Electrification of Transport

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Development of Inductive Power Transfer (IPT) Roadway Transportation Systems

- Electrification of road transport: benefit of reducing emissions
- The overall EV% is still miniscule
- Barriers: *Range anxiety factor & high upfront purchase cost (dollars of batteries)* etc.

**Inductive Power Transfer Technology = Wireless transfer of Power**

(Zaheer and Covic, 2016)

2. Research Project 3723897, 2021 – 2026, MBIE Endeavour Fund 2021 - 2026
Why would one invest in wireless charging technology?

EV & AV Market outlook in 2035: [1]

- EVs: 16% of the LDV market (GlobalData)
- AVs: 25% market share of new car market
- 12M fully autonomous cars/year
- 18M partially autonomous cars/year
- Total AV market: 77 billion USD

Why wireless charging?

• Wireless charging allows self-driving EVs to recharge autonomously
  o “Who will plug in your self-driving car?” No one!

• Wireless charging simplifies the use of EVs
  o Reduces range anxiety, promoting EV adoption
  o Unique selling point of EVs

→ Wireless charging is essential for future automotive industry
Charging Solutions

Plug-in charging (PC)

Wireless charging (WC)

Stationary Wireless Charging (SWC)

Semi-Dynamic Wireless Charging (SDWC)

Dynamic Wireless charging (DWC)
Wireless charging – IPT

- Inductive Power Transfer (IPT) system (Zaheer and Covic, 2016): EVs can be energised wirelessly by embedding a wireless charging system.
IPT infrastructure for EVs

The Evolution of Qualcomm Halo
Wireless charging implementation

- Major technologies for commercialisation
- Wireless charging research labs and commercial licensing arm of the UoA
Growing interests from the Academia

Number of publications and patents per year related to wireless charging for EVs[1]

- Introduction of Nissan Leaf & the Tesla Roadster around 2008 until 2010, massive trend towards EVs & WC

Some performance figures: [1]

Conductive charging
- Up to 95% efficiency
- Up to 5 kW/dm³

Inductive energy transfer
- Up to 92% efficiency
- realise 1.5-2.5 kW/dm³

Wireless charging:
- A technological compromise - air gaps
- Trade-off: transmitter/receiver volume & the transmission efficiency.

Designing the “best” wireless chargers!

• Multi-physical
  – Power electronics
  – Electromagnetics
  – Control systems
  – Mechanics
  – Electromagnetic compatibility

• Multi-objective
  – System cost
  – Converter size
  – Transmission efficiency
  – Transmission range
  – System reliability

• Multi-mode
  – LDV
  – MDV
  – HDV

The best wireless charger is the **best mix** of all properties
→ Highly application-specific
→ Pareto-optimal design methods required
→ Optimisation cost-functions to be defined
More research needed

Research questions for wireless charging:

- Positioning of car exactly on top of charging pad?
- Communication from vehicle to ground? (no wires!)
- Detecting foreign objects (key) in air gap?
- Detecting living creatures (cat) in air gap?
- Electromagnetic compatibility?
- Mechanical issues: strength, heat, weather-proof?
- Health issues? Security? Safety?
- NZ should take the lead in this direction!

(1) FLIR image from WiseHarbor Spotlight Report, sept. 2015
IPT Roadway Project Team

Research Team:
- University of Auckland: Power Electronics & Inductive Power Research, Centre for Advanced Composites Materials, Transportation, Engineering Science, Business School
- GNS Science, Wellington
- Victoria University of Wellington, Robinson Research Institute
Optimisation Modelling & Economic Evaluation for Roadway IPT Implementation (LDV, MDV & HDV)

1. Optimise placement strategies to maximise network efficiency and benefit
2. Optimise strategies for sustainable implementation of roadway IPT
3. Evaluation of potential economic and environmental benefits of faster EV take-up through roadway IPT implementation
4. Engagement with Iwi to improve economic & sustainability outcomes

From left to right: A Prof Doug Wilson (CEE); Dr Prakash Ranjitkar (CEE); Dr Tumanako Fa’au (CEE); Prof Basil Sharp (EC); Dr Selena Sheng (EC); Dr Andrea Raith (ES); Dr Minh Kieu (CEE); Mr Ramesh Majhi
University joins global consortium for vehicle electrification

6 August 2020 | Faculty of Engineering, Science and technology

Work at the University of Auckland will play a significant role following this week’s launch of the National Science Foundation (NSF)-funded Engineering Research Centre for Electrified Transportation in Utah, USA.

