TETRA-project DEO
Draadloze EnergieOverdracht

Kick-off meeting

22/10/2024

VLAIO

Universiteit Antwerpen

KU LEUVEN

Agenda

1. Presentation consortium UAntwerpen & KU Leuven
2. Introduction to VLAIO-TETRA
3. DEO project: goal and work-packages
4. Introduction capacitive power transfer

5. Coffee break & demo

6. Introduction inductive power transfer
7. Interaction with the advisory board
8. Q&A

Agenda

Presentation consortium UAntwerpen & KU Leuven

Introduction to VLAIO-TETRA

DEO project: goal and work-packages

Introduction capacitive power transfer

Coffee break & demo

Introduction inductive power transfer

Interaction with the advisory board

Q&A

UAntwerpen – Research group Cosys-Lab

- Investigates the Co-Design for Cyber-Physical Systems
  - Sensors, embedded systems, control engineering, electromechanics, energy…
- 7 Professors, 1 valorisation manager, 4 post-docs, 30 PhD-students
- From fundamental to applied research
- Education: Industrial engineer

UAntwerpen – Research group Cosys-Lab – Division “Energy”

- 4 PhD students active on wireless power transfer

Ben Minnaert

Hamed Farbakhsh

Aris van Ieperen

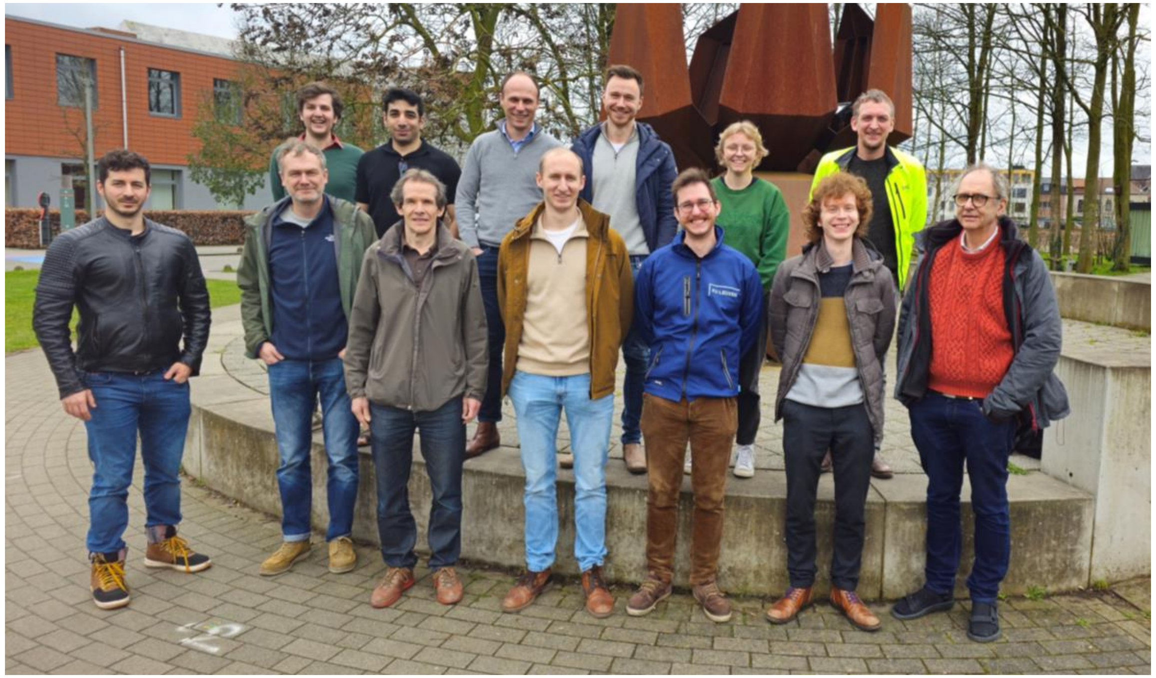
Kiran Peirens

TETRA DEO-project

Baptist Elst

KU Leuven – Research Group Electa Ghent

- Investigates Solar Energy, Energy Storage, Distribution Grids, Electrical mobility, Applied Power Electronics
- 3 professors, 2 Postdocs, 10 researchers
- Fundamental and applied research
- part of ELECTA (Leuven) and Energyville (Genk)



