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Feasibility analysis and development of on-road charging solutions for future electric vehicles

Towards new infrastructure materials for on-the-road charging

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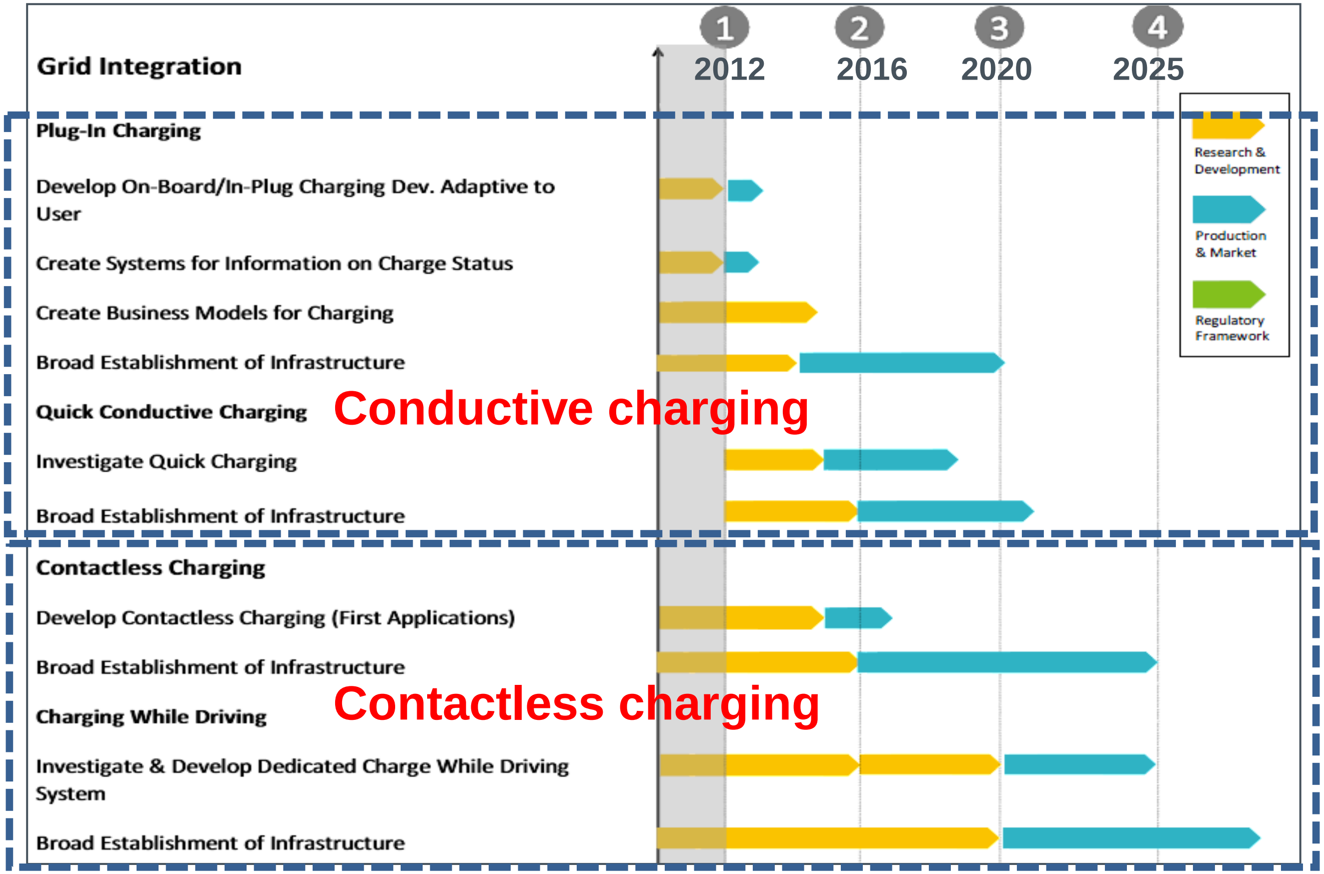
IEVC, Florence, 19th Dec. 2014

