INDIANA DEPARTMENT OF TRANSPORTATION INDOT

JOINT TRANSPORTATION RESEARCH PROGRAM Discovery with Delivery Since 1937 JTRP

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ASPIRE
NSF Engineering Research Center

Dynamic Wireless Power Transfer Pilot Project

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ASPIRE NSF Center Partnerships

CORE CAMPUSES
STRATEGIC PARTNERSHIPS
AFFILIATED FACULTY
NATIONAL LABS

INL Idaho National Laboratory

NREL NATIONAL RENEWABLE ENERGY LABORATORY

Colorado State University

UCCS University of Colorado Colorado Springs

UtahState University

THE UNIVERSITY OF UTAH

University of Colorado Boulder

UTEP

PURDUE UNIVERSITY

Cornell University

VIRGINIA TECH

Argonne NATIONAL LABORATORY

OAK RIDGE National Laboratory

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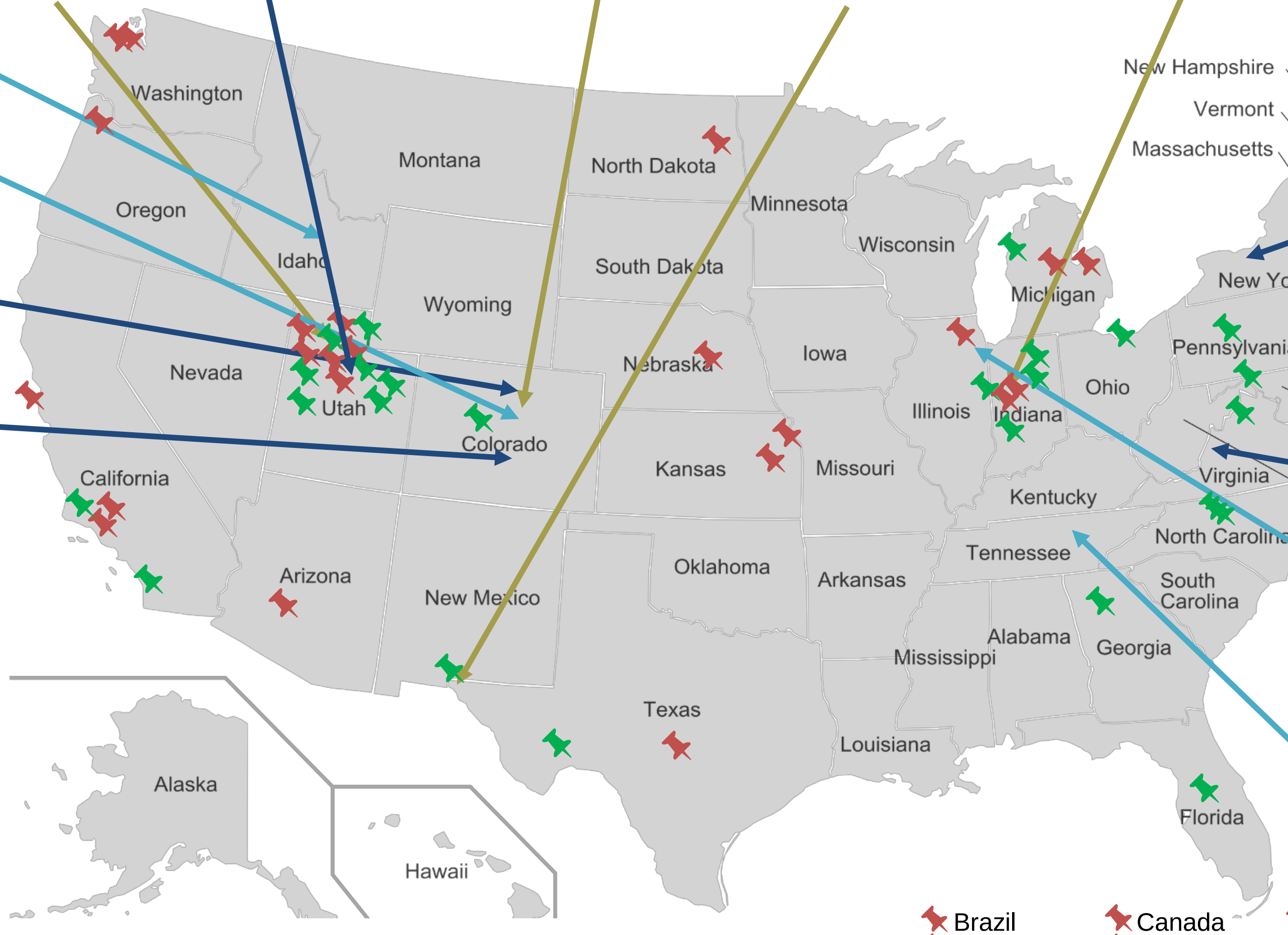