KU Leuven – projectteam TETRA DEO

Prof. Michael Kleemann

Dr. Cédric Lecluyse

MSc. Arthur Cloet

Competencies of the projectteam

Universiteit Antwerpen

KU LEUVEN

“Low-Power”

< 50 W

- electronics
- sensors
- embedded systems

“High-Power”

> 50 W

- energy
- power electronics
- distribution grids

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Companies and collaboration

Q&A

TETRA-programma

Programma voor

- **praktijkgericht onderzoek**

  door

- **hogescholen**
- **geïntegreerde opleidingen in de universiteiten**

  minstens 2/3 begroting

- Onderzoeksgroepen en -organisaties (EU-definitie!)
- grote onderaannemer(s): samen max 10% begroting

  voor

- **ruime doelgroep Vlaamse, pref. niet-R&D intensieve ondernemingen & social profit organisaties**
- **kennis stroomt door naar het onderwijs**

Bron: VLAIO

Doel TETRA-project

- Stimuleren van kennisoverdracht
- Brugfunctie tussen nieuwe technologie of recent afgewerkt onderzoek en concrete toepassings-mogelijkheden
- Vertaling en transfer van bestaande kennis
  - Projectresultaten op korte termijn na afloop van het project bruikbaar zodat de doelgroep sneller en efficiënter kan innoveren
  - Projectresultaten geven aanleiding tot economische (en maatschappelijke) voordelen bij de doelgroep
  - Meerwaarde voor de studenten

Bron: VLAIO

Eigendom en valorisatie van de resultaten

- **cfr. Europese kaderregeling inzake staatssteun**

- **Eigenaar van de projectresultaten =**
  projectconsortium (hoofdaanvrager + partner(s))

- Algemene inzichten → ruime verspreiding

- Economisch valoriseerbare resultaten
  → transfer van eigendoms- of gebruiksrechten (licenties)
  - niet-exclusief
  - aan marktconforme voorwaarden
  - elk geïnteresseerd bedrijf/organisatie in de EU

Bron: VLAIO

Begeleidingsgroep

- Ondernemingen en social profit organisaties, **representatief voor de brede doelgroep** en alle organisaties (collectieve centra, federaties, leveranciers, klanten, …incl. overheid) **relevant voor de brede uitrol** van de resultaten op het einde v/h project
- Leden geloven in het belang van de projectresultaten en ondersteunen het project met woord en daad (reeds van bij de voorbereiding)
- **Cofinancieren samen 7,5% (excl. Overheid, HS of Univ!)**
  - **Invulling cofinanciering ≈ maat voor betrokkenheid doelgroep**
- **Goede interactie met de doelgroepbedrijven is essentieel**
  - vóór, tijdens (± om 6 m) en na het project
  - **project opvolgen, bijsturen, klankbord voor valorisatie**

