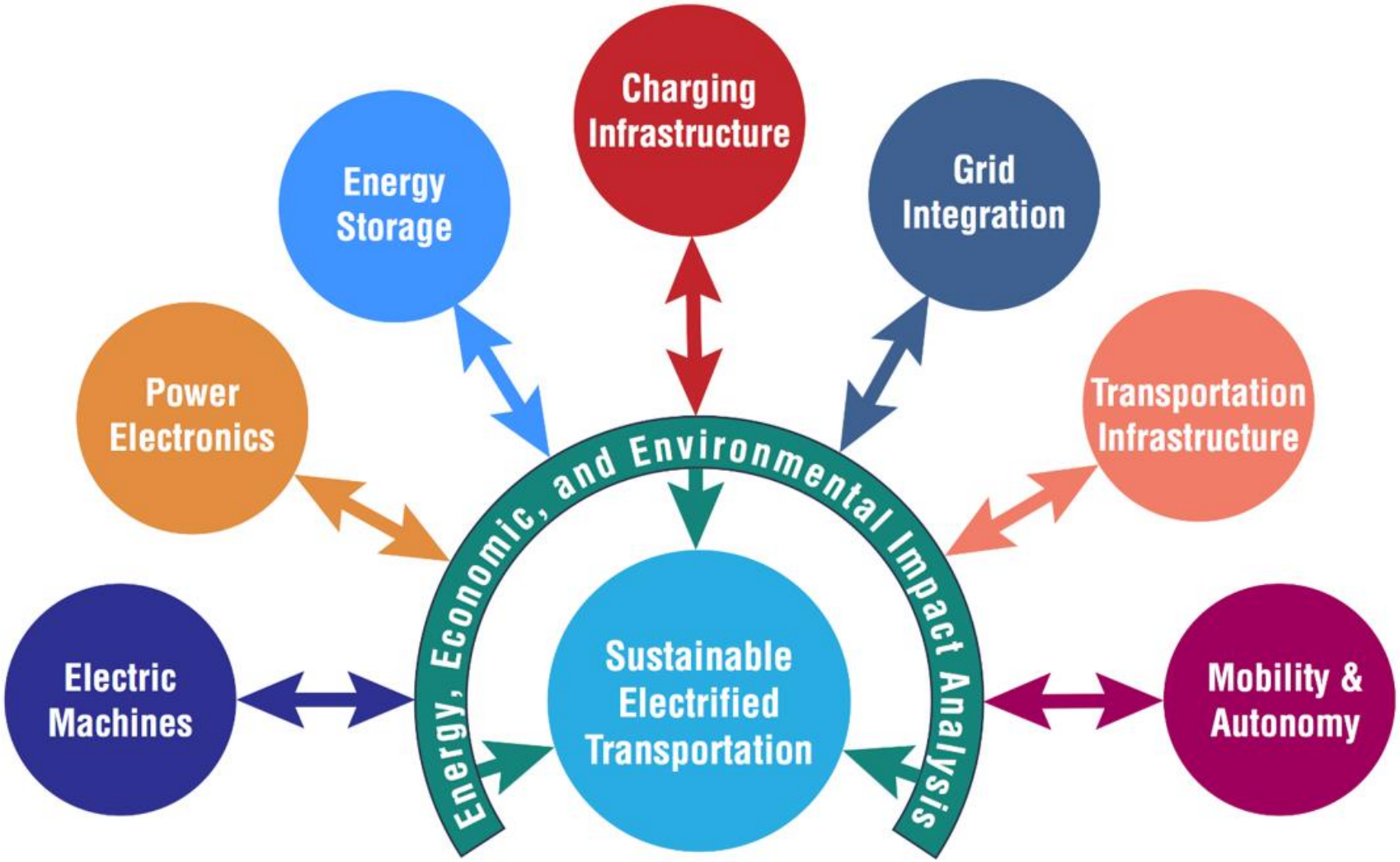
Trends in Electric Transportation
USU/SELECT Center Research