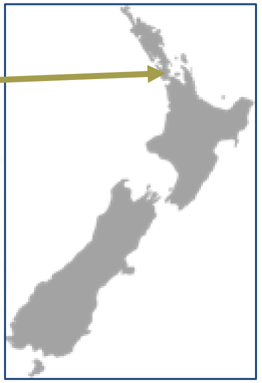

Innovation partners   Industry members

Brazil
Germany
South Korea
Canada
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Japan
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Industry & Innovation

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ABB
AECOM
CBMM INNOVATE • RESPECT • COMPETE
CRH
Cummins
DARKPULSE
DENSO
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electreon
ENRX
ep SYSTEMS
esri THE SCIENCE OF WHERE
Ford
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HYPERCRAFT
HYSTER-YALE
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INTEGRATED ROADWAYS
JOHN DEERE
KENWORTH A PACCAR COMPANY
MAGMENT
PCKA
ROCKY MOUNTAIN POWER A DIVISION OF PACIFICORP
Southwire
STELLANTIS
TOYOTA
WiTricity Powering life, wirelessly.

AAPA ESSENTIAL. RESILIENT. UNITED. SEAPORTS DELIVER
Argonne NATIONAL LABORATORY
THE BORDERPLEX ALLIANCE
CALSTART
CENTRAL FLORIDA EXPRESSWAY AUTHORITY
CONEXUS INDIANA
DFW
Hill Air Force Base
FORTH
HEAL UTAH HEALTHY ENVIRONMENT ALLIANCE OF UTAH
INL Idaho National Laboratory
IAPA Illinois Asphalt Pavement Association
ILLINOIS CONCRETE PAVEMENT ASSOCIATION ILCPA
IMTA INDIANA MOTOR TRUCK ASSOCIATION SINCE 1934
INDIANA DEPARTMENT OF TRANSPORTATION
ITS AMERICA
MICHIGAN OFFICE OF FUTURE MOBILITY & ELECTRIFICATION
Minnesota Asphalt Pavement Association
mn DEPARTMENT OF TRANSPORTATION
NACFE NORTH AMERICAN COUNCIL FOR FREIGHT EFFICIENCY
NAPA NATIONAL ASPHALT PAVEMENT ASSOCIATION
NREL NATIONAL RENEWABLE ENERGY LABORATORY
NORTH CAROLINA Turnpike Authority
North Central Texas Council of Governments
OAK RIDGE National Laboratory
OHIO TURNPIKE
PENNA TURN-PIKE
RMI
SANDAG
SMUD Powering forward. Together.
THE RAY
UAPA
UTAH CLEAN CITIES
UDOT Keeping Utah Moving
UTAH GOVERNOR'S OFFICE OF ENERGY DEVELOPMENT
UIPA UTAH INLAND PORT AUTHORITY
VDOT
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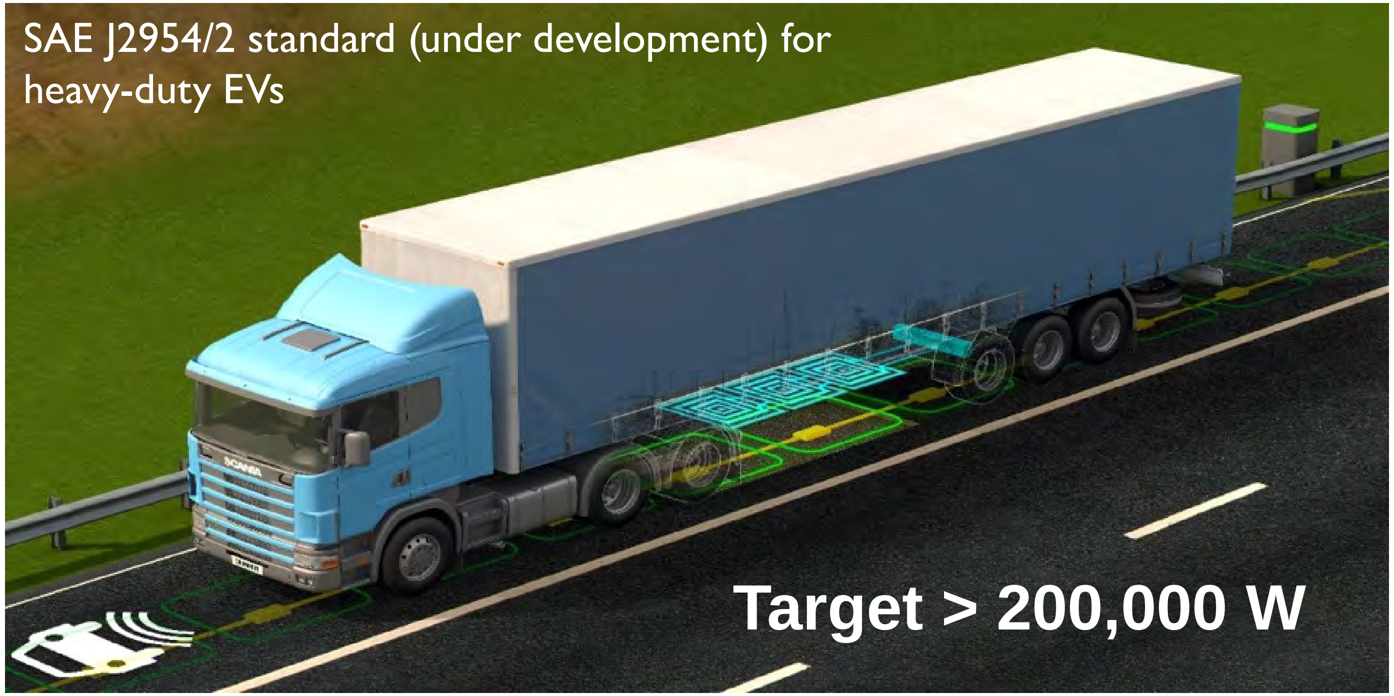
What is Dynamic Wireless Power Transfer (DWPT)?

