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INDIANA DEPARTMENT OF TRANSPORTATION
INDOT

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Dynamic Wireless Power Transfer on Indiana Roadways

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Wireless Charging

- Energy transferred using the phenomenon of electromagnetic induction between two coils
- Advantages: convenient, less clutter, safer (no exposure to electrical terminals)
- Disadvantages: complexity, cost

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

(Source: insideevs.com)

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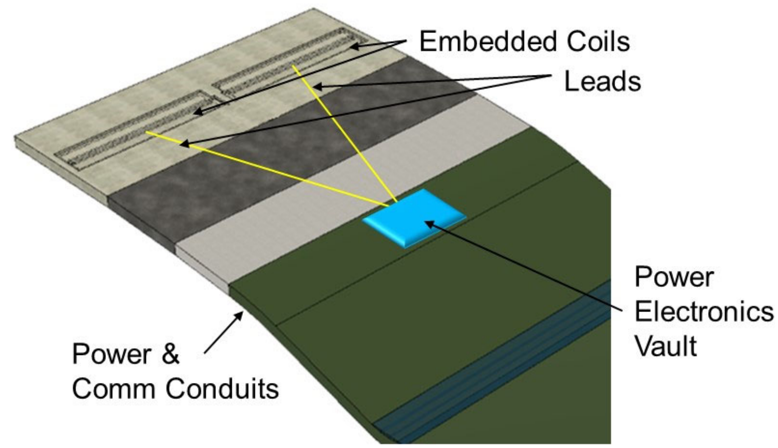
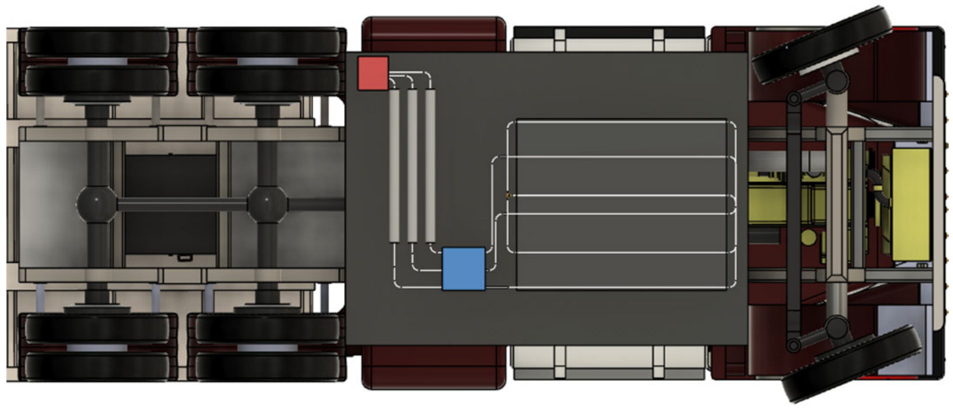
Dynamic Wireless Power Transfer (DWPT)

- Provide the power to propel/operate vehicle, keep battery at state of charge.
- Greatly reduce the size of the battery (cost) required for EVs
- Research questions Purdue/INDOT is addressing:
  - Is it financially feasible?
  - Is it technically feasible?

