The Future of the Power Grid Is Here

How Cooperatives Can Smartly Address Modernization

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Keynote Speakers

John Hewa
President and CEO,
Rappahannock
Electric Cooperative

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Southern Team Lead,
Electric Distribution

Agenda

- **Examining "Status Quo" Disruption**
  - Severe Weather
  - System Hardening
  - Aging Infrastructure
  - Consumer Adoption Impacts
- **Essential Planning & Analysis**
- **How Cooperatives Can Smartly Address Modernization**

Rappahannock Electric Cooperative

Quick Facts:

22 Counties

4,000 sq. mi. Territory

18,000 Miles of Line

172,000 Accounts

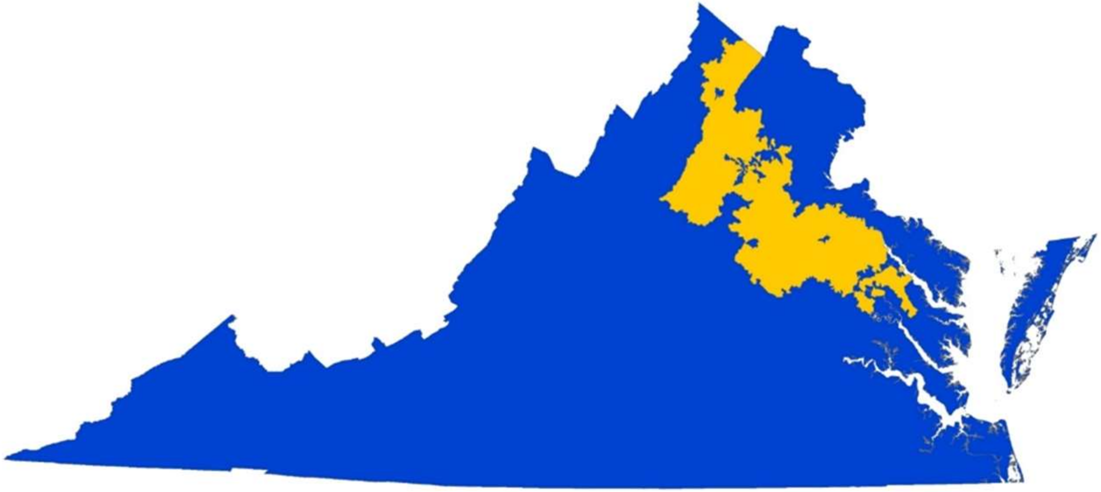
$440M Annual Revenue

431 Dedicated Employees

820 Miles of Backbone Fiber

2,000 Miles of leased FTTH (in progress)

> $1B Assets



REC's Advanced Planning for Grid Modernization & Consumer Adoption

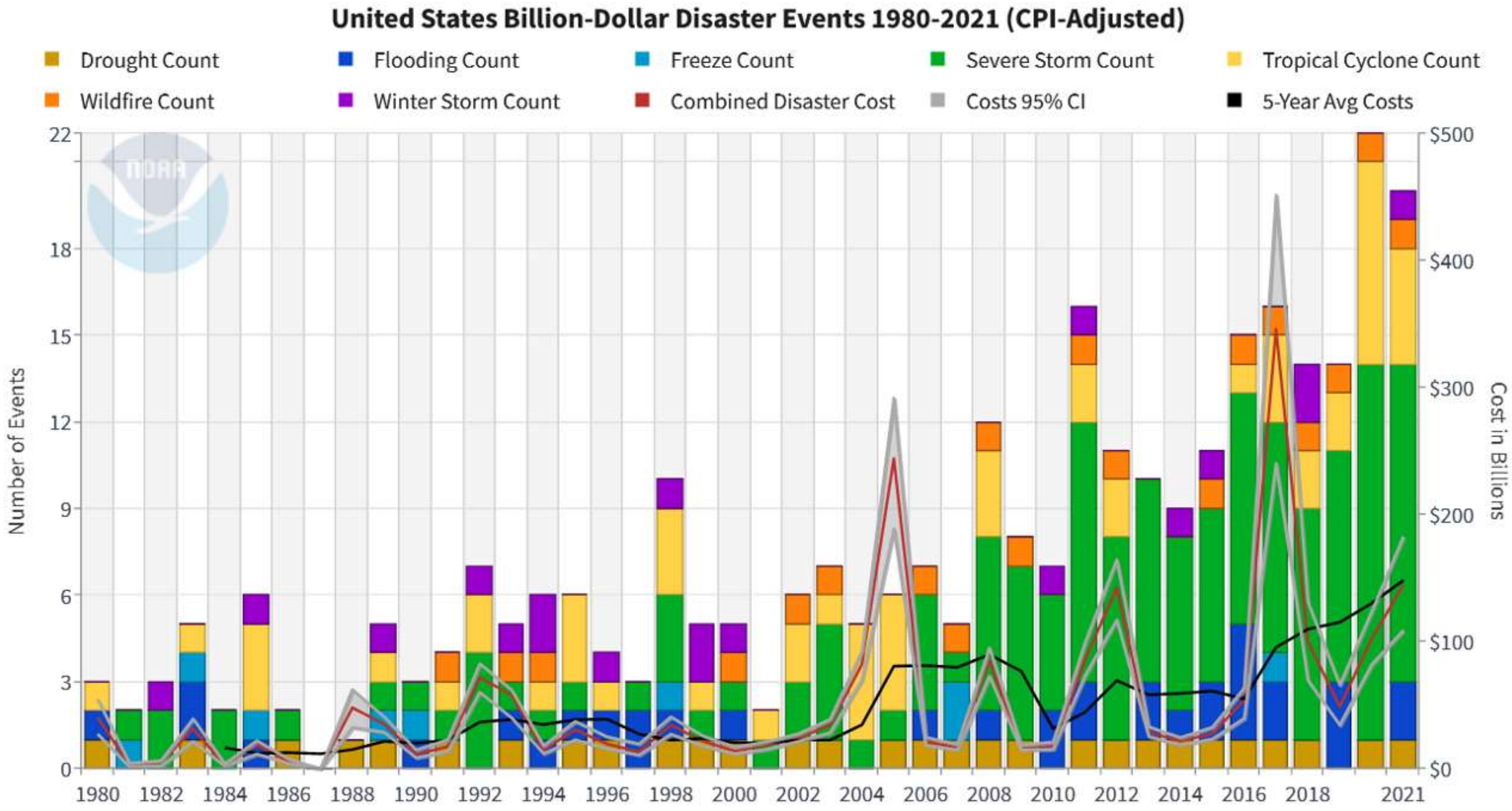
Hardened Design Standards
Pike Engineering

Aging Infrastructure
Burns & McDonnell (1898 & Co.)

Electric Transportation Business Objectives
ScottMadden

Electric Transportation Demand Modeling & Analysis
Burns & McDonnell (1898 & Co.)

