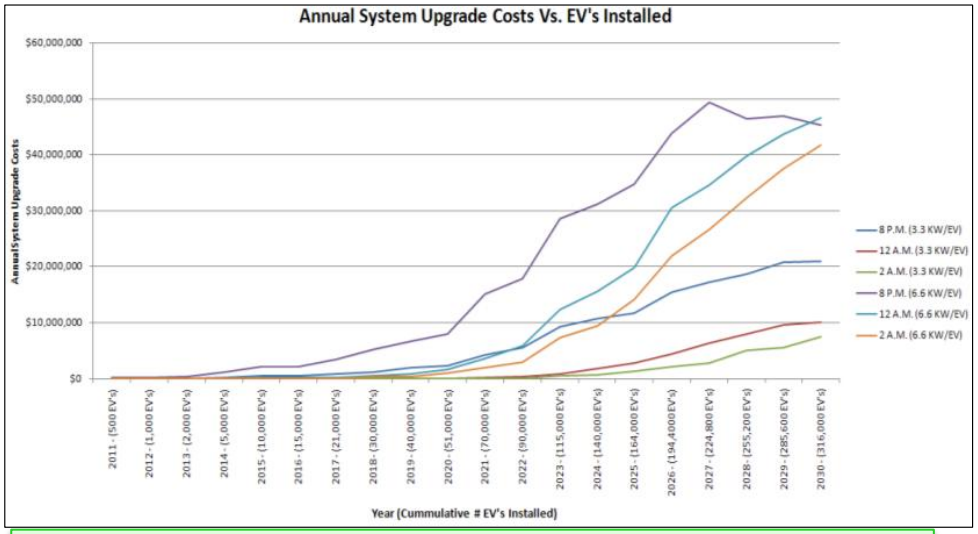
Benefits of Smart Charging



EPRI Phase I Analysis

Charging Level (kW)	Average Unit Cost Txf/Service	Subst/Ckt Exit Unit Cost	Total Unit Cost	Estimated Three Year Revenue	Payback (years)
3.3	146	150	296	636	1.38
6.6	334	303	637	636	2.97
9.9	440	459	899	636	4.20
13.2	632	632	1264	636	5.91
16.5	753	793	1546	636	7.22

