U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

# Overview of Electric Vehicles Grid Integration & Cybersecurity R&D

## NAESCO Technology and Financing Conference 2019

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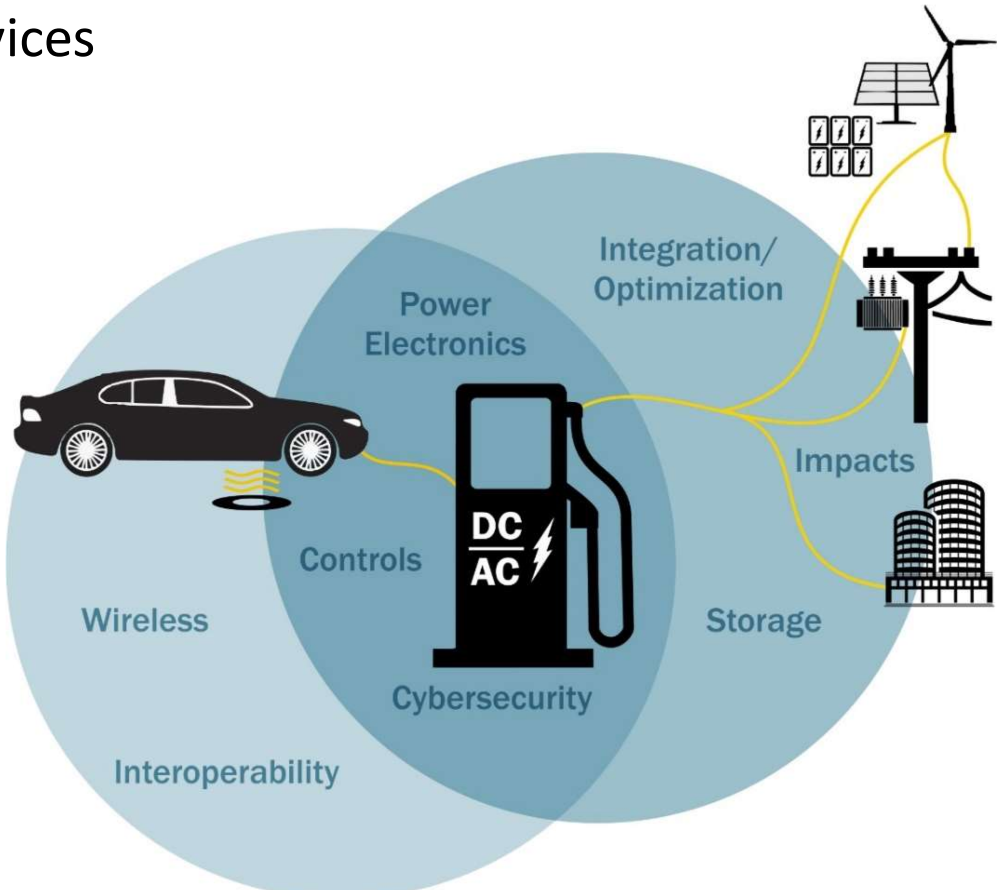
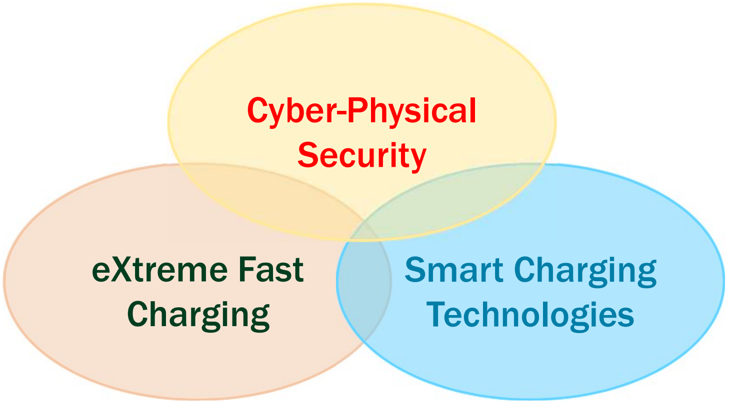
# DOE VTO Grid & Infrastructure Program Goal

The G&I Program will identify systems pathways and conduct research to facilitate the development and harmonization of a robust, interoperable, and cyber secure, electric vehicle charging and grid infrastructure which incorporates advanced charging technologies, distributed energy resources, grid, and grid services



# VTO – Electrification Activities

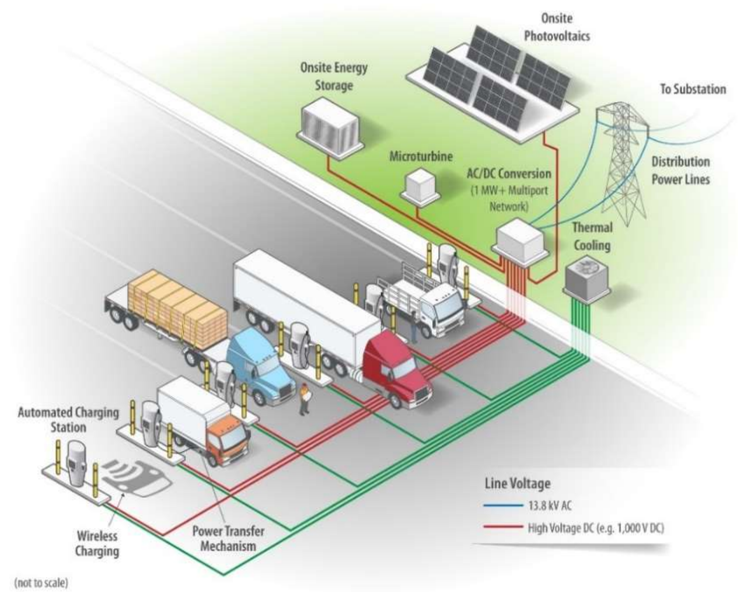
VTO's Electrification activities address challenges in cyber-physical security, eXtreme fast charging, and smart charging to support EVs at Scale




- Cyber-physical security of EVs and charging protects our critical infrastructure
- R&D supports advanced EV charging security at the Grid edge

- XFC infrastructure enables EVs to charge similar to today's vehicles refueling
- R&D supports advanced energy conversion from the Grid

- Smart charging of EVs enables efficient use of locally produced energy
- R&D supports advanced strategies for reducing cost of electricity delivery