Increasing Trend of High-cost Disasters

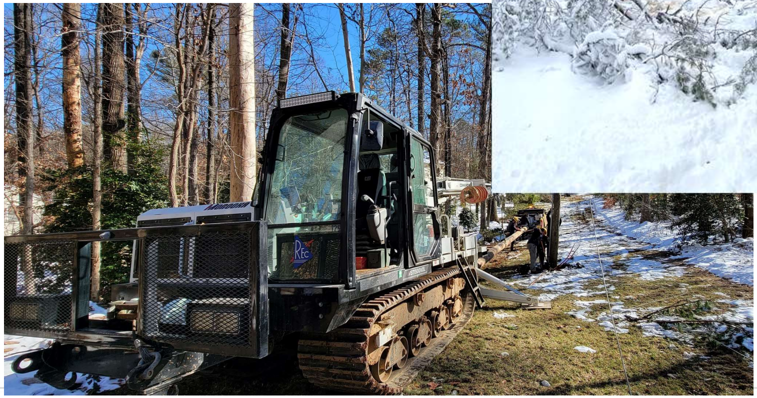


Source: NOAA

Winter Storm Frida

- Peak outages – 100,196 on January 3 at 4:00pm
- Total events 3,760 (non-outages included)
- 60% of member accounts experienced outages
- Broken poles – at least 640
- Transformers damaged – over 280
- Transmission disruption to 14 substations
- Financial impact - ~$22M
- Lineworkers from VA & 13 additional states
- Total workforce over 1,400
- Restoration safely completed in 8.6 days

- Website hits – 3,435,508
- Social media – 24,300 interactions



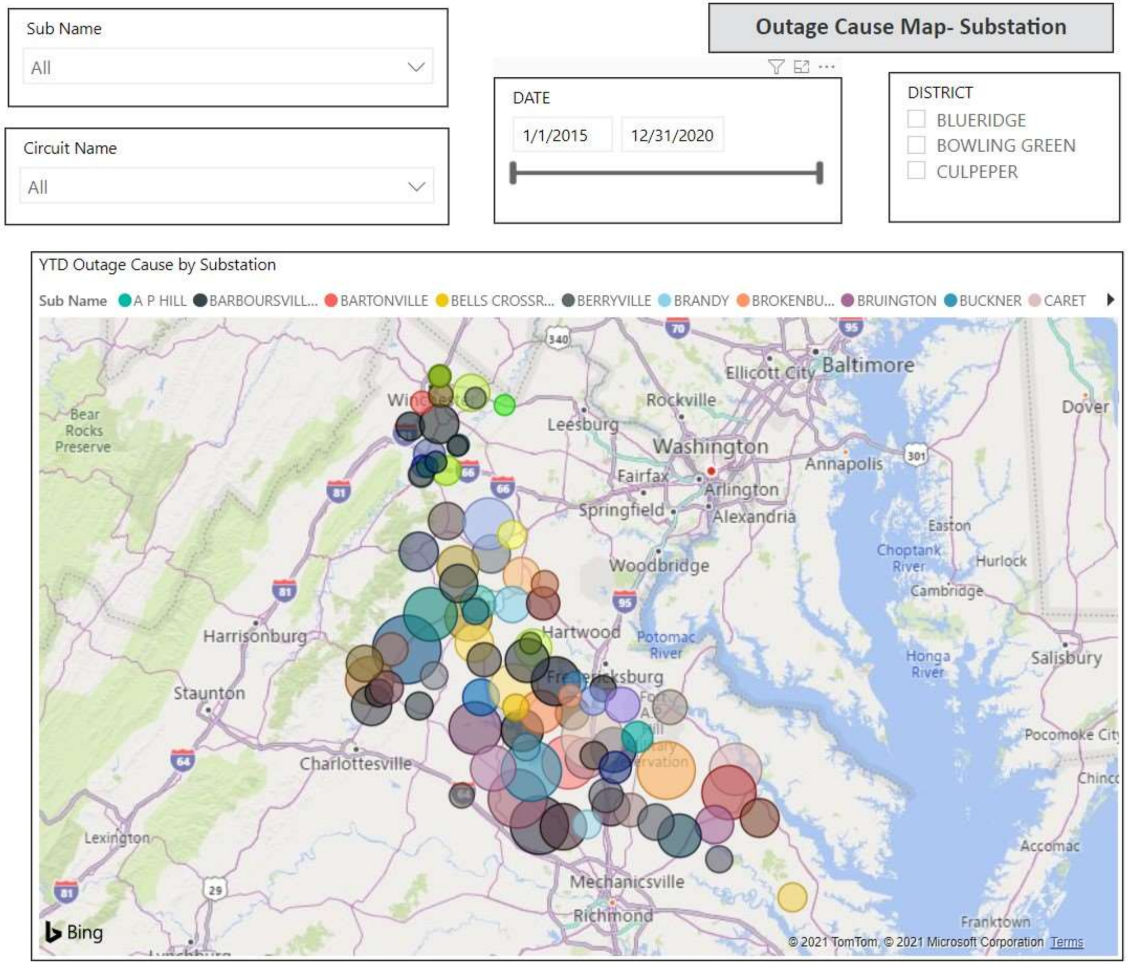
U.S. Aging Grid Drives $60B in Annual Distribution Spending

- The **distribution system accounts for 92% of all electric service interruptions**, a result of aging infrastructure, severe weather events, and vandalism.
- Spending on electricity distribution systems has risen 54% over the past two decades, from $30 billion to $60 billion annually.
- According to the U.S. Department of Energy, 70% of power transformers are 25 years of age or older, 60% of circuit breakers are 30 years or older, and 70% of transmission lines are 25 years or older.
- Over the past decade, investment in overhead poles, wires, devices, and fixtures such as sensors, relays, and circuits has **risen by 69%,** and spending on substation transformers and other station equipment has **increased by 35%.**

System Hardening & Resiliency Study

In 2021, REC conducted a study resulting in numerous construction standards advancements including:

- Stronger class poles
- Stronger fiberglass cross arms
- Heavier conductor
- Stronger framing
- Underground system design
- Improved lightning protection
- Protection and recovery schemes