SELECT
Sustainable Electrified Transportation Center
Utah State University

SELECT Center Research Core



Partnerships

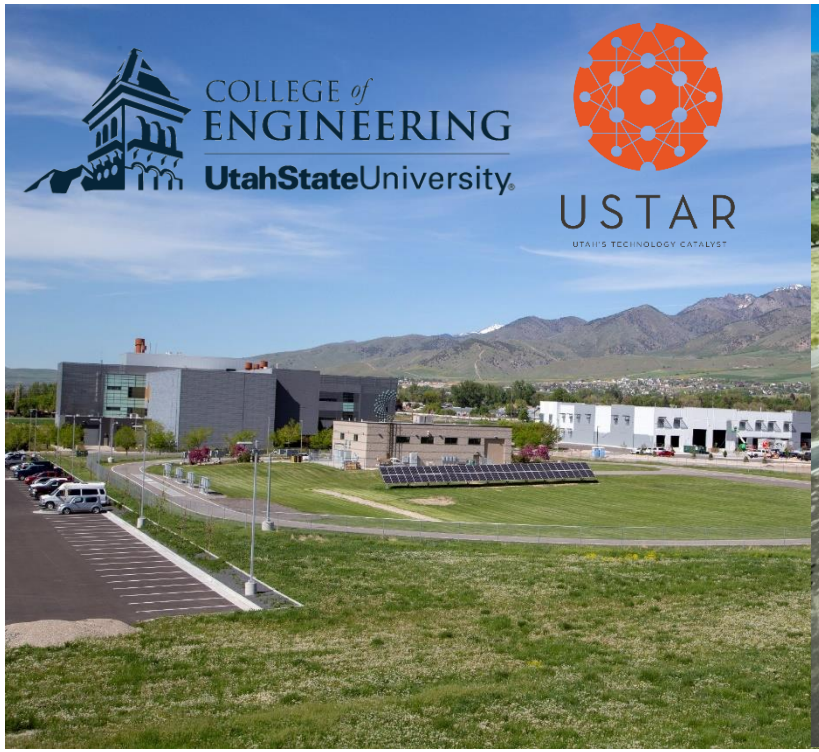
- Current Paid Industry, Non-profit, and Government Members

AECOM
ASI Autonomous solutions Inc.
HDS Hybrid Design Services, Inc.
LINEAR TECHNOLOGY
THE RAY Let's drive the future.
INL Idaho National Laboratory
OPAL-RT TECHNOLOGIES
ep SYSTEMS
TOYOTA
NREL NATIONAL RENEWABLE ENERGY LABORATORY
UDOT Keeping Utah Moving
ROCKY MOUNTAIN POWER A DIVISION OF PACIFICORP
HYSTER-YALE
WAVE Wireless Advanced Vehicle Electrification
GOVERNOR'S OFFICE OF ENERGY DEVELOPMENT Advancing Utah's Energy Future
JOHN DEERE
LG Chem
FCA FIAT CHRYSLER AUTOMOBILES
REGENT POWER CLEAN ENERGY CHAMPIONS
NIKOLA MOTOR COMPANY
TransChill
Schneider Electric
RISE
UTAH CLEAN CITIES Clean Fuels • Clean Strategies • Clean Air

Additional and Developing Collaborations

Ford
SIEMENS
Honeywell
ecamion
GM
PARK CITY 1884
SAMSUNG
Raytheon
RICARDO
ARRIVO
Hill Air Force Base
CDOT CO COLORADO Department of Transportation
BOMBARDIER
SALT LAKE CITY
UTA
WiTricity
PACKSIZE
MAVERIK
INTEGRATED ROADWAYS
DENVER INTERNATIONAL AIRPORT
chargepoint
wsp
MoDOT
Illinois Tollway
U.S. Department of Transportation Federal Highway Administration
innova ev
Kiewit
Cummins
SOUTHERN CALIFORNIA EDISON
CALSTART
TTSI
CBMM INNOVATE • RESPECT • COMPETE
U.S. DEPARTMENT OF ENERGY
SCANIA
EATON

Electric Vehicle & Roadway (EVR) Facility



- Electric Vehicle & Roadway (EVR) Research Facility and Test Track
  - 750 kW utility, 4800 ft^2 dual high bay, ¼ mile electrified track, Dynamometer, Vehicle Lifts, L2 and DCFC EVSE, DC & AC micro-grid, 20 kW solar array, 100 kWh on-site energy storage
  - Multiple concrete embedded, in-road power transfer coils in high bay building and test track
- Utah Power Electronics Lab, BLAST Lab, SMASH Lab

BLAST Lab

- Battery Limits and Survivability Testing Laboratory
- $1.3M upgrade to jet engine test cell (joint USU/USTAR/EP Systems project)
- Capability: contain and filter smoke and fire (and explosion as necessary) for thermal integrity testing of lithium ion batteries and energy storage technologies
- Major equipment: wet filters/blowers, carbon filters, HEPA units, venting, thermal sensors, video cameras/monitors, power supply, data acquisition, Dewetron configuration software