- Wireless charging in motion
- Energy transferred using electromagnetic induction between two coils

Qi (chee) standard for inductive charging. (Source: HP)

SAE J2954 standard for light-duty EVs (<11,000 W)

Source: WiTricity



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Our Goal: make transportation cheaper, safer, and more reliable

Can heavy-duty electric vehicles (HDEVs) reduce TCO for fleet operators?

- Key advantages:
  - Much higher efficiency → **lower fuel cost**
  - Universal energy user → **energy independence**
- However,
  - Batteries are expensive and heavy
  - Range is limited/variable

DWPT could reduce battery needs by up to 90%

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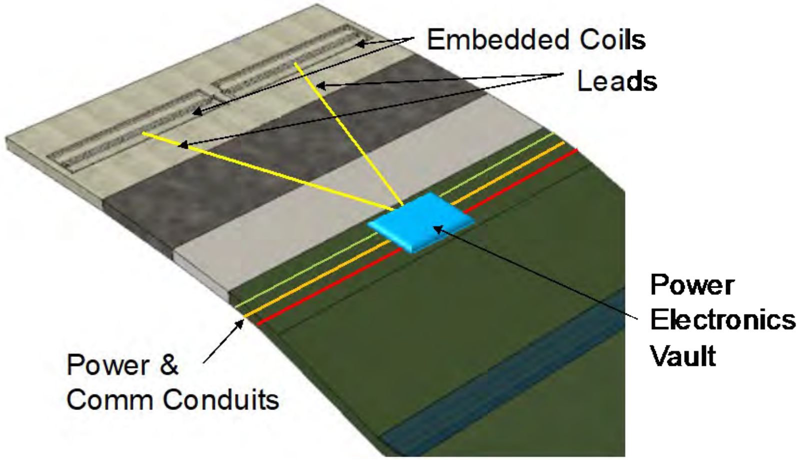
How electrified roadways would work

- Electrify main corridors, all interstate and major highways (~3% of total road network)
- Keep on-board battery energy for 50–100 miles range
- Add DWPT receiver assembly underneath vehicle
- Use in-pavement DWPT charging coils to power vehicles/charge batteries

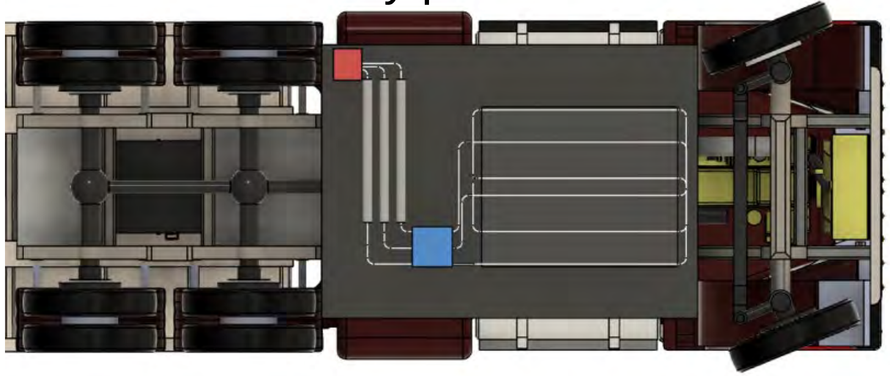
Questions Purdue/INDOT are addressing:

- **Is it financially feasible?**
- **Is it technically feasible?**

Transmitting components placed in roadway



Receiver assembly placed underneath vehicle



Initial Financial Feasibility Study

ROADWAY

The **capital cost** is the component, construction, and installation cost of the electric roadway.