Aging Infrastructure Study

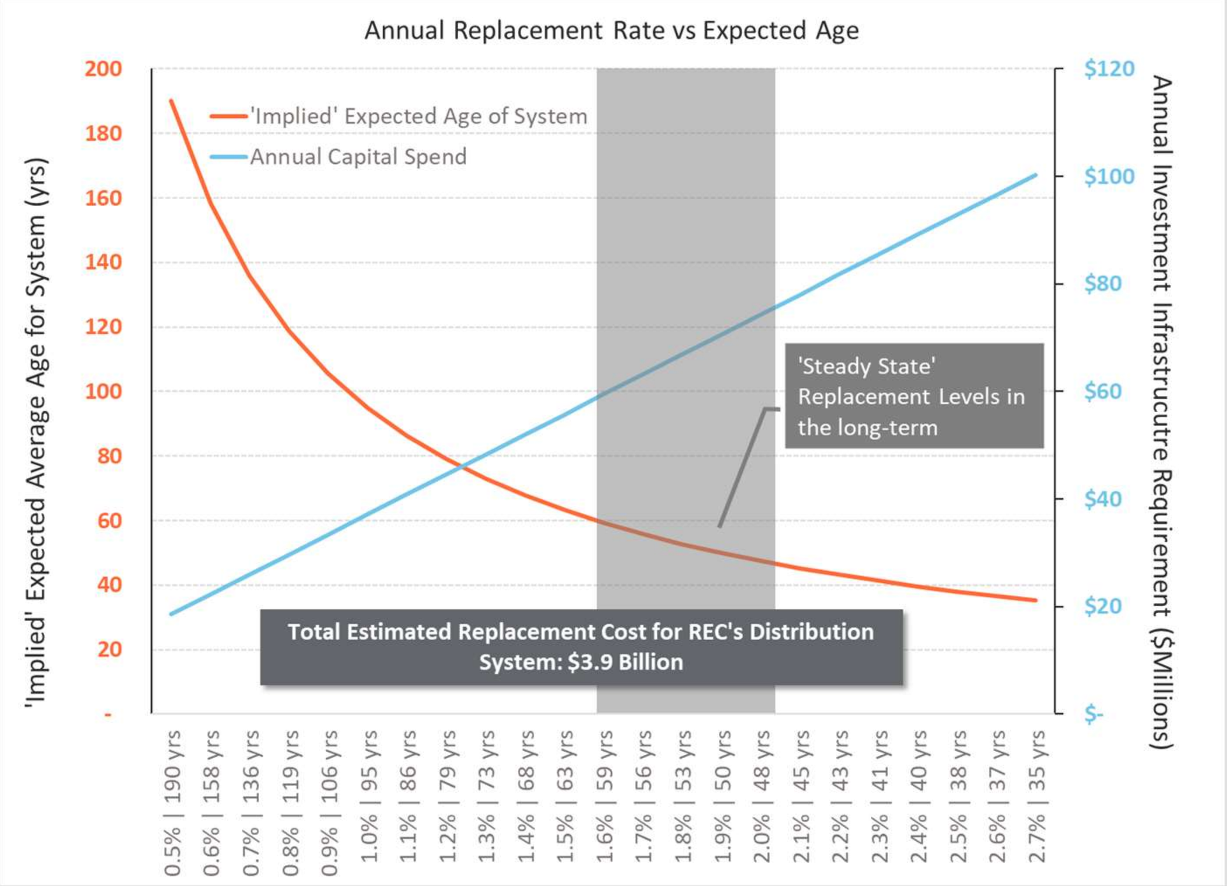
REC conducted a study of aging infrastructure seeking to determine appropriate annual capital investment.

- System aging data was analyzed for the overhead and underground systems
- Various rehabilitation paths were studied for cost-benefit
- Timely analysis given the age of the system, storm deterioration, and future expectations for reliability and capacity

How Much Should We Be Spending?

The Theory

- Spending levels for asset renewal ‘imply’ an expected age for the system. The T&D asset base has an expected life of 45 to 65 years depending on environment, design, loading, maintenance, and other factors.
- Spending levels also need to be based on age and condition of the system.
- Analysis for figure to the right is based on linear growth of the system. Investments above and below the ‘Steady State’ range are recommended for periods of time when the system is relatively young and old.
- It can be challenging to identify when to pivot to ‘Steady State’ investment.



REC's Expanding Energy Services Suite

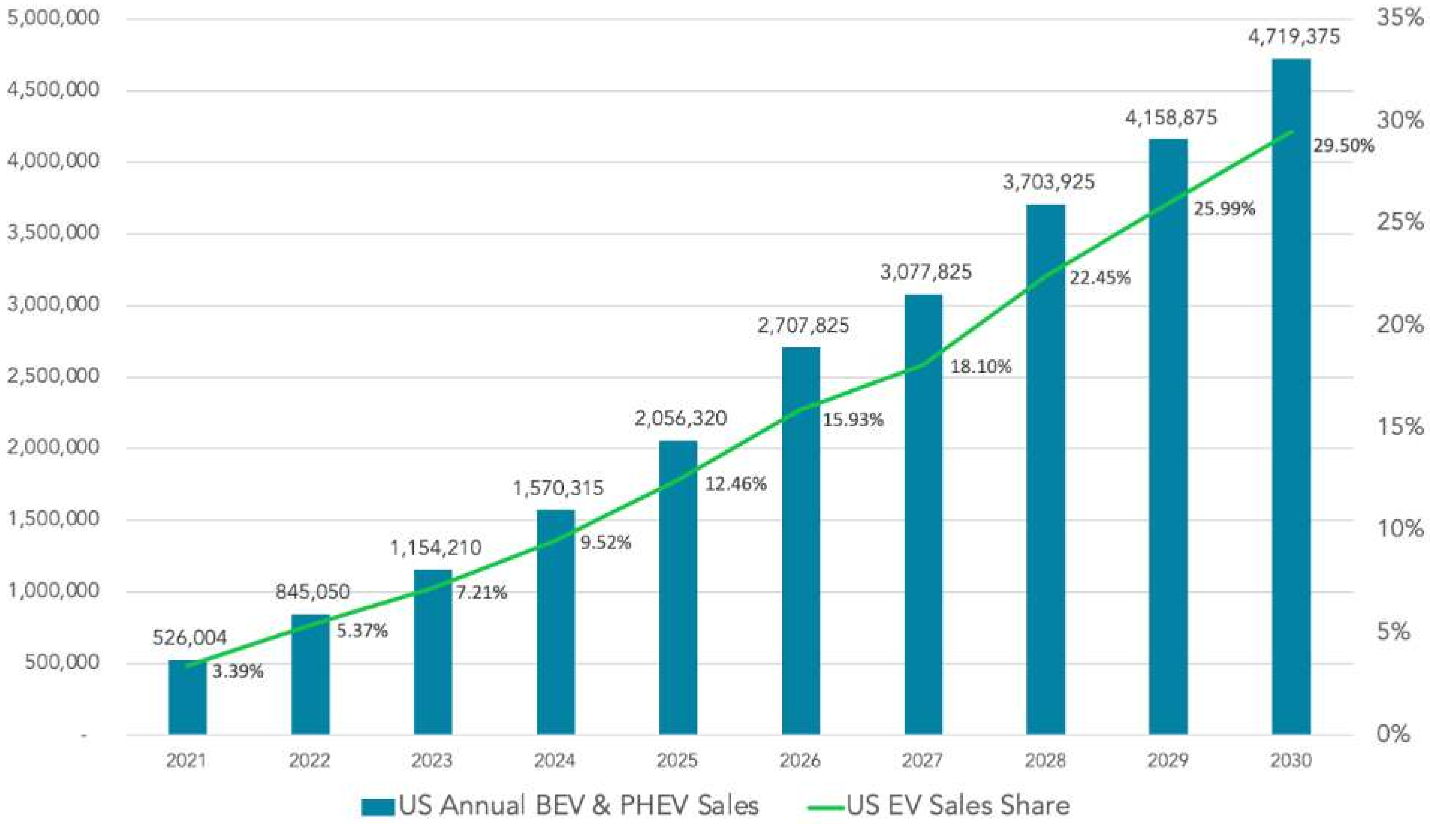
Vividly Brighter Charging

- EV Rates & Incentives
- Workplace Charging
- School Buses, Fleets, Public Charging
- Installation & Financing

Vividly Brighter Solar

- Solar Calculator
- Net Metering Online Application Portal
- Solar Installation & Financing
- Cooperative Sunshare

