

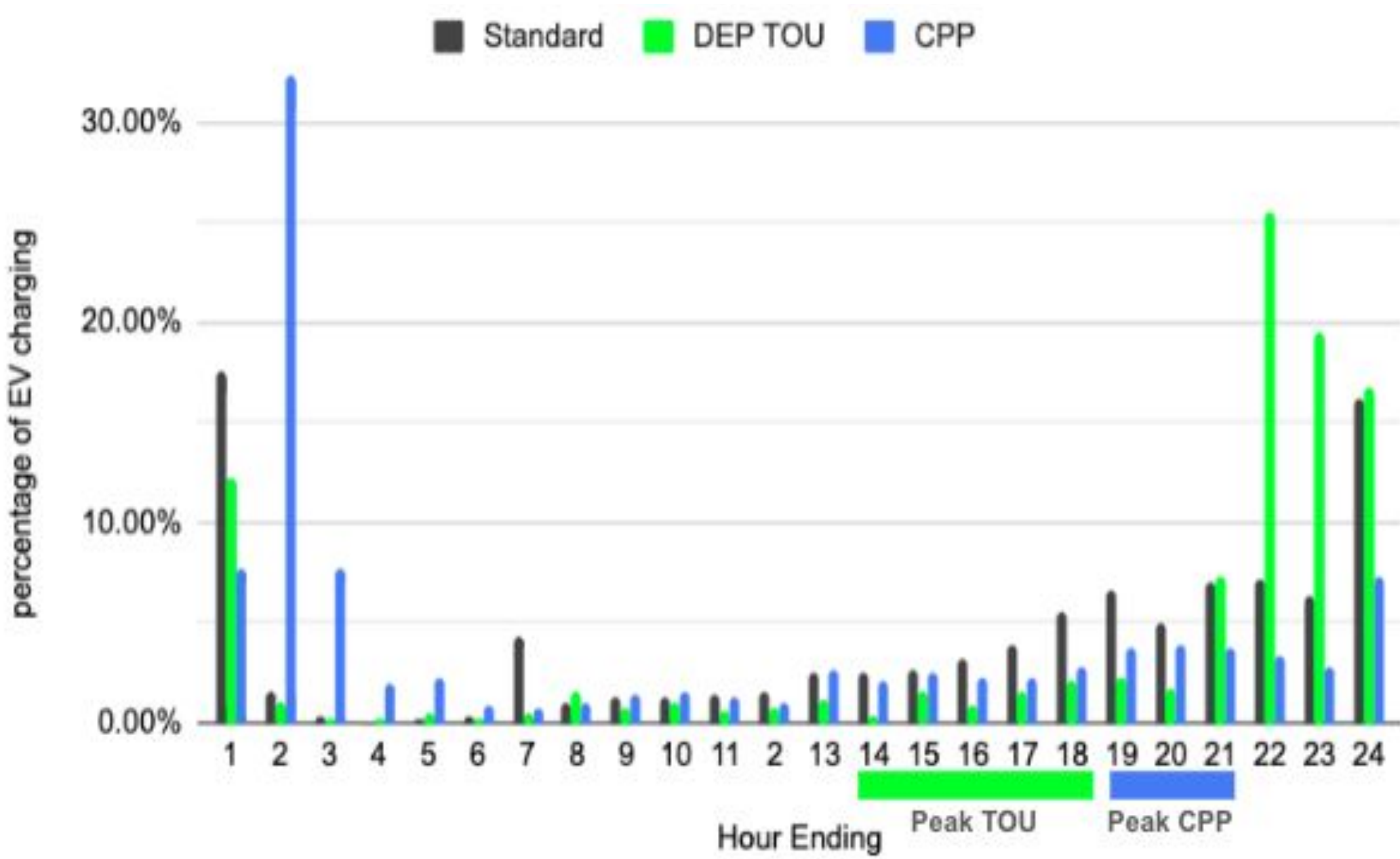
Impacts of Managed Charging and Other Innovative Rates for Electric Vehicle Charging on EV Customer Load and Utility System Grid

