U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

R&D Experiences in Smart Charge Management

A Business Case for Bidirectional EV charging

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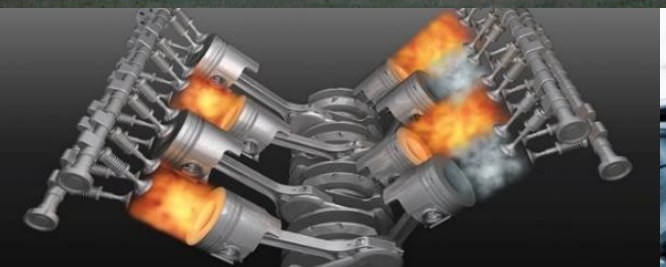
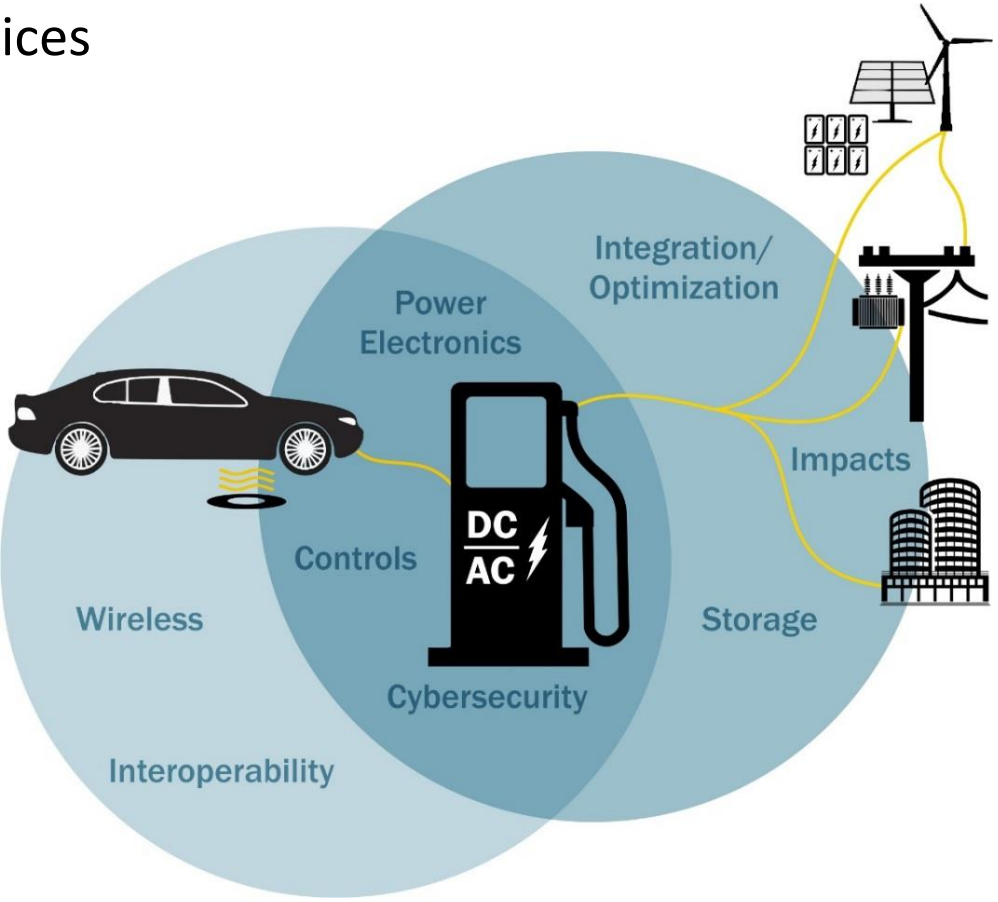


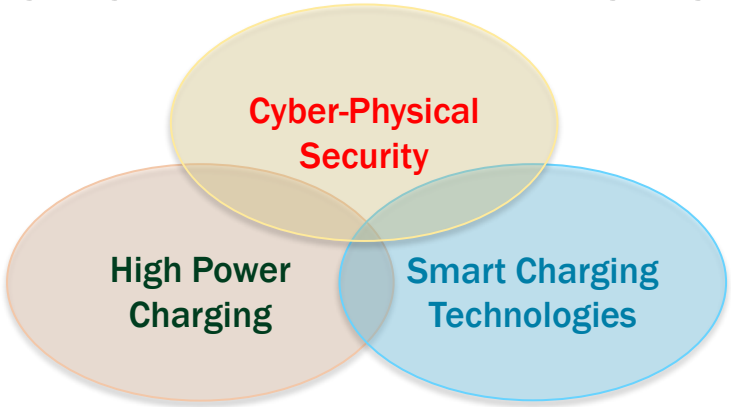
DOE VTO Grid & Infrastructure Program Goal

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

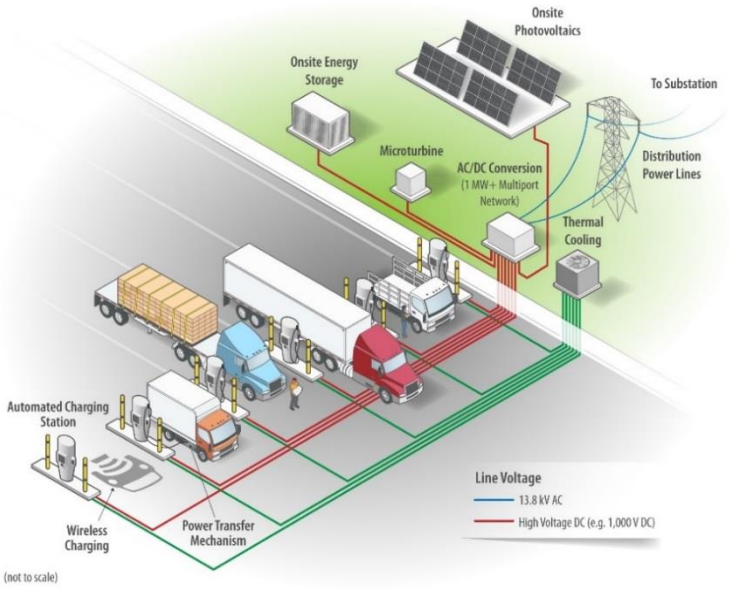
VTO's Electrification activities address challenges in cyber-physical security, eXtreme fast charging, and smart charging to support EVs at Scale