Preparing for U.S. Electric Vehicle Sales Outlook



Source: EVAdoption

ScottMadden provided a high-level forecast of expected BEVs in the REC territory for the next decade

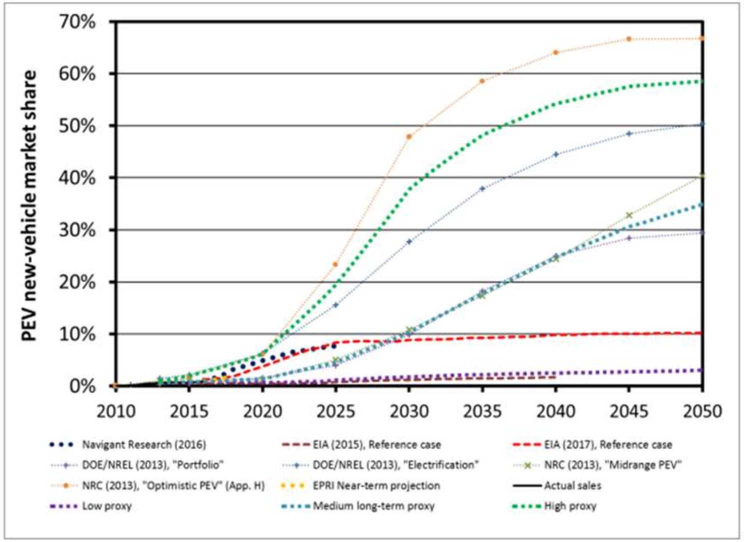
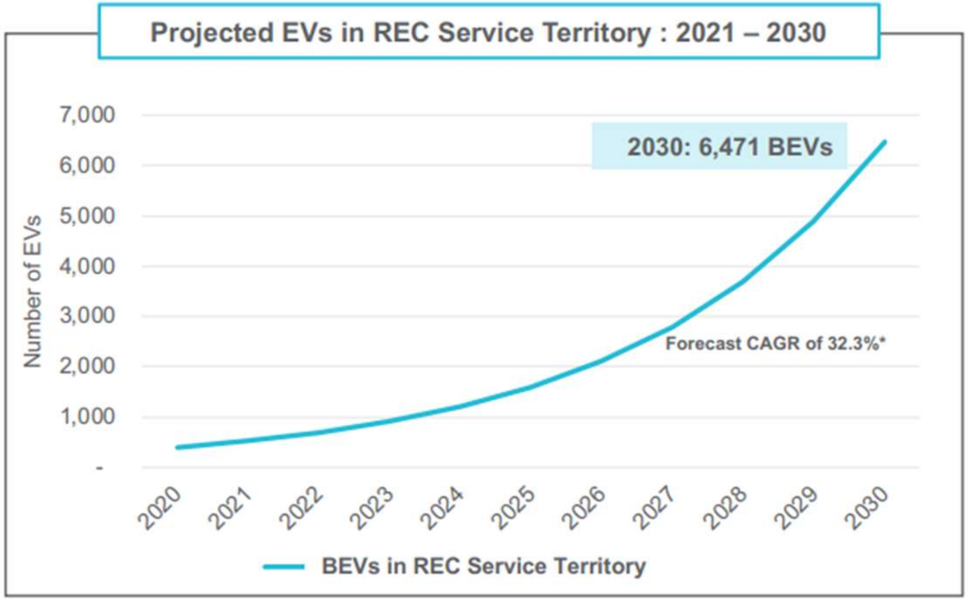


Figure 1-2
Down-selected External Projections with Proxy Scenarios



EPRI: Plug-in Electric Vehicle Market Projections

scottmadden MANAGEMENT CONSULTANTS

EV Market: Vehicle Specifications

Available

2022

2022

Available

Development

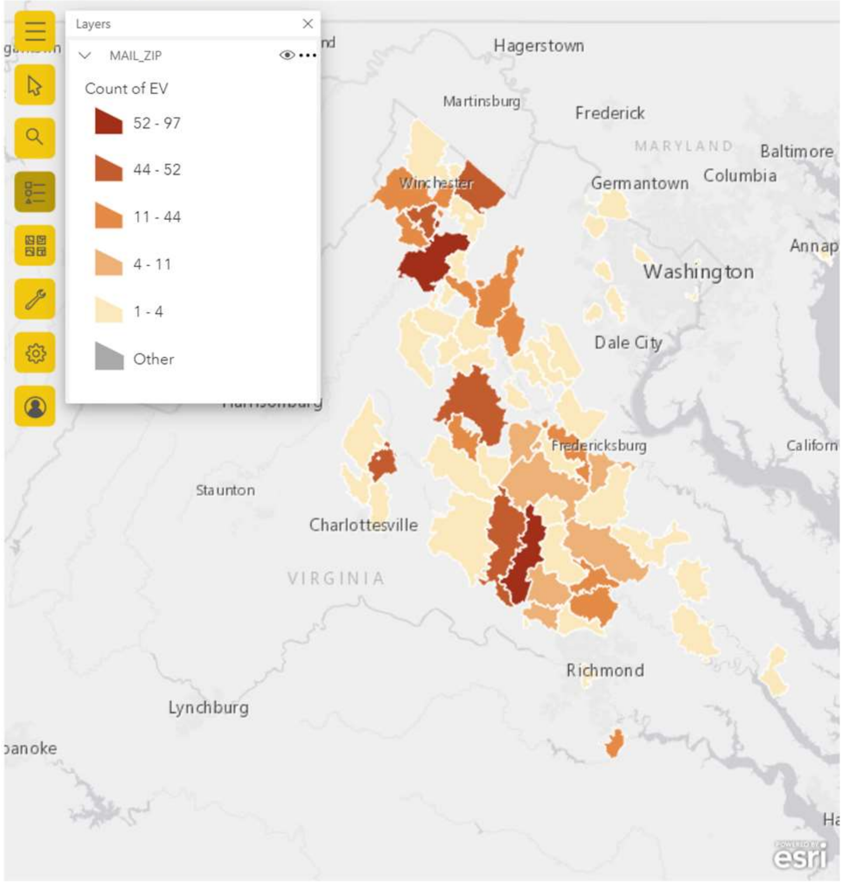
Pilot/Drayage in CA

Vehicle Type	Efficiency (kWh/mi)	Range (mi)	Battery Size (kWH)	Charge Rate (kW)
Class 1 Passenger Car & Small SUV	0.25-0.35	150-350	40-100	Level 2: 7-11 kW DCFC: 50-350 kW
				Typical Peak Residential Demand ~ 5-7kW
Class 1 &2 Pickup Trucks and Large SUV	0.4-0.6	100-300	100-200	Level 2: 11-19.2 kW DCFC: 150-350 kW
Class 2/3 Light Duty Vehicles	0.5-1	120-150	67-140	Level 2: 19.2 kW DCFC: 50-150 kW
				Typical Depot: ~20-100kVa (Lighting/HVAC loads)
Class 3-5 Buses/Utility Vehicles	1-1.5	105-205	110-230	Level 2: 13-19.2 kW DCFC: 50-150 kW
Class 6-8 Bucket Trucks	2-4	~90 (With Aux Power)	250-350	Level 2: 19.2 kW DCFC: 150 kW
Class 6-8 Trucks/Tractor Trailers	2+	125-250	230-500	Level 2: 19.2 kW DCFC: 50-250 -> 1MW+ in the future