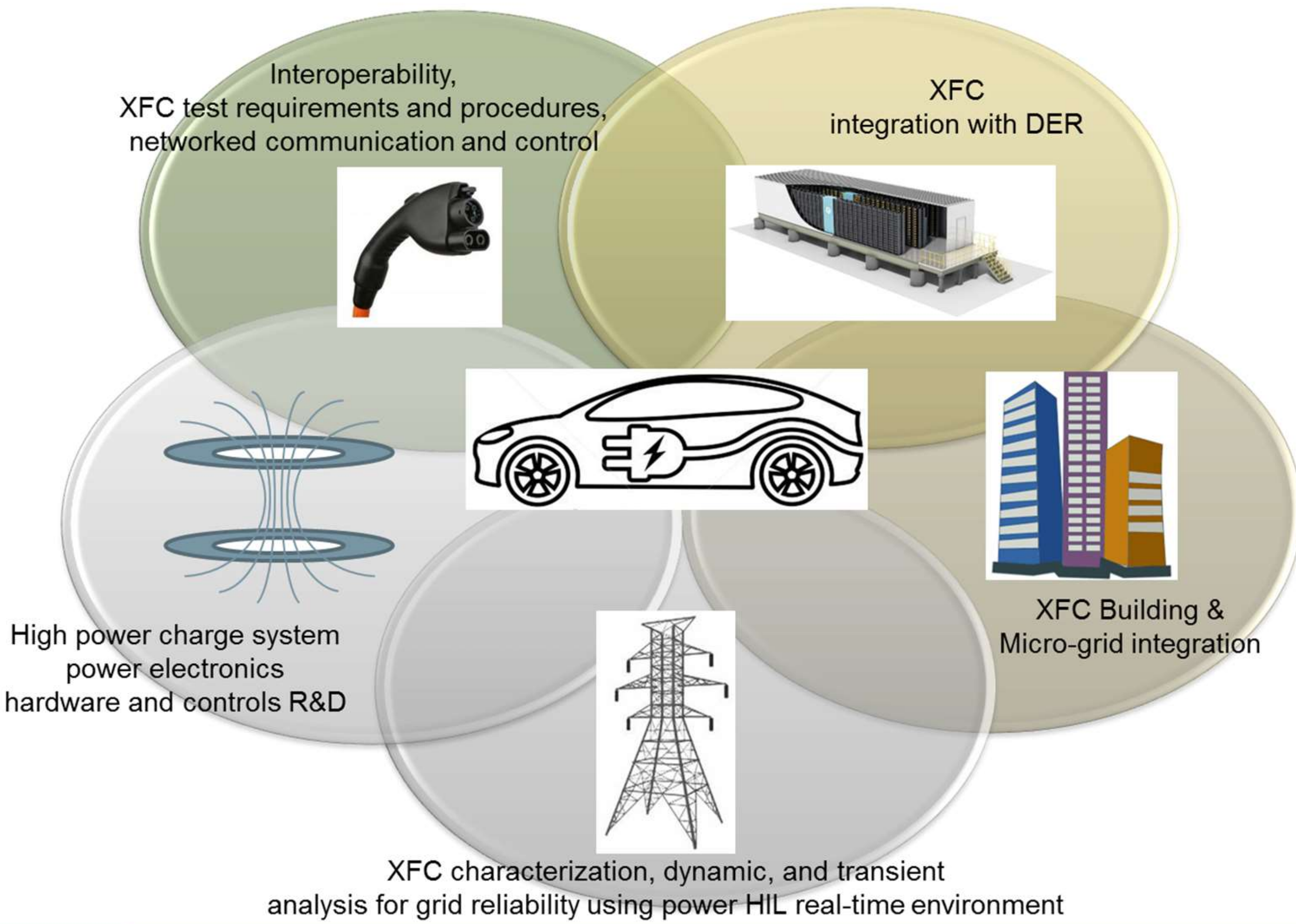


# Charging Infrastructure Basics

| Charging Level | Vehicle Range Added per Charging Time and Power | Supply Power | EVSE Unit Cost Range (single port) |
|---|---|---|---|
| AC Level 1 | 4 mi/hour @ 1.4kW<br>6 mi/hour @ 1.9kW | 120VAC/20A | $300-$1,500 |
| AC Level 2 | 10 mi/hour @ 3.4kW<br>20 mi/hour @ 6.6kW<br>60 mi/hour @ 19.2 kW | 208/240VAC/20-100A | $400-$6,000 |
| DC Fast Charging | 24 mi/20min. @24kW<br>50 mi/20min. @50kW | 208/480VAC 3-phase | $8,000-$35,000 |
| Extreme Fast Charging | 466 mi/20min. @400 kW | 480VAC 3-phase | TBD |

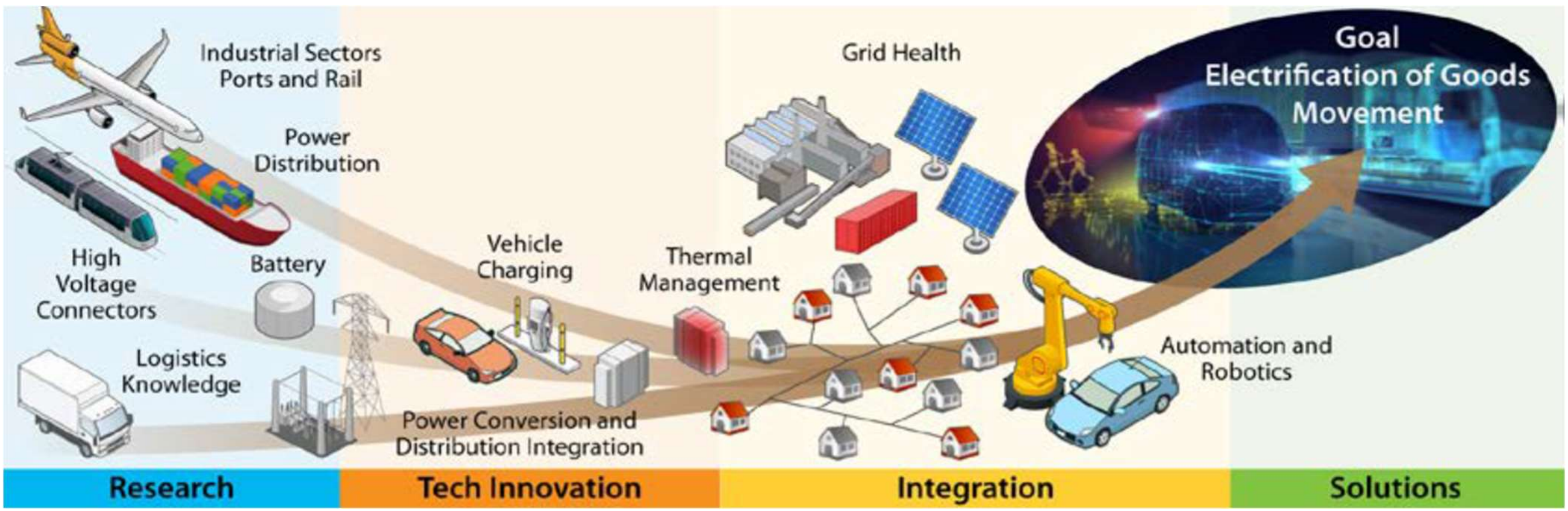
# eXtreme Fast Charging (XFC)

- R&D portfolio for XFC infrastructure – interoperability, grid impacts, DER integration, cyber, controls, & integration



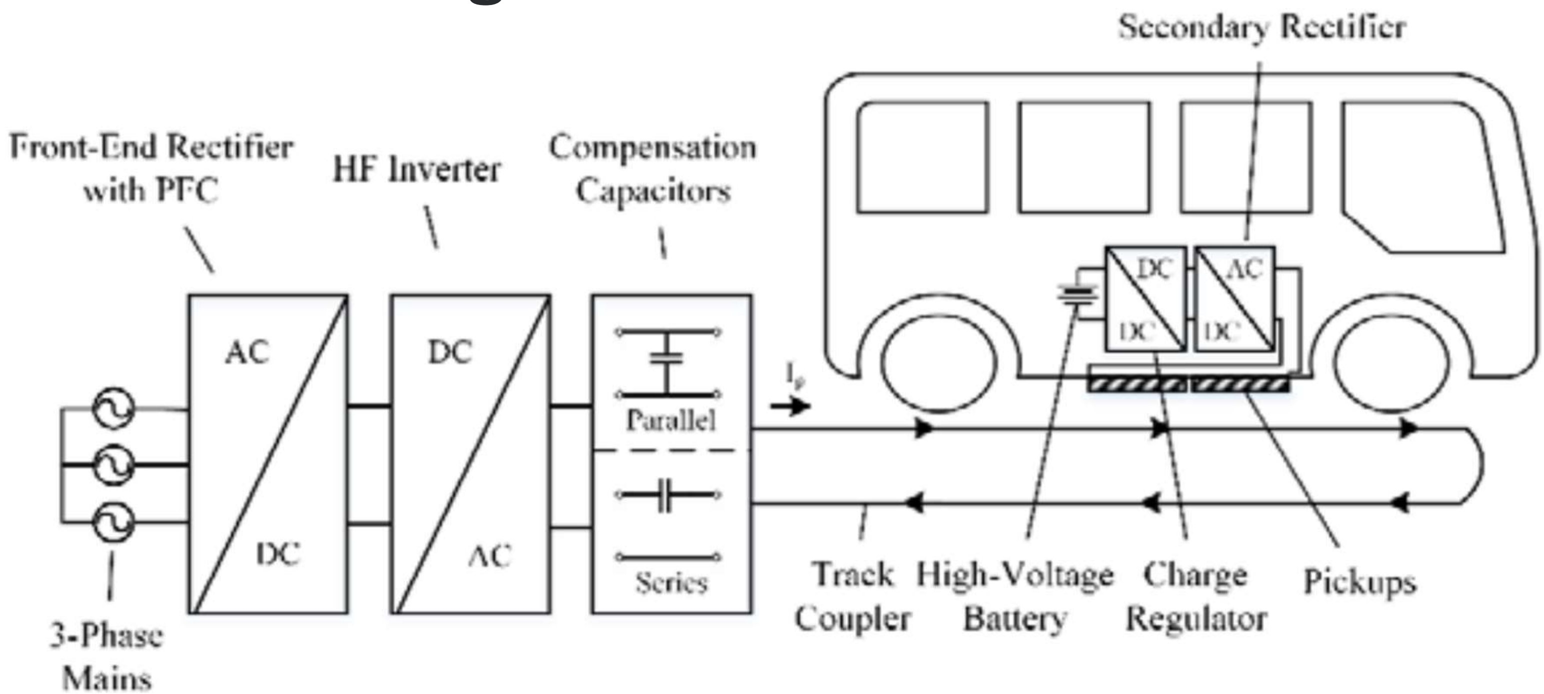
# eXtreme Fast Charging (XFC) and Beyond