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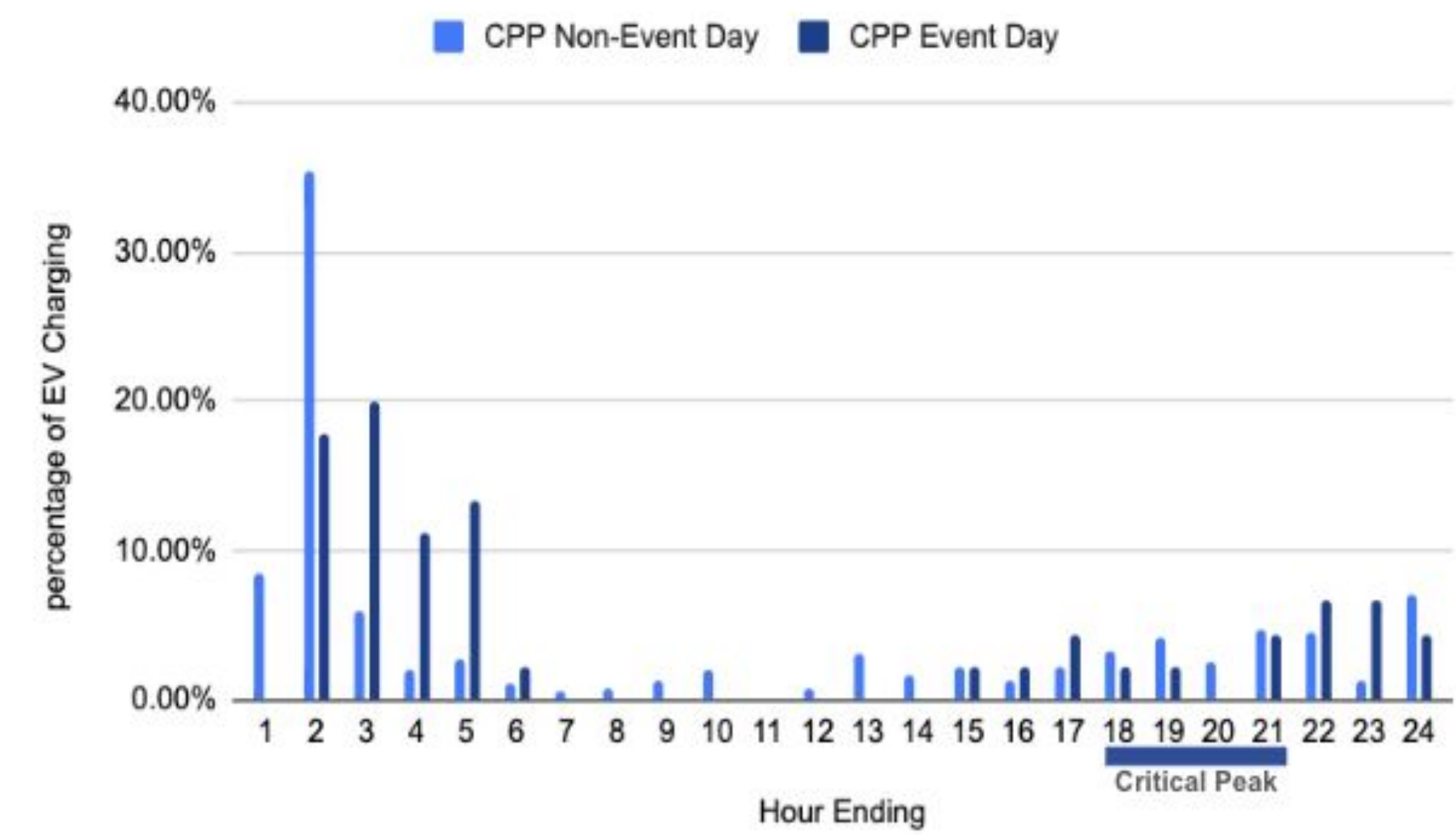