"Sustainable, electrified transportation and the enabling technologies that support this, such as the electrified road, are key to the global future."

Professor Dawn Freshwater
Research Methodology/Scenarios

Simulation Model Scenarios

- EV characteristics Based
  - SOC State
    - Threshold – 20%
    - Recommended level (40-80 percent)
  - EV Category
    - Car
    - Public Transit – Bus
  - EV Range
    - Small (<150 km)
    - Medium (150-250 km)
    - High (>250 km)

- EV user Based
  - Route choice Behavior
    - Exclusive path
    - Shared path
    - Single route
    - Multiple route
      - Travel Time
      - Presence of charging facility
      - Presence of toll

- EV demand Based
  - Charging lane Behavior
    - O-D route
    - SOC level, driving experience
  - EV Trip Demand
    - 40%, 50%, 60% of HBW Trips
  - Total Trip projection
    - Current trip (2016 O-D Data)
    - By 2026 and 2036
  - IPT Characteristics
    - Slow (<20 kW)
    - Medium (20 kW-100 kW)
    - High (>100 kW)
    - Efficiency (70%, 80%, 90%)
Project 1: Auckland Motorway SH1 Corridor

Case Study

- A microscopic traffic simulation model - AIMSUN
- Calibrated & validated based on 2016 data
- Only light fleet are considered - Nissan Leaf 2011 model
- DWC scenarios for different energy parameters & traffic flow conditions
- Optimal placement of the IPT facility on a larger road network
Findings and future works

-ve relationship:
- Length of charging sections & Energy demand
- DWC power supply & energy transfer efficiency
Project 2: Bus Route 70 – Botany to Britomart

Simulation Map in SUMO
Methodology
Average speed of 95 buses trips

- Speed_0veh/hr
- Speed_200veh/hr
- Speed_500veh/hr
- Bus Stop location
Main findings

• Battery size: 219 kWh complete the trip; no charging

• -ve correlation between velocity of the bus & the SOC

• Largest costs:
  
  1) Variable cost associated with the length of the charging transmitters
  
  2) Battery size

• Capital intensive - multiple services using the same route
Project 3: EV, Public Charging Facilities and Early Adoption Effect

Main factors

- Availability of Public chargers (2018 & 2020)
- Distance to CBD
- Transport mode
- Vehicle ownership
- Social and economic factors

Figure 3 - Number of Electric Vehicles adoption
Main Tests

• **Spatial autocorrelation**: to test if EV-charging infrastructure has a “neighbourhood effect” on EV uptake

• **Marginal effects**: to examine if EV adoption by technology enthusiasts during the early-adopter phase could affect subsequent adoption once the technology becomes more widely spread
Project 4: EV, Public Charging Facilities & Solar Potential (with Vector) - Data matching

EV data from MoT
- 148 area units
- Aggregated format

PV data from Vector
- 533 SA units
- standard ‘sa22018_v1_00_name’ by StatsNZ for (GIS)

1. Name sorting

<table>
<thead>
<tr>
<th>EV Areaunit</th>
<th>PV SAA name</th>
<th>PV count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albany</td>
<td>Albany Central</td>
<td>1</td>
</tr>
<tr>
<td>Albany</td>
<td>Albany Heights</td>
<td>12</td>
</tr>
<tr>
<td>Albany</td>
<td>Albany South</td>
<td>17</td>
</tr>
<tr>
<td>Albany</td>
<td>Albany West</td>
<td>7</td>
</tr>
</tbody>
</table>