- To address challenges associated with MW-scale charging infrastructure for MD/HD EVs
  - Create hardware and system models as well as power and charge control methods and hardware
  - Develop solutions to enable 1+ MW charging systems for MD/HD EVs to maximize utilization



# eXtreme Fast Charging (XFC) - Dynamic

- Goal: design, model, simulate, analyze, build, and validate a high power (~200 kW) static and dynamic wireless power transfer system
- Evaluate the effect of high power and dynamic charging on the electric grid

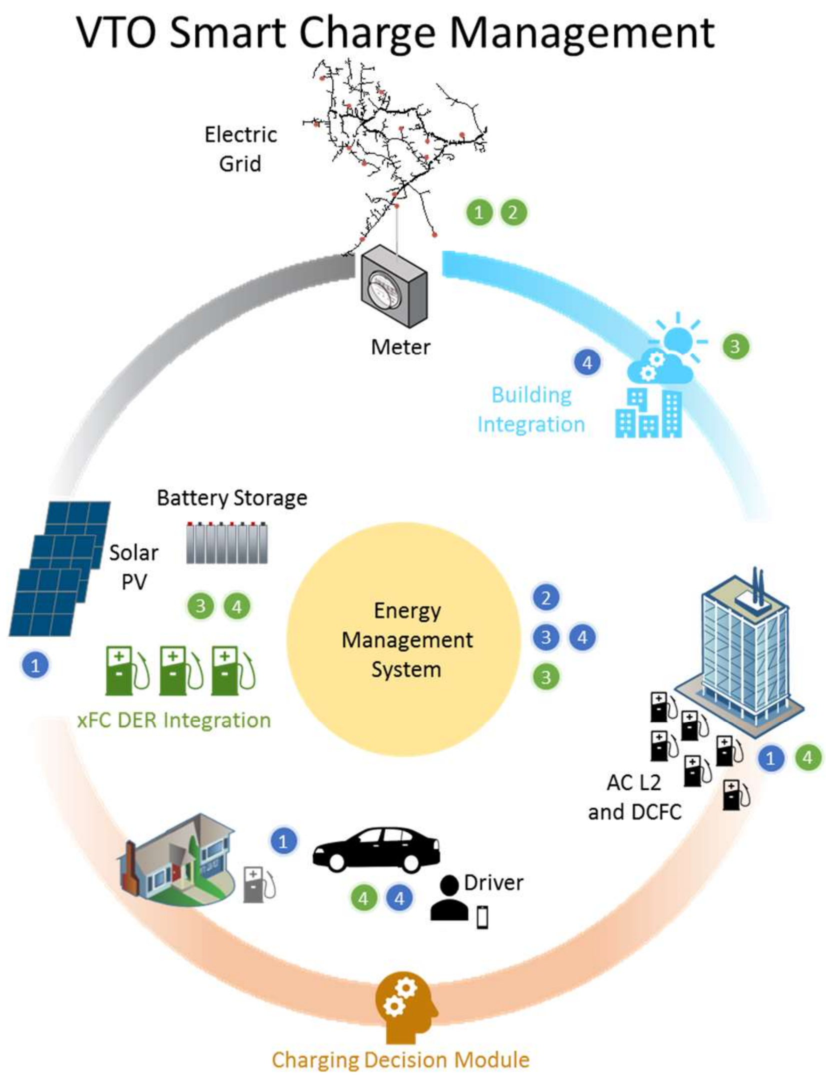


# VTO Smart Charge Management

**Smart Vehicle-Grid Integration**

1. Vehicle role for home and workplace energy management
2. Controls for grid integration (GMLC use cases)
3. Optimal control on customer side for grid resilience and stability
4. Enabling technologies and tools development

TIMESTEP
Sub-second to hours




**Smart Electric Vehicle Charging for a Reliable and Resilient Grid (RECHARGE)**

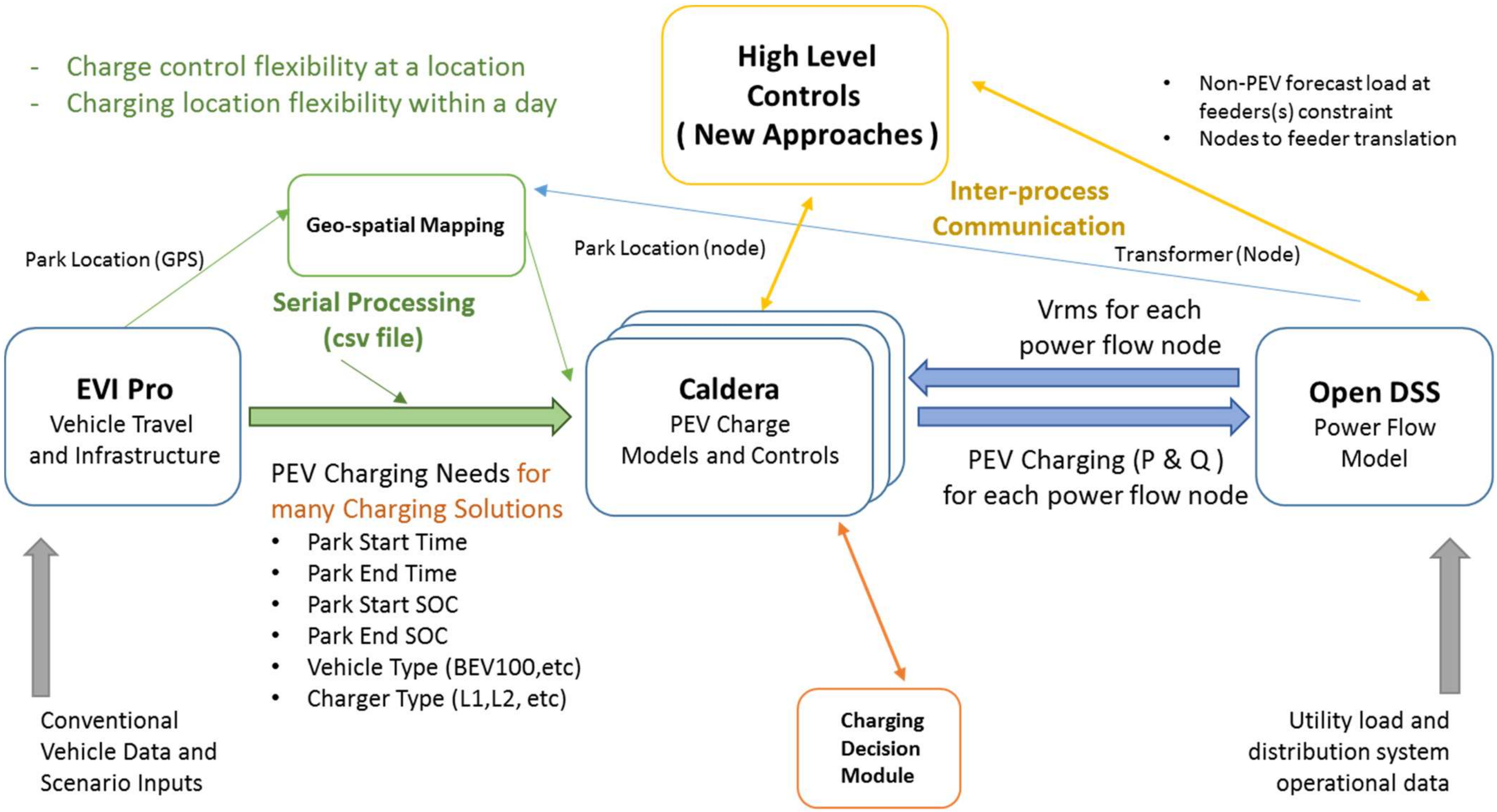
1. Simulation and controls development to minimize distribution impacts
2. Regional modeling for distribution operations & capacity planning
3. Forecasting-enhanced charging integration with buildings and DER
4. Predictive and interactive charge decision making

