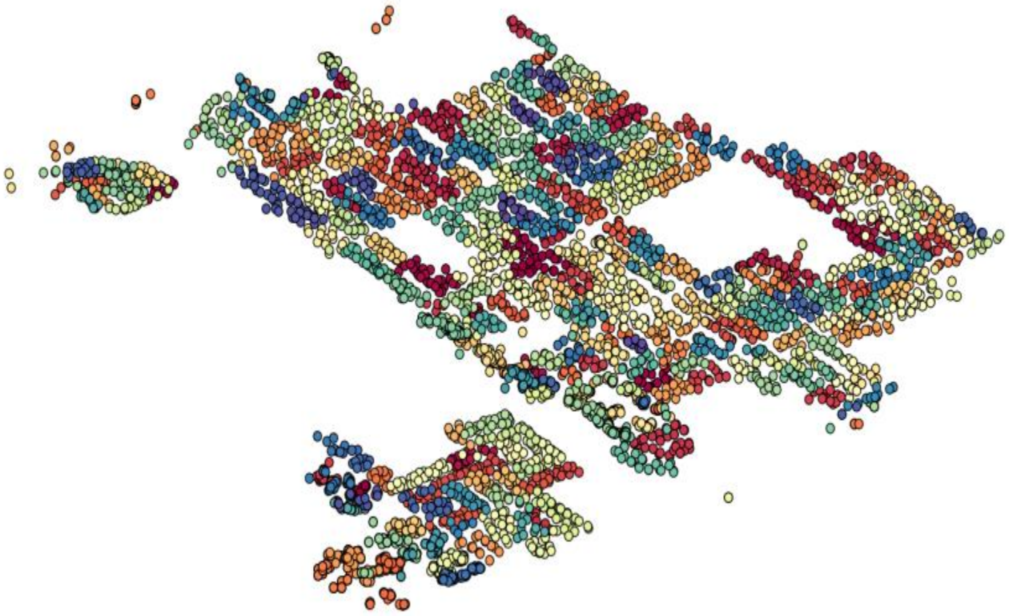
# EPIC 2.14 – Phase ID

Oct 2017



# Agenda

# Which customer is powered by which phase?

## Problem

Inaccurate or unknown connectivity in the distribution network

## Context

Grid needs to be modernized to integrate more distributed generation systems

## Project Objective

Explore analytics and/or hardware methods to automatically map 3-phase electrical power

***Project start date: Sep 2015***

***Project end date: Jan 2018***

# Automatic Phase Identification

Collecting
Field Data

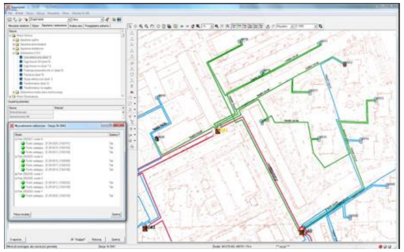
+

Additional data

Smart Meters

SCADA

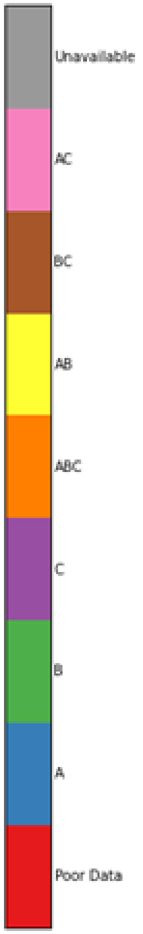
GIS



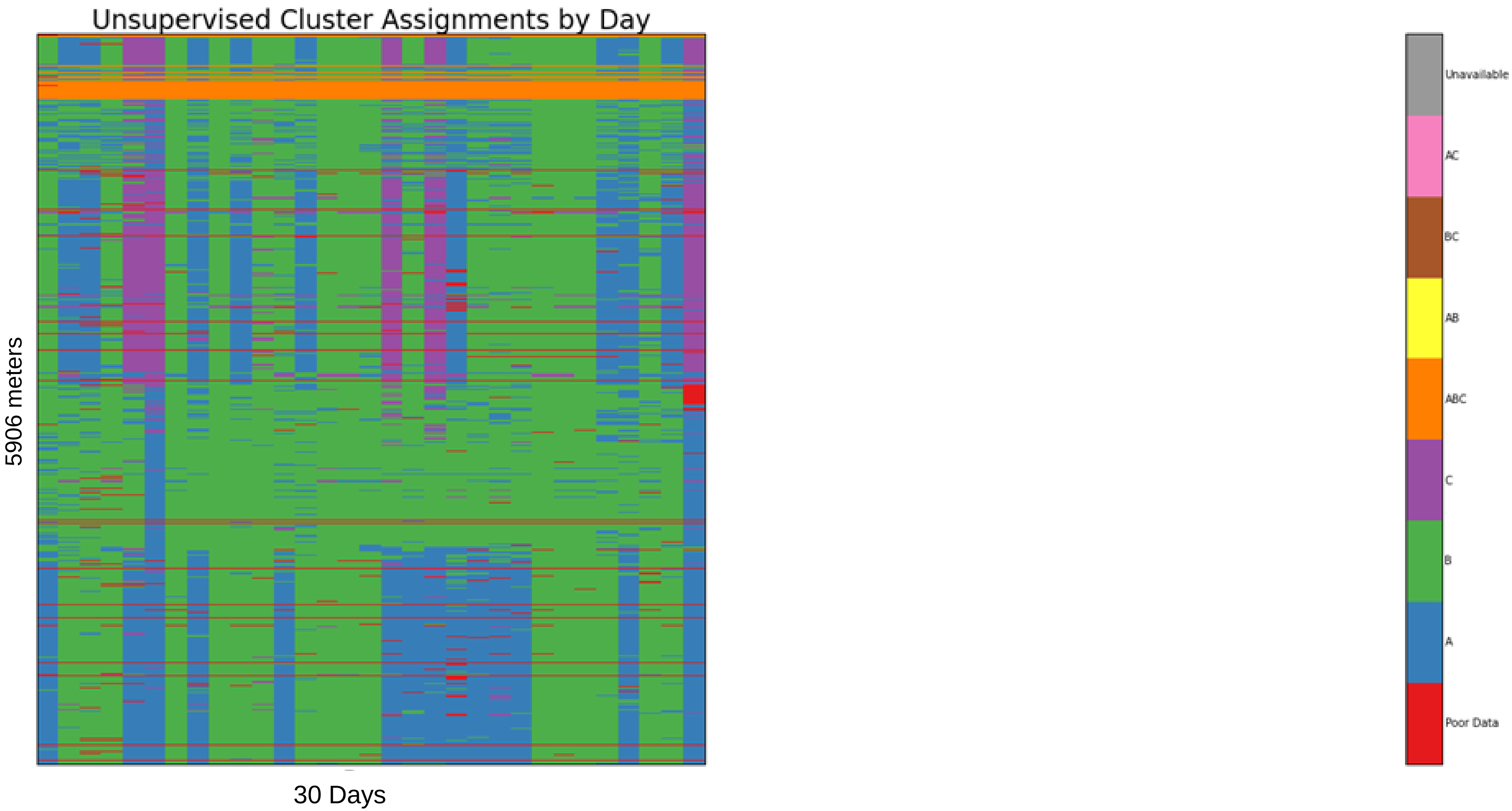
**Results**
Less boots on the ground work

Clustering Algorithms

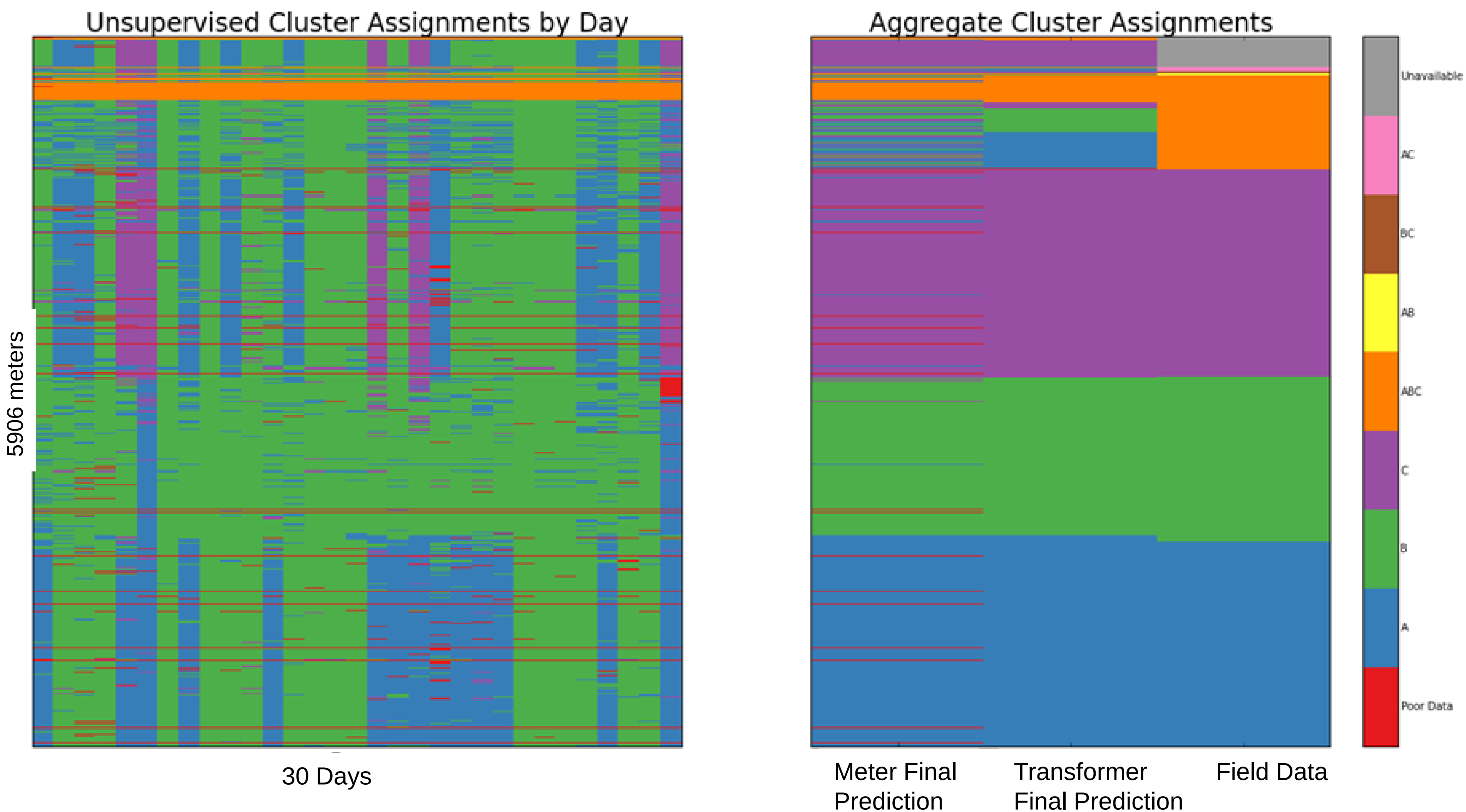
# Phase Identification Algorithm



# Phase Identification Algorithm



# Phase Identification Algorithm



## Project phase 1 - completed

- Three 21 kV (4 wire-system) circuits selected
- 2 Methods studied
- Comparison with 2 solutions (vendors/academic)
- 5 min interval data