Transmitting components/coils placed in roadway



Receiving components/coils placed underneath vehicle



Initial Financial Feasibility Analysis

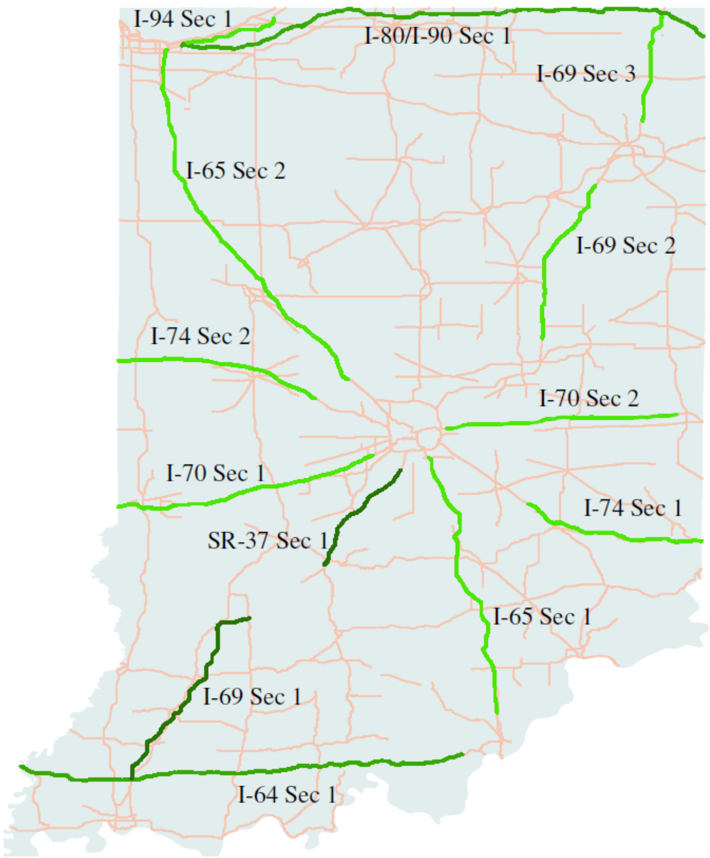
- Assessed feasibility utilizing levelized cost of roadway (LCOR), which is the minimum electricity selling price ($/kWh) that would ensure a break-even with investment
  - Included estimates of transmitter equipment and power installation costs
  - Included models of potential EV adoption rates
  - Resulted in understanding that WPT is financially feasible on roadways with heavy truck traffic

- Evaluated benefit to fleet manufacturers
  - Financially attractive relative to diesel technologies if LCOR < $0.32/kWh

D. Haddad, T. Konstantinou, D. Aliprantis, K. Gkritza, S. Pekarek, and J. Haddock, "Analysis of the financial viability of high-power electric roadways: a case study for the state of Indiana," *Energy Policy*, Vol. 171, Dec. 2022, 113275
https://doi.org/10.1016/j.enpol.2022.113275

Initial Financial Study Results

Road Section	Total length (mi)	Capital Cost (M$/mi)	LCOR (¢/kWh)	Capital Cost (M$/mi)	LCOR (¢/kWh)
		Scenario I		Scenario II	
I-64 Sec 1	242	3.48	25.1	3.43	34.0
I-65 Sec 1	212	3.83	14.6	3.64	17.7
I-65 Sec 2	197	3.85	14.1	3.65	16.9
I-69 Sec 1	155	3.37	57.9	3.36	87.1
I-69 Sec 2	118	3.71	16.9	3.6	21.3
I-69 Sec 3	67	3.7	17.2	3.54	21.8
SR-37 Sec 1	83	3.42	35.7	3.38	53.4
I-70 Sec 1	124	3.71	15.2	3.58	18.7
I-70 Sec 2	102	3.8	13.9	3.64	16.7
I-74 Sec 1	112	3.63	19.1	3.47	24.5
I-74 Sec 2	127	3.6	22.4	3.49	29.5
I-80/I-90 Sec 1	269	3.51	23.9	3.43	32.4
I-94 Sec 1	61	3.79	16.1	3.64	19.6
Mean		***3.65***	***22.9***	***3.53***	***30.8***



Most Profitable
More Profitable
Less Profitable

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

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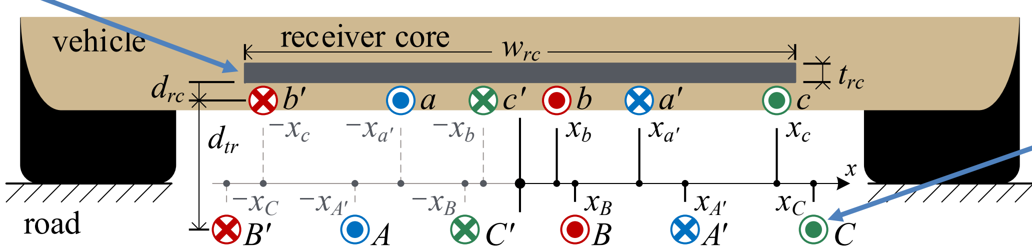
Addressing Technical Feasibility

- Power required for heavy-duty vehicles at highway speeds is large (~180 kW)
  - Highest power level DWPT being considered in U.S. (and globally)