TIMESTEP
Minutes to weeks

# RECHARGe: smaRt Electric vehicle CHArging for a reliable and Resilient Grid

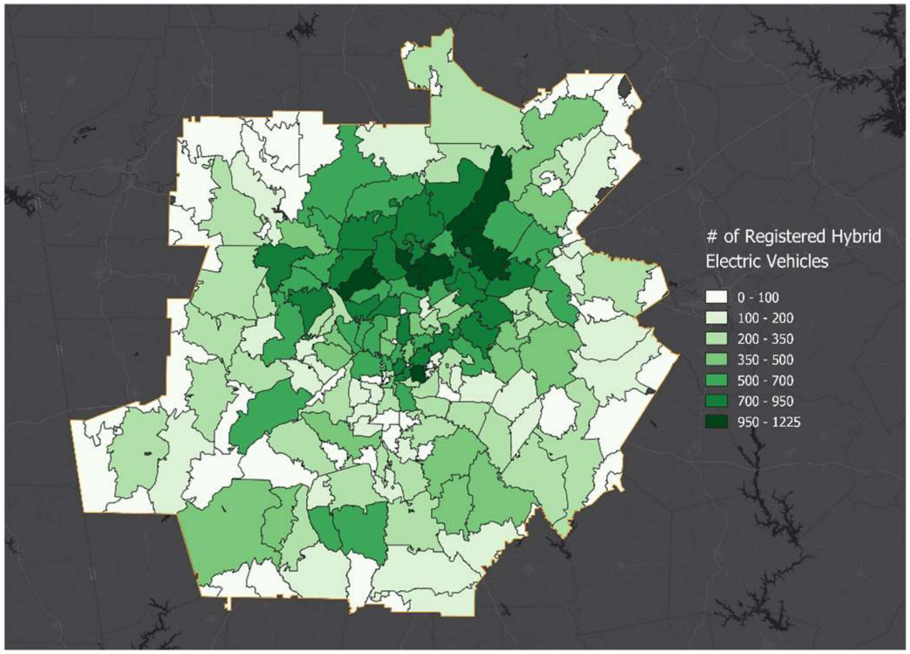
- How to manage PEV charging at scale to avoid negative grid impacts and satisfy charging needs
- Quantify the effects of uncontrolled charging of at scale PEV adoption
- Analyze the effectiveness of multiple control strategies in mitigating negative grid impacts
- Rank the benefits & costs of the control strategies in avoiding grid upgrades, providing grid services, & improving resiliency
- Overcome technical barriers to implementing high-value control strategies