Outline

- ❑ Introduction
  - Different Charging solutions
- ❑ Wireless Power Transfer (WPT) Solution
- ❑ Challenges from the road infrastructural perspective
  - Structure and maintenance
  - Road materials→ Electromagnetic loss
  - Environment

1. Introduction

- Electrification of Roads- Charging solutions



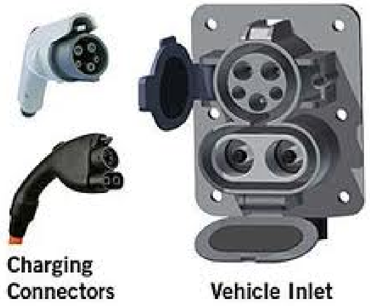
Charging infrastructure (European Roadmap,2012)

1. Introduction

- Conductive Charging solution

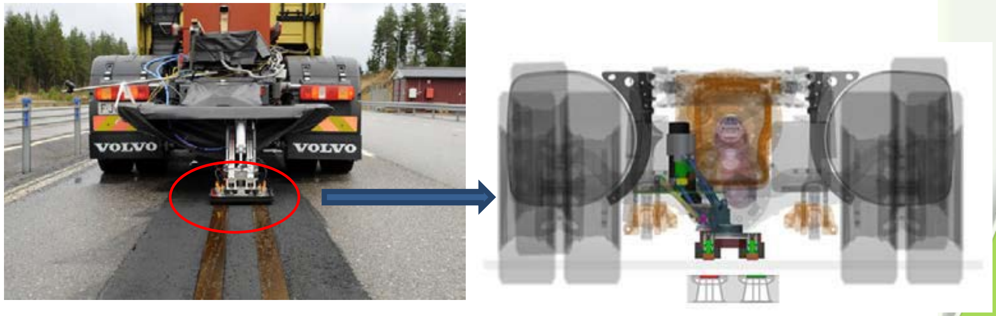
Light cars

Plug-in charging devices



Heavy trucks

Scania test site



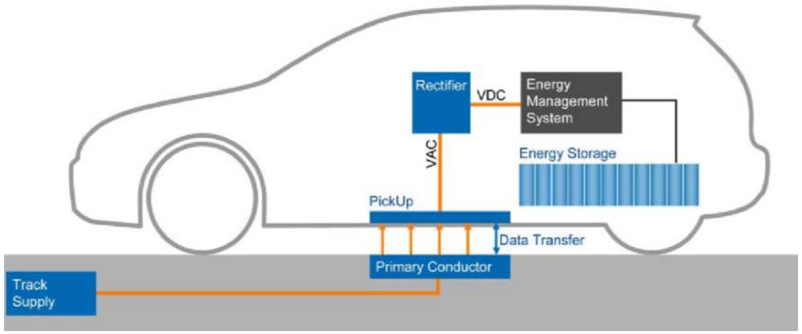
Volvo test track

1. Introduction

❑ Contactless Charging solution

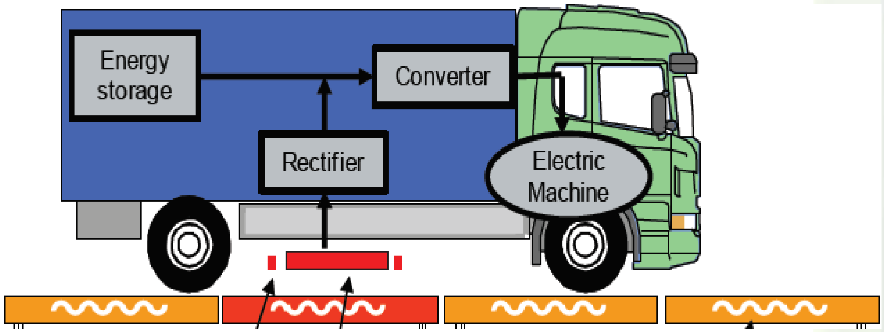
Static way

- Transmission performance 3,3 kW
- Frequency 140 (+50 kHz / -20 kHz)
- Air gap 50 - 170 mm
- Max. length x wide: 1m x 1m (both)
- Efficiency ≥ 90 % (at 135 mm air gap)
- Positioning tolerance: ± 100 mm
- Positioning support