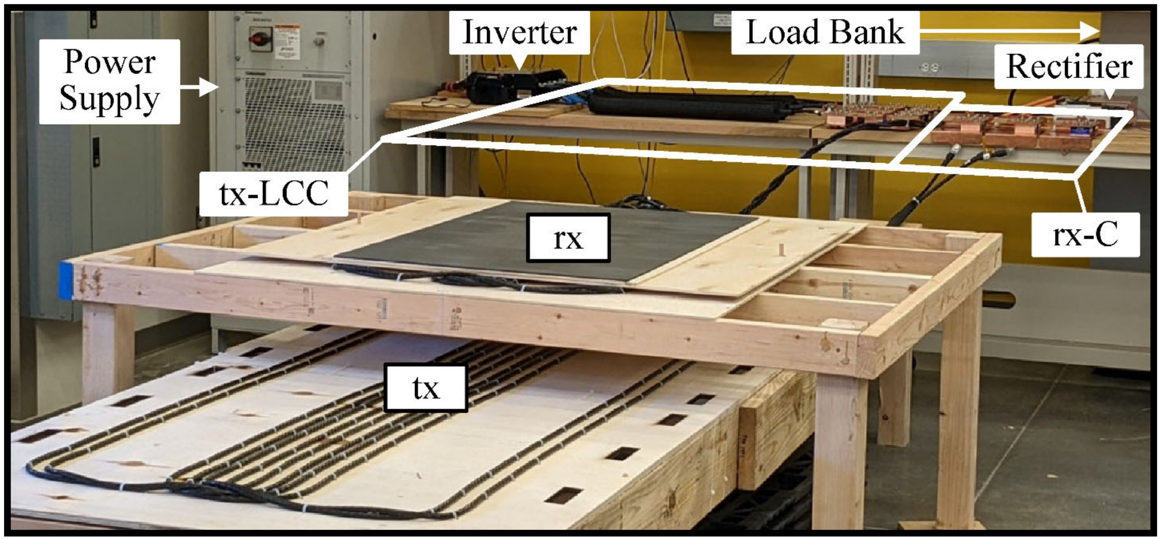
- High power required rethinking transmitter/receiver system
  - Purdue established a new three-phase planar DWPT topology
    - Reduces oscillations in power
    - Less stress on components compared to single-phase designs
    - Power scales with receiver length – interoperability across vehicle classes