## Project phase 2 – in progress

- Three 12 kV (3 wire-system) and one 21 kV circuits (4 wire-system)
- Method 2 from phase 1 studied.
- Comparison with 4 solutions (vendors/academic)
- 15/60 min interval data

## Phase ID Results by Feeder – High Resolution Data

| Phase ID Method | Feeder 1 | Feeder 2 | Feeder 3 | Total |
|---|---|---|---|---|
| PG&E Method 1 | 62.8% | 69.5% | 77.7% | 70.5% |
| PG&E Method 2 | 94.5% | 97.2% | 94.7% | 95.7% |
| Method 3 (Vendor 1) | 94.2% | 92.7% | 93.4% | 93.3% |
| Method 4 (Vendor 2) | 90.8% | 94.0% | 91.8% | 92.4% |

## Method 2 results by data source

| Data Source | Max Voltage Decimals | Sampling Time | Feeder 1 | Feeder 2 | Feeder 3 | Total |
|---|---|---|---|---|---|---|
| High Resolution | 1 | 5 minutes | 94.5% | 97.2% | 94.7% | 95.7% |
| Medium Resolution | 1 | 60 minutes | 94.4% | 89.2% | 87.1% | 89.9% |
| Low Resolution | 0 | 60 minutes | 33.8% | 48.9% | 30.3% | 38.8% |

# Project Benefits

**Affordability**

**Reliability**

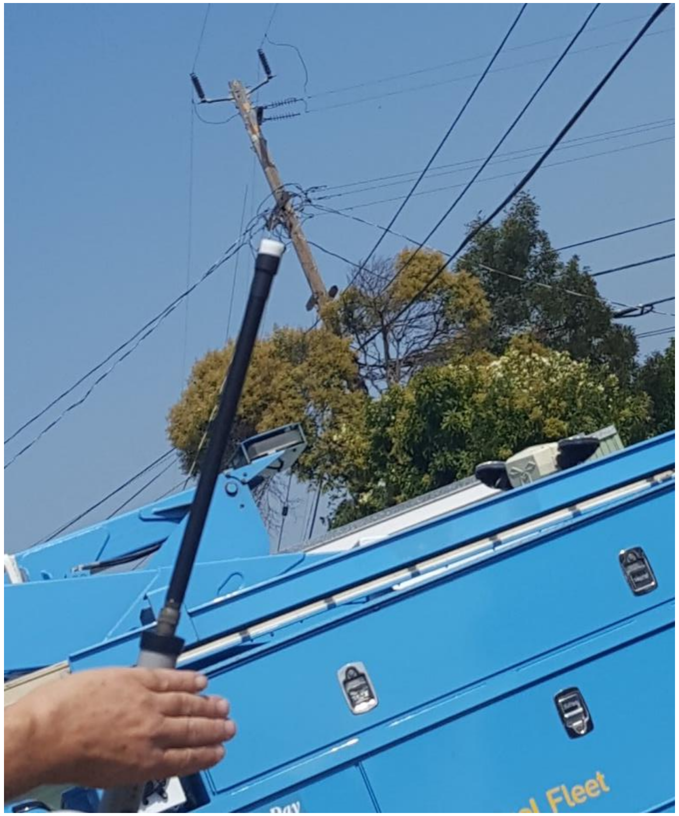
Avoid a much more costly boots-on-the-ground approach

Phasing will allow improved:

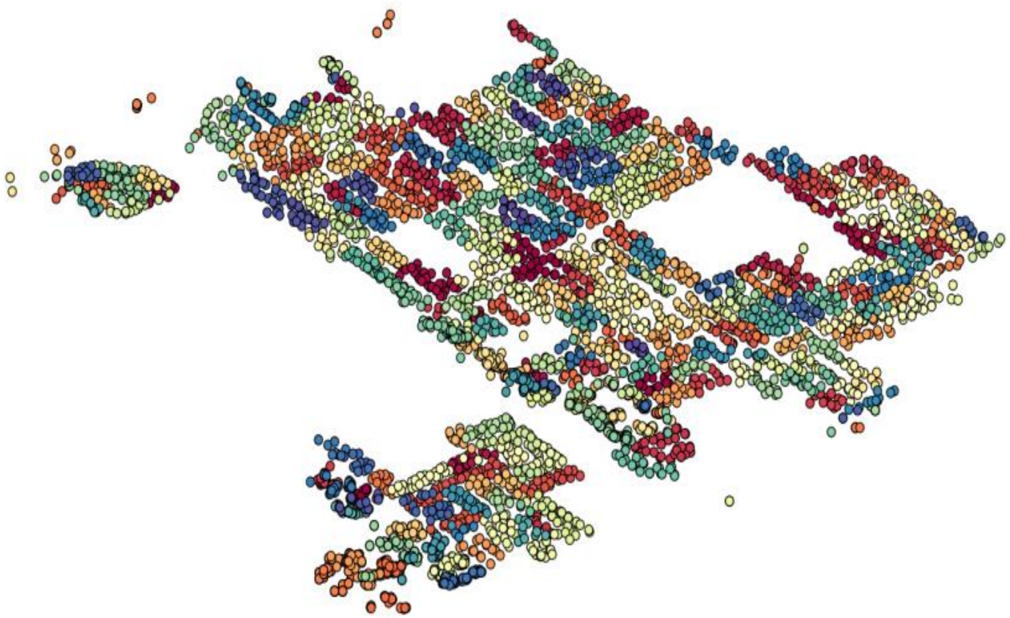
- load balancing
- load flow modeling
- outage accuracy
- fault location
- advanced functionality and phased load flow for ADMS implementation.

# Lessons Learned

- **Robust Data Cleaning** help reduce the effect of having Multi-Vendor and Vintage Metering Equipment
- **Sorting by meter connection type** using GIS asset management or other databases could potentially alleviate issues caused by mixed configurations.
- **Computing Resources** to run algorithms
- **Field Validation:** Getting the right tool and doing the right calibration



# Q&A



**Thank you for your attention**

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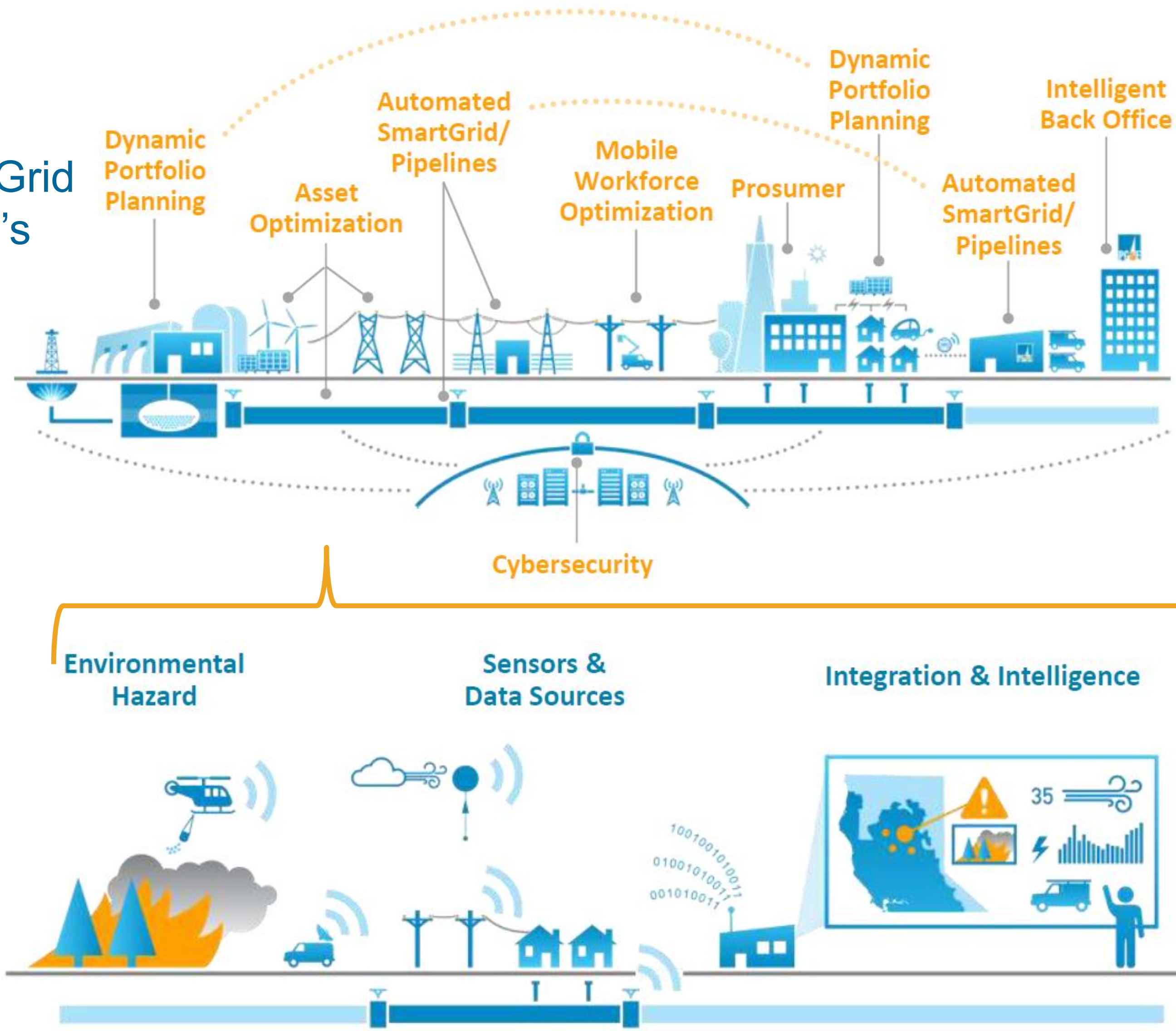
# PG&E EPIC: Demand Reduction Through Targeted Data Analytics