Innovative Rate Study

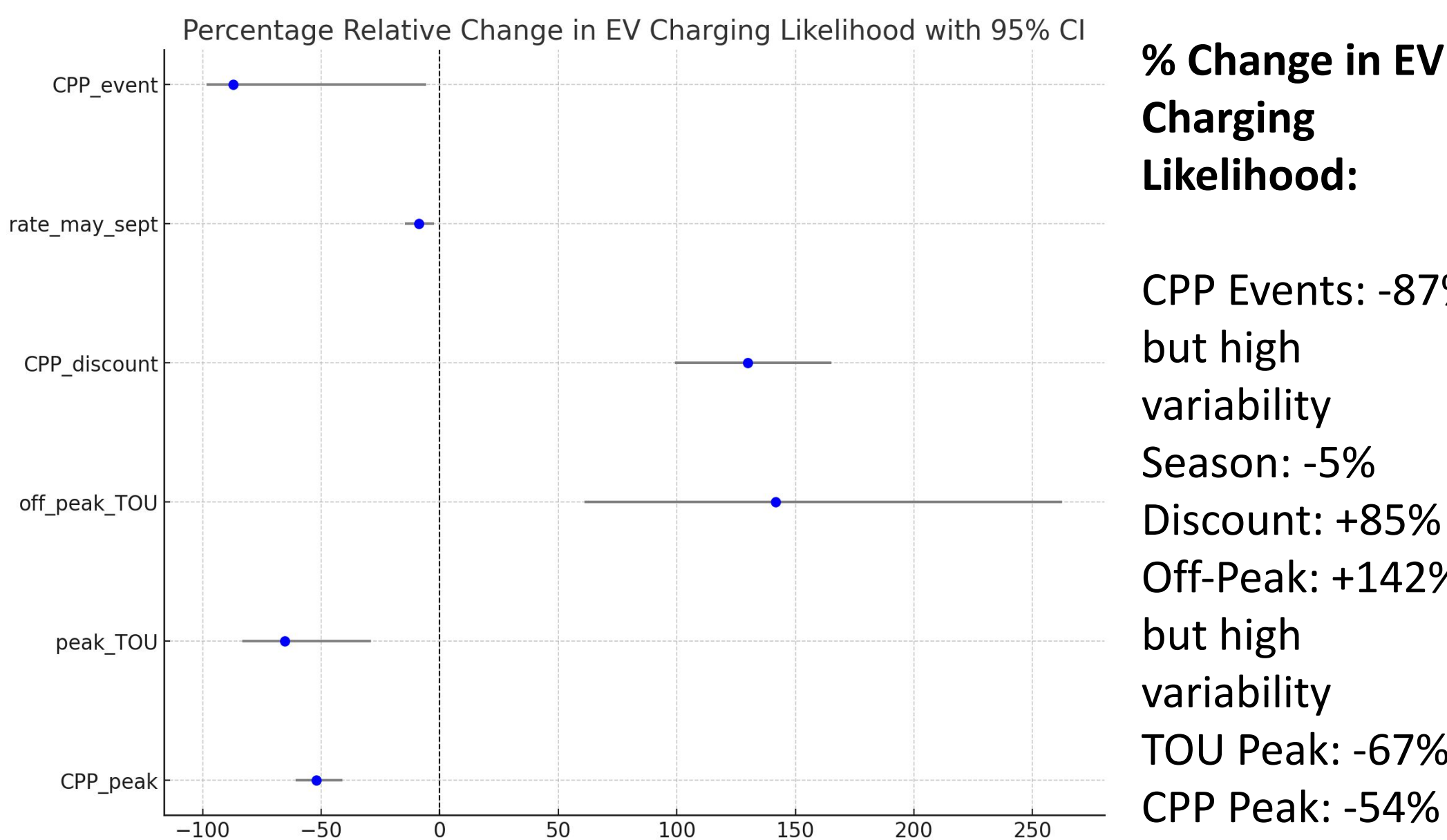
EV Charging Distribution for May-September 2021 to 2023



Charging Distribution for CPP on CPP Non-Event and Event Days May to September 2023