Bron: VLAIO

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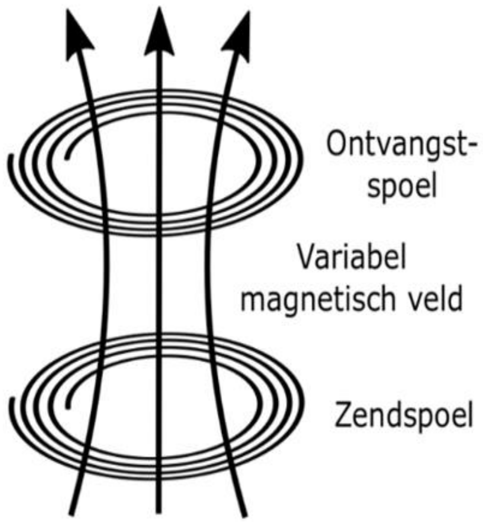
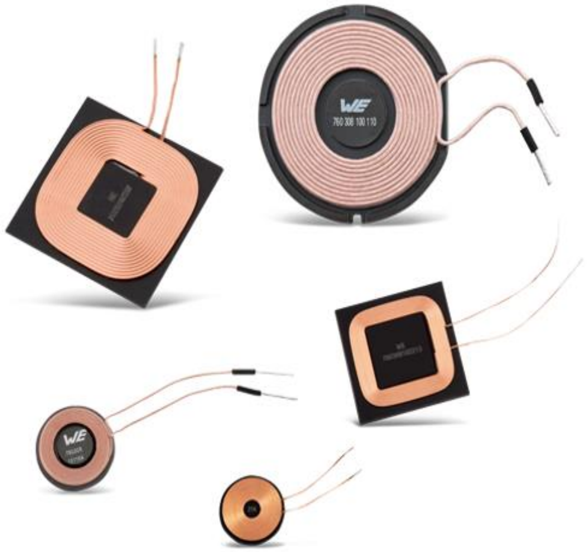
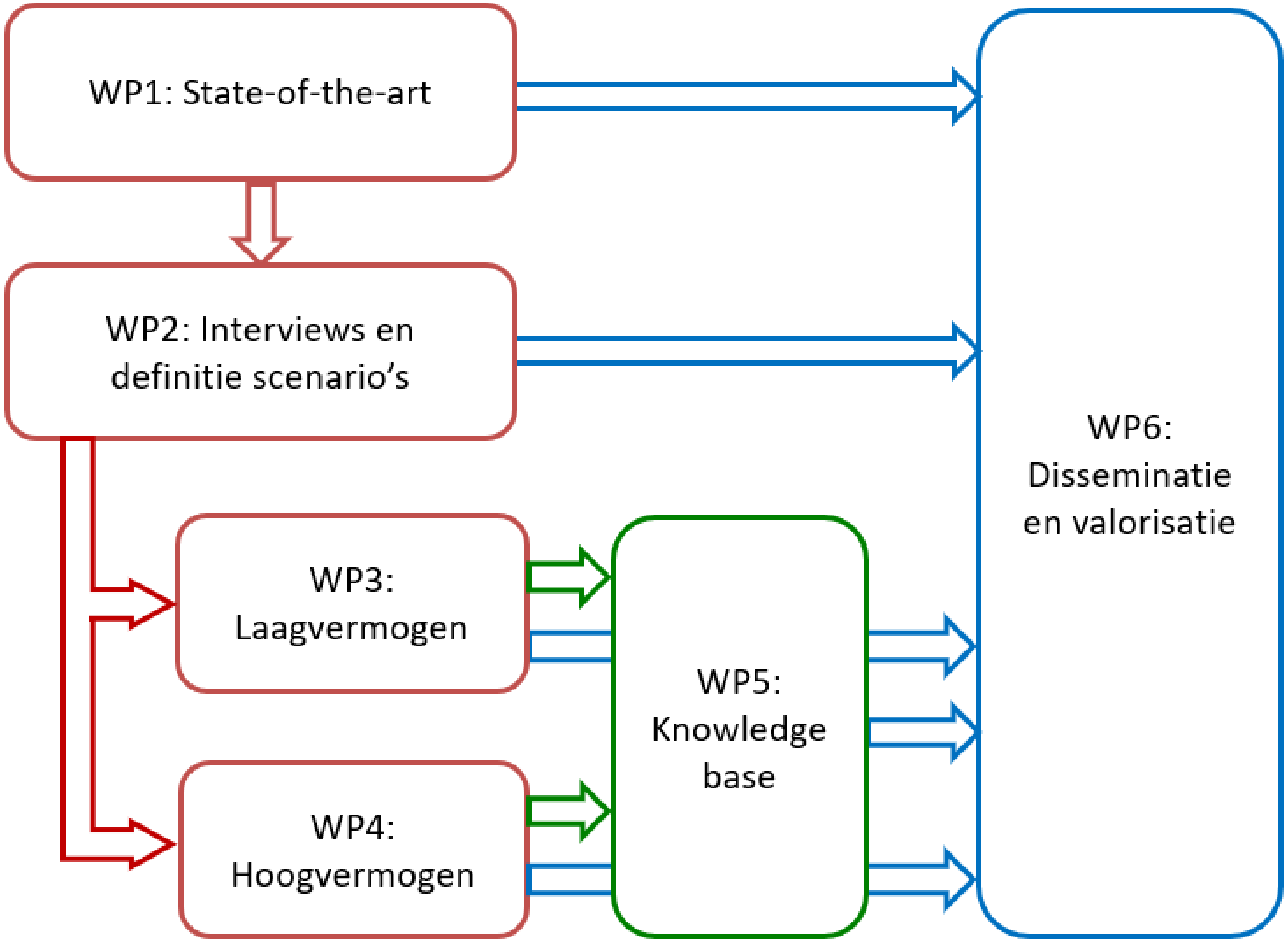
Goal of the project