- EPIC Fall Symposium
- October 2017
- JP Dolphin

# Agenda

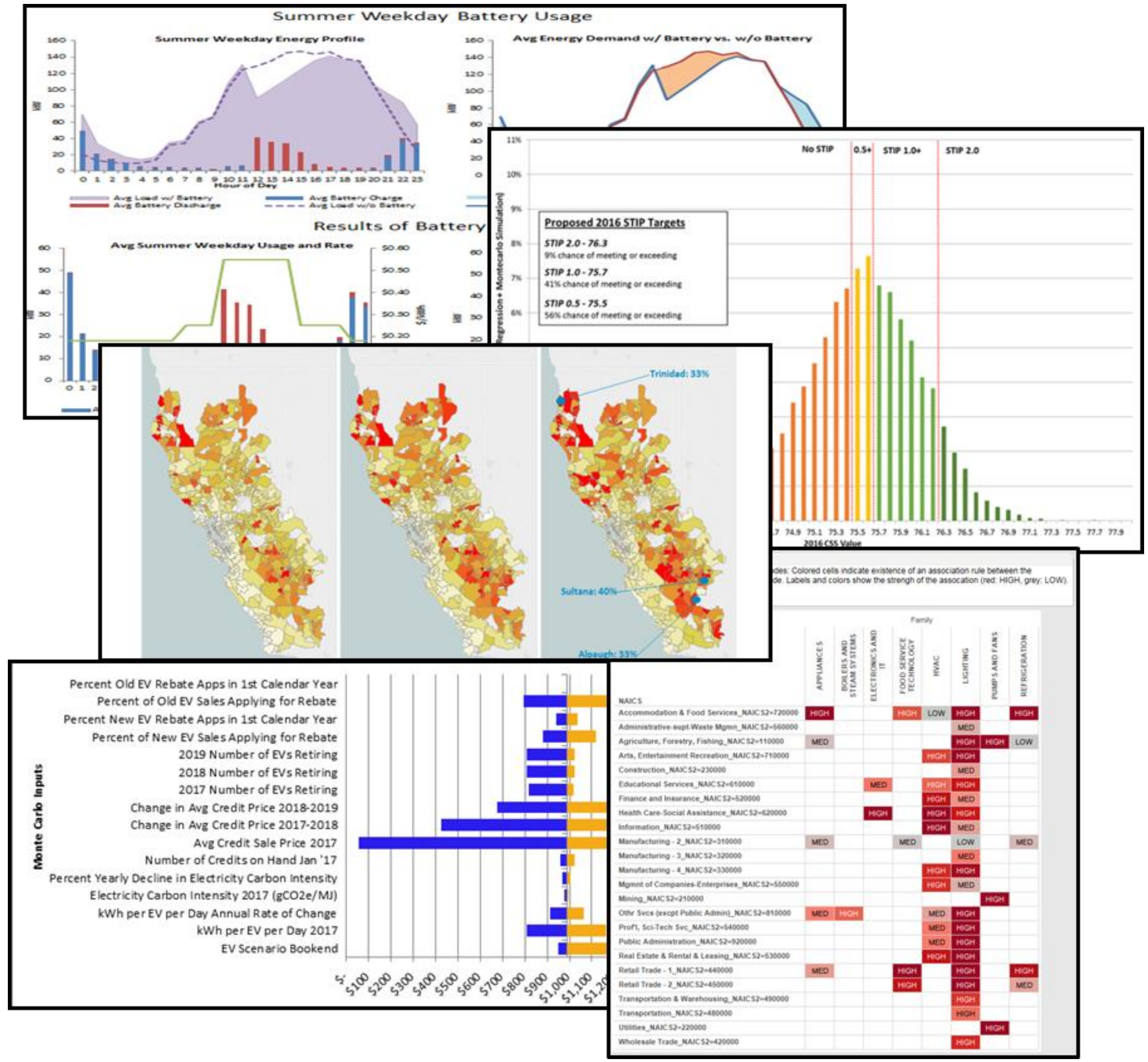
1. Introduction to PG&E's Grid Integration & Innovation's Data Analytics Team
2. Project Description
3. Project Status
4. Lessons Learned
5. Project Benefits
6. Q&A



# Grid Integration & Innovation – Data Analytics

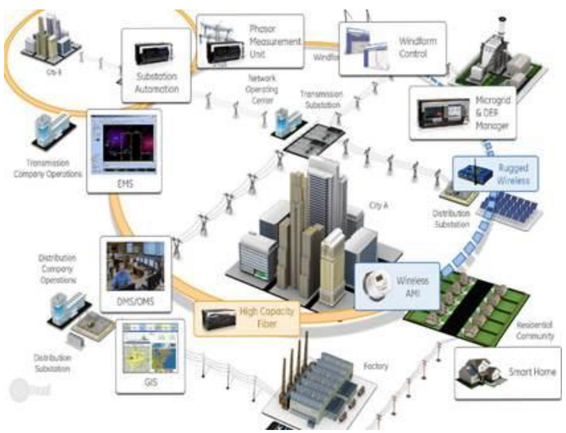
**Vision:** Utilize best in class modeling techniques and industry leading data science to drive PG&E's transition to the sustainable energy network of the future through quantitative decision-making.

Historically part of PG&E's Customer Care division, transitioning to a broader range of data problems across PG&E



- This project uses grid, smart meter, customer demographic, DER load impact, and other data sources to:

1. Proactively identify non-wires alternative opportunities
2. Recommend an optimized portfolio of Distributed Energy Resources technologies (Demand Response, Energy Storage, Solar PV, etc.)
3. Supply specific customer and technology recommendations



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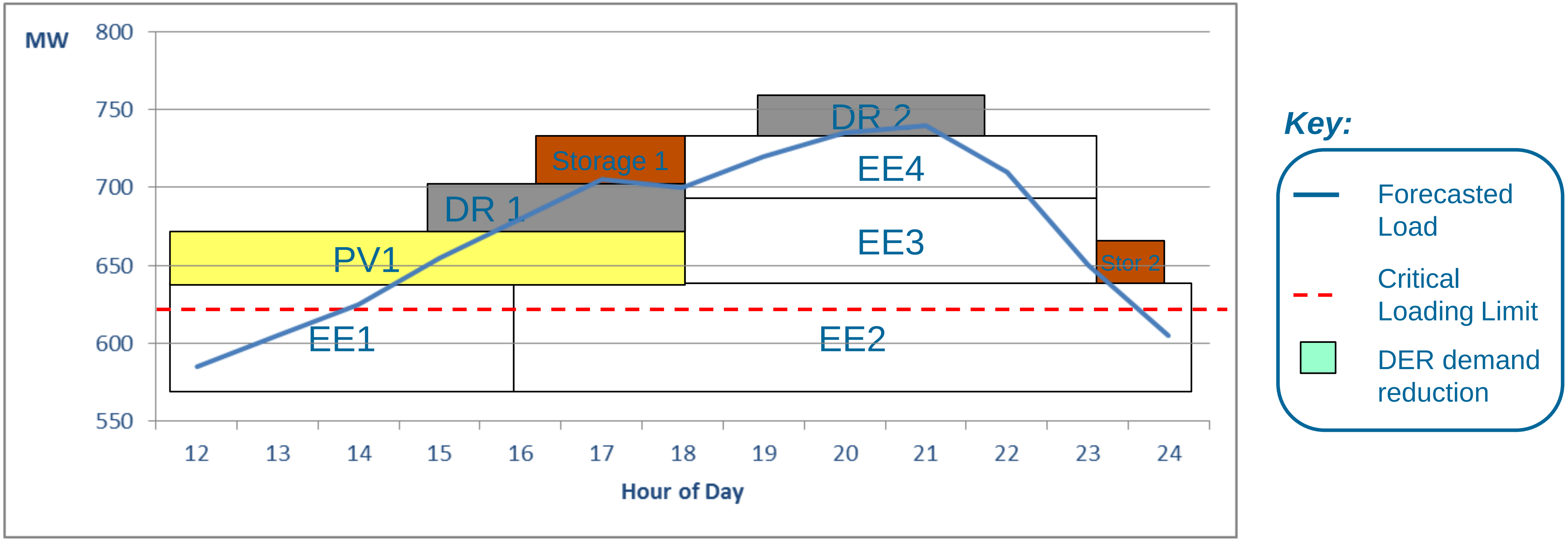
# Beyond TDSM

Targeted Demand Side Management (TDSM) is the foundation of the Demand Reduction Through Targeted Data Analytics EPIC project

This project takes a scalable and integrated analytics approach, incorporating a myriad of data sources and optimizing to ensure affordability