USTAR
UTAH'S TECHNOLOGY CATALYST

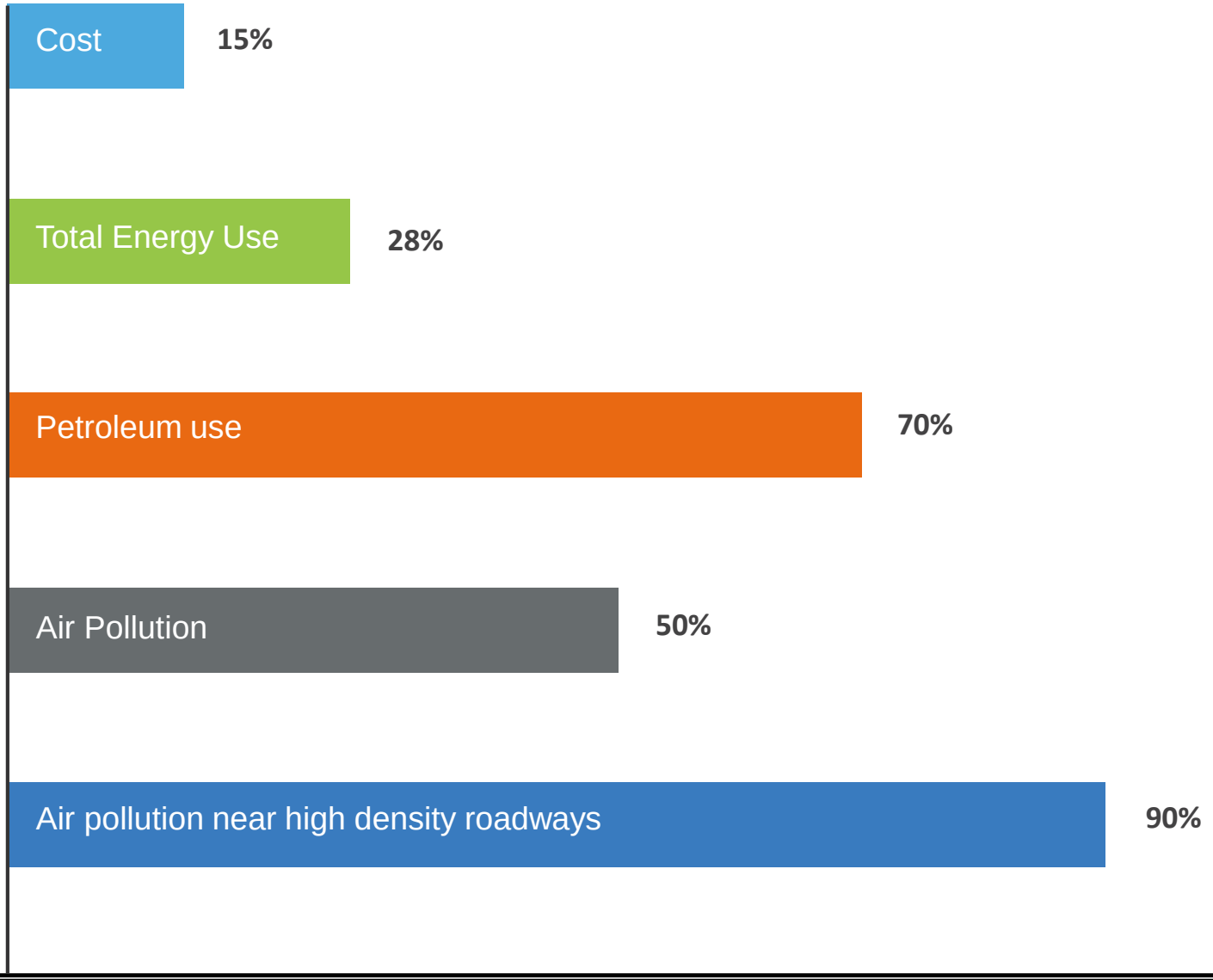
EP SYSTEMS

COLLEGE of ENGINEERING
UtahStateUniversity

USU/SELECT Center Impacts Snapshot (2012-2018)

- More than $12M in research funding
- SELECT Center established February 2016
  - 30 faculty from 10 universities (including UofU, BYU)
    - USU is Center lead; 10 faculty across five departments/two colleges
  - 17 Paid Industry Members; additional non-profit and government lab members
  - Annual Meeting, CERV, Monthly Webinars, and quarterly Area Interest Groups reach hundreds of stakeholders and collaborators across 12 countries
- $5M+ new facilities: EVR, Power Lab, BLAST Lab
- Upward trajectory and gaining momentum
- Pre-2012 Inductive IP portfolio licensed to WAVE
- Past six years: 13 disclosures, 11 patents pending, 3 patents issued