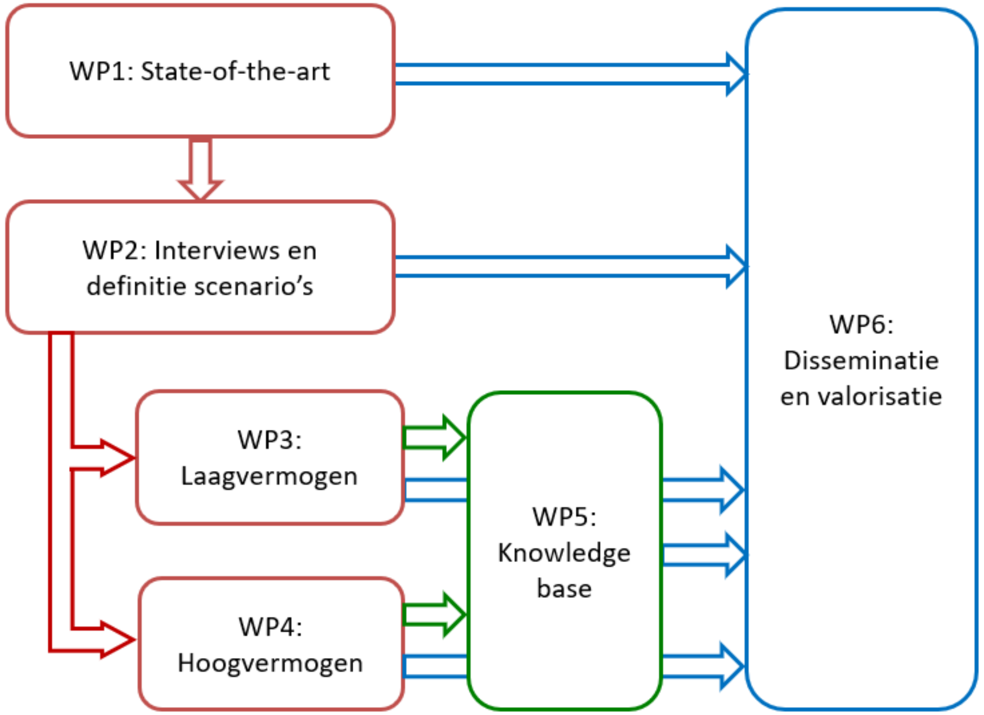
- The aim of the project is to provide companies with tools and answers so that they can implement wireless power transfer (WPT) more quickly and efficiently in their product range and services
- Focus on near-field (distances 1 mm up to 5 cm)
- Including atypical configurations, not covered by any standards