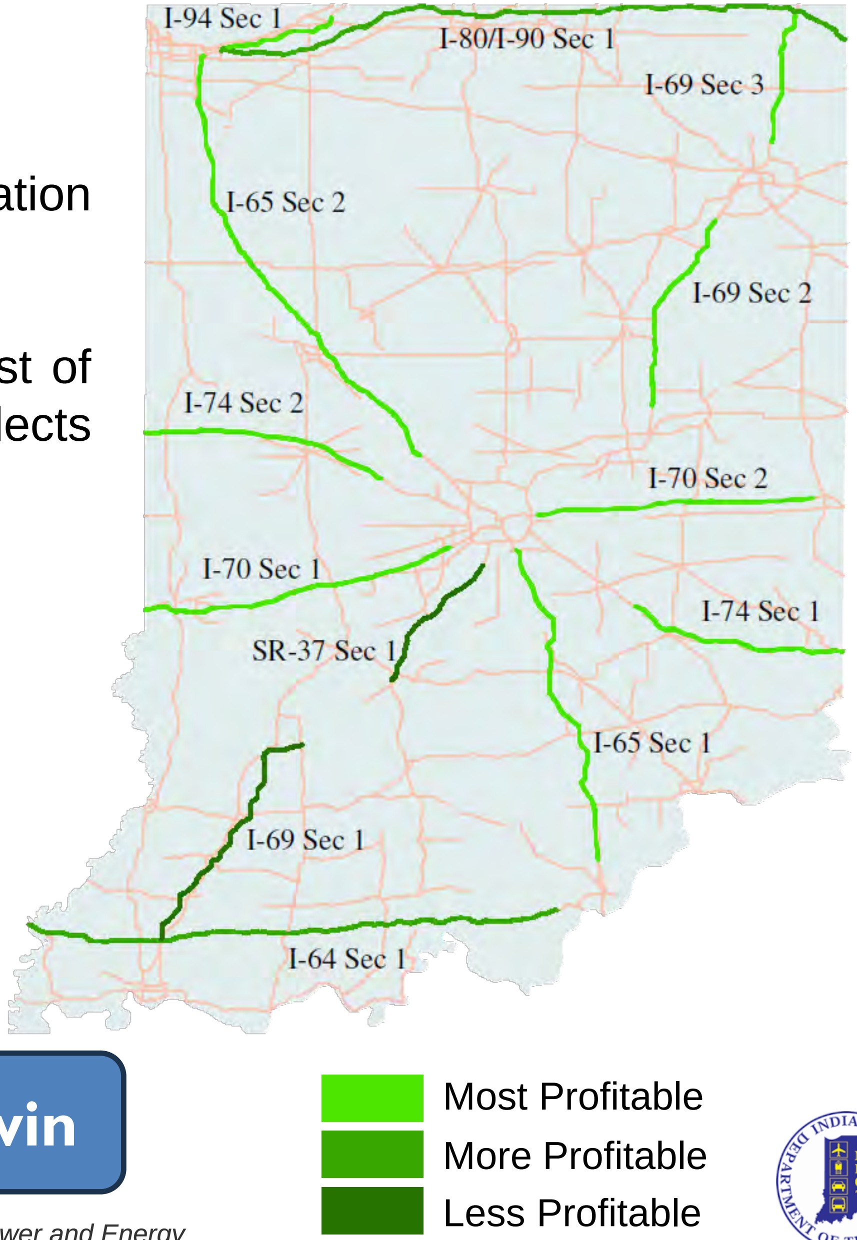
The **levelized cost of roadway (LCOR)** is the minimum cost of electricity delivered to EVs to break even on investment. It reflects the cost of equipment installation, maintenance, and more.