Sample Feeder - 2019 Peak Day Load Curve



# Changes to Planning Process Triggered Project Need

## Distribution Resources Plan (DRP)

**① Assumptions, Scenarios & Scope**

Develop forecasts, assumptions and planning scenarios

- Demand forecasts
- DER forecasts
- DER growth scenarios

**② Distribution Planning Assessment**

Distribution Grid Studies

- Thermal
- Voltage
- Protection
- Safety
- Reliability

**③ Distribution Grid Needs**

Distribution Grid Needs

- Load serving capacity
- DER hosting capacity
- DER aggregator requirements
- Coordination with transmission planning

## Integrated Distributed Energy Resources (IDER)

**④ Evaluate Options**

Prioritize Grid Needs

↓

Locational Net Benefit Analysis (LBNA)

**⑤ Sourcing**

Sourcing Process To Satisfy Needs Identified In IDPP

| Current TDSM Approach | Proposed Platform Goals |
|---|---|
| Manual process, difficult to scale | Scalable to all 3,200+ feeders using a single platform |
| Reactive | Proactive |
| Subjective | Create rigorous, repeatable methods in a well-documented model; leverage propensity models and customer-product matching algorithms |
| Limited opportunity for continuous improvement | Continued year-over-year improvements through constantly improving optimization |
| Limited technology scope | All DERs considered |

# Analytics Components and Data Sources

## DER Product / Program Library

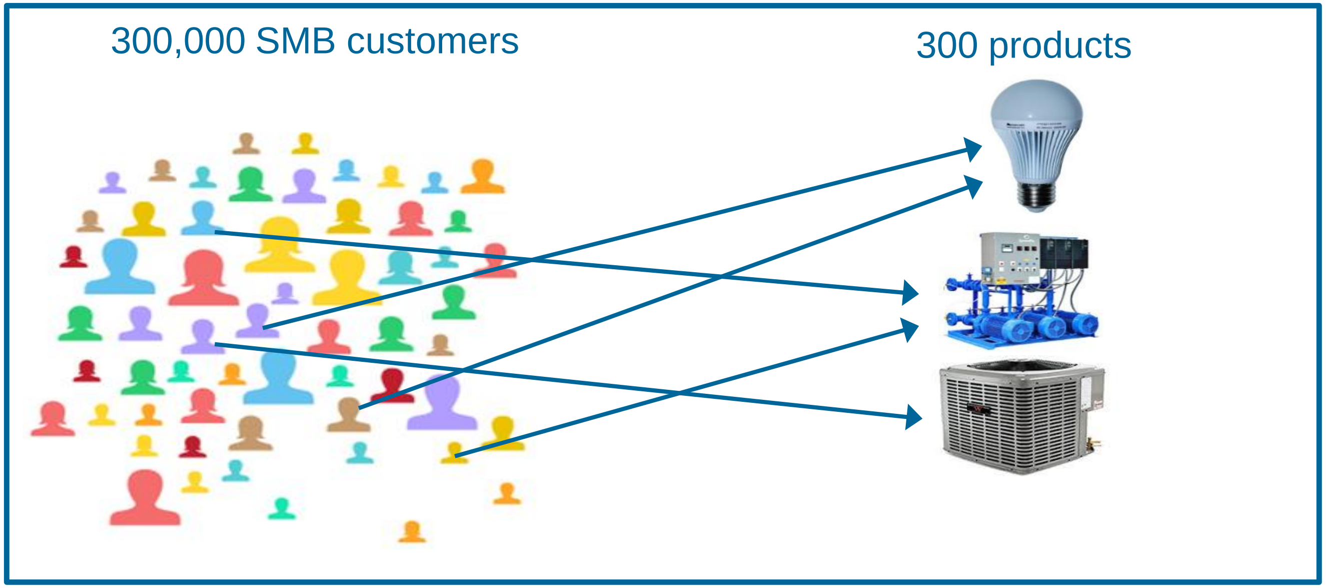
| Data | Data Source |
|---|---|
| Addressable market potential by customer segment | Potential studies + SMEs |
| DER cost/benefit | Existing cost/benefit calculations |
| Annual load curve or dispatch characteristics | DEER load curves + SMEs |
| Adoption propensity by customer | Associative Rule Mining for EE, HVAC Disaggregation for SmartAC, eligibility for BIP, DG Adoption Propensity Models for Res/non-Res DG, E3 Linear Program Model for Storage |

## Locational Characteristics

| Data | Data Source |
|---|---|
| Amount and timing of demand reduction needed | Grid Planning, SCADA, IDA, DER forecasts, Dist. Planning SMEs |
| Locational deployment benefit | Dist. Planning SMEs, emerging local cost/benefit methodology |
| Customer mix / characteristics | CDW / IDA |
| Interval data customer coincident peak usage | IDA |
| Existing DER saturation | CDW + other CES data silos |

# DER Adoption Propensity Example: Customer and Product Matching

- Associative Rule Mining: "People like you also bought this"




Customer Characteristics → Products

**Past Adoption** → **Patterns** → **Future Adoption**

**Historical data:**

- 2009 - 2016
- 300,000 rebates

**Analysis:**

- Over 10,000 statistically significant relationships

**Recommendations:**

- 400,000 customers

# Optimization Overview

- For each asset level (161 Banks or 3,200+ Feeders):

$$Min\ C = \sum_{p}^{products} x_p c_p$$

where:
$x_p$ = product count of product p (portfolio)
$c_p$ = cost to implement product p

$$\sum_{p}^{products} x_p c_p \leq B$$

$$x_p \leq M_p$$

Constraint on number of available products:
$x_p \leq M_p$

Hourly overload constraints:
$Overload_h - \sum_p^{product} x_p l_{p,h} \leq 0$

where:
$M_p$ = maximum eligible customers for that product
$Overload_h = Load\ Foreacst_h - Capacity_h$ = overload in hour h
$l_{p,h}$ = load impact of product p in hour h

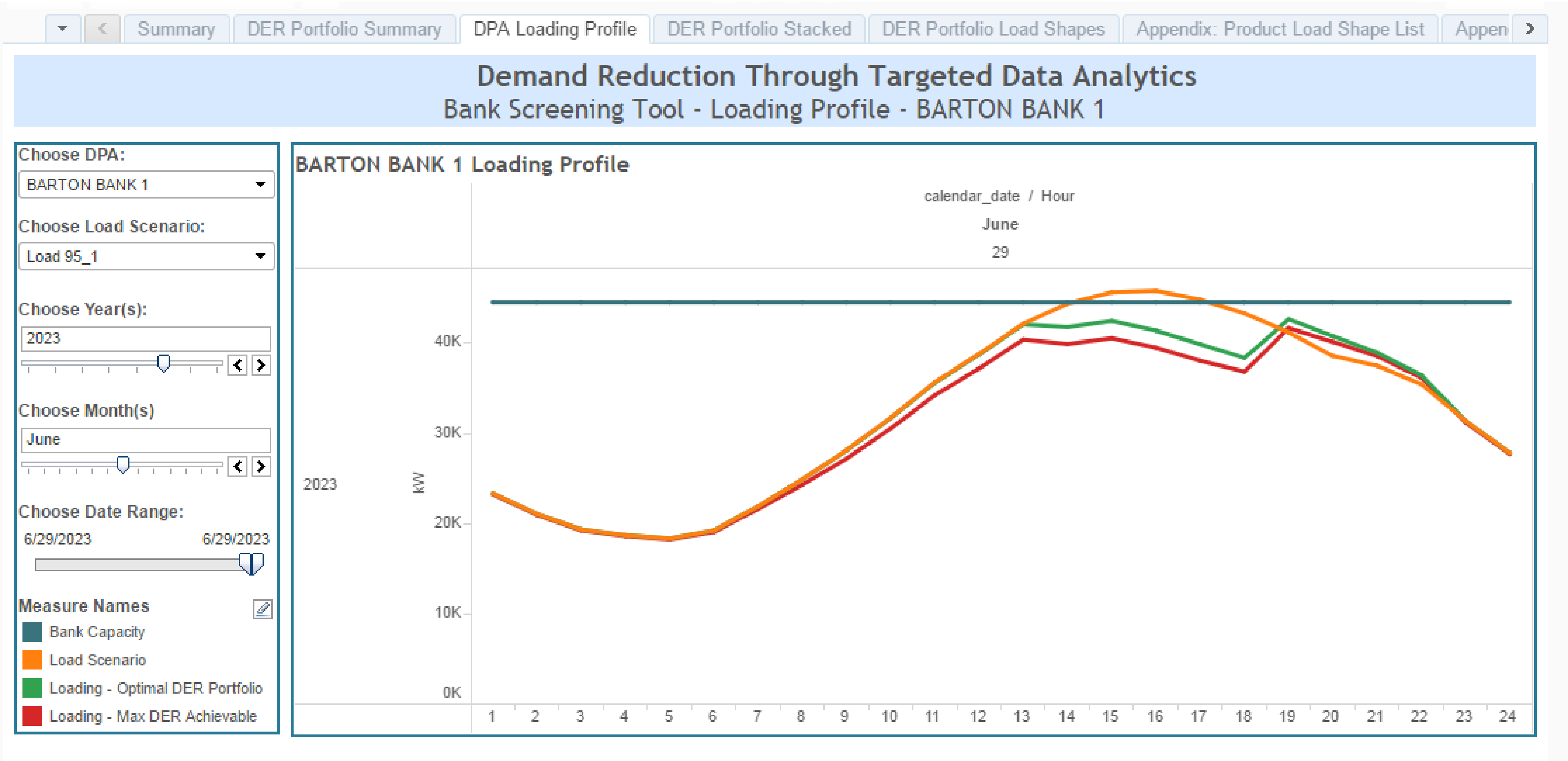
Problem Statement:

- Solve the linear program for each asset independently
- Solve the linear program for each year 2019-2026 successively