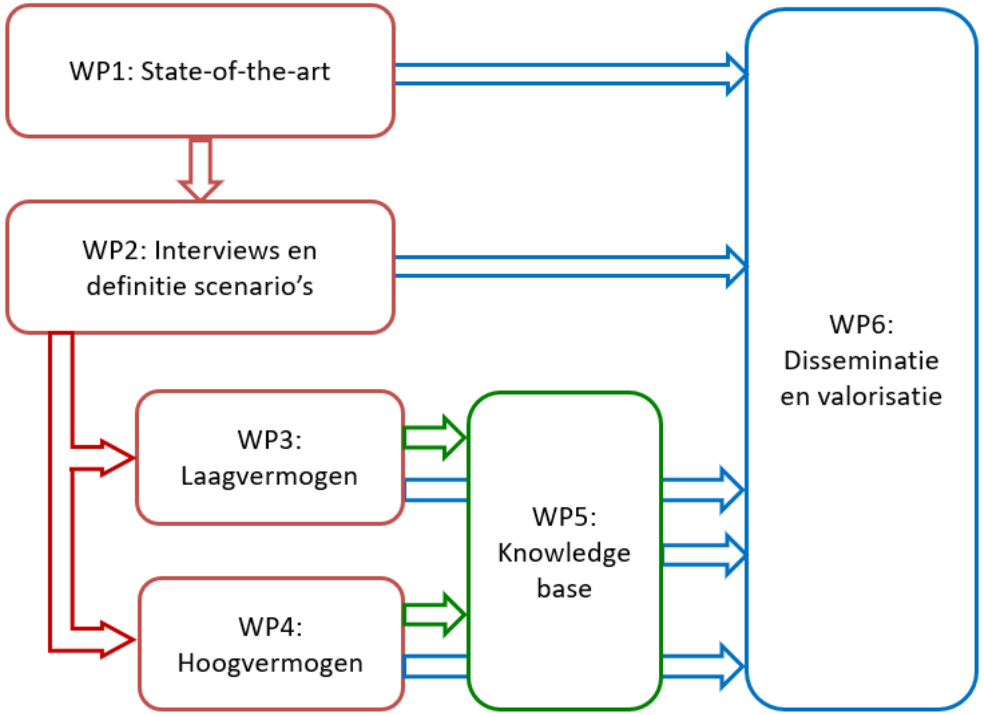

WP1: State-of-the-art
WP2: Interviews en definitie scenario’s
WP3: Laagvermogen
WP4: Hoogvermogen
WP5: Knowledge base
WP6: Disseminatie en valorisatie

WP1: State-of-the-art



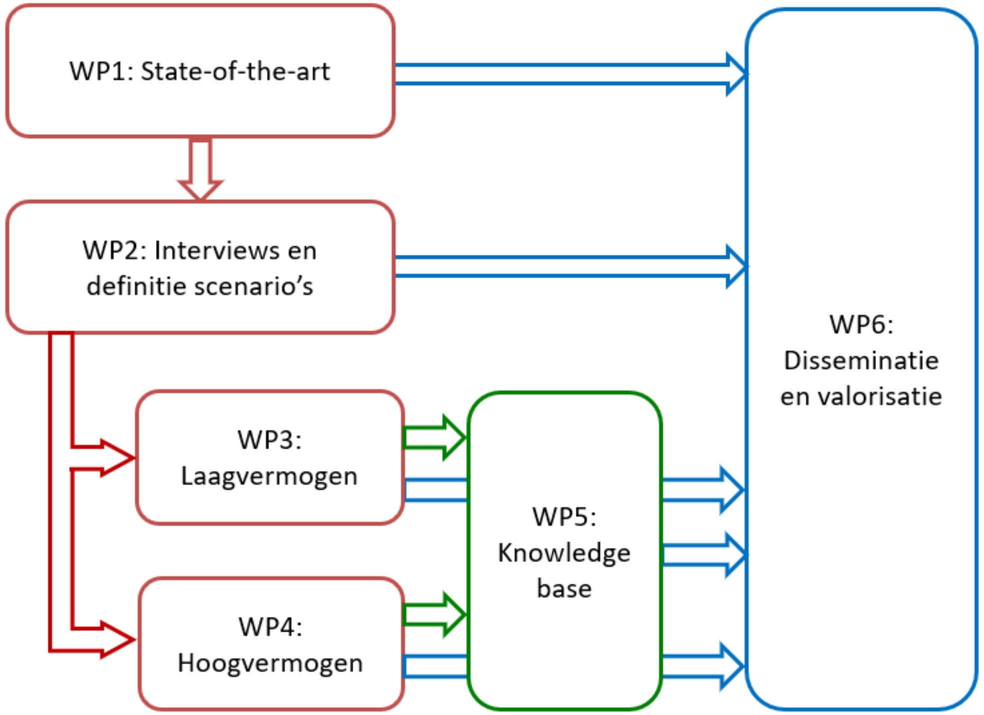
- WPT: rapid growing and evolving market
- Legal and Safety Framework
  - Safety and EMC/EMI issues
  - EU regulations
  - Freedom to operate / patent landscape
- Technological State-of-the-Art
  - Review of current wireless energy transfer standards (e.g., Qi, AirFuel, SAE J2954).
  - Focus on practical implementation and limitations.