Estimated DWPT costs on Indiana Interstates

Capital Cost	LCOR
\$3.53-3.65 million / mile	23-31¢ / kWh

FLEET

Compare with estimated fleet operators' TCO **breakeven fuel cost** (electricity price at which diesel and DWPT-electric HDV TCO is equal): **32¢/kWh**



If LCOR < 32¢/kWh, electrified roadway is a win-win

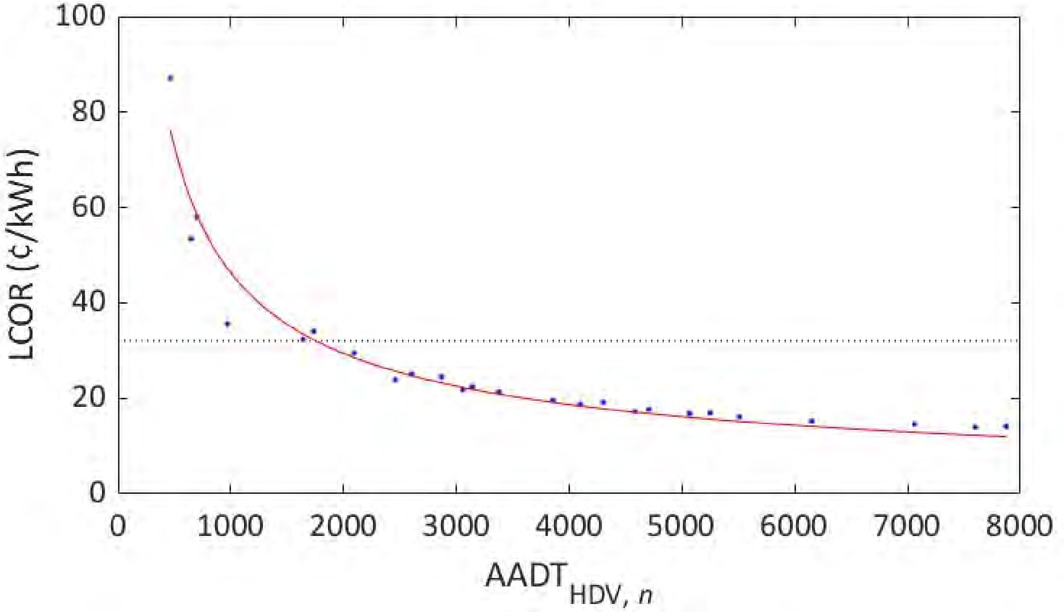
D. Haddad *et al*., "Economic Feasibility of Dynamic Wireless Power Transfer Lanes in Indiana Freight Corridors," *2022 IEEE Power and Energy Conference at Illinois (PECI)*, 2022, pp. 1-8, doi: 10.1109/PECI54197.2022.9744037

Key Takeaways from IN Financial Feasibility Analysis

- Electrified roadways could be a win-win in Indiana:
  LCOR 23–31¢ / kWh < TCO breakeven fuel cost 32 ¢/kWh

- Strong correlation between LCOR and **HDV** penetration

Electrified infrastructure must focus on HDVs (first)



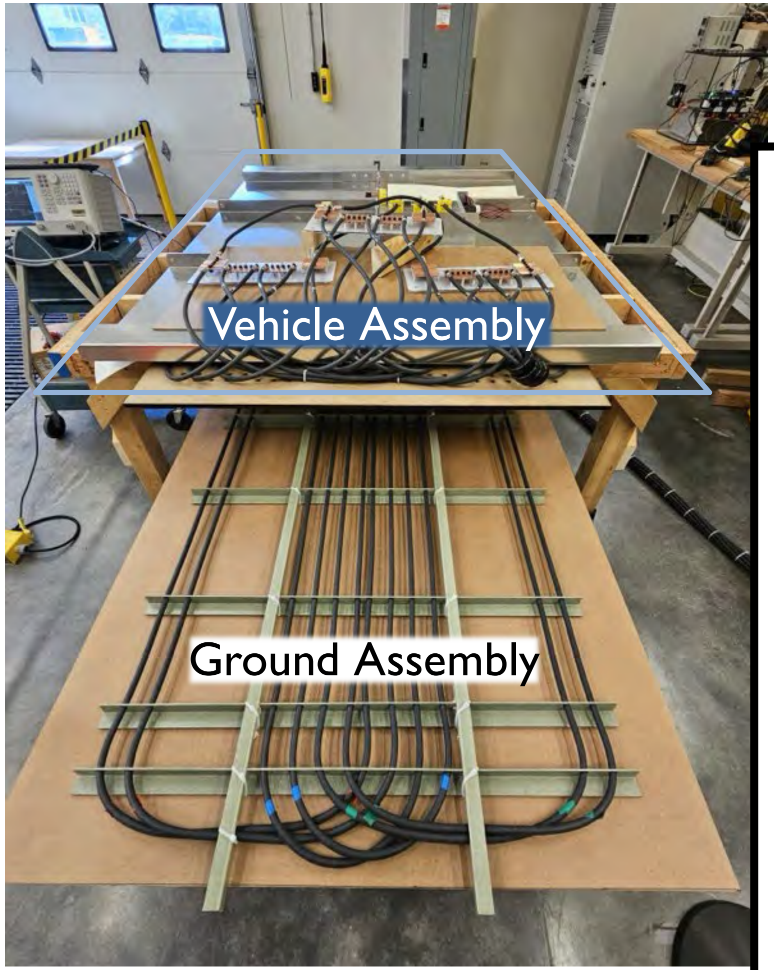
T. Konstantinou *et al.*, “Feasibility Study and Design of In-Road Electric Vehicle Charging Technologies,” FHWA/IN/JTRP-2021/25, Jun. 2021. doi: 10.5703/1288284317353.