Project German DKE GAK 353.01, 2013

Dynamic way



BOMBARDIER test site, Mannheim, DE

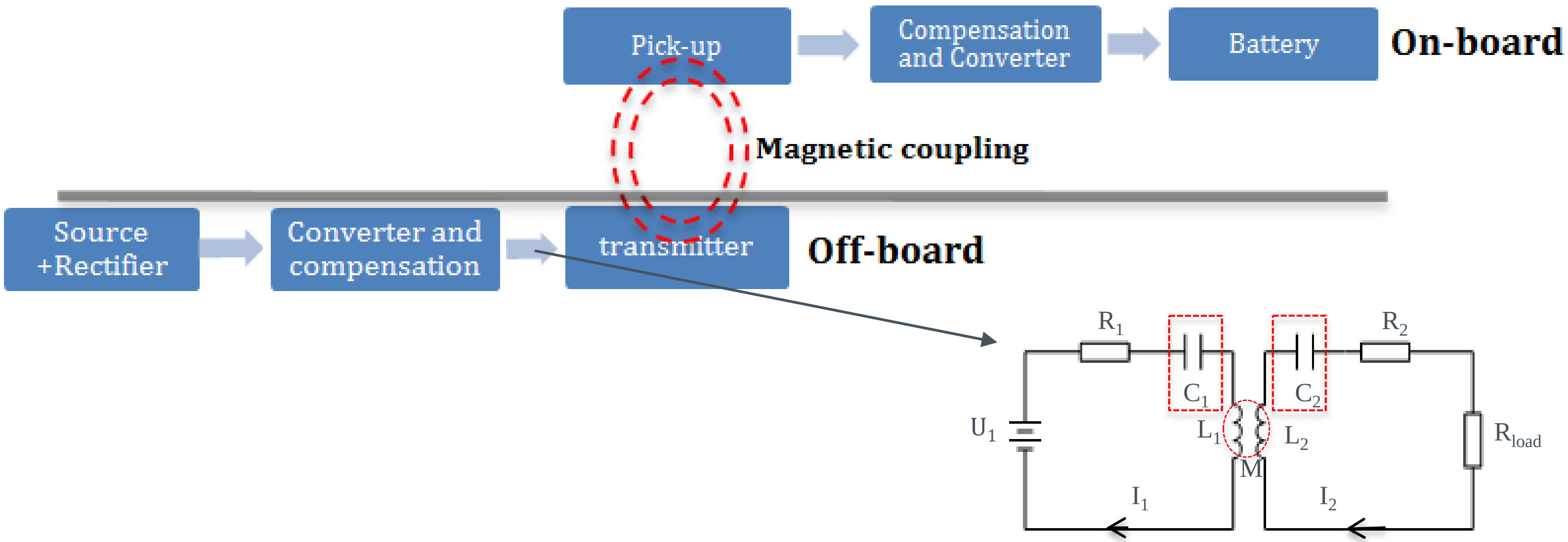
Favourite choice for Electrified-Road!!!

❖ Opportunities:

- Eliminate the limitations (cost and range);
- More convenient and possibly safer;
- Lower energy cost;
- Integrate renewable resources (wind, solar).