Count of Known EVs to REC and Estimated Vehicles

Vehicle counts were used to estimate potential number of light duty vehicles in the REC territory

Count of EV by MAIL_ZIP



Vehicle OEM	Count of EV
Unknown	64
Tesla	55
Chevy	46
Nissan	15
Ford	5
Volkswagen	4
BMW	2
Hyundai	2
Toyota	2
Audi	1
Chrysler	1
Plug-In Hybrid	1
Total	**198**

County	Count of Known EV
Spotsylvania	28
Frederick	23
Hanover	18
Culpeper	17
Warren	17
Louisa	15
Orange	15
Caroline	13
Greene	12
Fauquier	10
Clarke	9
Town of Berryville	6
Rappahannock	5
King & Queen	2
Albemarle	1
Essex	1
Goochland	1
Total	**198**

There is an average of 2 cars per Household in VA
Source: DATA USA

Potential Light Duty (LD) Vehicles by Household Zip Codes:
857,000

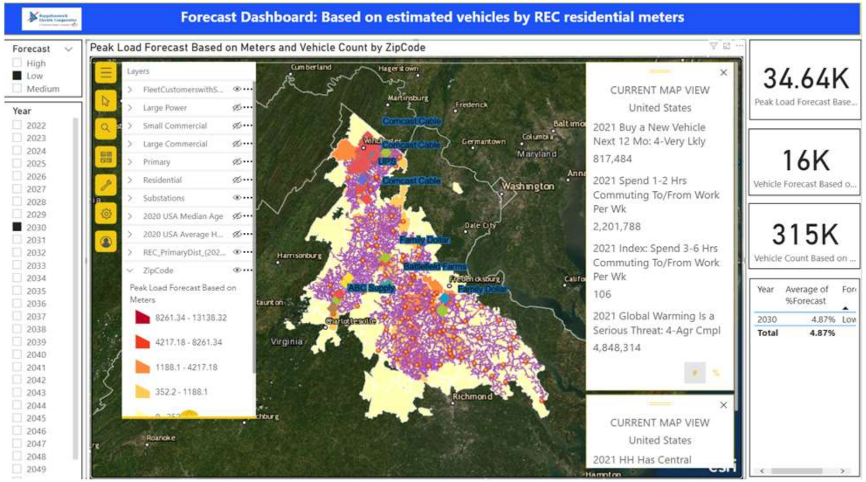
Potential LD Vehicles in REC By Number of Residential Accounts (A1 and A01):
315,000

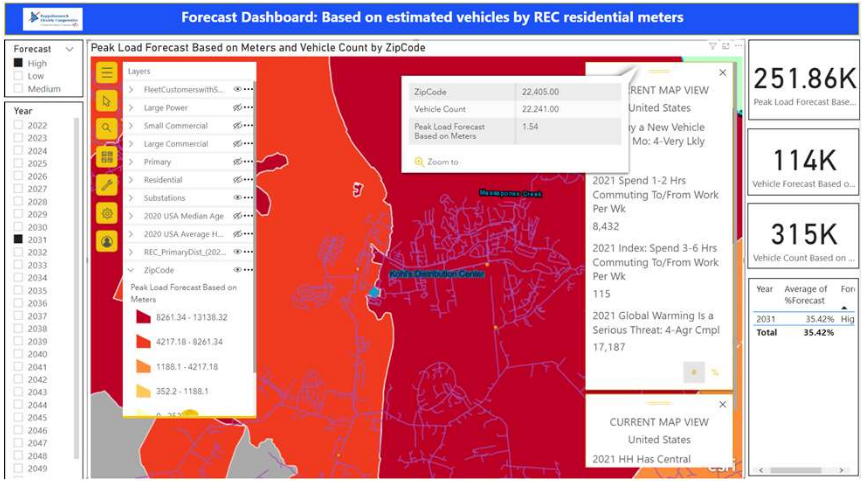
EVs known to REC:
198

Potential EV Based on EV Registration Data:
~1600

1898 & Co. created a high-level screening dashboard and forecast to identify 6 circuits for detailed analysis

- Using ESRI income demographics, each zip code was given a “likelihood of adoption” score
- A “diffusion of innovation” forecast was estimated based on scoring criteria and likelihood of adoption
- Circuit and Fleet Customers were added to GIS along with light duty forecast to show potential EV hot spots
- The number of light duty EVs was estimated by using REC meters and an estimated (2) vehicles per household.
- A breakout of vehicle types (cars/CUVs/SUVs/Minivans/Pickups) was based on the percentage of registered vehicles in VA
- In collaboration, REC and 1898 & Co. used this dashboard to select 6 target circuits for detailed analysis