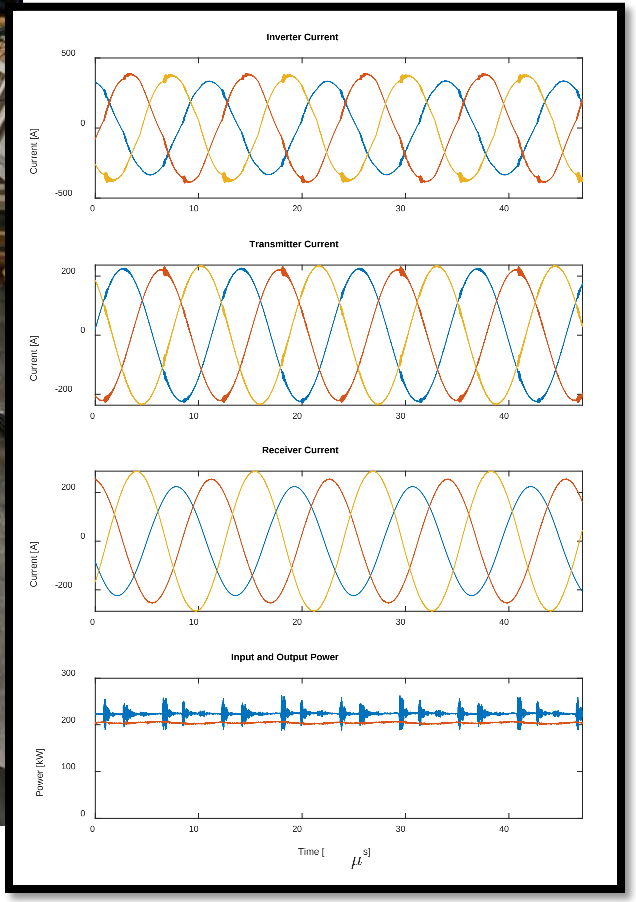
D. Haddad, T. Konstantinou, D. Aliprantis, K. Gkritza, S. Pekarek, and J. Haddock, “Analysis of the financial viability of high-powered electric roadways: A case study for the state of Indiana,” *Energy Policy*, vol. 171, p. 113275, Dec. 2022, doi: 10.1016/j.enpol.2022.113275.

Purdue Heavy Duty 3-Phase Design (patent pending)

- Designed for
  - Low power ripple
  - Balanced phase currents and reduced current/voltage ratings (lowest cost)
- Simple in-road installation
- No ferrite in roadway
- Meets international standards for field emissions (safe)
- Readily scaled across vehicle classes: change rx length
- Interoperable with static topologies

Lab Prototype Gen 2 (220 kW)





Safe, high power, simple install, interoperable

Testing: Structural and Thermal Assessment

- Constructed two small-scale pavements (**flexible** and **rigid**) with embedded DWPT components in the Accelerated Pavement Test (APT) facility

- Investigated the mechanical and thermal interaction of the pavement with an embedded DWPT system

- Full-scale APT testing used to assess the pavement performance due to embedded DWPT components

No performance degradation due to DWPT coil

Indiana DWPT Pilot Project

- Validate model predictions
- Establish/demonstrate construction techniques
- Demonstrate safety of technology
- Supports modeling of grid/transportation coupling
- Demonstrate interoperability across vehicle classes
- Explore health of pavement with embedded coils
- Advance community understanding of technology
- Pilots motivate standards alignment
- Advance Indiana business, health, environment