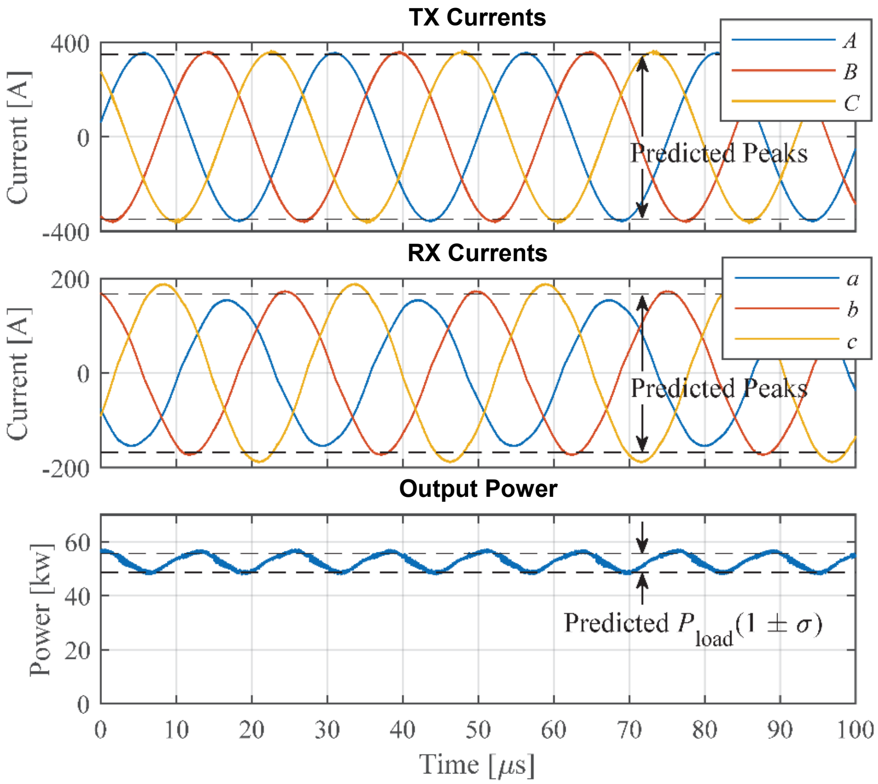
Purdue planar three-phase receiver



Purdue planar three-phase transmitter

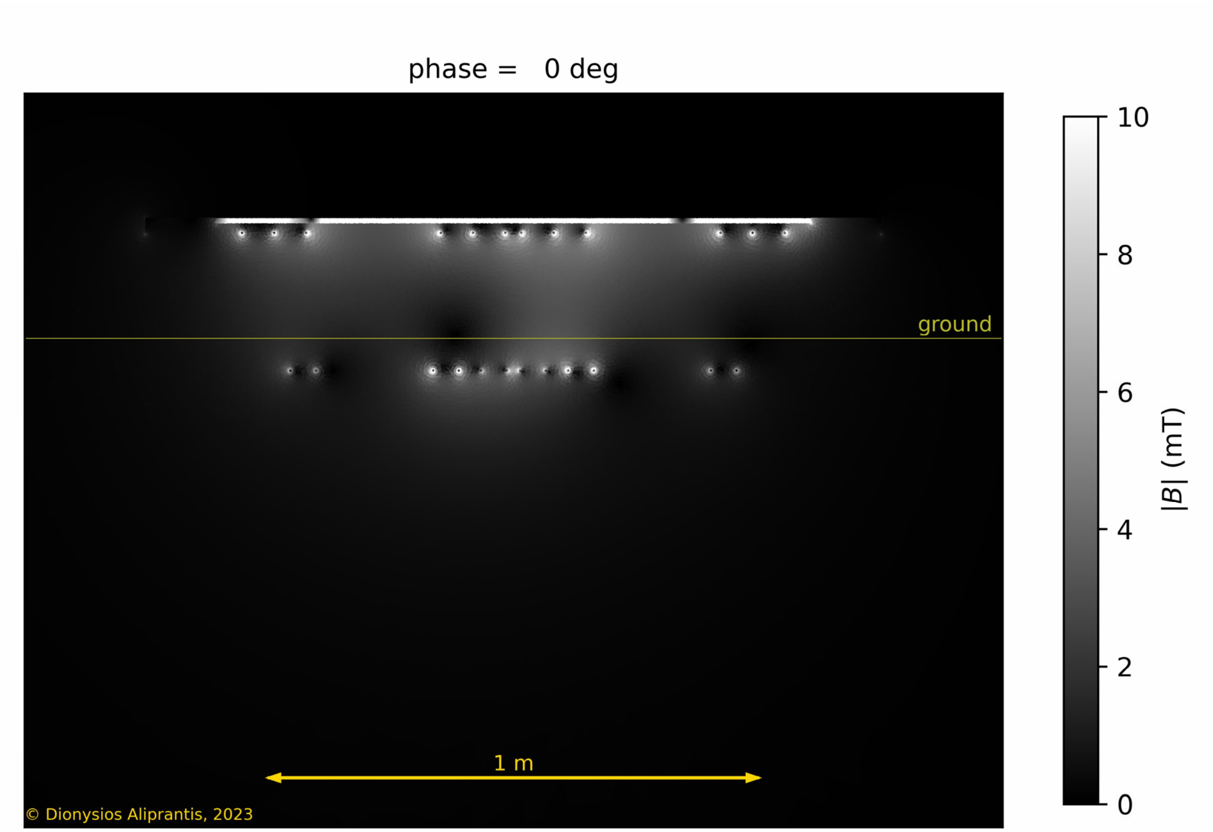
Validation in Purdue Laboratory





- Transmitter/receiver instantiation relatively straightforward
- No magnetic material in roadway
- Meets expected performance
  - Low power ripple
  - Nearly balanced phase currents