Innovative Rate Study



Impacts of EV Charging: Overview of Model

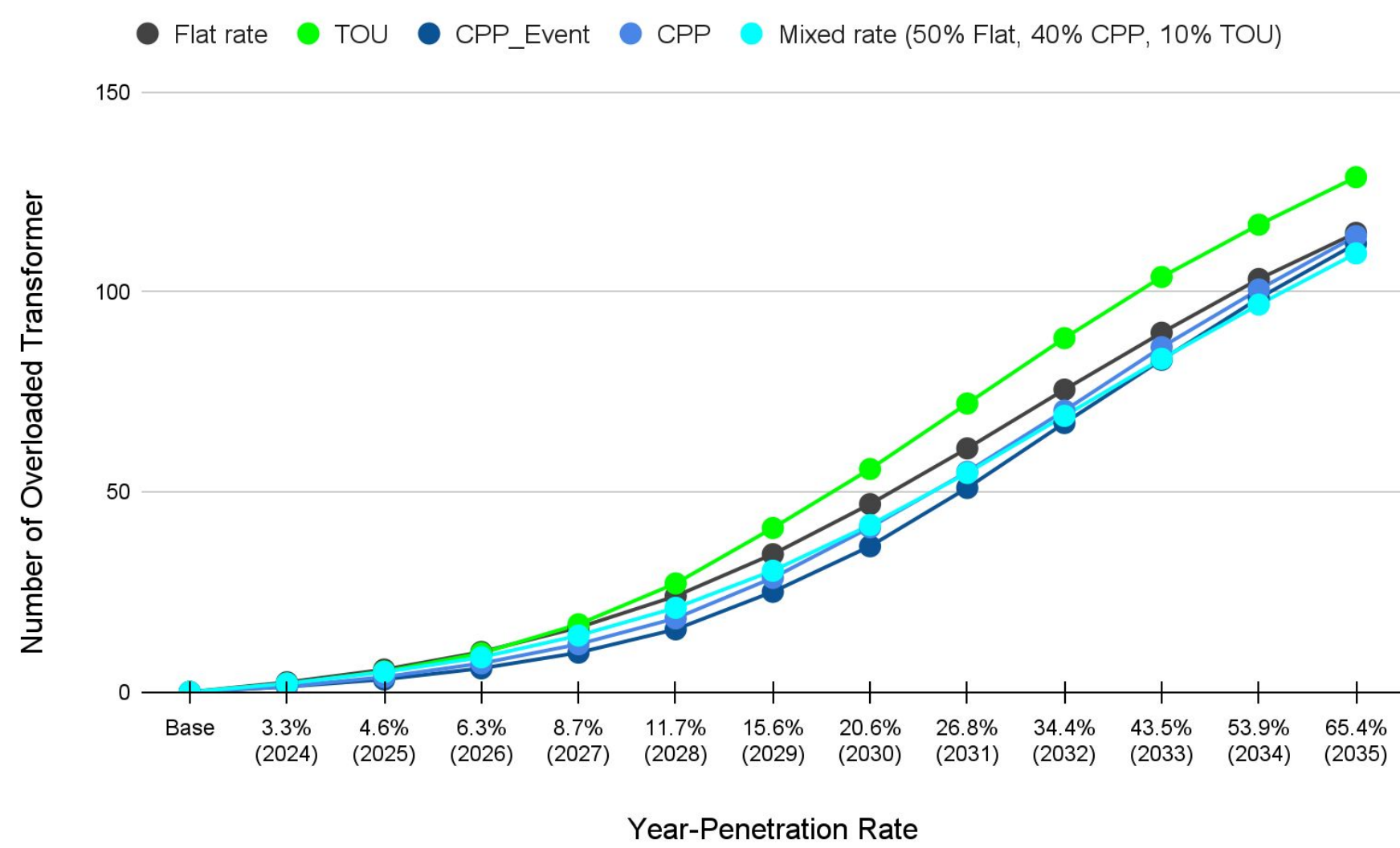
Circuit Model: DEP Urban Circuit

- Wake County EV Penetration Forecast Considered (Max: 65% in 2035)
- Total number of EVs Added to 2035 Simulation: 2,270
- Total Number of Single-Phase Residential Customers: 1,799
- Base Circuit Peak is 8586 kW (With no EV)