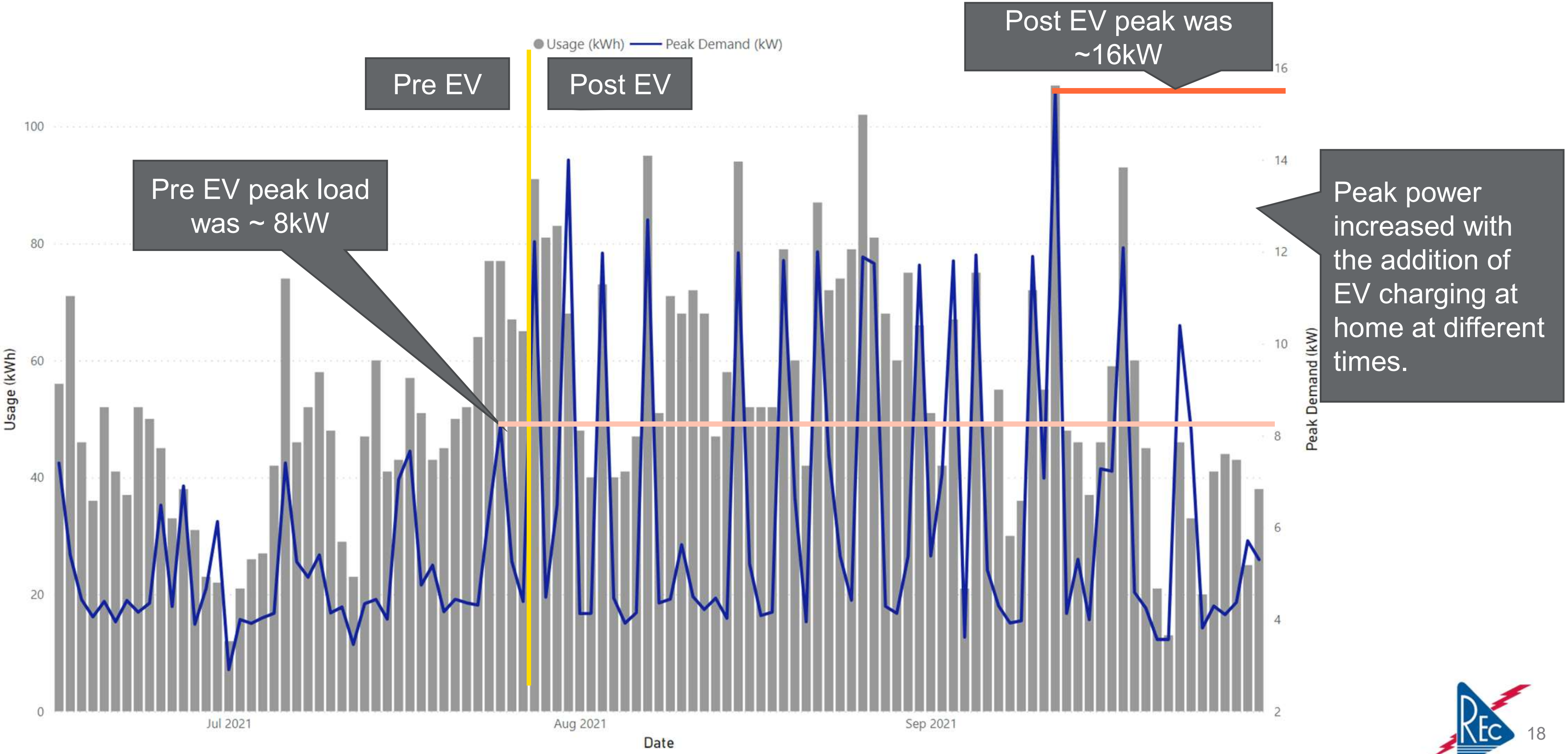




See appendix for additional dashboard images.

Example Load Profile of a Home with One EV

In this example, the vehicle is a Tesla Model 3 with a 7kW Level 2 charger charging at a 2,000 sq. ft. house.



Slabtown – Lee's Hill Potential EV Scenario

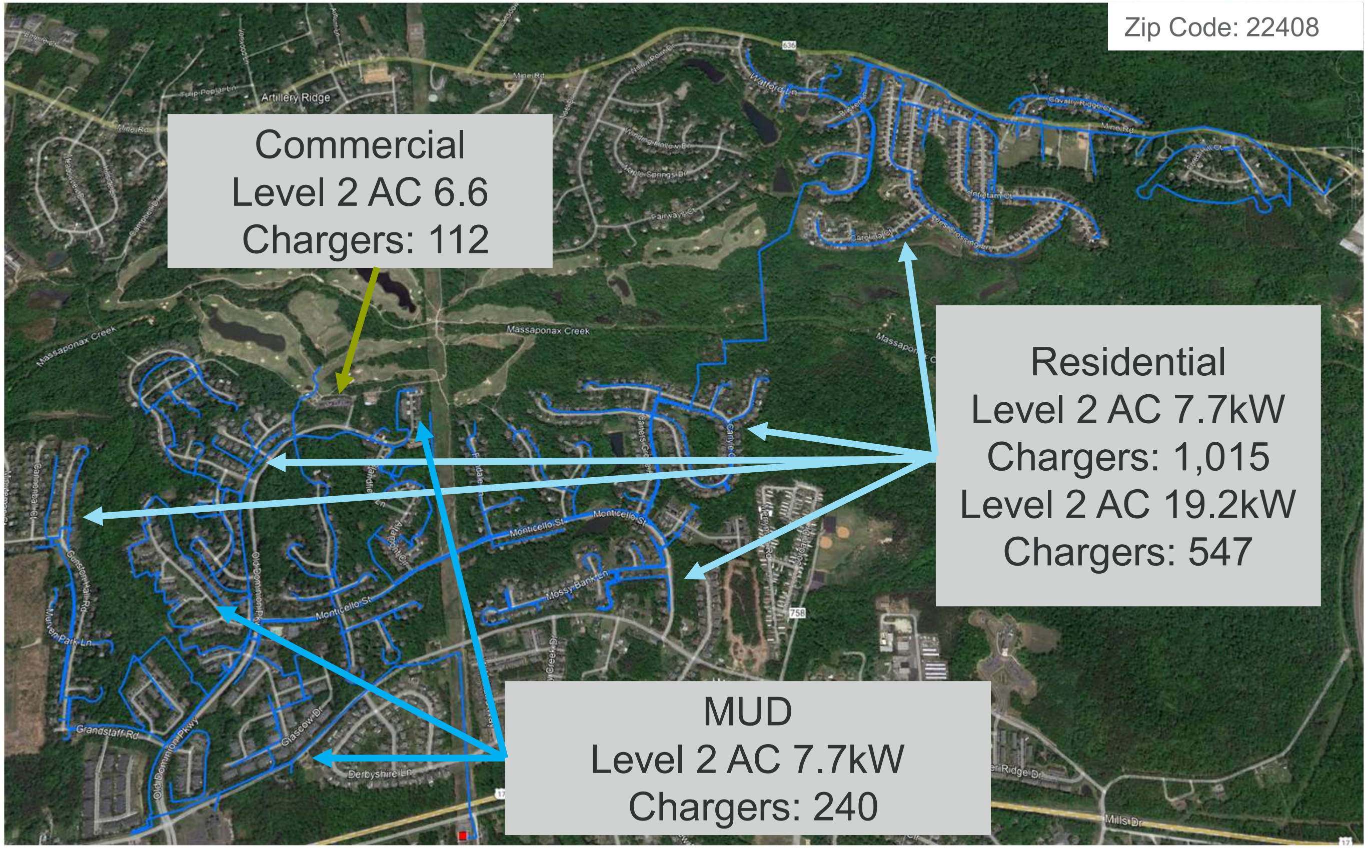
Number of chargers shown is the estimated maximum potential for chargers at full electrification.

At 100% potential, which is the maximum number of chargers we assumed for this circuit:

For Multi-Unit Dwelling (MUD) charging we identified the number of meters at the premises and assumed a charger is shared between (2) apartments or in other words (1) charger per (2) parking spaces.

For Commercial charging we assumed several chargers aligned with the number of parking spaces at the premises.

For residential charging we assumed (1) charger per household based on the number of meters. And split the number of 7.7 kW and 19.2 kW chargers 65/35 respectively.