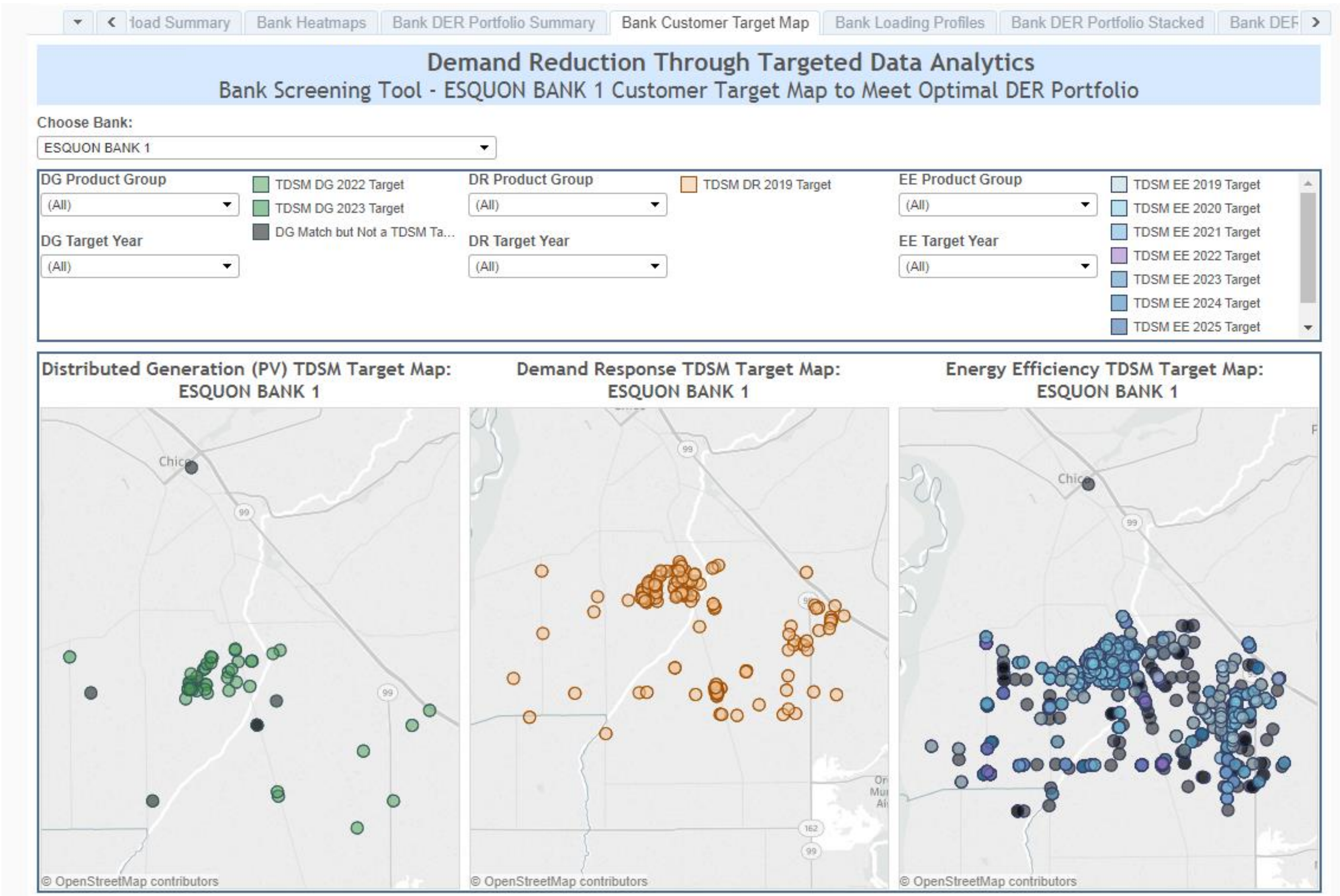
Subject to:

- Annual budget (or annual asset upgrade cost)
- The number of eligible / matched customers for that DER product

# Visualization Mock Up



# Identifying Customers

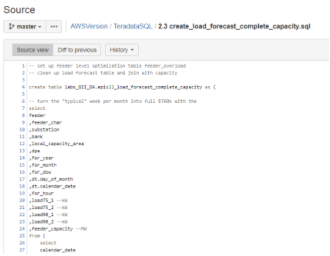


# Value that a Cloud Microlab is Bringing

- An environment to run distributed data operations using open source languages
- Allows for Data Science notebooks that can be easily shared, and documented before production
- Agnostic to visualization/front-end
- Enables on-demand analysis by non-technical business users

Business Users

Data Acquisition




Data Preparation

Collaborative Analysis

Operationalization

Rapid Iterations by Data Scientists



# Project Benefits

## Distribution Resources Plan (DRP)

**1. Assumptions, Scenarios & Scope**

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- DER forecasts
- DER growth scenarios

**2. Distribution Planning Assessment**

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- Reliability

**3. Distribution Grid Needs**

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## Integrated Distributed Energy Resources (IDER)

**4. Evaluate Options**

Prioritize Grid Needs

↓

Locational Net Benefit Analysis (LBNA)

**5. Sourcing**

Sourcing Process To Satisfy Needs Identified In IDPP

## Optimization

**1 Inputs**

- DER load shapes (currently disparate)
- Customer-specific usage & demographic data
- Customer DER propensities
- Load and DER forecasts

**2 Economic Optimization of DER Portfolios**

- Costs
- Benefits
- Budget

→

**3 Load Reduction Optimization**

- Modular customer-to-DER product matching, adoption, sizing, dispatching, scheduled acquisition and geospatial allocation

**4 Outputs:**

- Least-cost, best-fit DER portfolio recommendations
- Ranked customer list tagged with specific DER product recommendations
- Feeder level, future load curve scenarios

## Platform

1 2 3 4 5 +

- DIDF supports proactive deferral opportunity identification, feasibility assessment, economic screening, and prioritization
- Forecasting/Predicting DER growth from the bottom-up
- Model grid conditions from future load growth/change
  - System wide and for specific load pockets using TPP or other assumptions
- Analyze grid reliability issues from DERs & DER impact on assets
- Fees for services to external parties *(CCAs, RFO responders, etc.)*
- Internal TDSM & NWA support
- Supply customer data to STAR to help inform risk assessments
- Central repository for DER load shapes with governed data access
- Streamlined DER reporting and single source of data on customer-grid interactions *(Smart Grid Annual Report, EPIC, Demos, CAISO, etc.)*

# Q&A

- Thank you for the opportunity
-
- JP Dolphin
- Pacific Gas & Electric
- Grid Integration and Innovation
- Manager, Data Analytics

# Appendix

# Data Flow

## Multiple Data Silos

IDA | PI | CDW | IGP | Energy Insight | ENOS | CEDSA/ EDGIS | Other Access, Excel, etc

### Grid Capacity Constraint (by Relevant Asset Level)

IGP
SCADA
AMI/Interval Data
DER Geospatial Scenarios

*Reconciliation*

Customer Demand Reduction Required by Hour of Year

### DER Adoption Potential (by DSM Product and Customer)

Addressable Market– Saturation
*
Adoption Propensity
*
Coincident Peak Impact
Σ
Products and Customers

Cross-DER Adoption & Coincident Demand Reduction Impact

### DER Cost Effectiveness (by DSM Product and Relevant Area)

(Locational Cost/Benefit Calculation TBD)
*
DER Measure Adoption
Σ
Product Mix and # Deployment

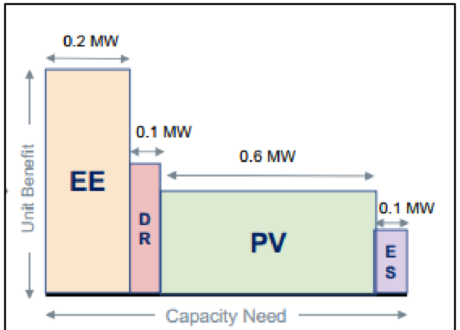
Deployment Benefit / Cost

*Consolidate insights in single analytical platform*

## Summary and Output

Coincident demand reduction achievable, at what cost

Program/product recommendation by customer




Optimized Portfolio of DER

# Analytics Modules

1. Prepare input tables and data
2. Create two primary tables from input data
    - feeder_product_cost_unit: available DER product/programs on each circuit/feeder and their associated implementation costs
    - feeder_overload: load impact shapes for each DER aligned with the circuit/feeder forecasts from 2019-2025
3. Run optimization model for each asset (feeder or bank) in parallel for 2019. This returns an optimal DER portfolio for each asset for 2019.
4. Subtract out optimal portfolio and run optimization again for next year. Repeat this for all years until 2025.
5. Prepare optimization results for front end.
6. Identify individual customer targets based on DER propensity scores and / or dispatching. Triangulate optimal portfolio with ranked propensity scored customers for each DER product / program.

Create the partitioned linear program / optimization to execute in parallel using PySpark or Scala

# Integrate demand side approaches into utility planning

- EPIC FALL SYMPOSIUM
- OCTOBER 2017
- RICK ASLIN

# Agenda

1. Introduction
2. Description
3. Project Benefits
4. Lessons Learned
5. Q&A

# Project Description

- Fulfill Assembly Bill (AB) 327/ Section 769, which require transparent, consistent and more accurate methods to cost-effectively integrate DERs into the distribution planning process. AB 327 recognized that achieving this objective requires advancing the analytical methods, tools and mechanisms by which DER are deployed.

- Utilize the vast amount of customer and operating data that PG&E is collecting in order to better inform both traditional (wires) and alternative (non-wires) future infrastructure investment.

- Establish transparent process to incorporate the amount and composition of DER adoption that are being projected at the DPA, bank and feeder level and how DER adoption may impact the location, timing and need for future distribution infrastructure investment.