Impacts of Transportation in the US



Motivation for Electrified Transportation

- Reduce energy consumption and cost
  - Transportation accounts for 28% of US energy use
  - Electric vehicles consume 5x less energy
- Reduce impact on environment
  - Transportation accounts for 57% of fine particle emissions in the greater Salt Lake City area
  - Transportation accounts for 27% of greenhouse gas (GHG) emissions in the US
  - Transportation is the fastest growing source of emissions
- Displace petroleum as energy source
  - Transportation accounts for 71% of oil use in US
  - Petroleum comprises 93% of US transportation energy use
- Reduce utility rates
  - Properly managed can increase off-peak load to improve grid utilization, reduce rates for area sources

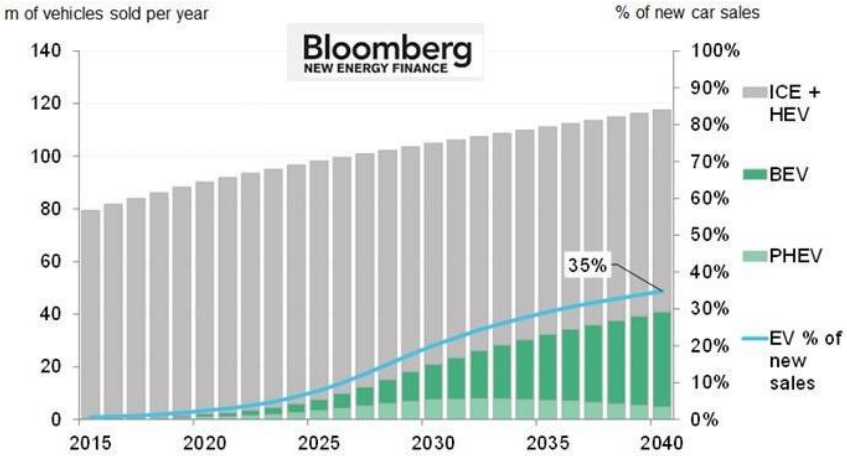
Zero Tailpipe Emissions

75 % reduction in PM10 / 2.5

50% reduction in CO_2

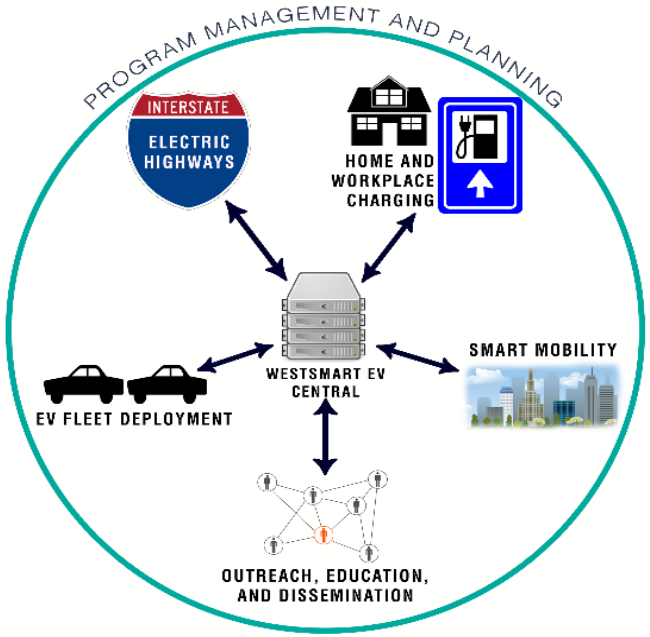
Battery electrification has arrived

- **Chevy Bolt**
  - 238 mile range, 0-60 in 6.5 sec
  - $37k (before tax incentives)
- **Tesla Model 3**
  - 215 mile range, 0-60 in <6 sec
  - $35k (before tax incentives)
- **Nissan LEAF**
  - 200+ miles, ProPILOT
- **Ford small SUV**
  - >300 mile range
  - By 2020
  - Also: PHEV F-150 & Mustang
- **Lower Total Cost of Ownership (compared to ICE)**
- **Up to 5X overall reduced emissions**