2. Wireless Power Transfer (WPT) Solution

- Inductive Power Transfer (IPT) technology



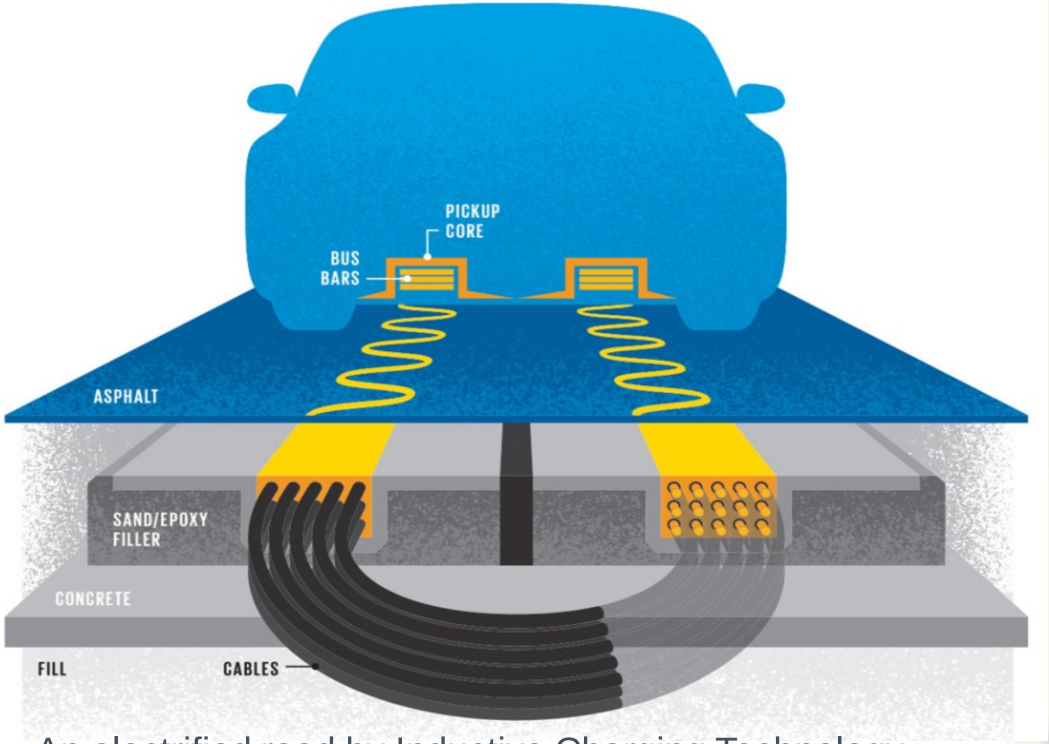
Rectifier: DC output voltage
Converter: to achieve high output frequencies
Compensation: a capacitance to reduce the switching losses

$$Resonance: C_1 = \frac{1}{\omega_0^2 L_1}, C_2 = \frac{1}{\omega_0^2 L_2}$$

3. Road infrastructure

❑ Challenges for an Electrified Road

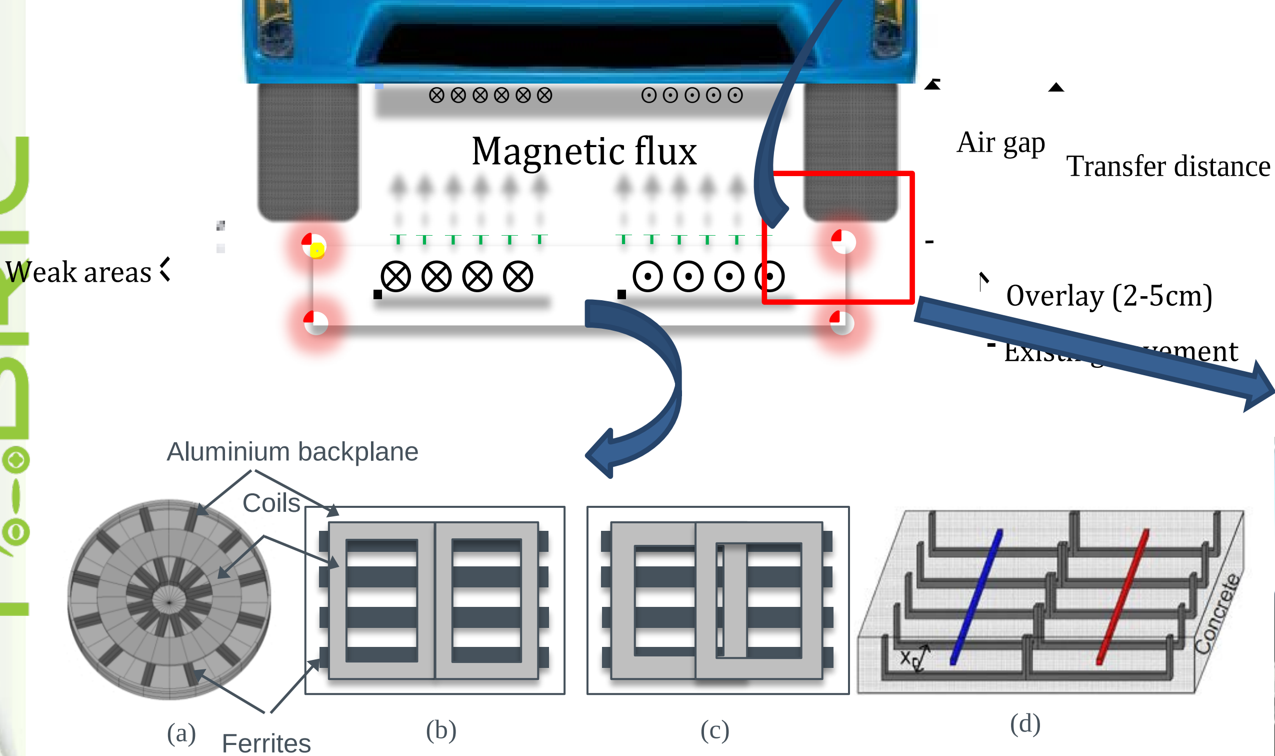
- **Structure**
- **Material**
- **Environment**