WP2: Interviews and definition scenarios



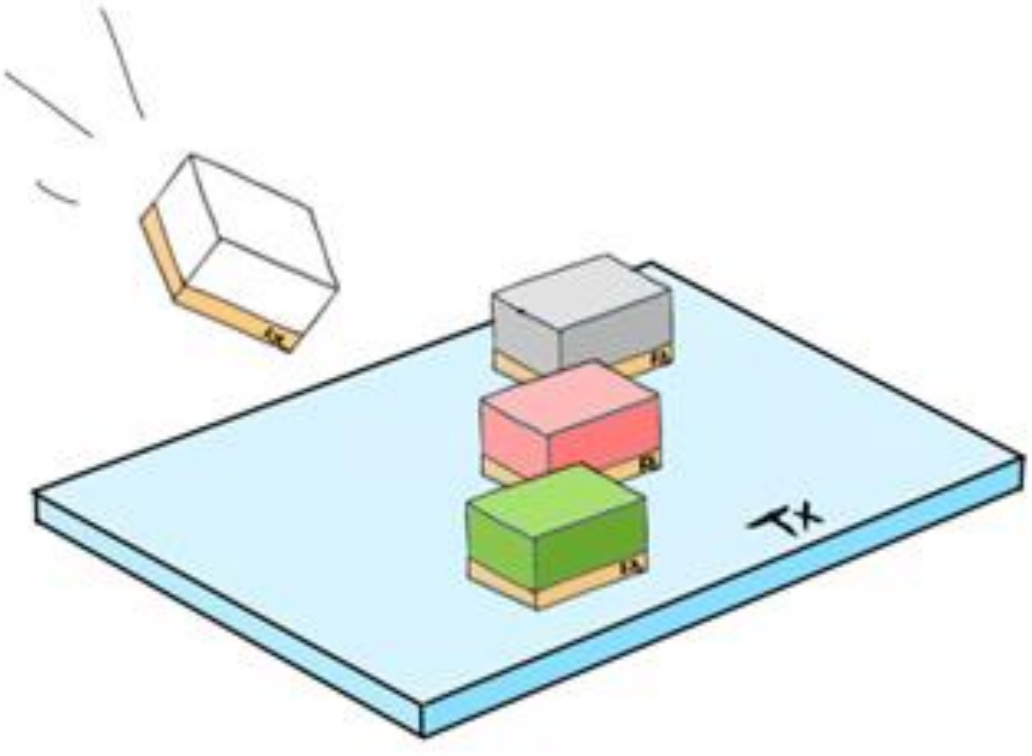
- Refining of the scenarios based on **your** input
  - Interviews with companies in the advisory group
  - Expand the advisory group by involving additional interested companies.
- Define requirements, objectives, and limitations (e.g., power levels, dimensions, distance, form factors, materials,…).