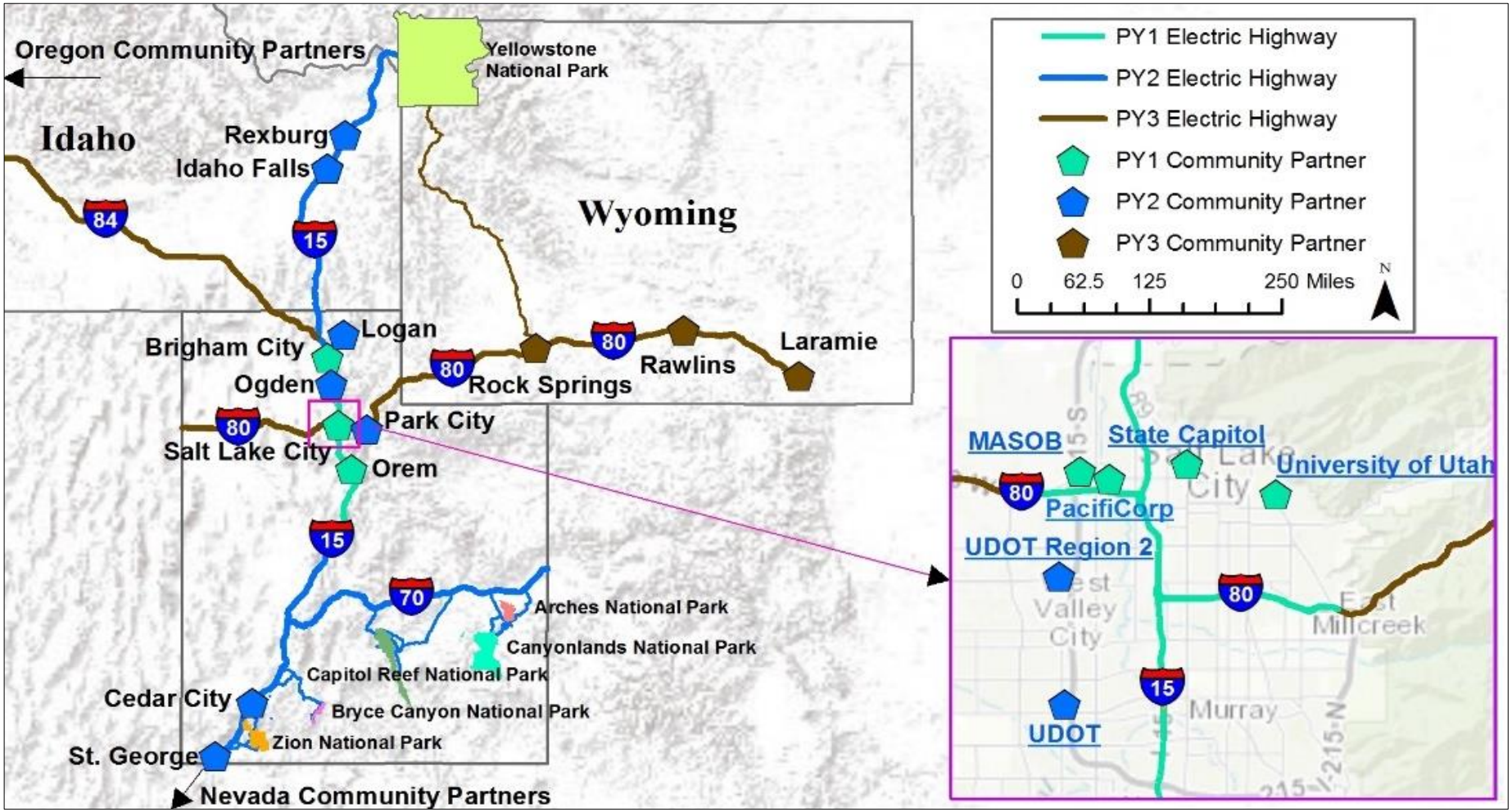
WestSmartEV Program

- Bold charging infrastructure rollout
- $4M DOE funding, $6M RMP incentives with $4M RMP follow on funding
- Targets
  - Double PEV growth rate from 20% to 40%
  - 1,500 miles electric highway corridors: Utah, Idaho, Wyoming - including national parks
    - DC fast chargers, every 30-70 miles
    - Public Level 2 AC at least every 50 miles
    - Coordinated and connected to corridors in Colorado, Oregon, Nevada
  - Workplace charging
  - EV Fleet conversion: SLC, State of Utah, Enterprise
  - Smart mobility: e-buses, e-bikes, EV rideshare



Electrification gaining momentum across US

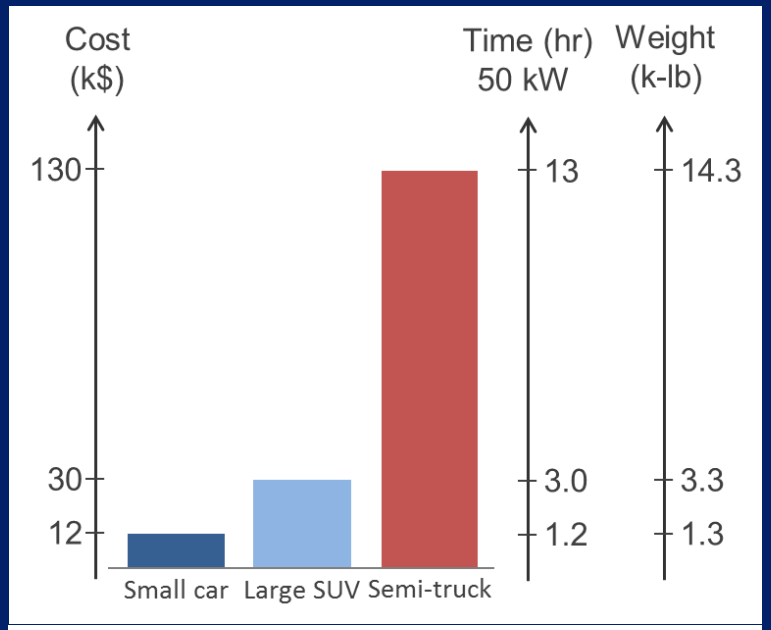
- PacifiCorp-USU led team; 3-year Phased Rollout
- $4M DOE, $10M STEP (Utah Sustainable Transportation & Energy Plan)