Total Cost Impact of PEV: Duke Service Territory



Total Cost Impact of PEV: SMUD Service Territory

PEV charging level is a dominant driver compared to PEV charge time

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General Study Findings

Negligible Impacts

- System losses
- Primary voltage
- Power quality
- Voltage imbalance

Potential Impacts

- Service transformer overloads
- Low secondary voltages

Planning Adjustments

- Equipment sizing
- Asset-to-customer allocations
- Transformer ratings

Minimal impacts at near-term penetrations

Phase II Project

System wide screening tool to identify overall asset risks

Need System Wide Evaluation

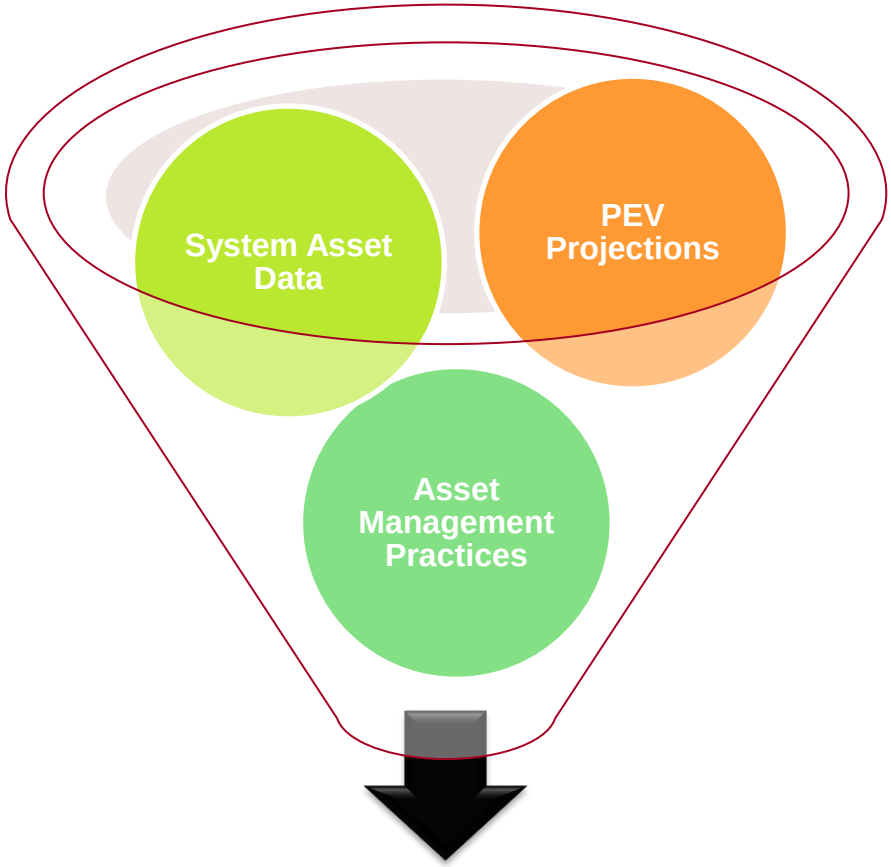
Advanced tools are required to evaluate and justify potential benefits & impacts

Assess:

- System wide impacts
- Risk sensitivities
- Cost analysis

Accounting for:

- Potential PEV penetrations
- Changing customer behavior
- Entire system asset
- Planning practices
- TOU rate and market influences



Risk-based Assessment Management

Area Wide Asset Risk Planning and Evaluation – Phase II Study

Screening Tool

PEV Forecasts → Asset Risk Assessment → Quantify Impacts → Planning and System Upgrades

Forecast Models

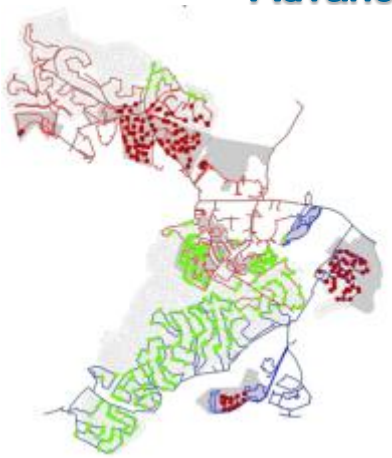
AMI integration

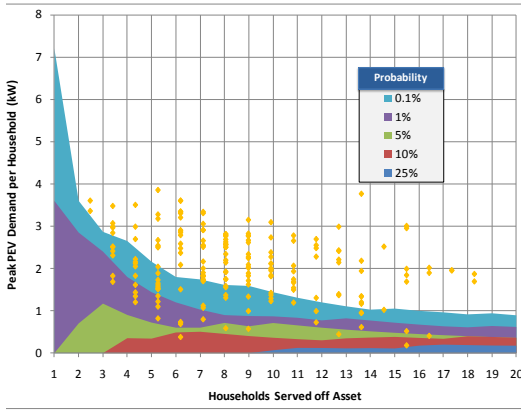
"Hot Spot" Analysis

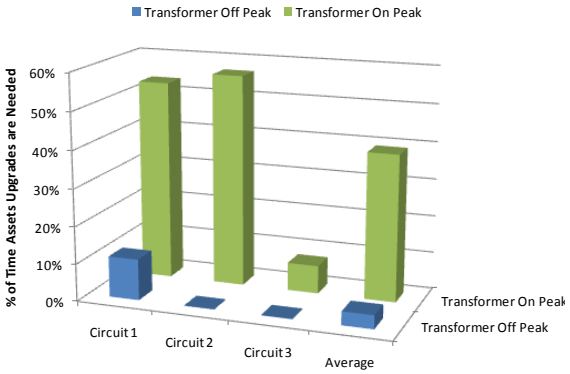
Asset Management & Investment

Advanced Load Models

EV Rate Impacts







Development of a Planning and Assessment Tool

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