An electrified road by Inductive Charging Technology (PATH, 1994)

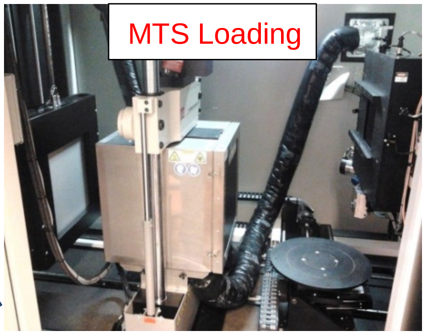
3. Road infrastructure

- Structural integrity



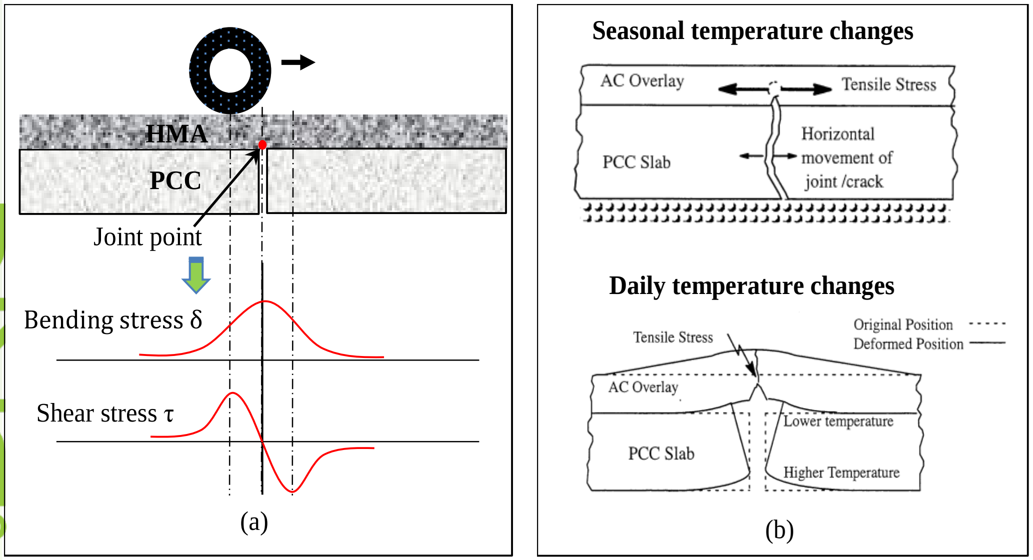
Cracking

Rutting



3. Road infrastructure

- Structural integrity



Example: failure mechanisms of HMA overlay due to: (a) Traffic and (b) Environment

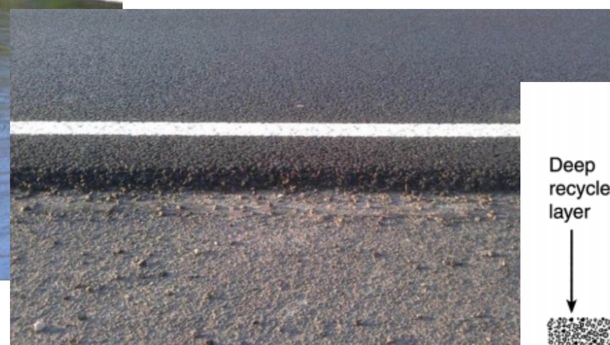
Structural improvement methods	
Overlay systems	Increased thickness
	Reinforced HMA materials
	Open graded structure
Closed Joint systems	Joint materials
	Geometry design
Interlayer systems	Stress absorbing membrane interlayer
	Geosynthetics interlayers
	Reinforcement interlayers