Plug-in: Light Duty Vehicles

- Plug-in charging meets most light duty needs
  - Smaller battery needs (though still a challenge)
  - Charge at home, work, retail
  - 2-3X lower energy needs, 2X lower maintenance compared to internal combustion engines
- Plug-in charging currently covers about 1/3 of Total Available Market (TAM)
  - Currently missing larger light duty as well as medium and heavy duty vehicles

Some Challenges



Battery cost, charge time, weight - 250 mile range

01 Battery Size, Cost, Time to Charge

02 Additional Charging Infrastructure

03 Missing 2/3 TAM

Frequent extreme fast charging implications

- Existing solutions don't meet needs for
  - Larger vehicles: SUV to semi truck
  - Continuous operation vehicles
- XFC: Charge in less than 15 minutes (4C rate or higher)

Battery cost

- $0.15/mile Sedan
- $0.85/mile Semi-tru

Energy cost

- $0.18/mile Sedan
- $1.02/mile Semi-tr

Small scale operator

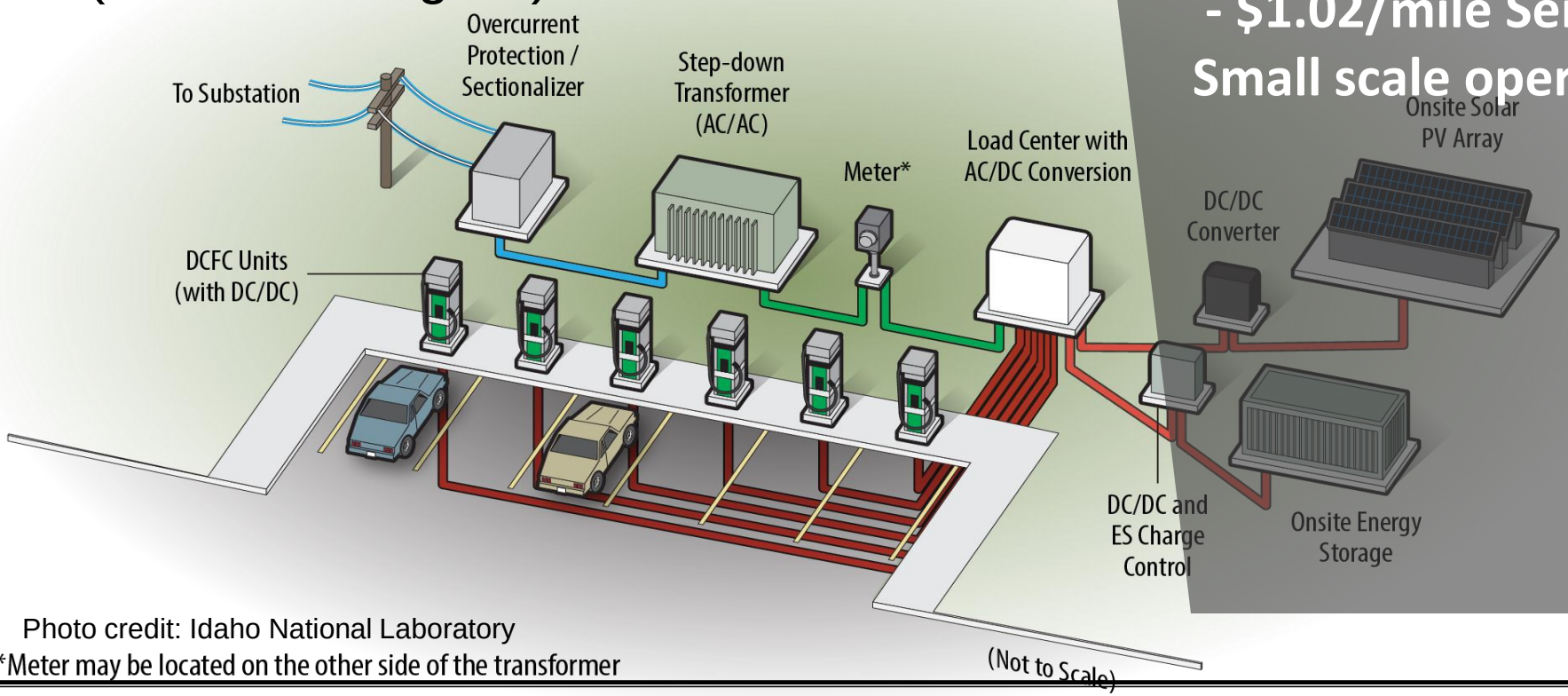


Photo credit: Idaho National Laboratory