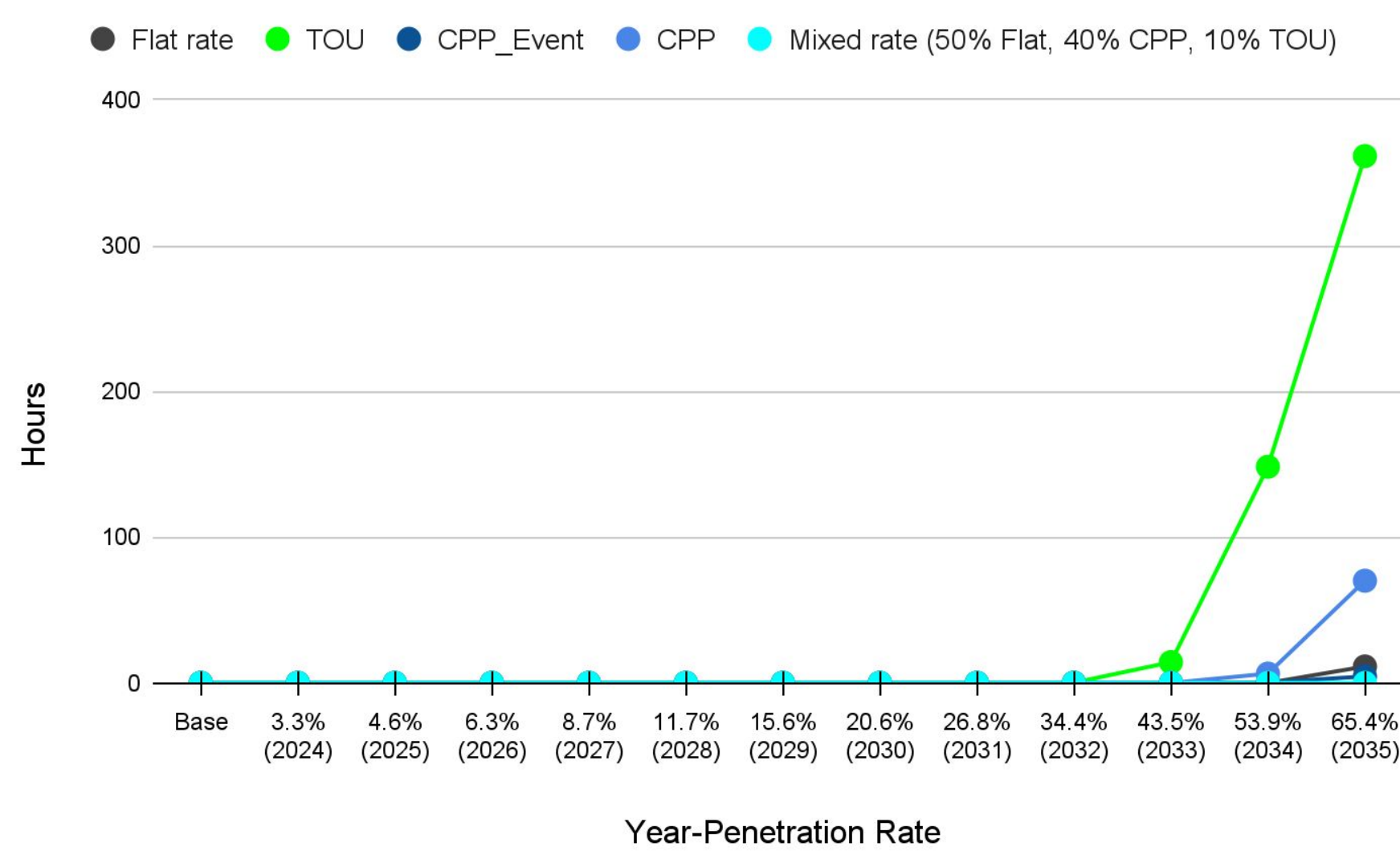
DEP Planning Thresholds

Transformer Loading Threshold	130% (Summer)
Bus Voltage Range	122-126V (DEP)
Conductor Loading Threshold	50% (Summer)

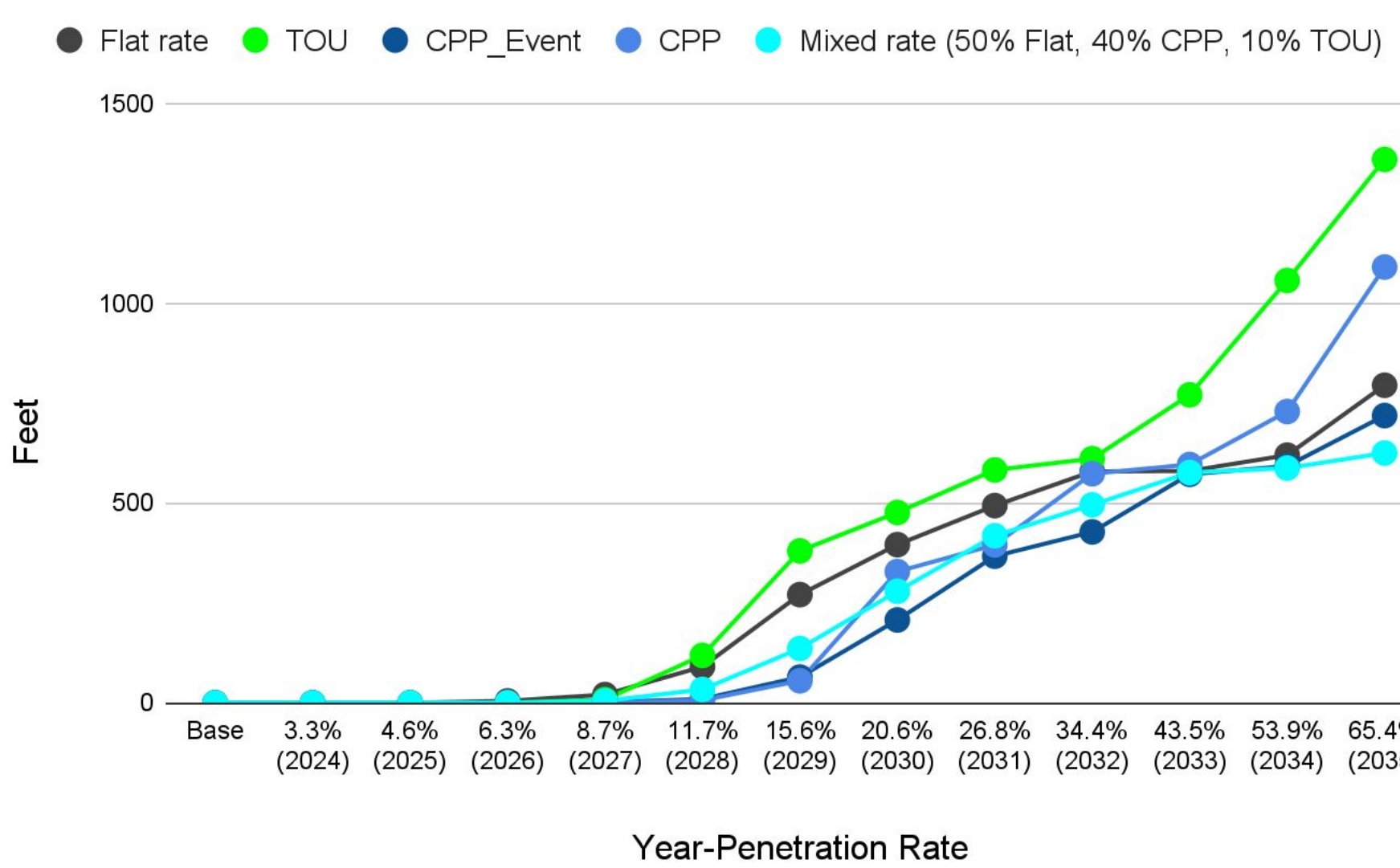
Results: Number of Overloaded Customer Transformers