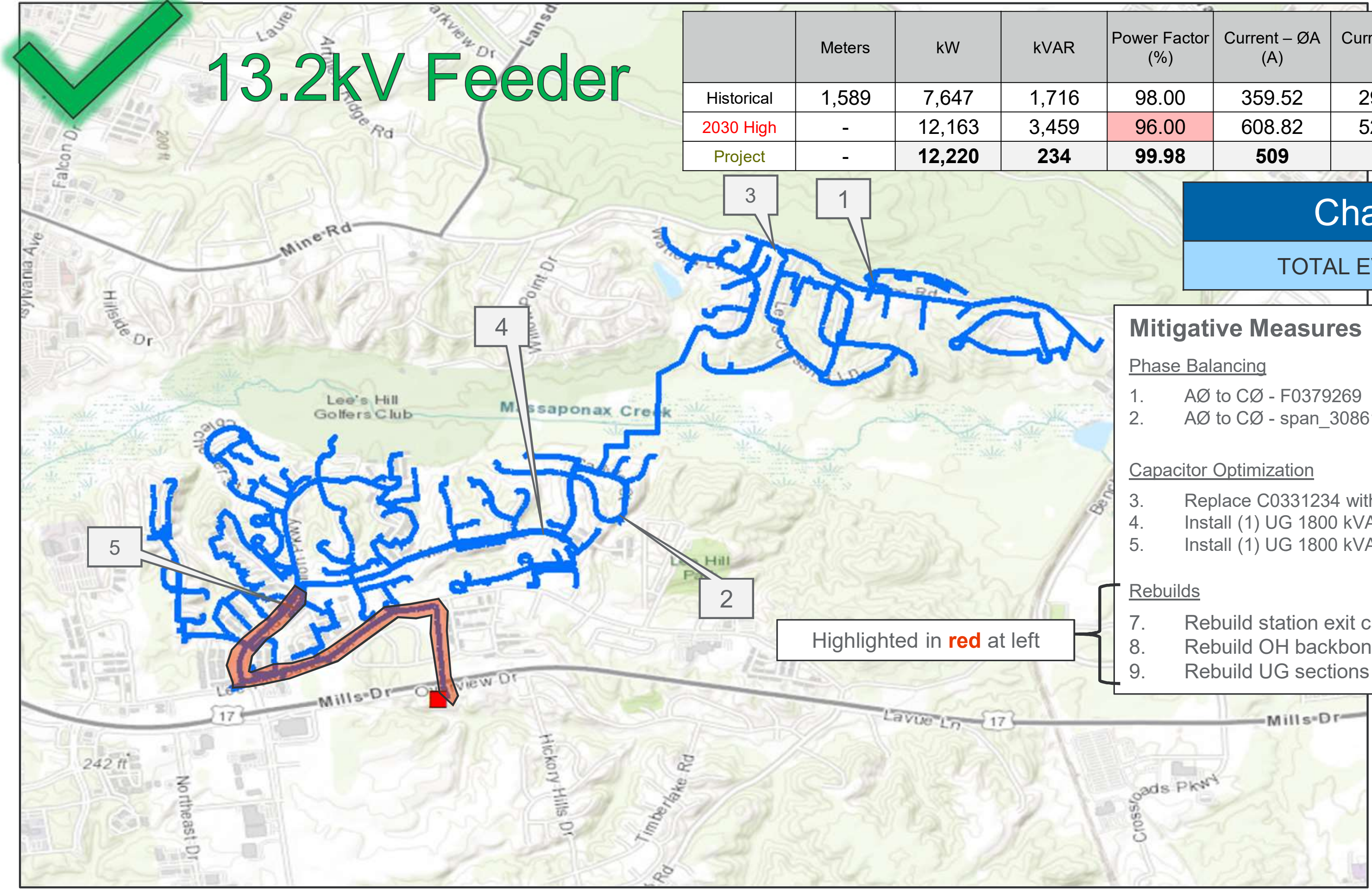
Slabtown Station – Lee's Hill

Forecast	2030
Low	10.91%
Med	21.63%
High	42.89%

PROJECT
PRELIMINARY!

13.2kV Feeder

	Meters	kW	kVAR	Power Factor (%)	Current – ØA (A)	Current – ØB (A)	Current – ØC (A)	Min. Element Voltage (V)	Max Element Voltage (V)	Max Element Loading (%)
Historical	1,589	7,647	1,716	98.00	359.52	293.56	339.23	119.49	124.52	154.00
2030 High	-	12,163	3,459	96.00	608.82	522.21	467.26	114.99	125.06	381.21
Project	-	**12,220**	**234**	**99.98**	**509**	**501**	**527**	**118.5**	**125.44**	**97%**



Highlighted in **red** at left

Charging Load - 2030 "High"

TOTAL EV CHARGER LOAD (kW)	4,493

Mitigative Measures

Phase Balancing

1. AØ to CØ - F0379269
2. AØ to CØ - span_308618

Capacitor Optimization

3. Replace C0331234 with 1800 kVAR bank
4. Install (1) UG 1800 kVAR capacitor bank
5. Install (1) UG 1800 kVAR capacitor bank

Rebuilds

7. Rebuild station exit cables to parallel 1000MCM
8. Rebuild OH backbone to UG transition to 795 ACSR
9. Rebuild UG sections in backbone to 1000MCM (**loaded at 95%**)

ROM Cost Estimate (using latest CWP unit costs)