*Meter may be located on the other side of the transformer

Possible next paradigm: Electric Roadways

01 Provide continuous power from the road while in-motion

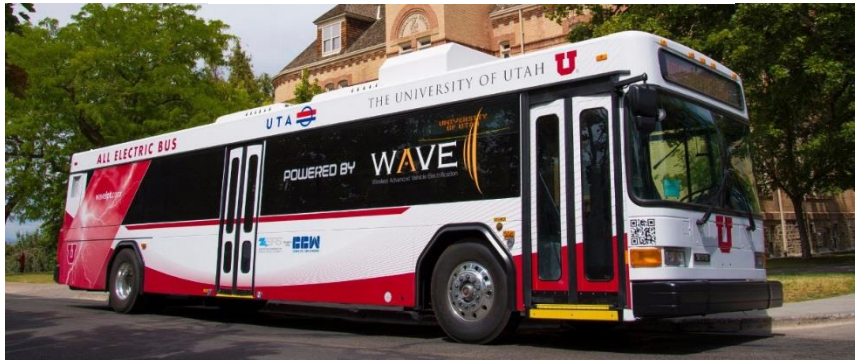
02 Relatively predictable load actively managed **<u>at utility scale</u>**

03 Compatible across LDV - HDV

04 Battery Friendly
- Smaller, longer lasting
- Low C-rates
- Low depth of discharge

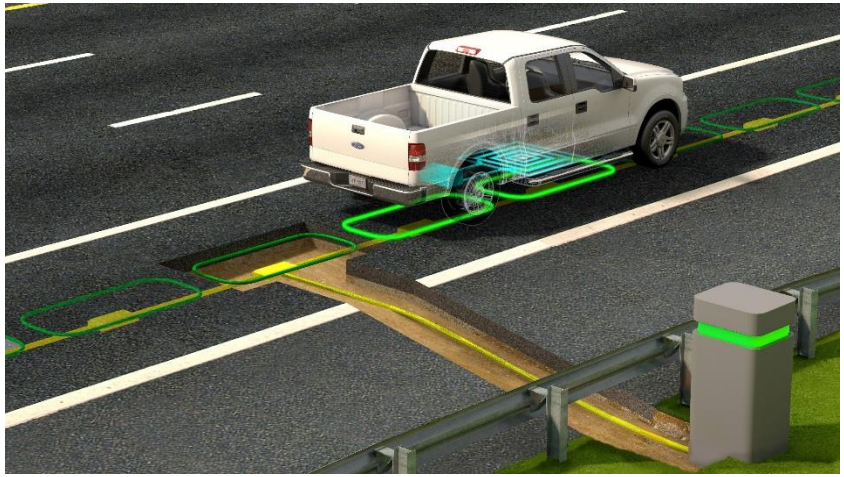
Utah Wireless Charging Legacy and Future

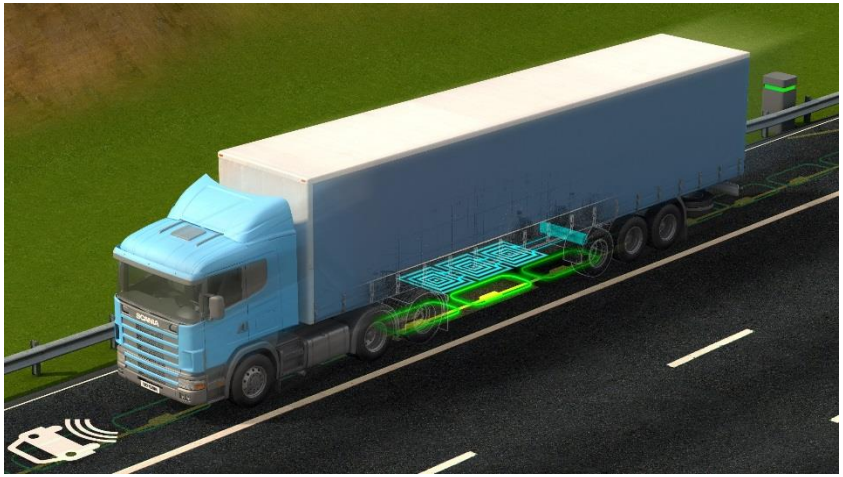
- USTAR, DOE investment
- WAVE—USU spin-out 2012
  - First in nation demo—50kW stationary wireless charging (SLC)
  - Now delivering first in nation commercial 250kW stationary wireless bus charging in Palmdale, CA
  - More than $11M in current contracts
- Expanding into new technology and markets
  - Shipping/ports off roadway vehicles with Hyster-Yale
  - In-motion collaboration with USU/WAVE
  - Pending collaborative proposal w/ USU and Scania for Sweden pilot deployment