WP3: Low power (< 50 W)



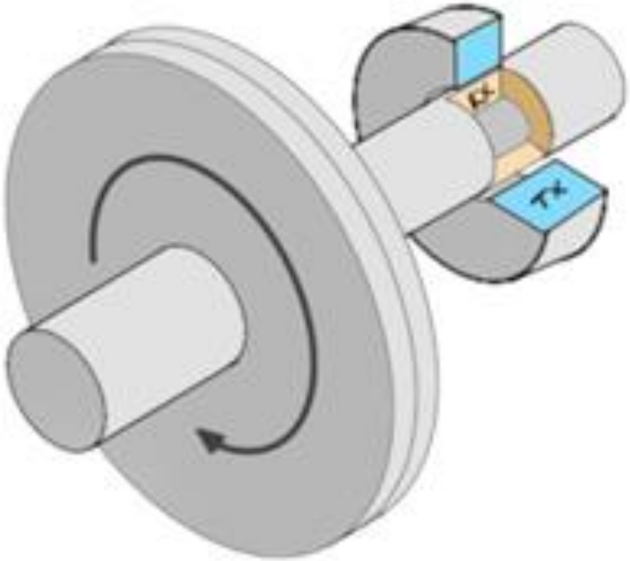
- Implementation of two low-power scenarios that cannot be realized with existing standards.
- Emphasis on the design and implementation process to provide companies with tools to apply similar scenarios using off-the-shelf components.

WP3: Low power



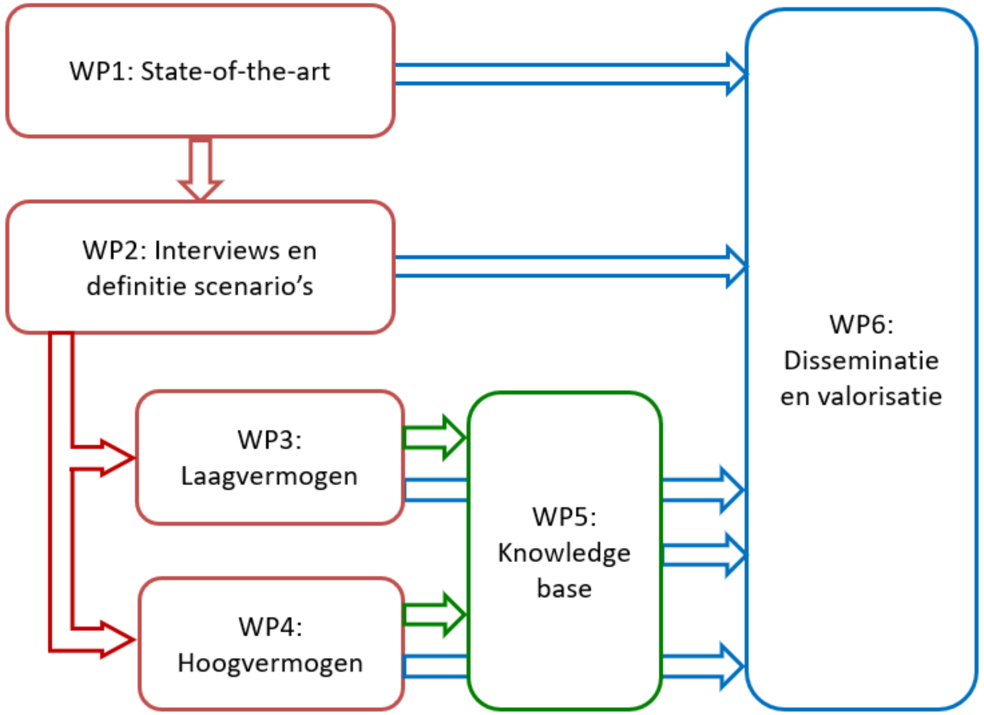
- **Demonstrator 1: "One Tx to many Rx”**
  - Traditional systems use one charging station per device. This setup uses one transmitter to charge multiple devices.
  - Capacitively coupled wireless energy transfer is probably more efficient and cost-effective for this configuration.
  - Receivers will be positioned above the transmitter with adjustable distances.