3. Road infrastructure

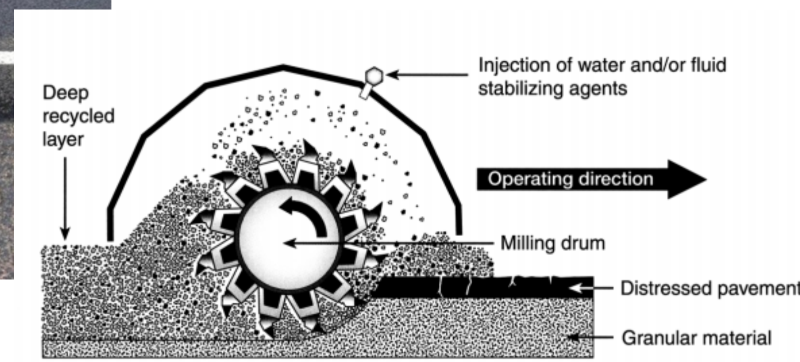
- Long term maintenance principles

Periodic activities

Resurfacing



Large rehabilitation



What about the electrified road?

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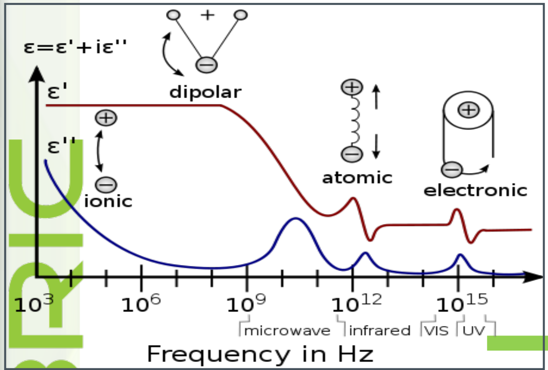
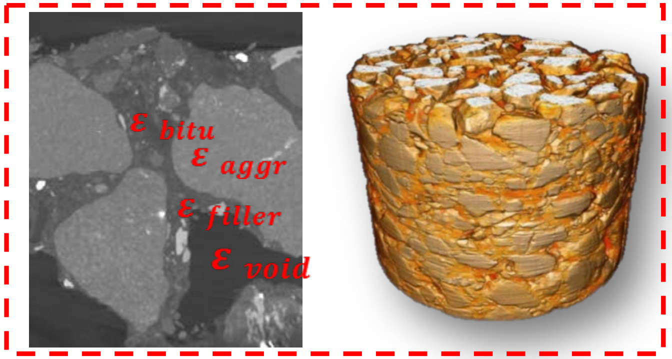
3. Road infrastructure

❑ Road materials → Electromagnetic loss

Permittivity: $\varepsilon = \varepsilon' + i\varepsilon''$



HP 4284A Precision LCR Meter, 20 Hz to 1 MHz



Permittivity $\varepsilon = \varepsilon' + i\varepsilon''$

$P_{loss} = F(\varepsilon'', \omega, t, h, f, I,)$

Mixing models

CRI model $\varepsilon_{eff}^{\beta} = v\varepsilon_e^{\beta} + (1-v)\varepsilon_m^{\beta}$

LLL model $\varepsilon_{eff}^{\beta} = v\varepsilon_e^{\beta} + (1-v)\varepsilon_m^{\beta}$

Lichtenecker model $\varepsilon_{eff} = \varepsilon_e^{v}\varepsilon_m^{1-v}$

Chieh-Min model $\varepsilon_{eff} = c\left(\sum_{i=1}^{n} v_i \varepsilon_i^{\alpha}\right)^{\beta} + k$