- High power charging infrastructure enables EVs to charge similar to today's vehicles refueling
- R&D supports advanced energy conversion to/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

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



VTO Funded V2G Project Experiences

- **Bi-Directional Wireless Power Flow for Medium-Duty Vehicle-to-Grid Connectivity**
  - CALSTART (lead), ORNL, UPS, Workhorse, Cisco
- **Vehicle-to-Grid Electric School Bus Commercialization Project**
  - BlueBird (lead), NREL, Nuvve, SCE, SCAQMD (co-fund)
- **Comprehensive Assessment of On-and Off-Board V2G Technology Performance on Battery and the Grid**
  - EPRI (lead), Flex Power Control, FCA, Kitu, NREL, ORNL
- **Advancing Transportation through Vehicle Electrification Ram 1500 PHEV**
  - Chrysler (lead), EPRI, Michigan State University, University of Michigan, SMUD, UC Davis, NAVTEQ, MAGNA

R&D Gaps in V2G

- **Majority of EV charging occurs at homes due to ease**
- **Suitable candidates for V2G are residential and workplace**
  - Maximum dwell times and flexibility of charge requirements
- **Residential chargers are either AC L1 or L2**
  - Onboard bi-directional inverter is the missing piece for V2G
  - DC chargers are typically not residential
- **Integration and development of foundational technologies for 'V2H' or 'V2B' is the first logical step**
- **Extension of V2G follows next with coordinated operations of utility distribution networks**

Thank you!!

For additional information contact:

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EV Charging Grid Impacts

- What are the impacts of uncontrolled EV charging on utility operations?
- Quantify impacts of wide-spread uncontrolled charging
- Gauge and verify the potential of EVs@Scale to provide grid services
- Understand cybersecurity risks with control of EVs@Scale
- Demonstrate the benefits of controlled charging of EVs@Scale

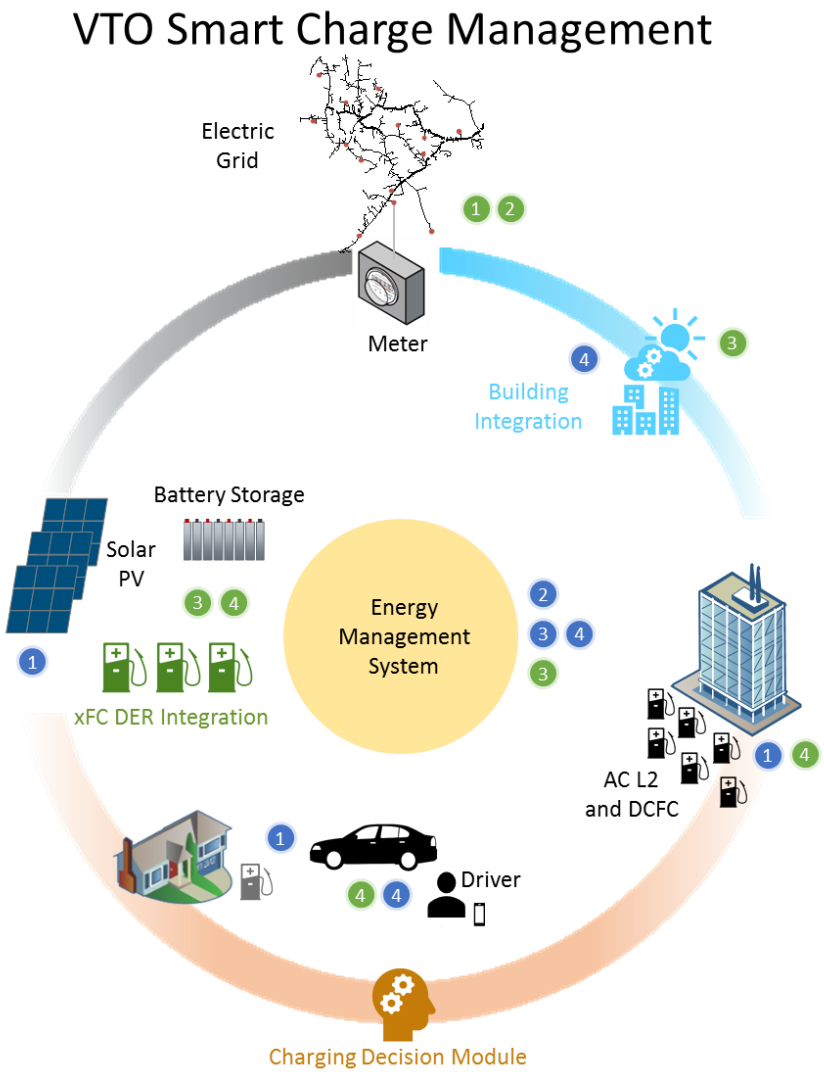
Secured Smart Charge Management

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

Argonne NATIONAL LABORATORY
INL Idaho National Laboratory



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

INL Idaho National Laboratory
NREL NATIONAL RENEWABLE ENERGY LABORATORY
Sandia National Laboratories

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