In-motion Induction Development at USU

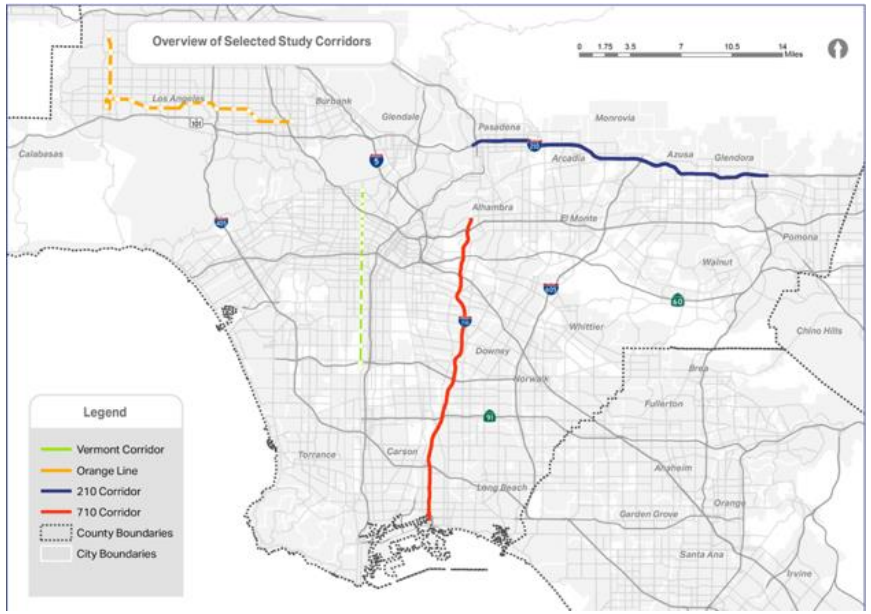
- 25kW charging pads embedded in roadway (moving to 50kW)
- >87% efficiency grid to vehicle
- 7-inch ground vehicle coil spacing
- Single receiving pad on e-bus
- Vehicle detection, communications
- Concrete coil enclosures
- Magnetic field safety standards
- Autonomous vehicle control
- Pending pilot projects lining up





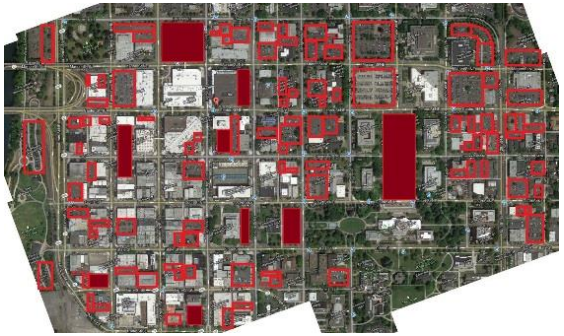
Feasibility Analysis of Electric Roadways

- DOE ARPA-E funding: analysis of freight and passenger vehicle corridors in lower Los Angeles County
- Evaluation of in-road inductive wireless and overhead conductive electric roadway solutions
- Results extended to other major US cities and interstates
  - Technology first adopters
  - Value proposition for incremental rollout
  - Technology gaps for accelerated market adoption
  - Localized impact on emissions reduction during rollout
  - Team: USU, CSU, Purdue, AECOM, So California Edison



Synergy with autonomy and smart cities

- Autonomy is coming
  - Safety, traffic flow, accessibility
  - Parallel with electrification
- Reconsidering vehicle ownership, urban landscape
  - Vehicles not parked >90% time
- Opportunity for self-driving, self-charging vehicles
  - Integrated grid and traffic optimization



Key Takeaways

- Electric vehicles promise significant impacts: energy, economy, environment
  - Electric vehicle technologies advancing rapidly
- Infrastructure and policy are critical drivers for adoption
- Utah is a leader
  - USU/SELECT
  - WAVE
  - Rocky Mountain Power
  - UDOT