# RECHARGe: smaRt Electric vehicle CHArging for a reliable and Resilient Grid

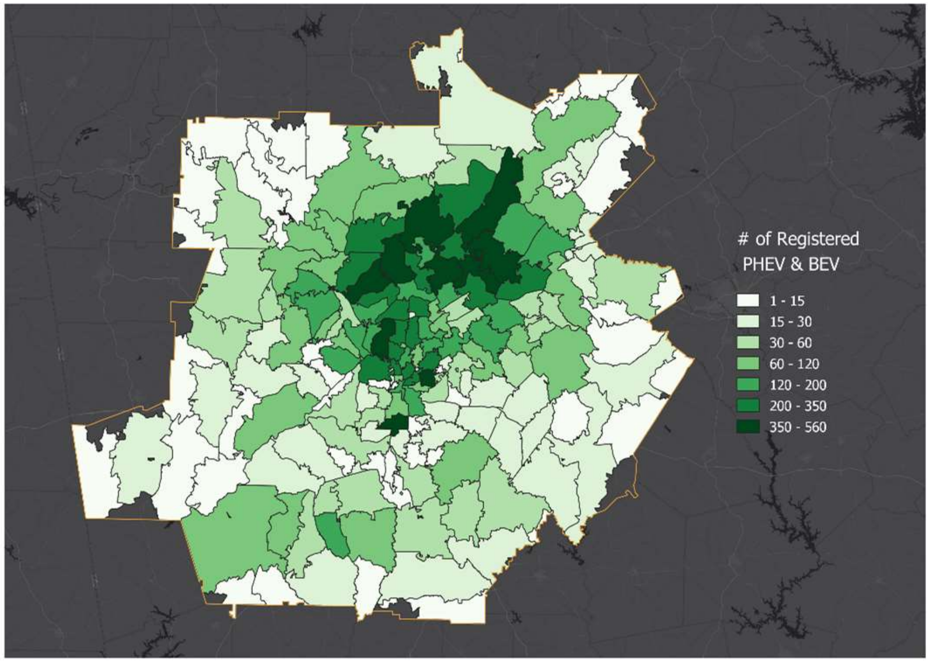


# RECHARGE – PEV and HEV Registration Atlanta Case

2017 HEVs

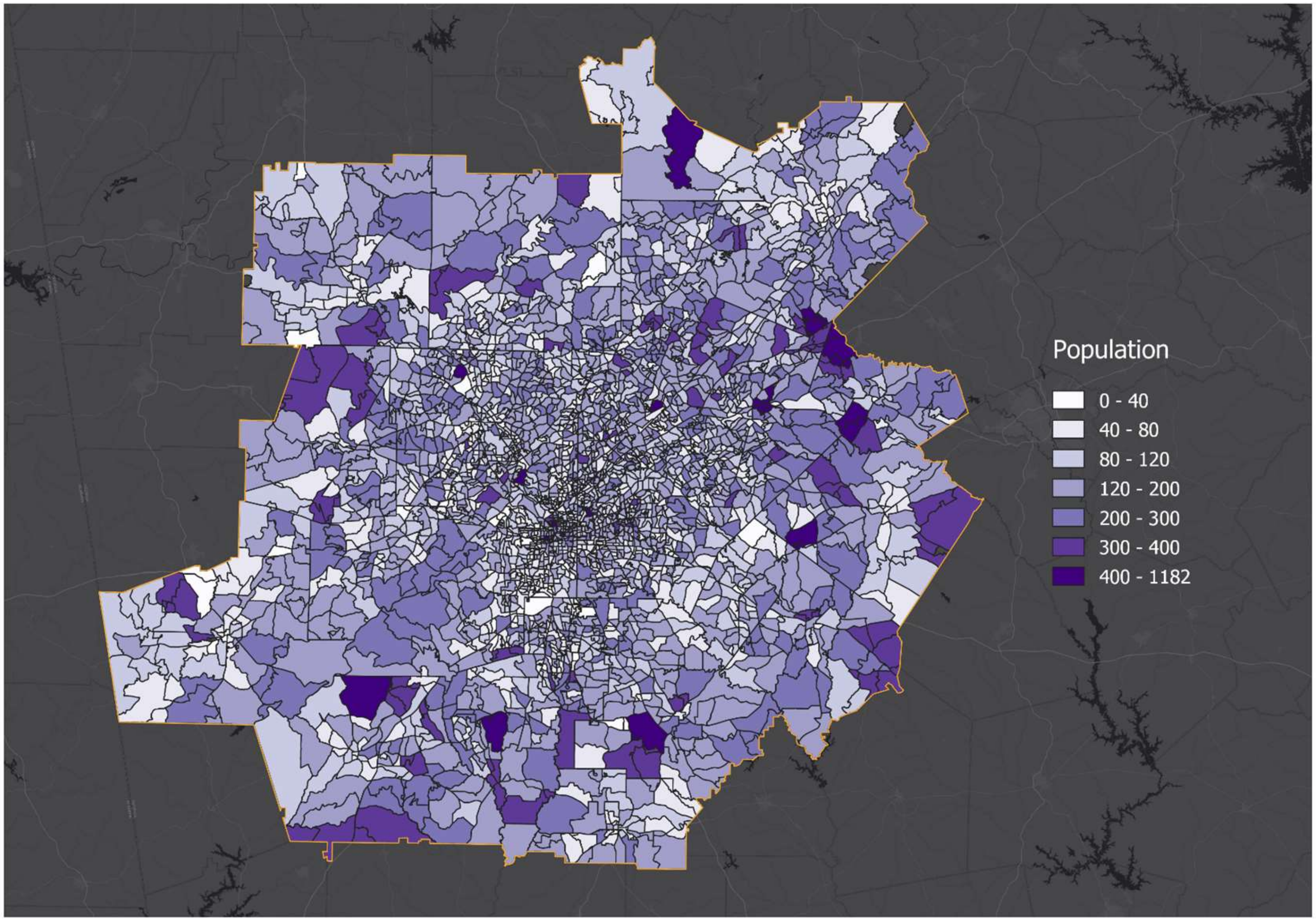



2017 PEVs

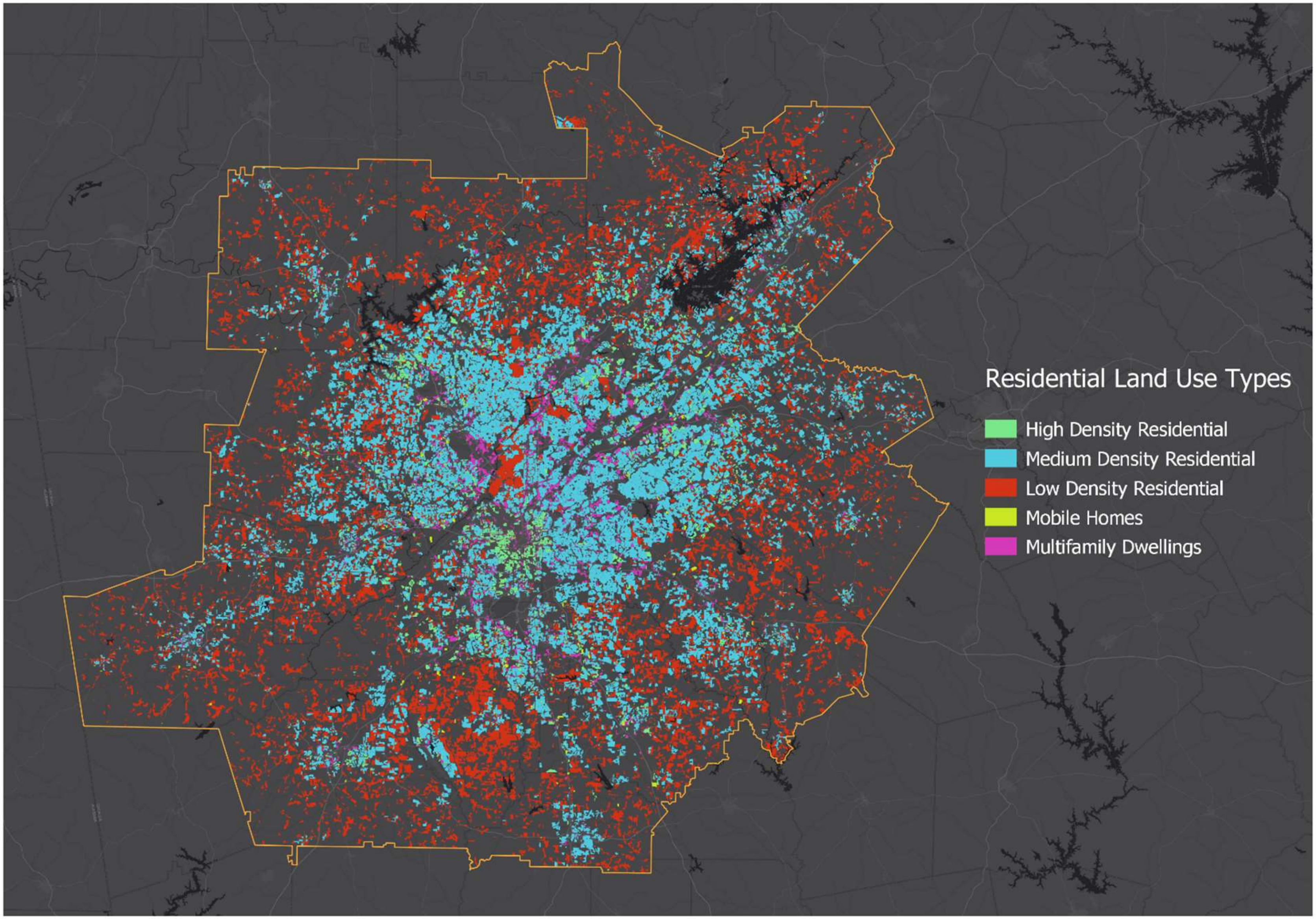



- HEV and PEV comparison:
  - HEV market ~10yrs more mature, an order of magnitude larger, and less spatially concentrated

# RECHARGE – Census Information Atlanta by Zip Code

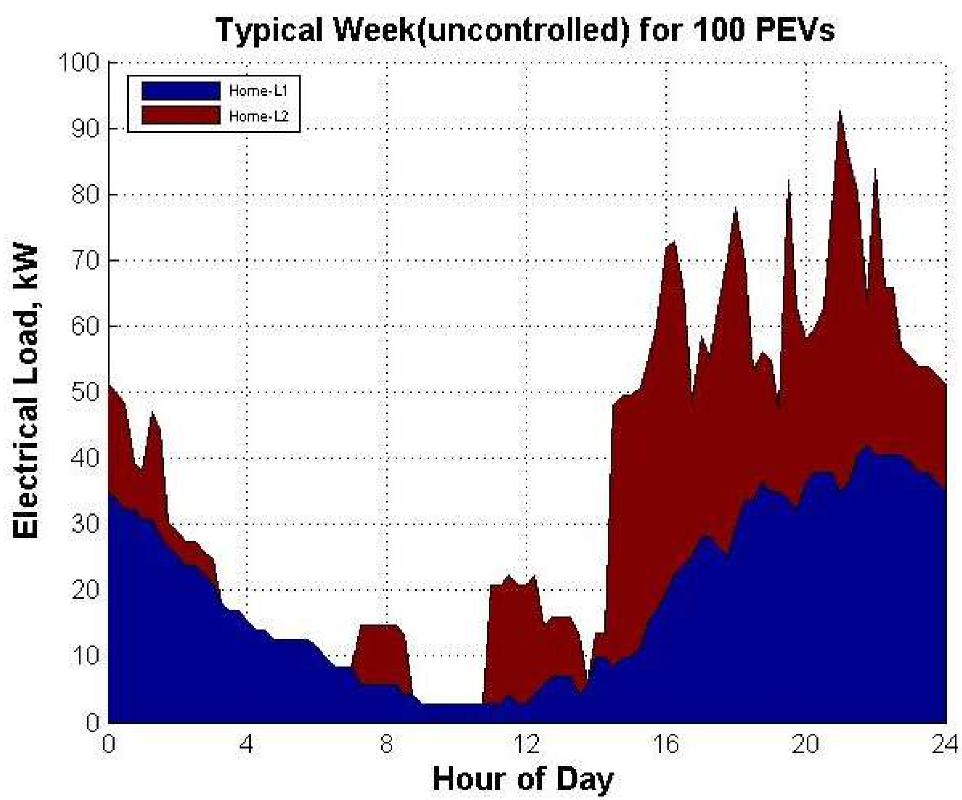


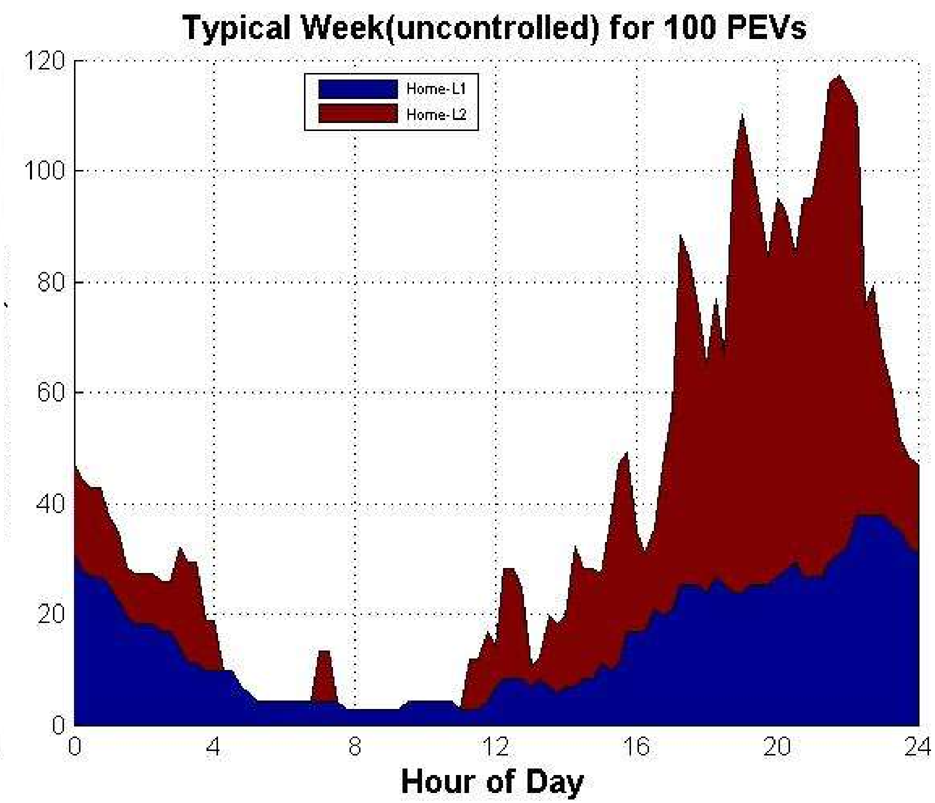
# RECHARGE: Spatial Disaggregation Residential Land Use Features for Atlanta