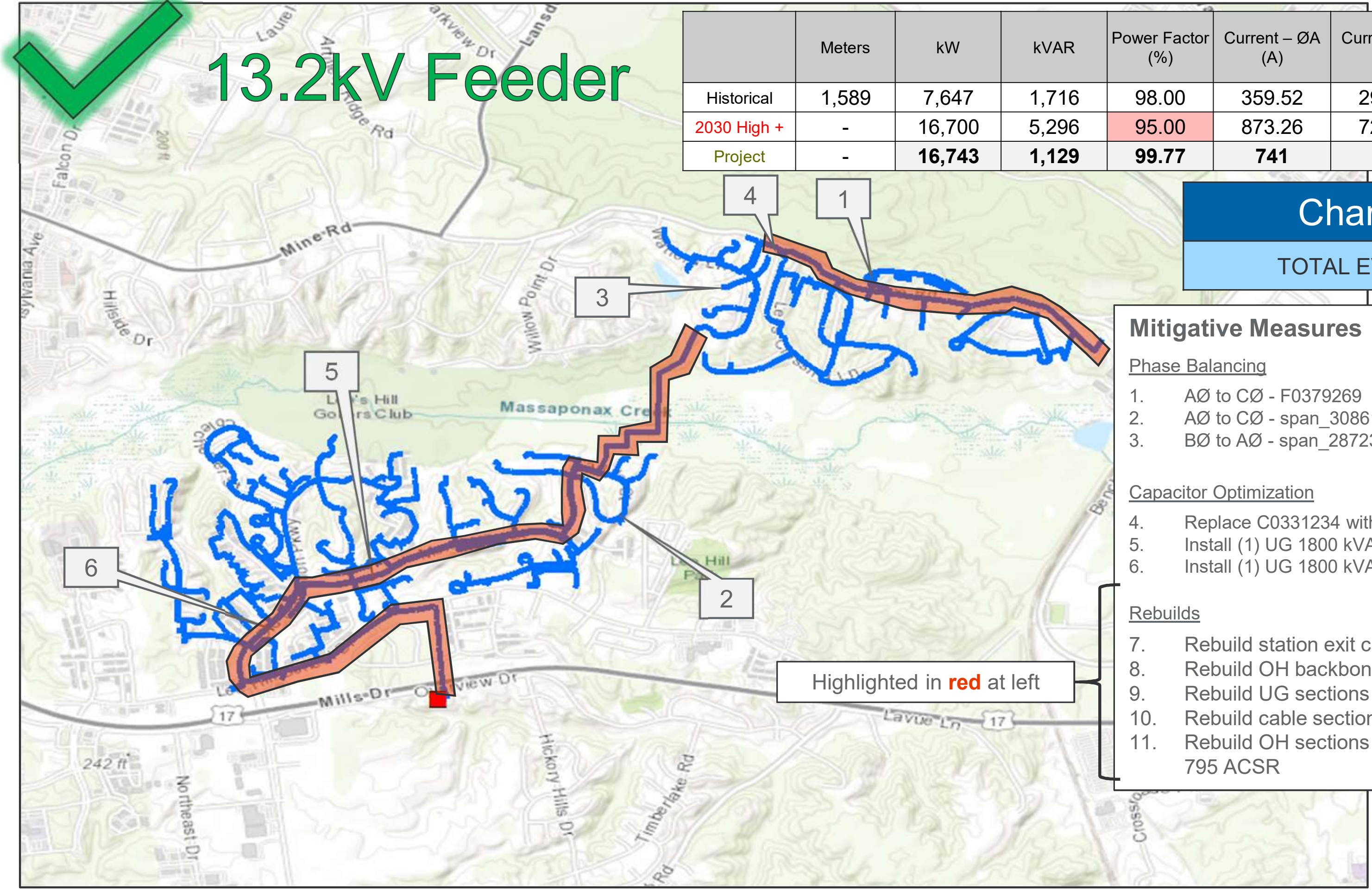
$709,084

MANAGED CHARGING SCENARIO

Slabtown Station – Lee's Hill

Forecast	2030
Low	10.91%
Med	21.63%
High +	42.89%

PROJECT
PRELIMINARY!



	Meters	kW	kVAR	Power Factor (%)	Current – ØA (A)	Current – ØB (A)	Current – ØC (A)	Min. Element Voltage (V)	Max Element Voltage (V)	Max Element Loading (%)
Historical	1,589	7,647	1,716	98.00	359.52	293.56	339.23	119.49	124.52	154.00
2030 High +	-	16,700	5,296	95.00	873.26	723.85	617.99	110.86	124.77	616.00
Project	-	**16,743**	**1,129**	**99.77**	**741**	**671**	**695**	**118.39**	**125.47**	**94.44**

Charging Load - 2030 "High +"

TOTAL EV CHARGER LOAD (kW)	8,986

Mitigative Measures

Phase Balancing

1. AØ to CØ - F0379269
2. AØ to CØ - span_308618
3. BØ to AØ - span_287231

Capacitor Optimization

4. Replace C0331234 with 1800 kVAR bank
5. Install (1) UG 1800 kVAR capacitor bank
6. Install (1) UG 1800 kVAR capacitor bank

Rebuilds

7. Rebuild station exit cables to parallel 1000MCM
8. Rebuild OH backbone to UG transition to 795 ACSR
9. Rebuild UG sections in backbone to parallel 1000MCM
10. Rebuild cable sections looking east from F0055759 to 750MCM
11. Rebuild OH sections from R0383475 to N.O. SW0218621-B from 336 ACSR to 795 ACSR

ROM Cost Estimate (using latest CWP unit costs)

$2,710,570

What will your member/consumer experience?

VS

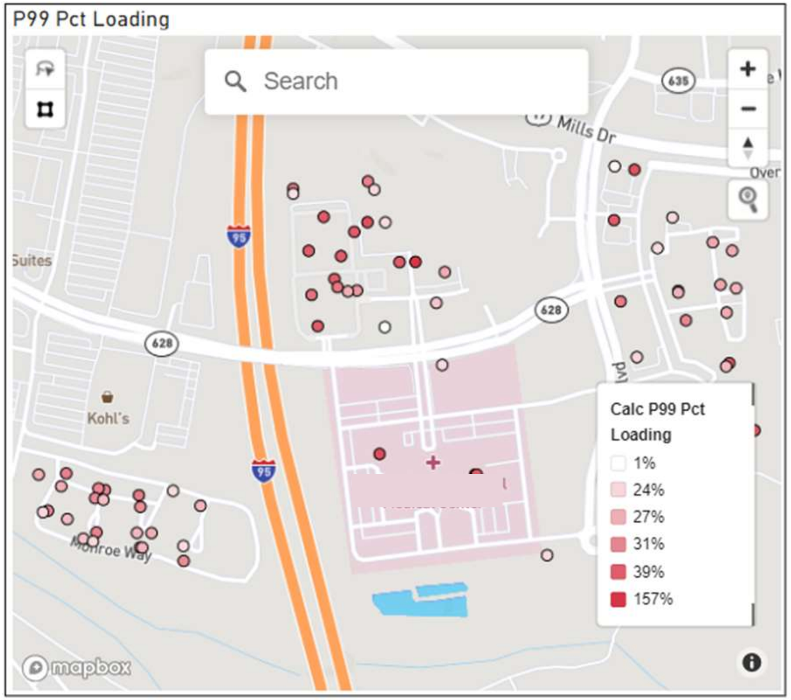
Distribution Transformer Loading Heat Map

Every REC distribution transformer is being modeled at peak load with the addition of a Level 2 Charger to determine its aptitude to meet future member **EV expectations**.

- ✓ Displays localized capacity
- ✓ Identifies risks for clustering
- ✓ Informs member services and engineering
- ✓ Allows REC to identify **EV-ready** accounts

Calculated Transformer Loading (Assumes 95% Power Factor*)

Circuit	Tx Bank ID	Rtd kVA	Rtd kW*	Max kW	Max % Load	P99 % Load	P95 % Load	P50 % Load
	0125797	15.00	14.25	22.53	158%	157%	143%	70%
	0071289	500.00	475.00	667.20	140%	86%	83%	67%
	0168342	15.00	14.25	11.16	78%	75%	55%	22%
	0352709	150.00	142.50	96.96	68%	65%	60%	24%
	0225595	2,500.00	2,375.00	1,324.32	56%	51%	48%	32%
	0006714	150.00	142.50	65.54	46%	44%	41%	5%
	0371029	167.00	158.65	89.22	56%	44%	38%	19%
	0343763	167.00	158.65	81.66	51%	42%	37%	18%
	0122790	167.00	158.65	77.70	49%	42%	36%	19%
	0147814	167.00	158.65	83.07	52%	42%	37%	18%
	0209946	167.00	158.65	73.60	46%	42%	36%	20%
	0077300	167.00	158.65	70.11	44%	42%	38%	1%
	0067387	2,500.00	2,375.00	1,048.32	44%	42%	38%	26%
	0312748	167.00	158.65	72.13	45%	39%	34%	16%
Total		**2,500.00**	**2,375.00**	**1,324.32**	**833%**	**422%**	**37%**	**9%**



Legend
Maximum
Selected
Minimum

Each circle represents one distribution transformer, with the color indicating the transformer's P99 Pct Loading value. The transformer with highest P99 Pct Load is red; the transformer with lowest P99 Pct Load is white; those between are shades of red/white, with more red indicating higher loading. Selecting circles turns them yellow.

Single-Page Selector

Multi-Page Selector

Advanced Grid Planning Summary

- Increasing storms and higher expectations for reliability require a hardened grid
- The age of co-op infrastructure is reaching a point of new challenges
- Awareness of future EV energy demands is essential to incorporate in future infrastructure decisions
- Individual transformer loading will enable or restrict immediate-term EV member satisfaction
- Business planning for energy services may reveal multiple value streams
- A new level of planning and analysis has arrived