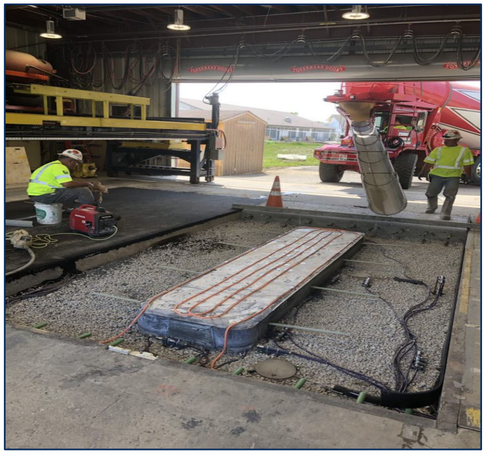
View of the Magnetic Field



Elmore Family School of Electrical and Computer Engineering

Magnetic field animations

Structural and Thermal Assessment at APT Facility

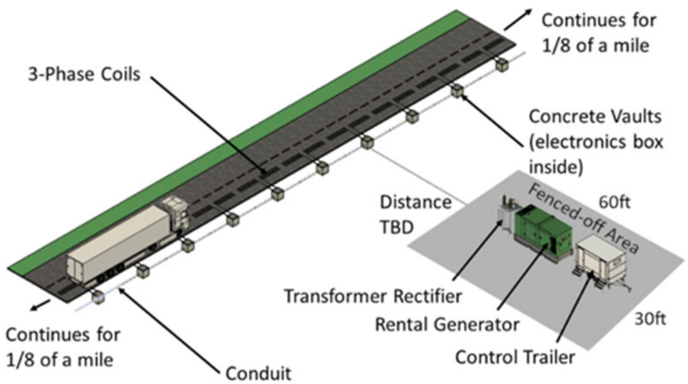


- Constructed two small-scale pavements (**flexible** and **rigid)** with embedded DWPT components in the Accelerated Pavement Test (APT) facility.

- 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.

Indiana Pilot Project Overview



Purpose of IN Pilot

- Validate model predictions
- Establish/demonstrate relatively straightforward 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 IN business, health, environment

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

Spring 2024

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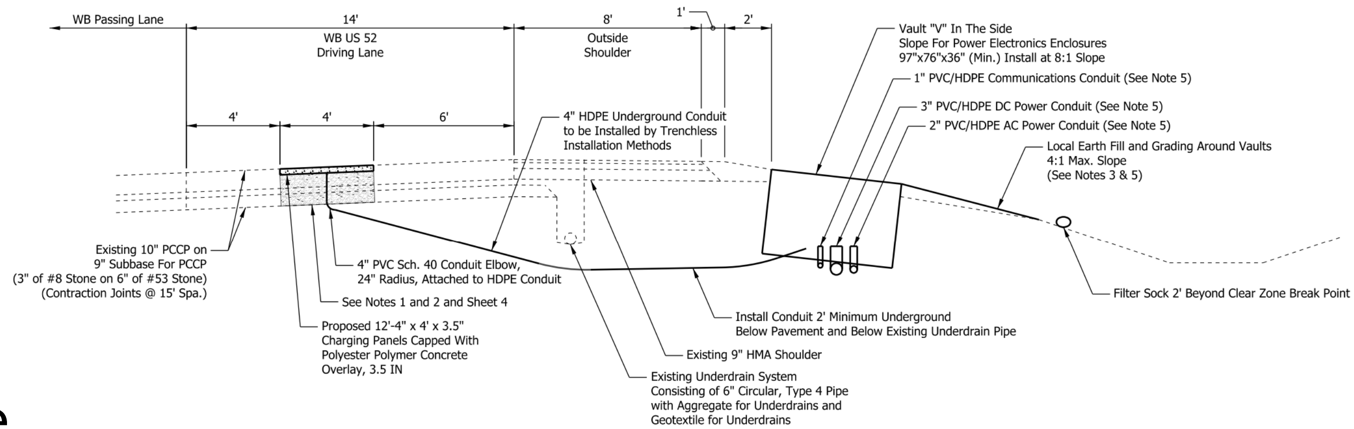
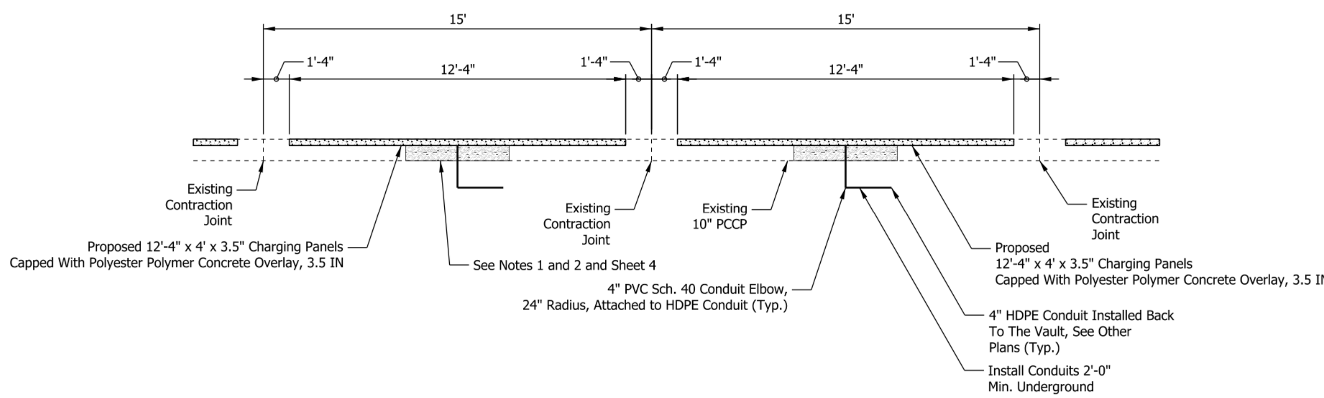
Pilot Design