U.S. 231/52 between Lindberg Rd.
& Cumberland Ave. - West Lafayette

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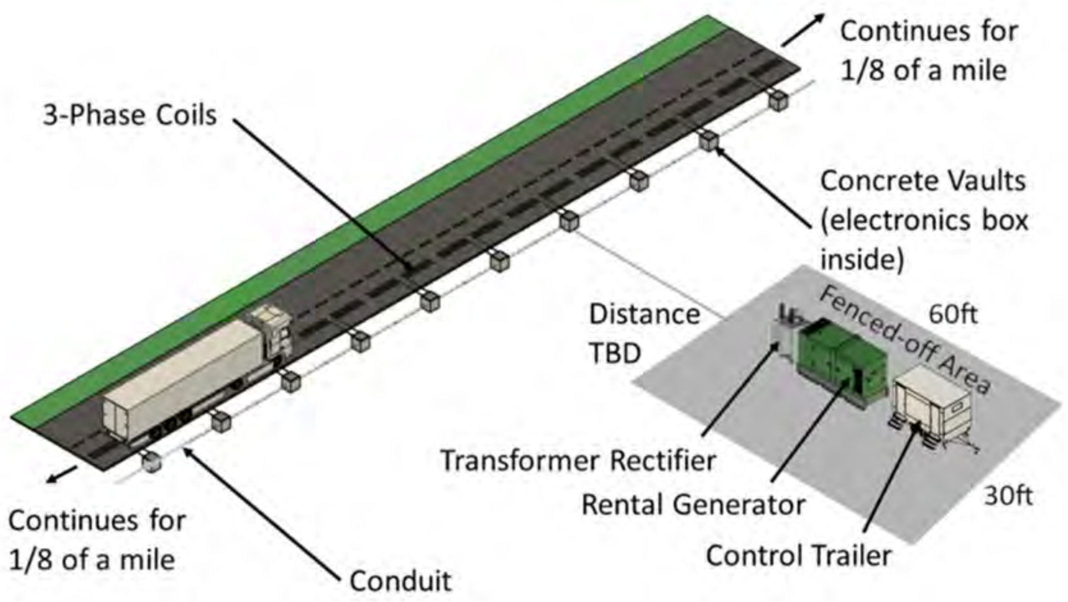
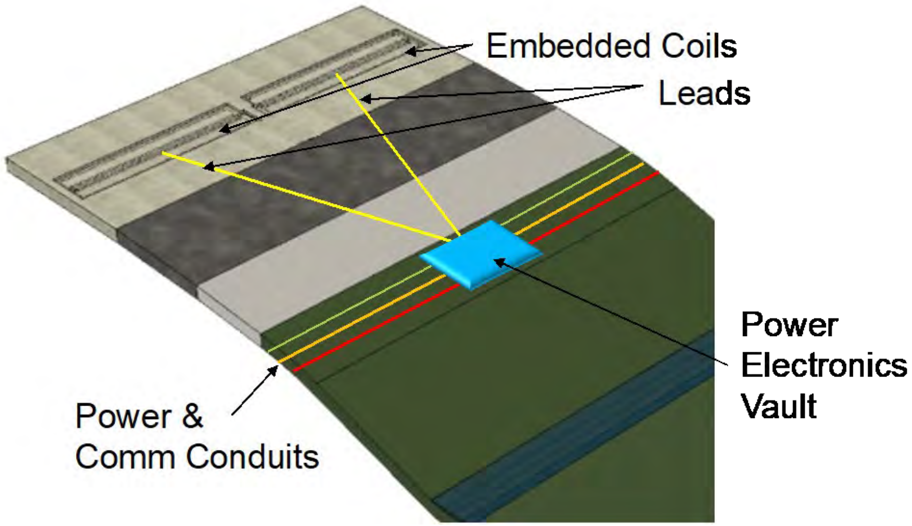
IN DWPT Pilot Parameters





- **Cummins** Class-8 E-Truck
- Delivers up to 230 kW per Tx coil
- DC power distribution (750 V)
- CAT6 & MMF **communications**
- Uniqueness: **Design and construction by Indiana-based organizations** (Purdue, White Construction, PCKA, Cummins)

IN DWPT Pilot Construction Overview

- Concept Lab Testing Phase
- Design Phase
- Bidding Phase
- Material Fabrication / Procurement
- Construction
- Pilot Testing

- Pad Milling
- Coring
- Trenching
- Horizontal Boring
- Setting Vaults
- Coil Fabrication
- Coil Installation
- Concrete Placement
- Install Inverters

Milling (Concrete Pavement): early April 2024

Pad Milling → Coring → Trenching → Horizontal Boring → Setting Vaults → Coil Fabrication → Coil Installation → Concrete Placement → Install Inverters

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Coring: late April 2024

Pad Milling → **Coring** → Trenching → Horizontal Boring → Setting Vaults → Coil Fabrication → Coil Installation → Concrete Placement → Install Inverters

Trenching for Conduits: late April 2024

Pad Milling → Coring → **Trenching** → Horizontal Boring → Setting Vaults → Coil Fabrication → Coil Installation → Concrete Placement → Install Inverters

Horizontal Boring: early May 2024

Pad Milling → Coring → Trenching → **Horizontal Boring** → Setting Vaults → Coil Fabrication → Coil Installation → Concrete Placement → Install Inverters