# Strategic Value

**Lower Costs**

- Including a DER adjustment forecast in an integrated, least-cost, planning framework could result in lower system costs by **avoiding or deferring system upgrades** where load growth will be offset by customer adoption of DERs
- May be able to target certain DER programs that have the shape and magnitude appropriate to potentially **defer** or **eliminate system upgrades**

**Greater Reliability**

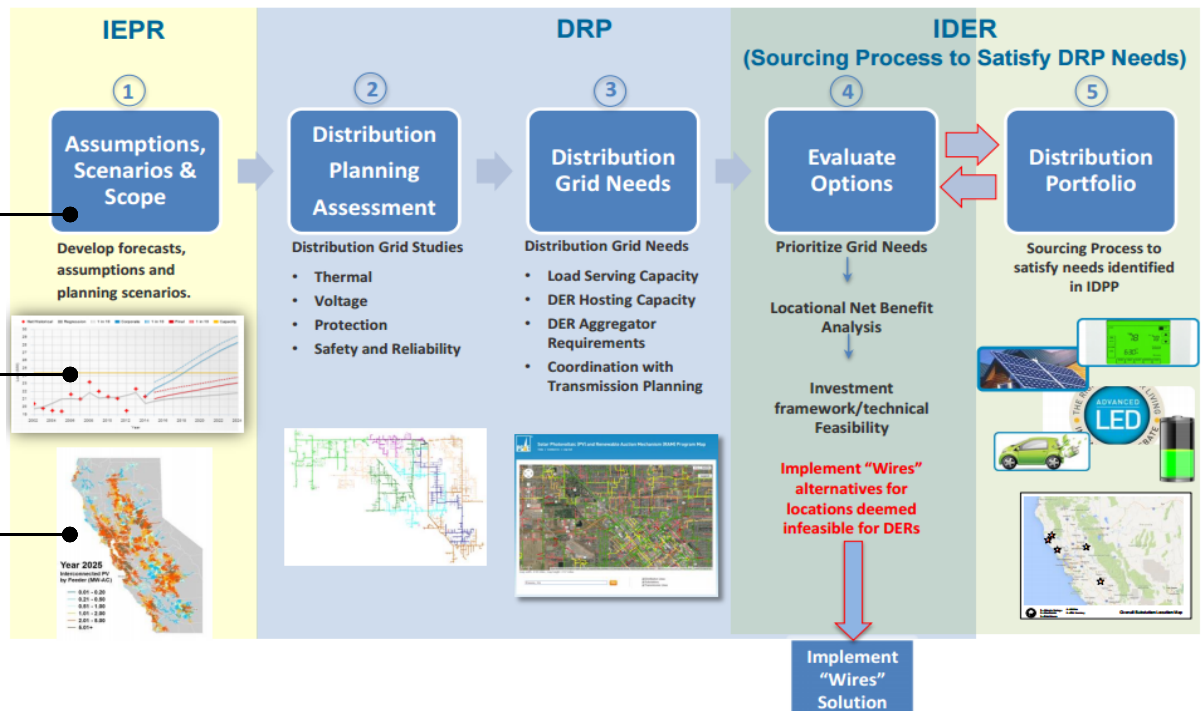
- With more accurate representation of load and DER adoption, can better model current and future grid conditions (direction and magnitude of power flows)
- Recommended infrastructure modifications and equipment specifications / settings can better match the actual conditions, right-sizing capacity work at the right time
- Supports the ability to decrease overloads, of which the wear on the system components inherently increase risk of outages

**Increased Safety**

- By hierarchically aggregating load shapes, can more accurately project the timeframe when power flow could reverse at certain distribution system components
- This is a condition that requires addressing, as equipment may be more likely to fail. Equipment failure can create a safety concern, such as a falling conductor.

## EPIC Project 2.23 addresses key Distribution Planning challenge: "Where and When are DERs going to be adopted?"

- The entire process depends upon accurate load forecast, improved based on use of 3 years of **actual** historic interval reads for over 5 million SmartMeters), not sample/research data.
  - It must **incorporate DER growth scenarios** in the Integrated Energy Policy Report (IEPR) stage




**Integrated Distribution Planning Process (IDPP) Flow Diagram**

# Tasks and Key Deliverables

## Tool Development

- Developed enhanced catalogue of customer class, bank and feeder hourly load shapes in Load Forecast (LF) tool, leveraging 2012-2014 SmartMeter interval data for all 5M electric customers (previously shapes were based on customer class research data)
- Developed over 320,000 new shapes, whereas the previous catalogue contained approx. 1000 shapes
- Reconciled customer class load shapes with SCADA data to assess customer class impact on the overall load shape
- Developed DER scenario projections and incorporated into the LF tool
- Developed interface between the LF and Power Flow Analysis (PFA) tools to be able to quickly provide Integration Capacity Analysis (ICA) results (within 48 hours)
- Integrated LF tool with PG&E databases containing customer energy usage data to automate and streamline process of gathering and processing data in LF tool
- Performed User Acceptance Testing (UAT) to verify the functionality of the software leveraging automated scripts

## User testing and Feedback

- Evaluated the interaction of the tool with users in producing a distribution needs assessment during the Jan-March 2017 planning cycle
- Gathered suggestions from users on how to further improve and standardize the new analytical process

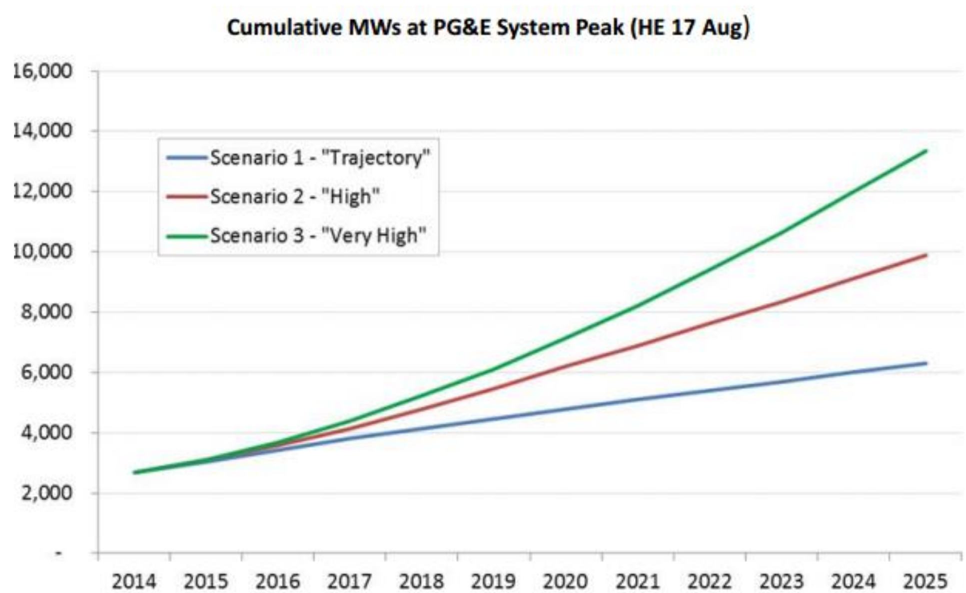
# DER Growth Scenarios Implementation

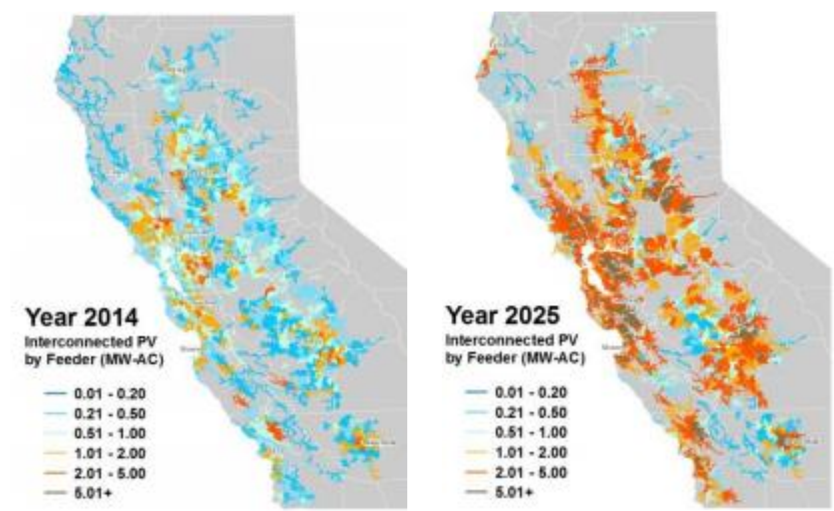
Specific DER forecasts were implemented for the three scenarios listed below as outlined in PG&E's DRP filing

**Scenario 1 - "Trajectory"**
This reflects PG&E's best current estimate of expected DER adoption, incorporates the following

**Scenario 2 – "High Growth"**
This reflects ambitious levels of DER deployment that are possible with increased policy interventions and/or technology/market innovations

**Scenario 3 – "Very High Growth"**
This is likely to materialize only with significant policy interventions such as those outlined in the DRP Guidance Ruling



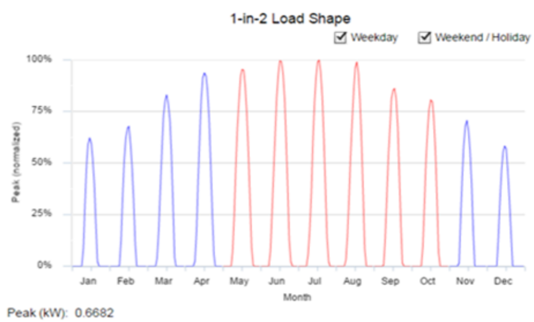
# New DER Load Shapes

The DER load shapes are normalized based on their full capacity/rated value, and can be location specific (e.g. PV, EE) or identical system-wide (e.g. EV).

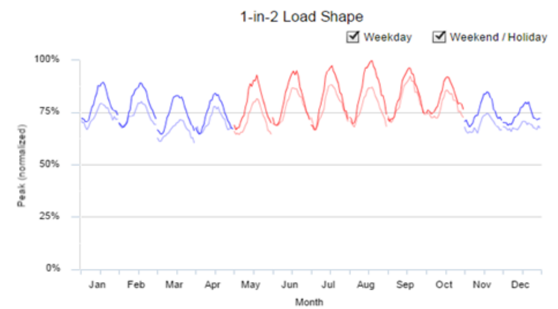
- 50th percentile probability load shape examples for each of DER groups is shown in the table below.
- Note that industrial EE load shape follows the industrial customer class load shape; energy efficiency scales down the load.
- In the industrial EE load shape example: the lighter line shows load reduction on the weekend/holiday, the thicker line during the weekday.