- Existing PCCP roadway
- Micro-milling & 4 ft square pavement removal for coils and conduit
- Polyester polymer concrete patch & overlay
- Directional bored conduit
- Vaults in foreslope



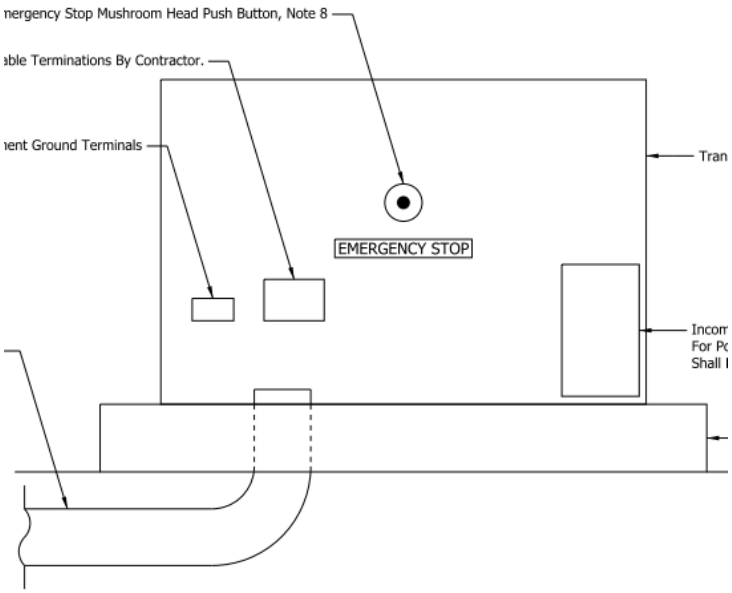
Typical Section - US 52
Sta. 100+00 to Sta. 115+00 Line "A"



Side View - US 52

Additional Details

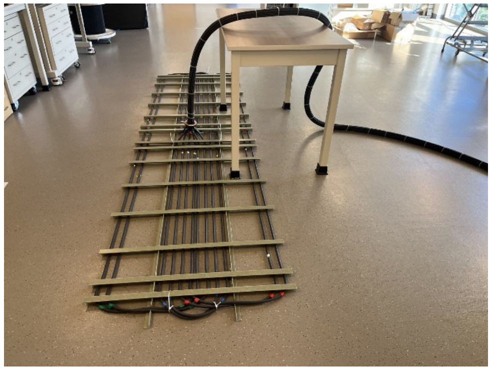
- Addressed wiring, electrical, safety needs
- Traffic control using signs, lane barriers, flagging
- Waters and wetlands investigation
- Roadway monitoring and testing plan
- Specifications for transmitter, electrical components, transformer/rectifier
- Acceptance testing



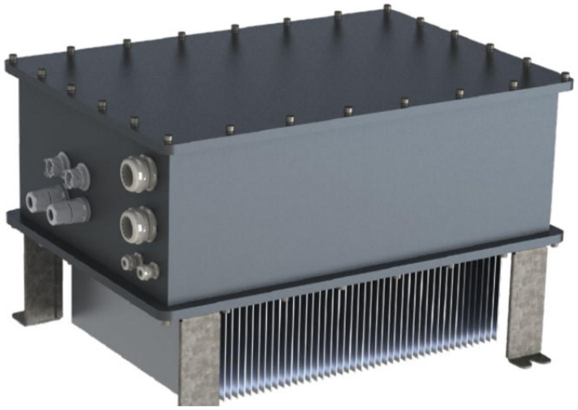
Initial Progress

- Developed rail-rung installation system that has been transferred to contractors
  - White Construction (Clinton, IN)
- Preliminary design review (PDR) of roadway electronics (12/7/23)
  - P.C. Krause and Associates (Indianapolis, IN)
- Development of receiver (vehicle)
  - Cummins (Columbus, IN)