Results: Voltage Violation Hours



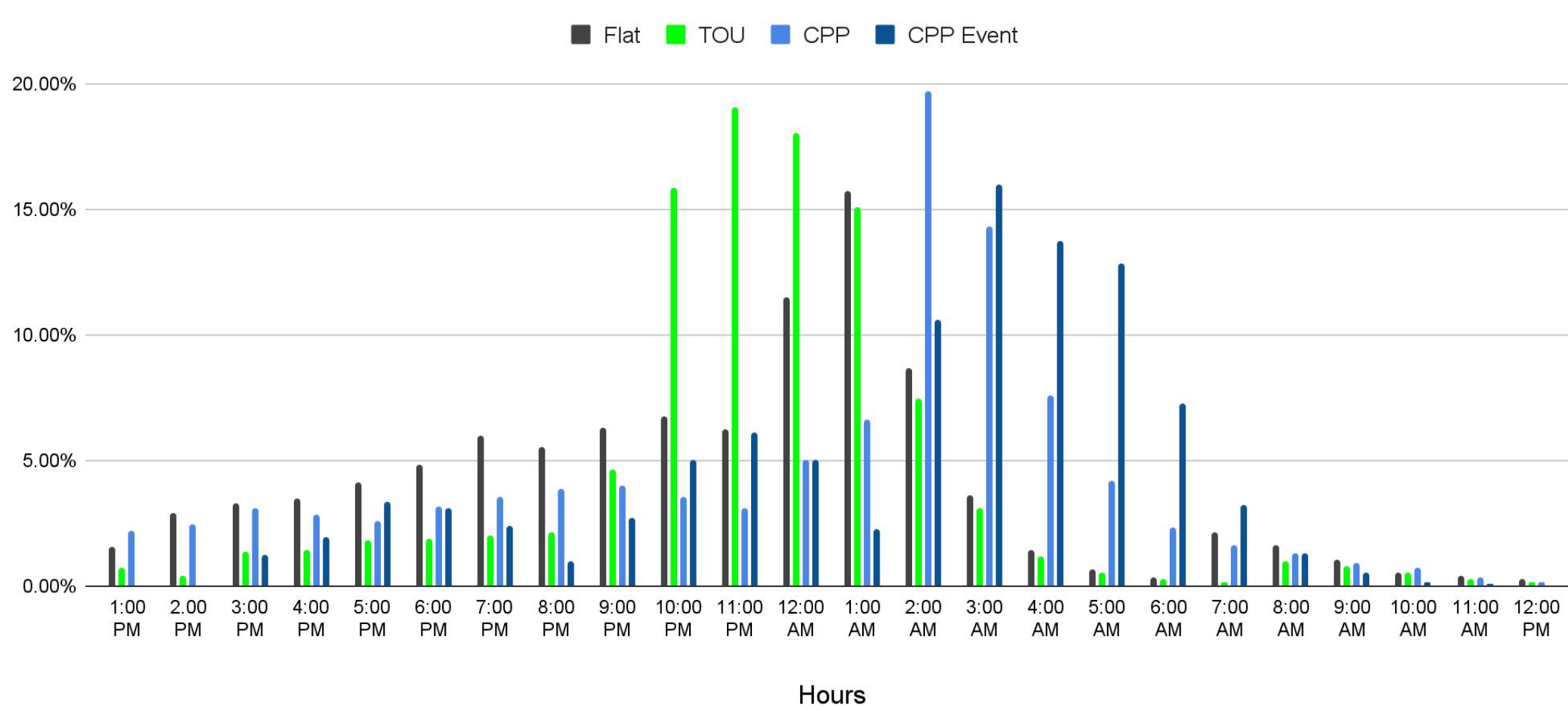
Results: Conductor Overloading by Feet



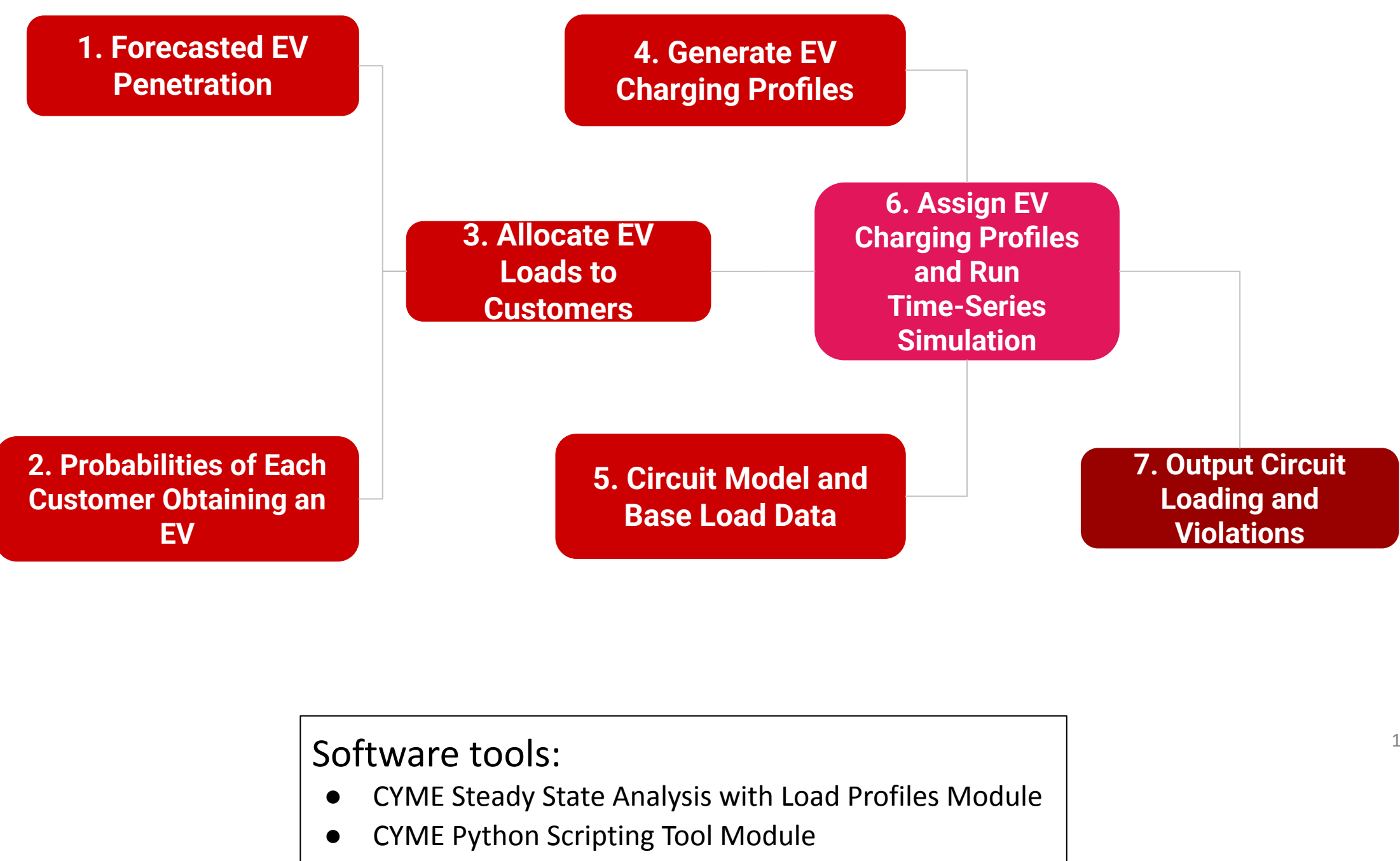
Key Findings for Economic Analysis

- TOU vs. CPP Daily Impacts:**
 - The larger reductions in peak charging observed for TOU compared to CPP.
- CPP Event Responsiveness:**
 - CPP customers are more responsive to critical peak events than to daily peak pricing.
- Behavioral Adjustments Across Time Periods:**
 - During critical peak events, the likelihood of charging drops sharply by 87%.
 - During low-priced periods, energy usage sees significant increases as customers respond to reduced rates, with an 83% rise during CPP discount periods and a 142% surge during TOU off-peak hours.
- Timer Peaks:**
 - Customers show a strong preference for beginning EV charging immediately at the start of discount or off-peak periods.