Vault Setting: early June 2024

Pad Milling → Coring → Trenching → Horizontal Boring → **Setting Vaults** → Coil Fabrication → Coil Installation → Concrete Placement → Install Inverters

Build Coils: mid June 2024

Pad Milling → Coring → Trenching → Horizontal Boring → Setting Vaults → Coil Fabrication → Coil Installation → Concrete Placement → Install Inverters

Install Coils: early July 2024

Pad Milling → Coring → Trenching → Horizontal Boring → Setting Vaults → Coil Fabrication → **Coil Installation** → Concrete Placement → Install Inverters

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Test Coils: July/August 2024

Pad Milling → Coring → Trenching → Horizontal Boring → Setting Vaults → Coil Fabrication → **Coil Installation** → Concrete Placement → Install Inverters

- Coils characterized twice before concrete – July 2024
- Again after concrete – Aug. 2024
- Again after winter – early March 2025
- Again after final cut – late March 2025

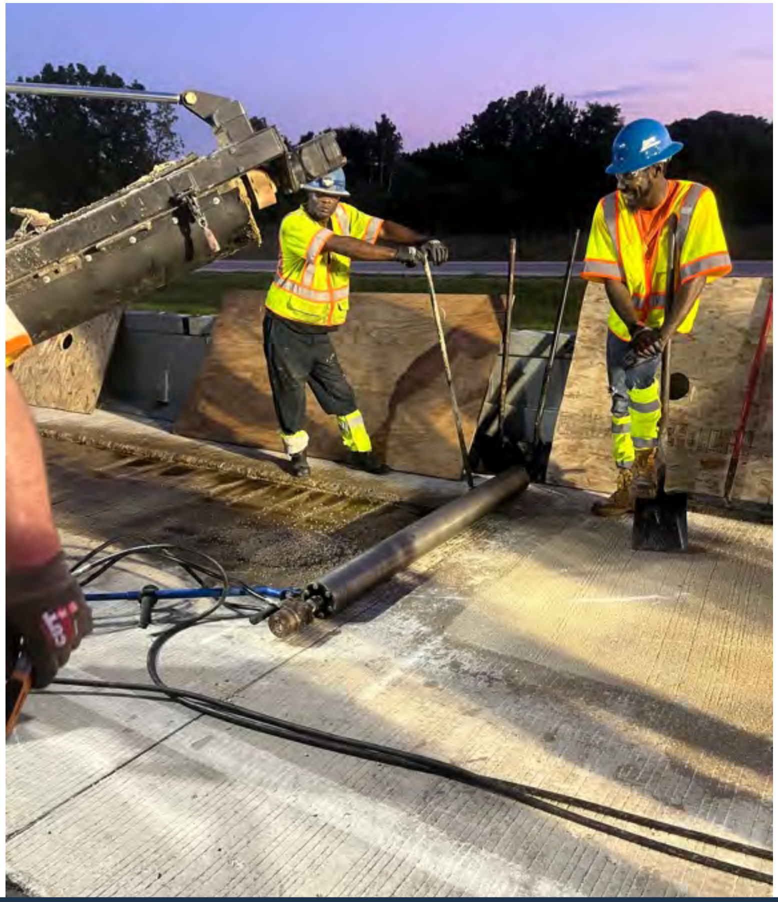
Test Coils: Results

Pad Milling → Coring → Trenching → Horizontal Boring → Setting Vaults → Coil Fabrication → Coil Installation → Concrete Placement → Install Inverters

- No coil failures
- No change over winter
- All 85 coils meet balance specification (5% SCF) and within ±10% of target inductance
- 72/85 meet strict balance target (<1% SCF)
- 78/85 within ±5% target inductance

Pour Concrete: early August 2024

Pad Milling → Coring → Trenching → Horizontal Boring → Setting Vaults → Coil Fabrication → Coil Installation → **Concrete Placement** → Install Inverters



Roadway construction completed ahead of schedule

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Inverter First Article Testing: August 2024

Pad Milling → Coring → Trenching → Horizontal Boring → Setting Vaults → Coil Fabrication → Coil Installation → Concrete Placement → Install Inverters

First article inverters passed specifications and cleared for production

Manufacturing of inverters is nearly complete

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Inverter Installation/Testing: March 2025 – Present

Pad Milling → Coring → Trenching → Horizontal Boring → Setting Vaults → Coil Fabrication → Coil Installation → Concrete Placement → Install Inverters

Final Thoughts

- INDOT, ASPIRE, and IN businesses are **global and national leaders** in this technology
- INDOT and Purdue are pursuing a **market-based approach**
  - Standards engagement
  - Cost reduction
- **Unlimited range**: a transportation system for the 21st century