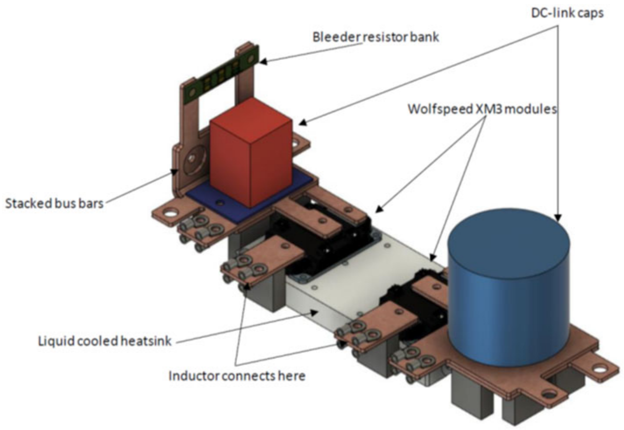
Cummins test vehicle



Rail-rung transmitter coil instantiation



Transmitter electronics (P.C.K.A)



Receiver electronics

Engagement/Outreach Efforts

Public/Community Engagement

Examine the surrounding community's perceptions and concerns before/during/ and post construction of the testbed

Working with INDOT Communications

Developed flyers & surveys

Blog, https://kim3432.wixsite.com/dynamic-wireless-pow/post/analyzing-the-safety-of-three-phase-dynamic-wireless-power-transfer

Internal Education Activities

Presentations to District/Central Office

FAQs

What are "electric roadways"?

Most EVs charge by plugging them in before you drive. New technology will let the EV charge through the road as they drive. The pavement uses big wireless chargers to send power to an EV with magnetic fields. This lets it charge its battery wirelessly without needing to stop.

Are electric roadways safe for my family?

EVs don't have tailpipes that spew harmful pollutants and cause health problems in adults and children [1-3]. In addition, wireless chargers can't electrocute you and only emit magnetic fields that are safe around people [4]. In case of emergency, electric roads come with multiple safety systems, including automatic shutoff sensors.

[1] ASPIRE USU. (2022). Frequently Asked Questions – ASPIRE. https://aspire.usu.edu/about/frequently-asked-questions/

[2] Gent, J. F., Triche, E. W., Holford, T. R., Belanger, K., Bracken, M. B., Beckett, W. S., and Leaderer, B. P. (2014). "in Children With Asthma." 290(14), 1859–1867.

[3] Bell, M. L., Mcdermott, A., Zeger, S. L., and Samet, J. M. (2004). "in 95 US Urban Communities , 1987-2000." Forestry, 292(19), 2372–2378.

[4] Sealy, Ky (2022). Analyzing the Safety of Wireless Electric Vehicle Charging. https://www.innovationnewsnetwork.com/analysing-safety-wireless-electric-vehicle-charging/20502/

FAQs

I don't have an EV. Will electric roadways benefit me?

Yes! In addition to making air cleaner, funding public charging infrastructure like roadways makes it cheaper to own an EV. Private at-home chargers currently add a lot of cost to EV ownership, but public chargers will make EVs more affordable and accessible [1].

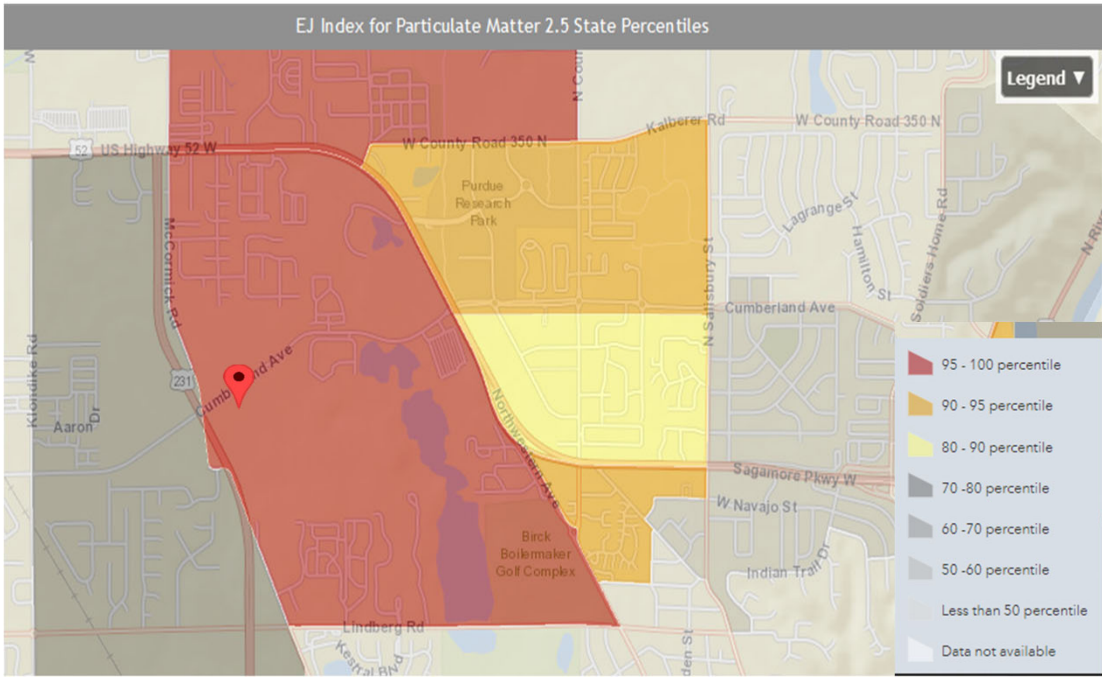
Will electric roadways cost me?