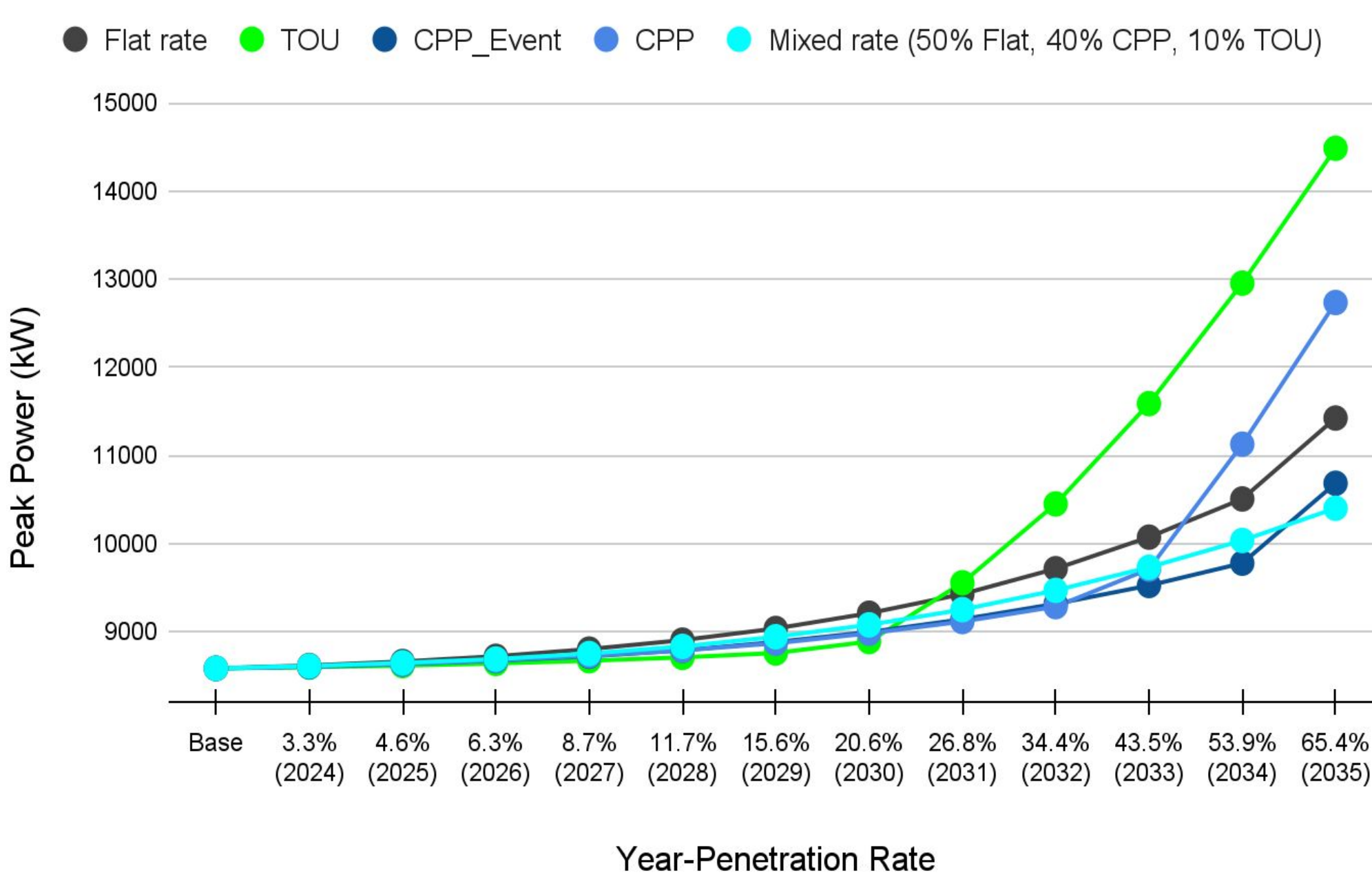
Distribution of Generated EV Charging Profiles (10,000 For Each Rate)



Impacts of EV Charging: Methodology Overview



Results: Circuit Peak Loading



- Base peak is 8586 kW

Key Findings for System Impact Analysis

- For all rate scenarios, customer transformer overloading is the most significant impact and occurs even at low penetration rates. Other impacts are not significant until the penetration rate exceeds roughly 20% (2030).
- The TOU rate by itself shows the most violations in all cases, even more than the flat rate.
- The CPP rate (includes CPP Event) by itself shows the least violations until the penetration rate exceeds roughly 20% (2030).
- The Mixed Rate (50% Flat Rate, 40% CPP, and 10% TOU) generally shows the least violations for penetration rates exceeding 20% (after 2030).

TimeHurdle Model Methodology

- Logit Model**, to estimate the probability of an EV charging event:

$$\ln\left(\frac{Pr(EVCharging_{it}=1)}{1-Pr(EVCharging_{it}=1)}\right) = \beta_0 + \beta_1 CPP_{it} + \beta_2 TOU_{it} + \beta_3 Peak_{it} + \beta_4 (CPP_{it} * Peak_{it}) + \beta_5 (TOU_{it} * Peak_{it}) + \beta_6 Discount_{it} + \beta_7 OffPeakTOU_{it} + \beta_8 season_{it} + \epsilon_{it}$$

Identifies charging through kWh usage jumps and incorporates pricing structures as predictors.

- Generalized Linear Model**, conditional on a charging event being detected (EV_charging = 1).

$$\ln(EV_{kwh}) = \beta_0 + \beta_1 CPP_{it} + \beta_2 TOU_{it} + \beta_3 Peak_{it} + \beta_4 (CPP_{it} * Peak_{it}) + \beta_5 (TOU_{it} * Peak_{it}) + \beta_6 Discount_{it} + \beta_7 OffPeakTOU_{it} + \beta_8 season_{it} + \epsilon_{it}$$

Estimates energy consumption, accounting for positively skew, increasing variance, and enabling % based coefficient interpretation, with robust standard errors to address heteroskedasticity.

$$AME = \frac{1}{N} \sum_{i=1}^N \exp(X_i \beta) * \beta_j$$

- Average Marginal Effects (AMEs)** for both of our GLM estimates, provides a meaningful average effect.