**DER Load Shape Examples by Month**

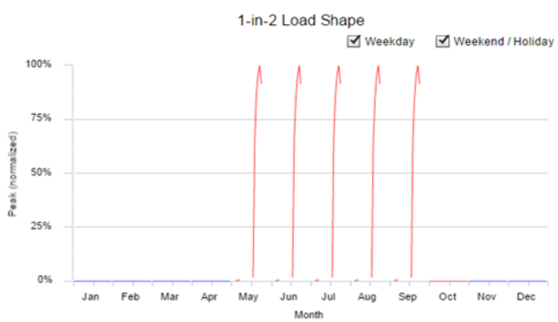
PV – Santa Cruz Planning Area



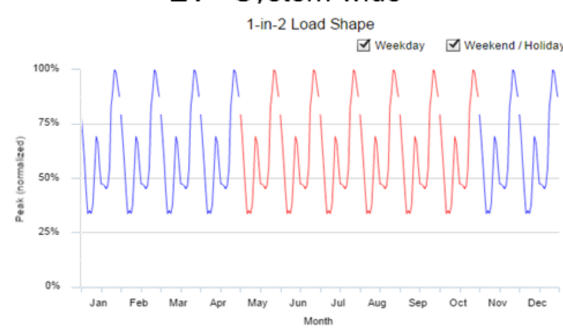

Industrial EE – South San Jose




Demand Response SmartRate




EV - System-wide



# Improved Distribution Planning for T&D Cost Reduction

## Distribution Planning is Enhanced by Granular DER and Usage Data

Successfully demonstrated that an enhanced tool with granular DER and usage data can enable potential alternative solutions to capacity needs as opposed to wired methods, and can enable potential deferment of investment.

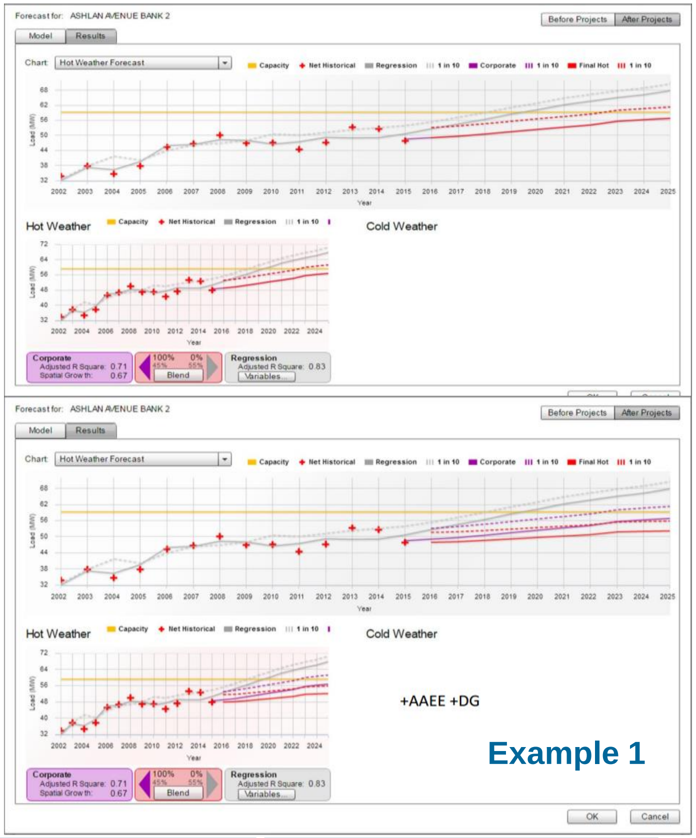
## Next Step: Continue to Leverage Tool in Future Planning Cycles.

### Example 1

- Load exceeded distribution one bank's capacity by 2022 when DER adjustments are not applied
- With Additional Achievable Energy Efficiency (AAEE) and PV adjustments, that bank capacity will not be exceeded in next 10 years, even under extreme (1-in-10) hot weather conditions
- Demonstrates how the enhanced load forecasting tool could help PG&E evaluate if DER growth could defer or even eliminate the need for future network upgrades

### Example 2

- On one bank, load forecast without DER projected an overload at 105% in 2020
- By using the forecast viewer to apply DER adjustments, the bank loading could potentially be reduced to 95% in 2020
- With DER growth forecast and targeted deployment opportunity, PG&E can assess the least cost option to mitigate the overload in 2020



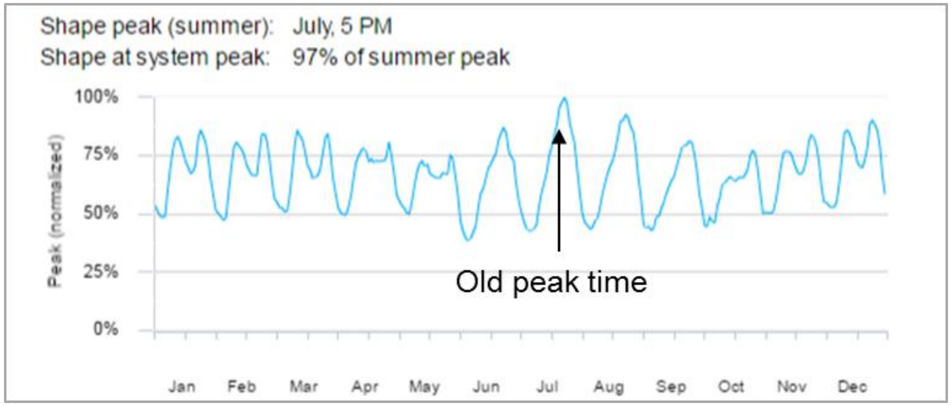
# Improved Understanding of Peak Times

## Enabled ability to more accurately assess peak times

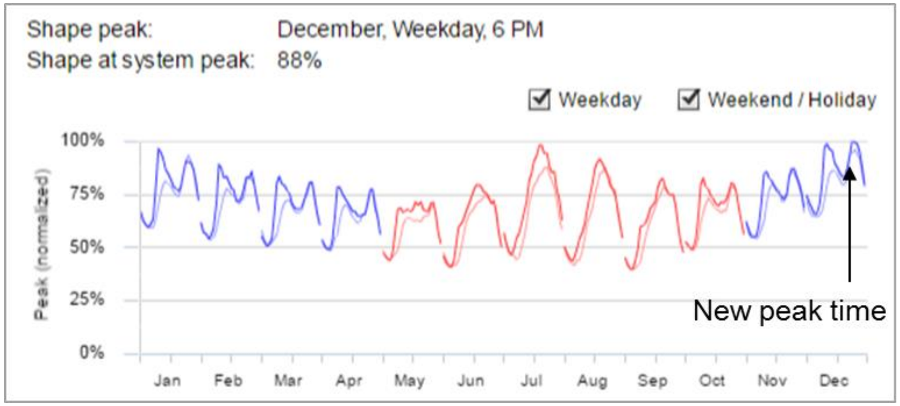
- The time of peak shifts in high DER adoption areas. For example, the location shown below appeared to peak in summer, but when adjusted based on granular usage data and inclusion of DERs, actually peaks in winter
- Timing change can have significant impact on solutions to load expansion or power quality problems
- Without adjusted view, may not have run a winter study, potentially missing a potential overload

## Next Step: Annual Update of Load Shapes

- Any impacts of the peak time shifts will be evaluated as part of the annual distribution planning process.