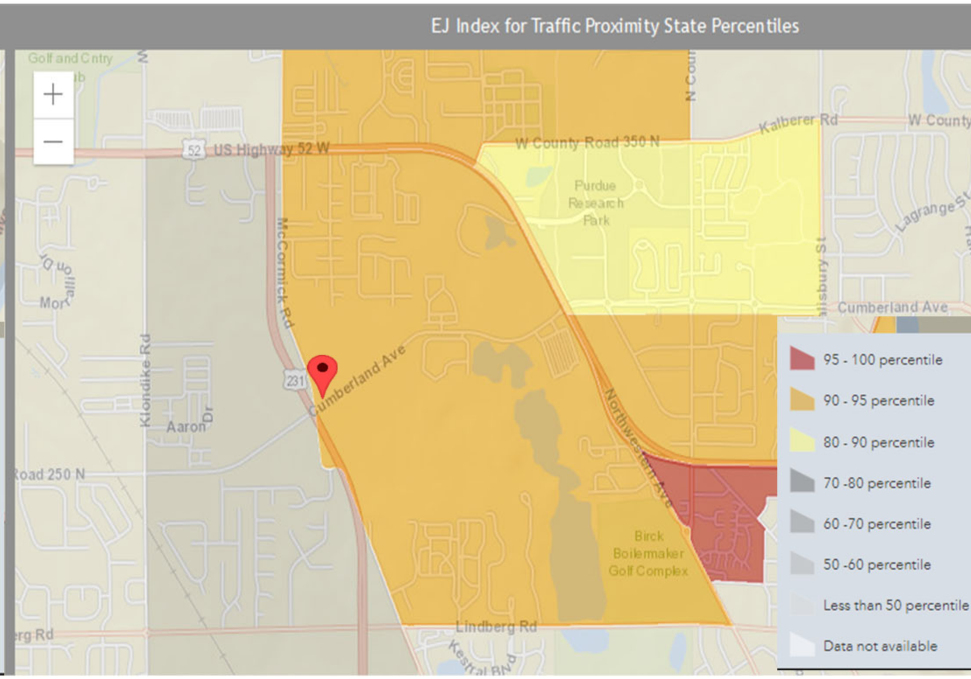
Public roads are currently subsidized through a gas tax. Indiana drivers currently pay $0.17/gallon [5]. As EVs become popular, this source of funding will be phased out, and drivers and communities will subsidize electric roads instead. This will provide money that ensures safer roads with cleaner air. By making chargers, owning EVs becomes cheaper for you, transit agencies, school districts, and more [1].

[1] ASPIRE USU. (2022). Frequently Asked Questions – ASPIRE. https://aspire.usu.edu/about/frequently-asked-questions/

[5] Indiana Department of Revenue (2023). Gasoline Use Tax Rate. https://www.in.gov/dor/files/dn02.pdf

Environmental Justice Near the Pilot





Particle pollution, also called Particulate Matter (PM). $PM_{2.5}$ describes fine inhalable particles, with diameters that are generally 2.5 micrometers and smaller.

Traffic proximity and volume: Count of vehicles at major roads within 500 meters, divided by distance in meters

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