2. QGIS to manually check overlapping areas

Solar potential effects: to test if the availability of PV panels has any impact on EV uptake
A feasibility study of solar PV-powered electric cars using an interdisciplinary modeling approach for the electricity balance, CO₂ emissions, and economic aspects: The cases of The Netherlands, Norway, Brazil, and Australia

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Abstract
Solar vehicles (SVs) are becoming increasingly attractive option to electric vehicles and economically offer lower global fuel consumption as well as CO₂ emissions associated with vehicle transportation. In general, the grid provides the electric energy which is essential for the charging of the electric vehicles. However, it is crucial to consider the different aspects of the electric vehicle (EV) charging network, such as the power generation, transportation, and distribution. This study aims to investigate the feasibility of solar PV-powered electric vehicles (SVP-EV) in different countries: Brazil, China, France, and the United Kingdom, with different levels of electricity generation and distribution. The findings of this study are of importance to the electrical grid operators, policymakers, and stakeholders for the optimal design and implementation of the solar PV charging network.

Key words
Solar, PV system, Electric vehicles, Economic analysis, CO₂ emissions, Grid energy efficiency

Short Communication
The integration of renewable energy sources and electric vehicles into the power system of the Dubrovnik region

Anamari Senić,1,2 Gorko Kojadinovic,1,2 Ivo Preluk,1 and Neven Dočić1

Abstract
In order to reduce greenhouse gas emissions, governments seek to replace fossil fuel by renewable energy. Therefore, more attention is given to electric vehicles in transport systems and the use of renewable energy in the power system. The aim of this study is to achieve 100% renewable and sustainable energy systems and to optimize the use of electricity in the transport sector. This study investigates the impact of renewable energy sources on the power system and the integration of renewable energy into the power systems of the Dubrovnik region until 2050.

Keywords
Renewable energy, Electric vehicles, Energy system, Power grid, Integration of renewable energy sources

Economic and environmental impacts of a PV powered workplace parking garage charging station

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Abstract
The use of photovoltaic (PV) based electric vehicle charging stations is an important tool for reducing greenhouse gas emissions in the transport sector. This study investigates the environmental and economic impact of photovoltaic (PV) based electric vehicle charging stations on the transport sector in a workplace parking garage in Florida. The results show the impact of PV-based workplace charging on the electricity consumption and emissions from the power grid. The findings suggest that integration of the electric charging system into the workplace parking garage is an effective way to reduce greenhouse gas emissions and improve energy efficiency. The results also highlight the potential benefits of using PV-based charging stations for reducing electricity consumption and emissions, which can contribute to a more sustainable and environmentally friendly transport sector.
Discussions

• Solar panels: +ve relationship with EV adoption
• Sustainable tech can be integrated into homes
• The use of smart metering technology in the residential charging systems
• Behaviour change programs
• Co-ordinated national program
• Investment wise - PPP?
Project 5: Existing/Prospective EV User’s Survey

1. Personal vehicles and travel patterns
2. Attitudes toward pure EVs
3. New Zealand’s Clean Car Discount - Financial incentive policy
4. EV Charging systems (Pure EV user only)/(Non-pure EV users only)
5. Demographic Questions

With wireless charging equipped on a pure EV in the future, it will also be possible to charge wirelessly at high efficiency when driving along selected charging lanes on a highway to keep your battery in a good state of charge and increase your range.

Figures 1 & 2 – examples of wireless charging roadways for pure EVs.

e) Prior to this survey, to what extent were you aware of wireless charging technologies and their benefits?
☐ Very
☐ Somewhat
☐ Not at all
Takeaway messages

• Transport system is a system of systems

• A widespread transition to e-mobility and introduction of congestion tax is economically feasible – but socially & politically desirable?

  ➢ Planned and strategic infrastructure network critical to supporting regional EV drivers

  ➢ “Chicken & Egg”?

• FCEV vs. EV? Hybrid trucks vs. e-trucks?

• Urban policy-making: priorities?
A selection of our works (2021-2022)


Thank you!

Source: The Economist, 2017

Questions?