SK model $\varepsilon_{eff} = \varepsilon_m + \dfrac{\sum_{i=1}^{n} v_i(\varepsilon_i - \varepsilon_m)\dfrac{3\varepsilon_m}{\varepsilon_i + 3\varepsilon_m}}{1 - \sum_{i=1}^{n} v_i \dfrac{\varepsilon_i - \varepsilon_m}{\varepsilon_i + 2\varepsilon_m}}$

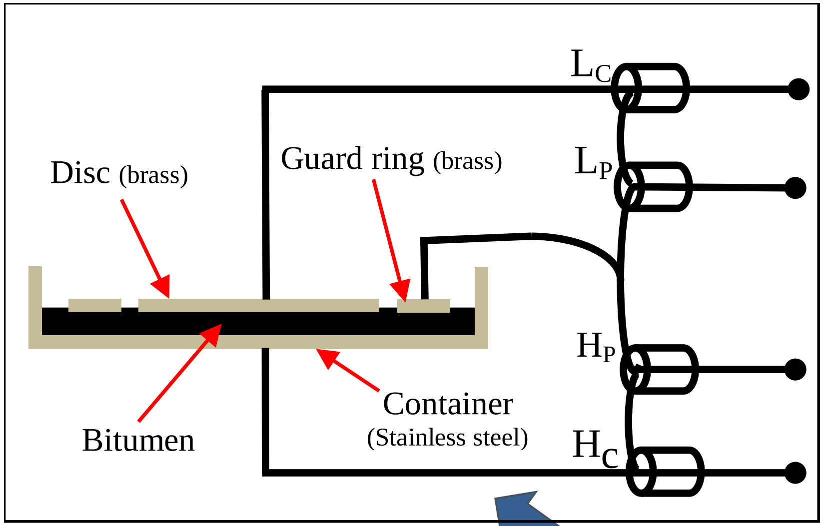
P&I model

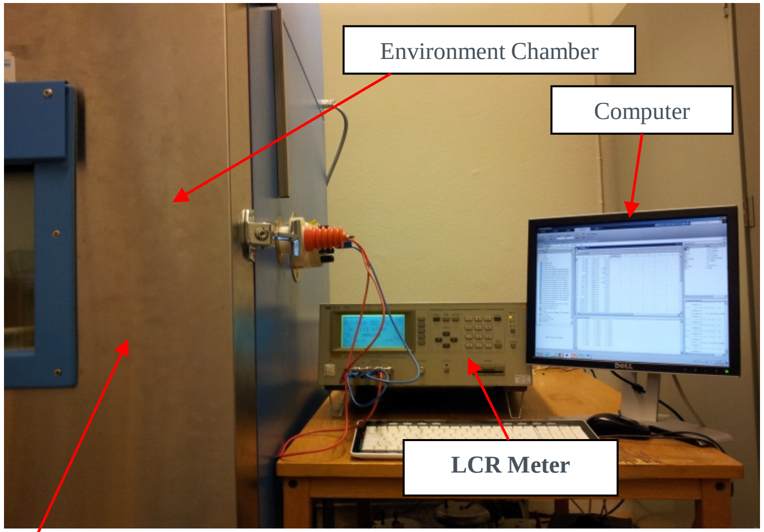
$$\varepsilon' = \sum_{i=1}^{n} v_i \varepsilon'_i + \begin{cases} \sum_{i=1}^{n-1}\sum_{j=i+1}^{n} v_i v_j (\varepsilon'_i - \varepsilon'_j) & for\, \varepsilon'_i \geq \varepsilon'_j \\ \sum_{i=1}^{n-1}\sum_{j=i+1}^{n} v_i v_j (\varepsilon'_j - \varepsilon'_i) & for\, \varepsilon'_i \leq \varepsilon'_j \end{cases}$$

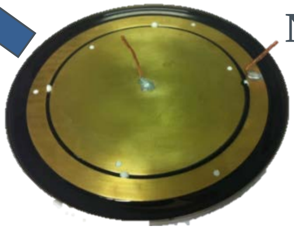
Where, ε'' - the permittivity loss part of road material; ω - the water content; t - temperature; h - thickness; f & I - working frequency & Current.