# Load Aggregation Models - Atlanta

Two random aggregations of residential load from 100 PEVs



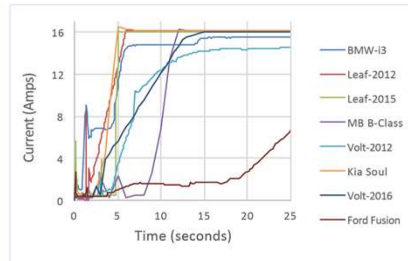
# Scalable Electric Vehicle Smart Charging Using Collaborative Autonomy

- With the anticipated increase in EV and charging infrastructure decentralized approach
- Develop and validate collaborative autonomy for smart chargers
  - Adaptive demand response, load shifting
  - Frequency/voltage support
- Real world demonstrations with PEV & chargers using Skynet (software platform)
- Scalability EVs at scale is easy with decentralized approach
- Charging network operators and/or individual vehicle owners may have conflicting needs

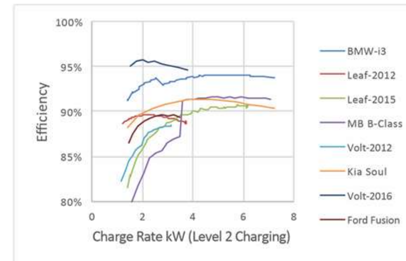
# Batteries and Electrification: EV Charging Grid Impacts

**Can PEVs provide grid services and improve grid stability?**

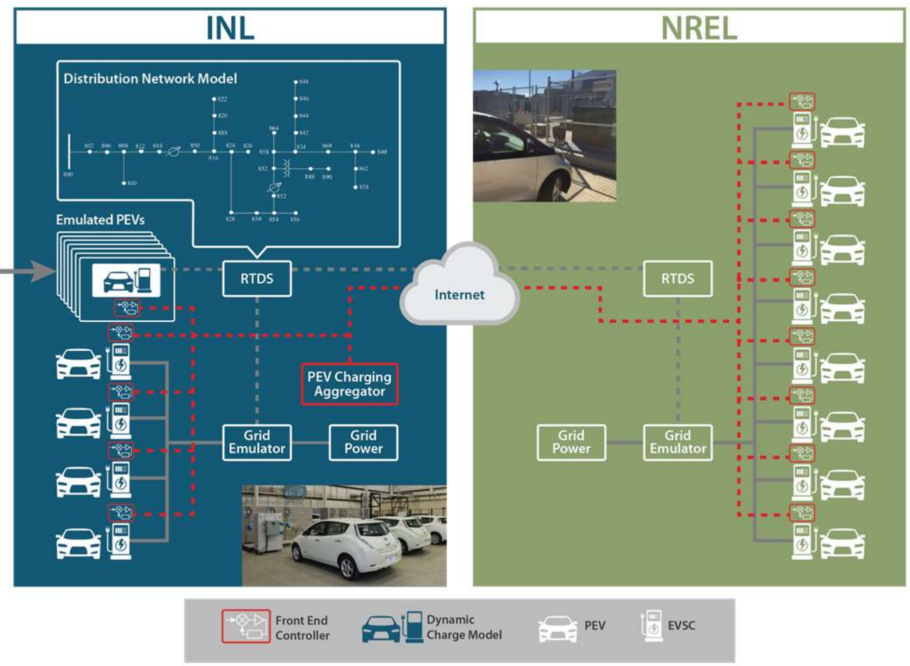
- Quantify impact of wide-spread uncontrolled charging
- Develop an open source control strategy to manage PEV charging that can provide grid services
- Understand cybersecurity risks
- Demonstrate uncontrolled and control of vehicle charging




PEV Charging Step Response




PEV Charging Efficiency

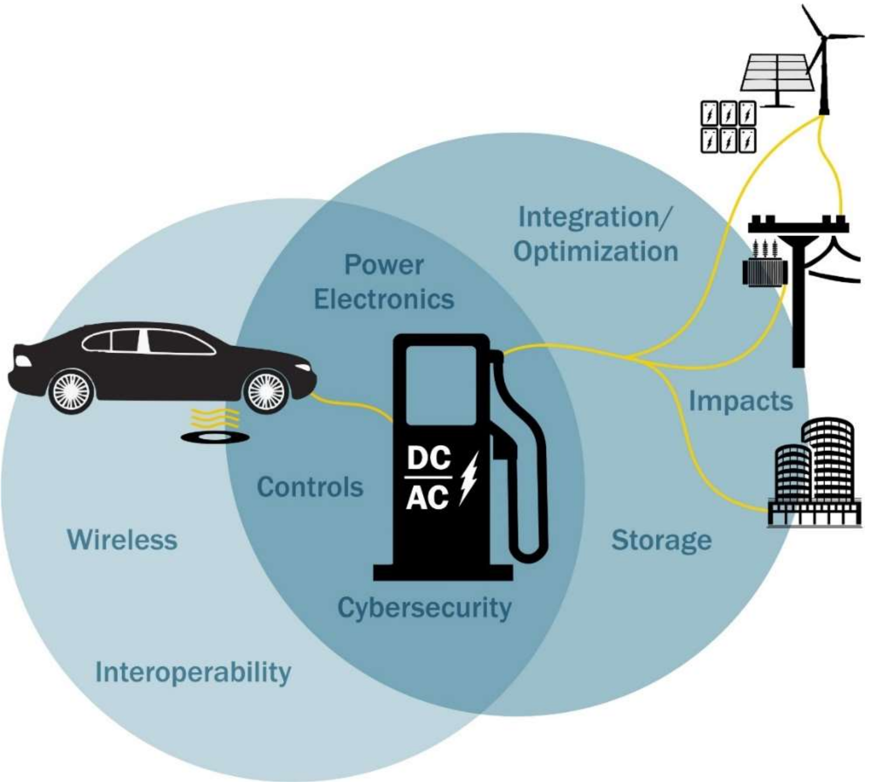



Hardware in the Loop Platform

# PEV Cyber Risks and Challenges

***Vehicles connecting to the grid open many new vulnerabilities***

- PII such as financial, vehicle location, and fleet routing
- Grid disturbances
- Pathways to back offices of utilities, OEM, & network providers
- Vehicle controls and safety
- Building energy management and EVSE control systems