**Before EPIC 2.23**

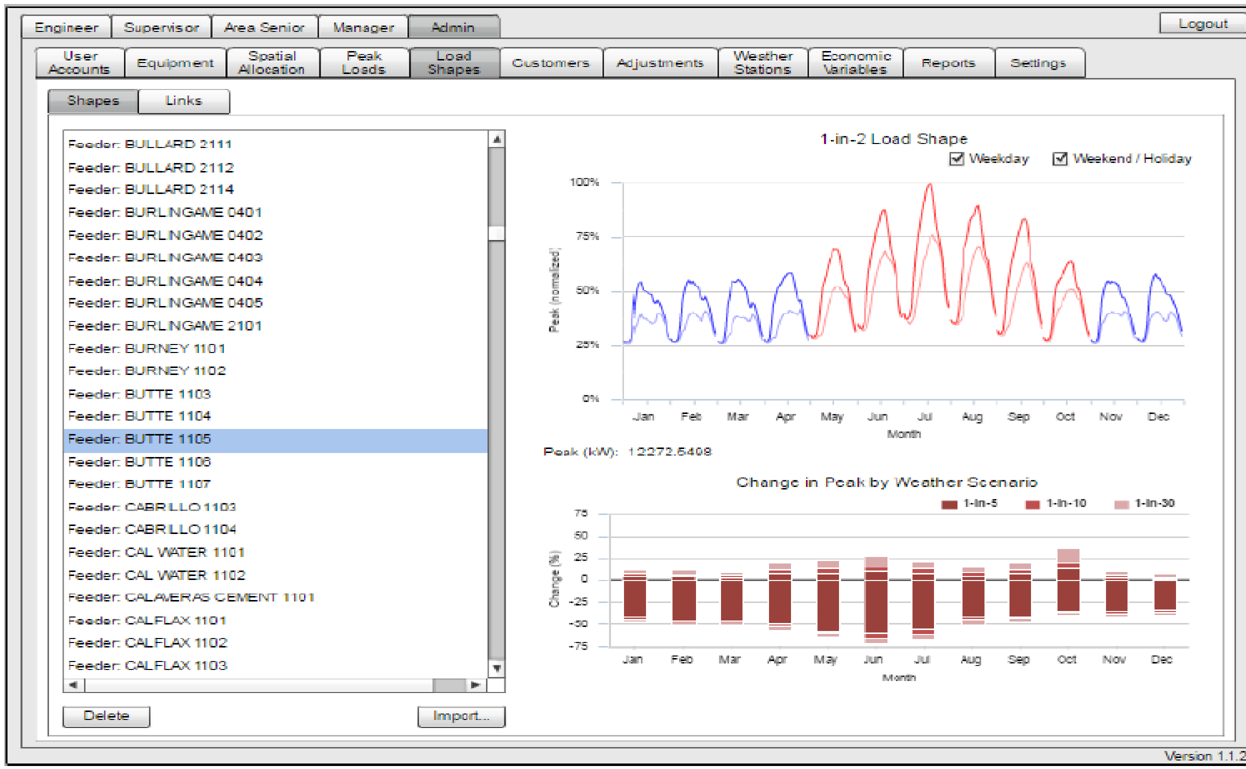



**After EPIC 2.23**

# Enhanced Targeting of DER Adoption

## Enabled ability to better target DER adoption programs for reduction in T&D costs

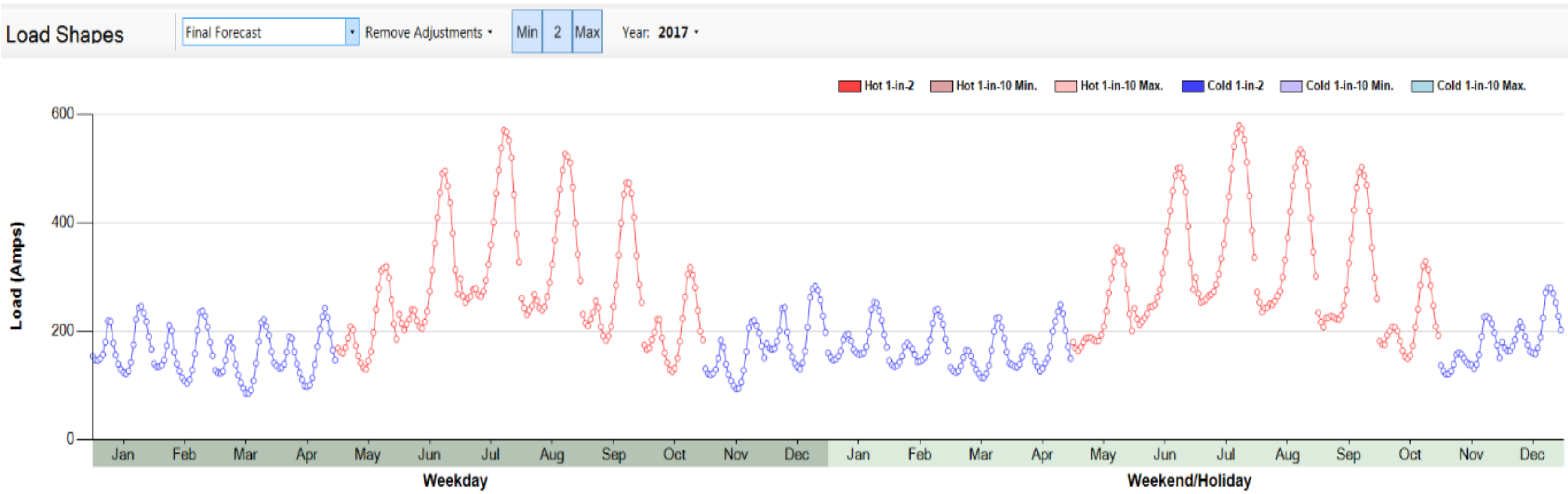
- HTML5 web-based application that pulls data from the LoadSEER Cloud Services
- Allows engineers to observe load shapes at different system levels (e.g. DPA, bank, and feeder) and by customer class for different weather scenarios
- Allows assessment of what types of customers may be large contributors to the peak load
- By identifying those customers, PG&E can target appropriate DER adoption programs that can potentially avoid investments in assets



# Assessment by Type of DER

## Granularity improves ability to determine best potential solution for capacity needs

- Improved understanding of magnitude and duration of potential overloads
- The impact of adjustments can now be properly modeled, not as the sum of peak values that may occur at different times, but as the sum of shapes that have complex interactions over time.
- DER adjustments can be toggled on/off to assess how DERs could impact the load shape in the future under different weather conditions
- Improves ability to assess what type of DER might work best to overcome system deficiencies. For example, apply a specific level of PV during daylight hour or energy storage charge/discharge curve.



# Streamlined Integration Capacity Analysis

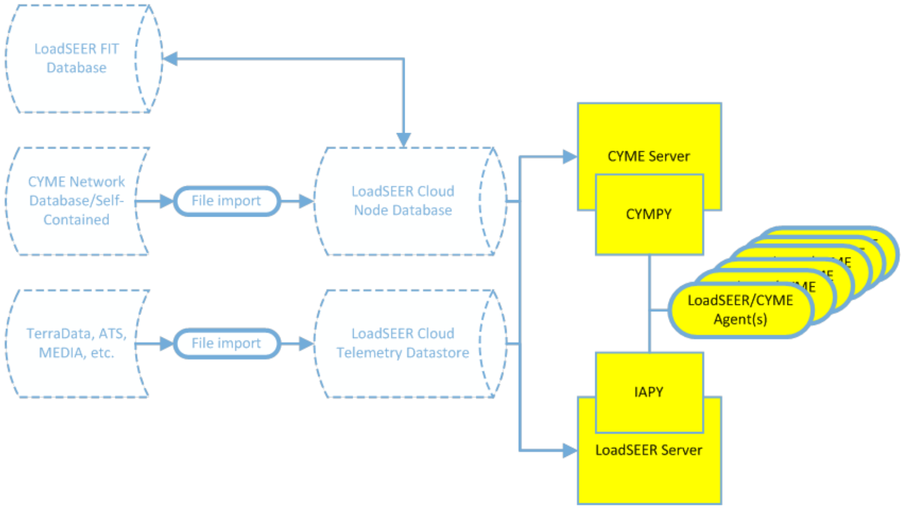
- LoadSEER and CYME integration within the ICA process established in the cloud environment, to demonstrate the advanced parallel computing capabilities to improve ICA processing time.

- PG&E Demonstration Project A (Enhanced Integration Capacity Analysis) leveraged two sets of 288 hourly load profiles generated as part of EPIC 2.23. Those two sets represent high and low load scenarios at the 90th and 10th percentile load profile, respectively.

- It takes 12000 hours of computation time (3 to 4 hours per feeder) to process the ICA analysis for:
  - 576 hourly intervals (representing load profile for one year)
  - 2 load scenarios (at the 90th and 10th percentile load profile)
  - 2 DER scenarios
  - 3 study years

## Reduced computational time

With 100 CYME licensees and 400 dedicated processors in place, the project reduced computation time to approximately **30 hours** to process all PG&E feeders. This time can be further reduced by creating more computing instances.




**CYME LoadSEER Integration in the Cloud Environment**

# Integrated and Automated Process

**Requires a Large Amount of Data Storage Capacity and Computational Power**

- Computational power required for both integrated analysis and post-processing raw outputs
- Generated significant amount of data (e.g. analysis of 6 million rows for each feeder) and required advanced data storage techniques
- Current process: send meter usage and SCADA data to vendor to host in cloud and provide the annual long-term forecast

**Next Step: Integrated and Automated Process Transition to Production**

- Review what solution architecture best serves the company's needs based upon enterprise strategy in the years to come
- Assessment will need to take into account not only the needs of the load shape profile update process, but also the needs of other PG&E large scale processes and analyses such as ICA and LBNA

# Additional Refinements

**Refine Load Shapes w/Additional 2 Years of SmartMeter™ Historic Data**

- Based upon the timeframe of the project, leveraged 2012-2014 interval data for demonstration.
- Plan to refine load shapes using 2015-2016 data and continue to update load shape profiles annually

**Fully Incorporate All Legacy Meter Data in Load Shapes**

- Some large customers metered using a legacy meter system were not initially included
- After including the legacy meter data in the load profile, the $50^{th}$ and $10^{th}$ percentile volatility was reduced to a normally expected range (from approximately 200% to between approximately 0-30%)
- In order to further improve load shape accuracy, legacy meter systems energy use data will be fully incorporated in the next annual revision of feeder load shapes

**Explore the Use of Even More Granular Data**

- During the demonstration, load shapes were created at a monthly level
- Plan to explore creating daily load shapes for even further refinement. This would allow more precise determination of how many days out of a month grid need is present

**Introduce New Methodology for Large PV Adoption Forecast**

- 8 feeders had agricultural PV adoption forecasts that depended on single, large (1-4 MW) PV systems to be installed in specific years, causing forecasted loads to drop
- This forecasted load drop, if leveraged in planning, could delay required infrastructure expansion work, or overload mitigation measures such as transfers
- Plan to introduce new methodology to allocate agricultural PV forecast adoption over multiple feeders in multiple years, as opposed to projecting the adoption to specific feeders in specific years

# User Feedback (Distribution Planning)

- Users' feedback was positive overall
- Allows truly integrated load forecasts
- Reflects the diversity of customer choices
- Allows a more robust hosting capacity analysis
- ICA analysis processing was greatly improved; scenario analysis, accuracy, and speed of analysis
- LNBA analysis improved by determining list of projects that are deferrable by DER
- Concern that DER adjustments were aggressive for some feeders, leading to the recommended next step to refine methodology for large PV adoption forecasts

# Conclusion

- EPIC Project 2.23 Delivered Value
  - EPIC 2.23 delivered an integrated process that provides more accurately forecasted load growth and load reduction due to DER
  - Location specific DER load shapes created as part of this project allow PG&E to perform distribution planning in an integrated least-cost fashion
  - Newly created DER load shapes and forecasts will be a key component in assessing DER efficacy to mitigate forecasted network capacity deficiency
  - The enhanced tool will support IDER/DRP proceedings, including Integration Capacity Analysis and Locational Net Benefit Analysis, Distribution Infrastructure Deferral Framework, Competitive Solicitation Framework and Grid Modernization Filings

- Next Steps Summary
  - Continue to leverage updated tool in production for distribution planning, with annual updates of load shapes
  - Further refine load shapes with more recent SmartMeter data, inclusion of all Legacy metering accounts, and creation of shapes at the daily level
  - Leverage feedback from engineers to inform process changes and training, such as methodologies for allocation of large PV for agricultural customers
  - Assess current architecture and agreement with vendor for cloud storage

- Thank you for the opportunity
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- Richard Aslin
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