3. Road infrastructure

- Road materials → Electromagnetic loss
  - Example: Permittivity test of bitumen 70/100



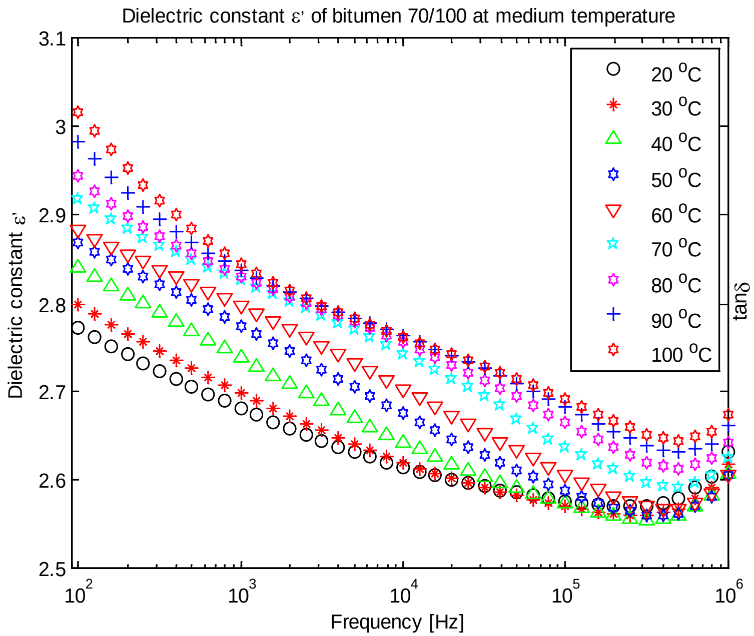


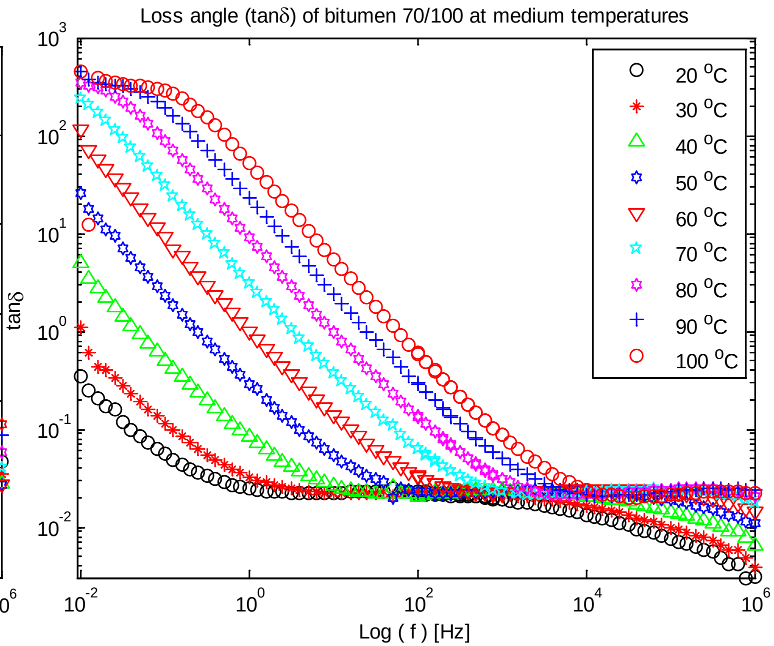


Novel Test Cell inside

3. Road infrastructure

- Road materials → Electromagnetic loss
  - Example: Permittivity test of bitumen 70/100 (tanδ=ε''/ε')



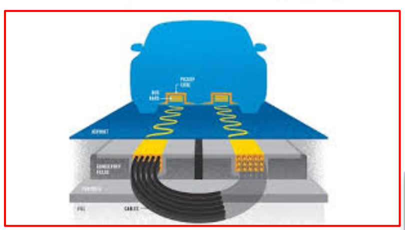


  - Permittivity of other road material components will be tested and influence factors e.g. water will be included.
  - EM loss estimation and control will be studied.

3. Road infrastructure

- Environmental performance

Electric Vehicle	?	Conventional ICE Vehicle
Fuel	>	Fuel
Vehicle	<	Vehicle
charging infrastructure	?	Petrol/gas stations



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Thank you!

- To be continued….

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