# DOE VTO Lab Call Projects on Cybersecurity

## Securing Vehicle Charging Infrastructure

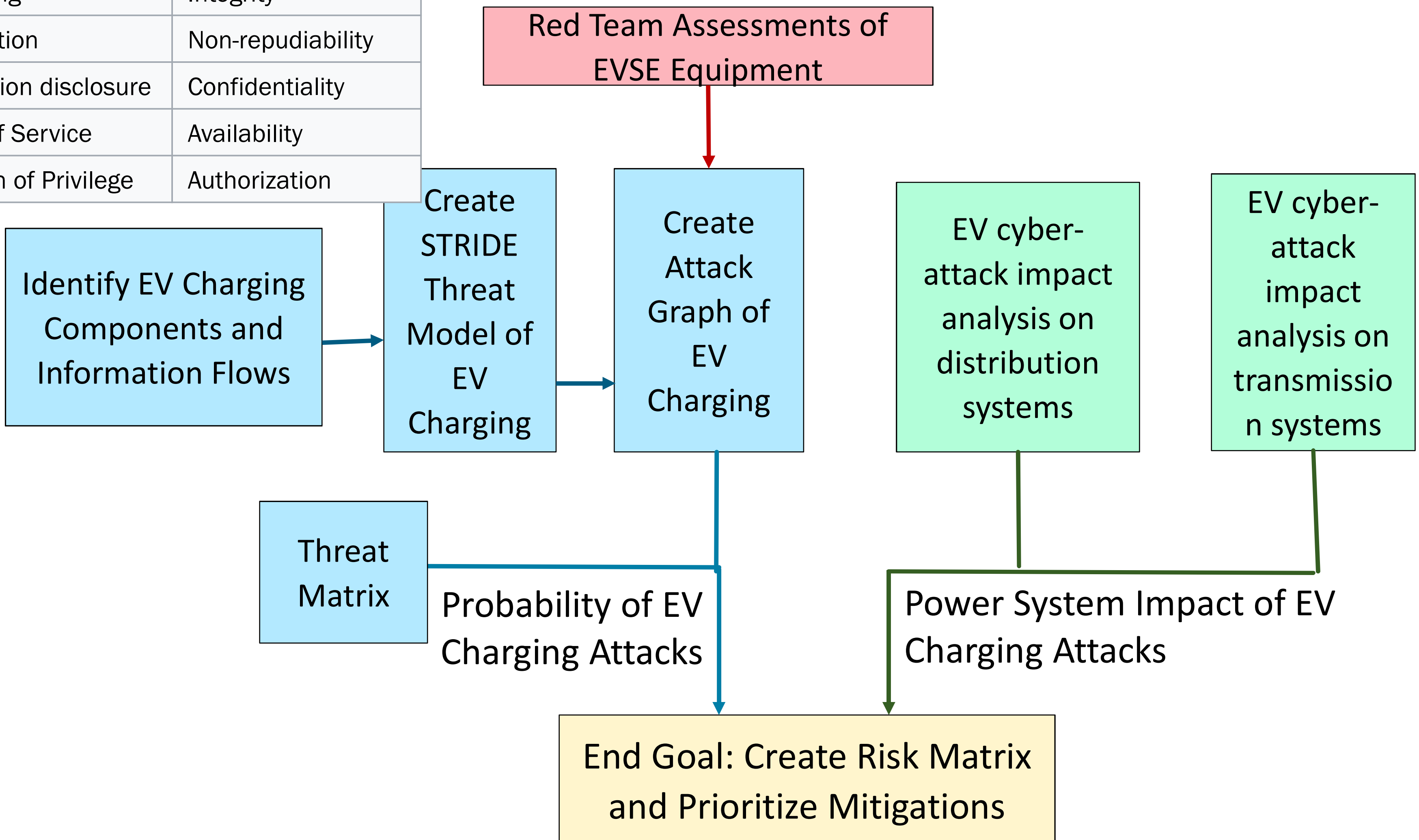
- Create a strong technological basis for securing critical charging infrastructure
  - Conduct adversary-based assessments of charging equipment
  - Create a threat model of EV charging
  - Analyze power system impacts for different attack scenarios
- 'STRIDE modeling' from Microsoft for threat vectors

## Consequence Driven Cybersecurity for High-Power Charging Infrastructure

- Determine the vulnerable attack vectors that enable High Consequence Events (HCE)
  - XFC charging site
  - Wireless power transfer (WPT)
- Develop mitigation strategies and solutions to secure the attack vectors that enable HCEs
- Feedback solutions, information, and lessons to industry

# Securing Vehicle Charging Infrastructure

| Threat | Desired property |
|---|---|
| Spoofing | Authenticity |
| Tampering | Integrity |
| Repudiation | Non-repudiability |
| Information disclosure | Confidentiality |
| Denial of Service | Availability |
| Elevation of Privilege | Authorization |



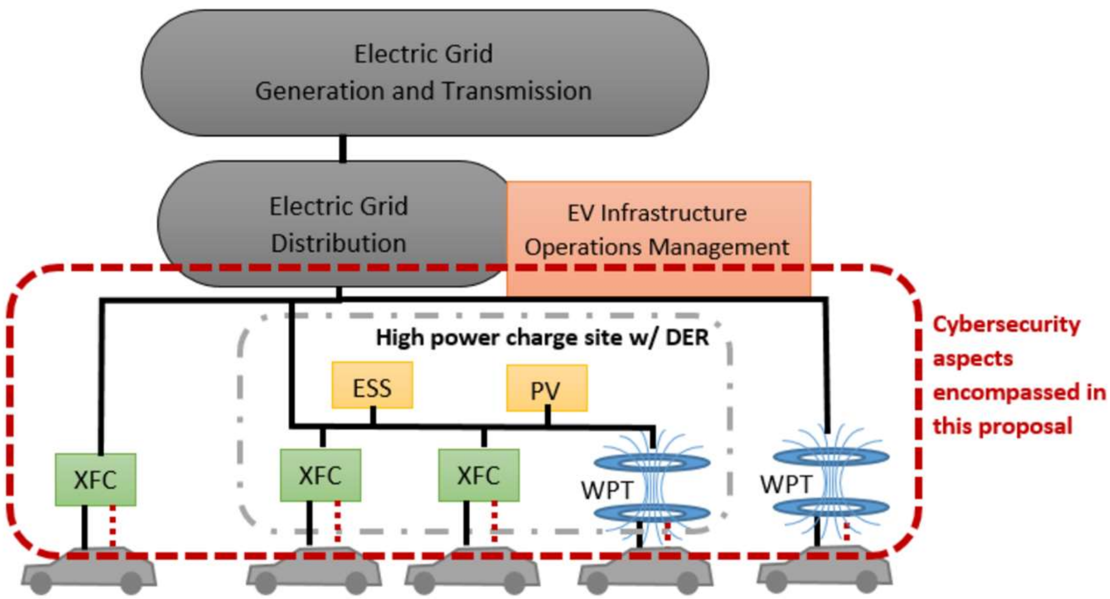
# Summary

- Both PEV adoption and battery sizes are increasing for LD, MD, & HD applications
- Charging infrastructure is evolving to provide faster charging rates
- EV and its infrastructure is increasingly getting connected via data and power
- Cybersecurity threats are constantly evolving and needs resilience by design approaches

# Back-up Slides

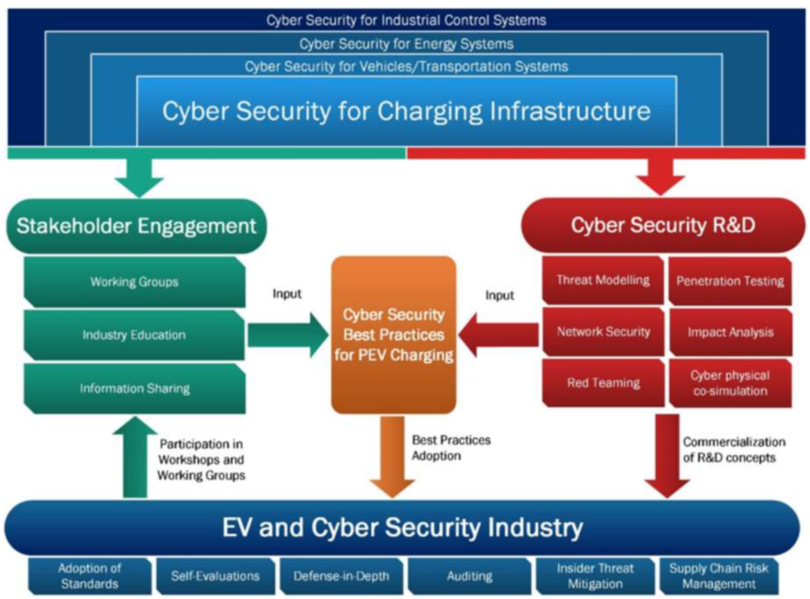
# Consequence-Driven Cybersecurity for High-Power Charging Infrastructure

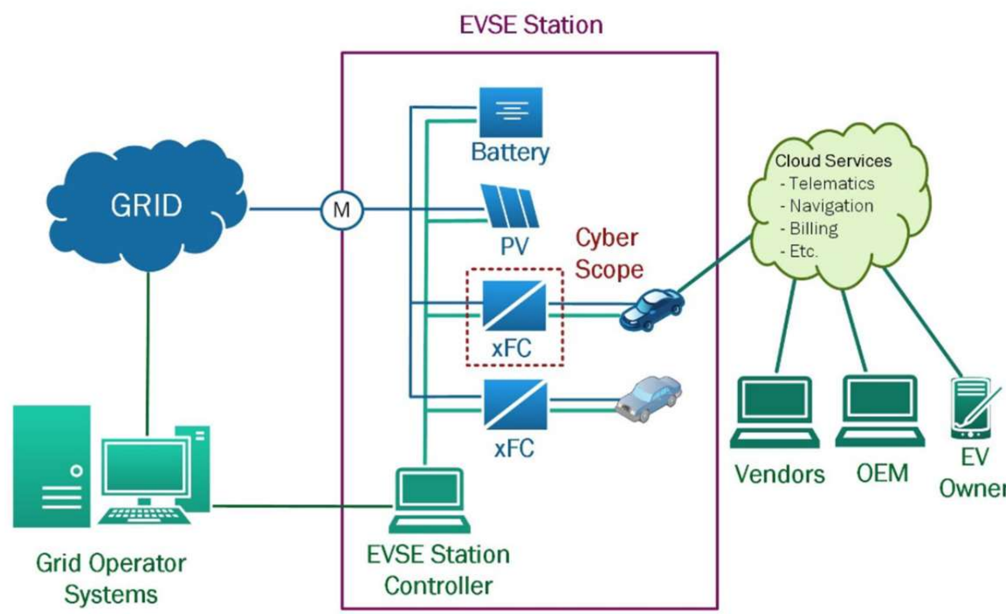
- **Full threat assessment of XFC and high-power Wireless Power Transfer (i.e., >200 kW) charging infrastructure ecosystems**
- **INL's Consequence-Driven Cyber-Informed Engineering (CCE)**
  - Consequence conceptualization; System vulnerabilities; Validation & prioritization of consequences; & Mitigation strategy
- **Focused on device-level and supervisory control systems (vehicles, EVSE, DERs, building and other third-party controllers, utilities)**



# Securing Vehicle Charging Infrastructure

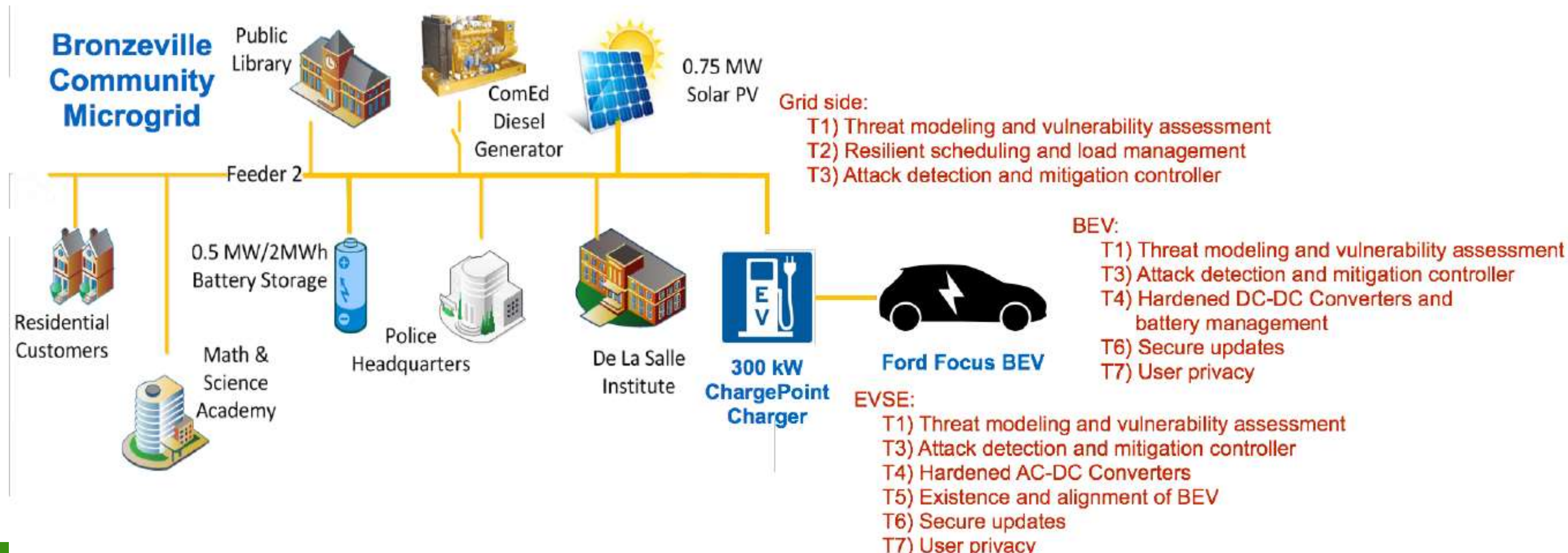
- Wide scope of assessing the cyber-security challenges and complete understanding of cyber-security challenges of charging infrastructure
- Foundational XFC cyber security research and development to improve the vehicle industry's cyber security posture
- Conduct networking and power system co-simulations to investigate cyber security defenses
- Develop and validate techniques and technology that provides cyber resilience



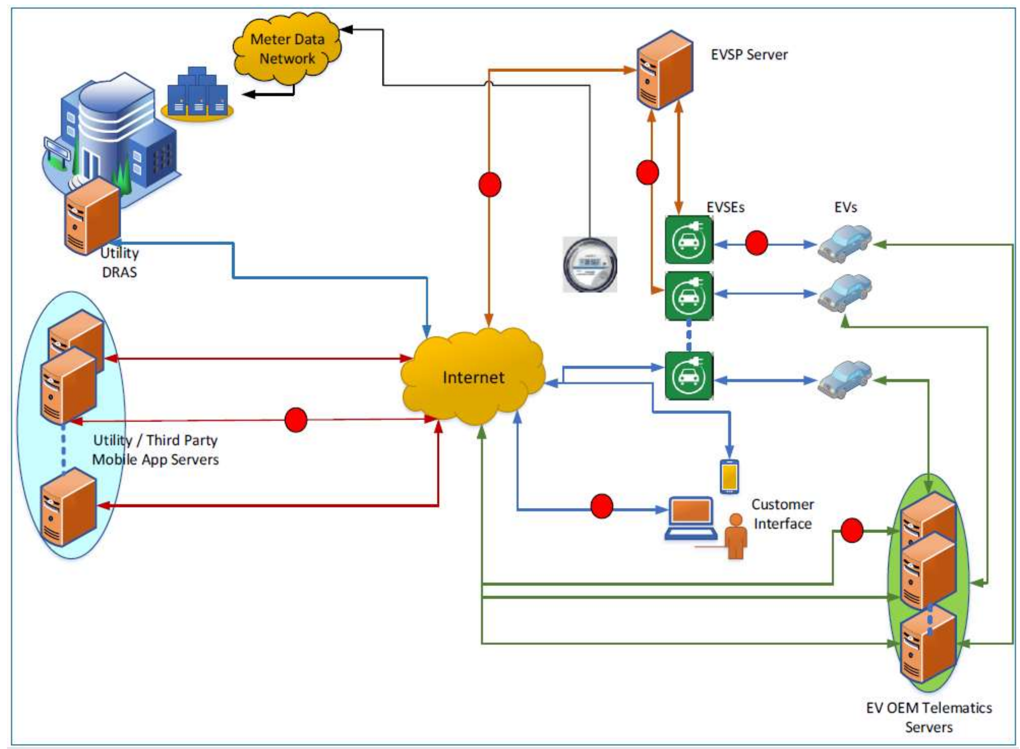
# Enabling Secure and Resilient XFC: A Software/Hardware-Security Co-Design Approach

- Led by VirginiaTech and GeorgiaTech, Utah State University, ChargePoint, Commonwealth Edison Company, Ford Motor Co., OnBoard Security
- Game-theoretic risk analysis and an automatic attack graph generator
- Comprehensive hardware and software cyber-physical security solutions using innovative approaches to demonstrate XFC infrastructure cyber-security



## Cybersecurity Reference Platform and Certification Framework Development for Extreme Fast Charging Electric Vehicle Infrastructure Ecosystem

- Led by EPRI and supported by NREL, GreenLots, ANL, Automation Research Group, BTC Power, & EFACEC
- Develop an open source cybersecurity reference platform centric to XFC charging infrastructure
- Formation of EV Infrastructure Cybersecurity Working Group (EVICWG)



# CyberX (Cybersecurity for XFC station)

- Led by ABB and supported by INL, APS Global LLC, & Thor Trucks Inc.
- Research, develop, and demonstrate a cyber secure charging station that reduces risk and impact of intrusions
- Develop cyber attack resilient control architecture and algorithms for grid connected XFC station