WP3: Low power



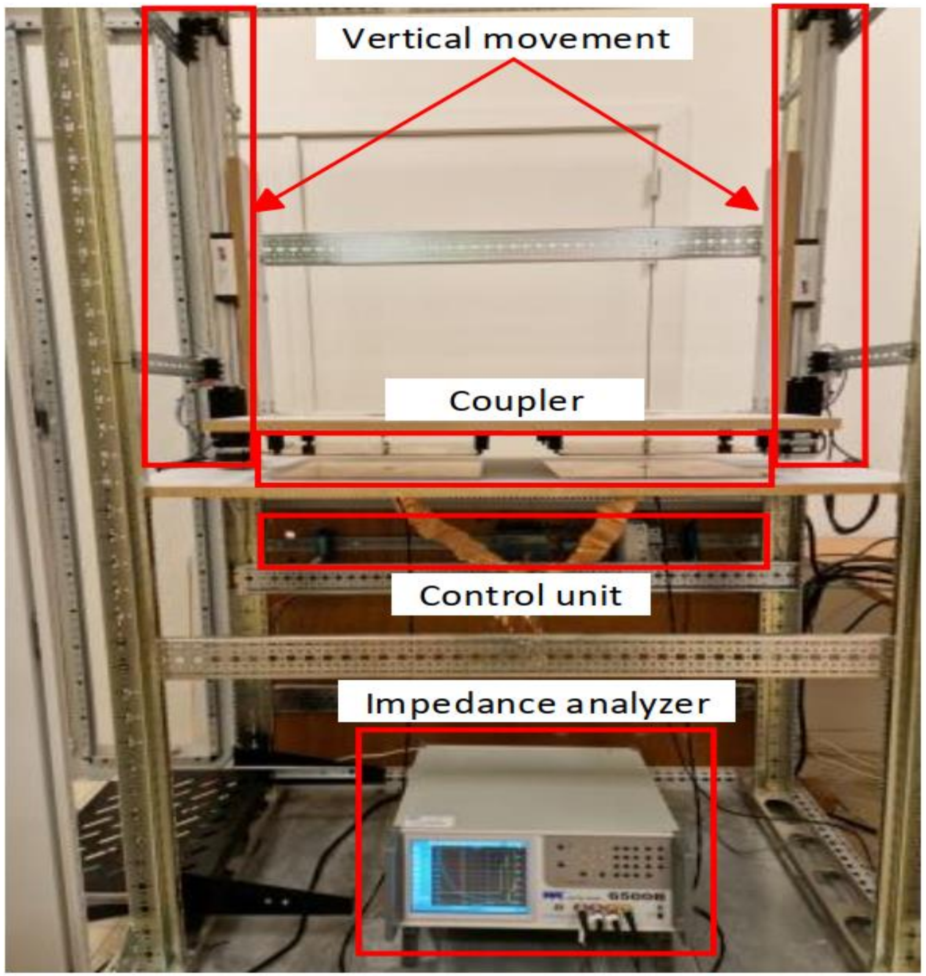
- **Demonstrator 2: “3D WPT”**
  - Implement a 3D demonstrator to charge non-planar, circular receivers, focusing on applications where planar alignment is not possible, e.g., rotating shafts (sensors on machinery).
  - Capacitively coupled WPT allows for more flexibility in 3D designs.
- Design Focus
  - Minimize component volume
  - Off-the-shelf parts.
  - Static setup
  - Distance 1 – 10 mm

WP4: High power (> 50 W)



- Implementation of high-power scenarios
- Emphasis on the design and implementation process to provide companies with tools to apply similar scenarios using off-the-shelf components.

WP4: High power



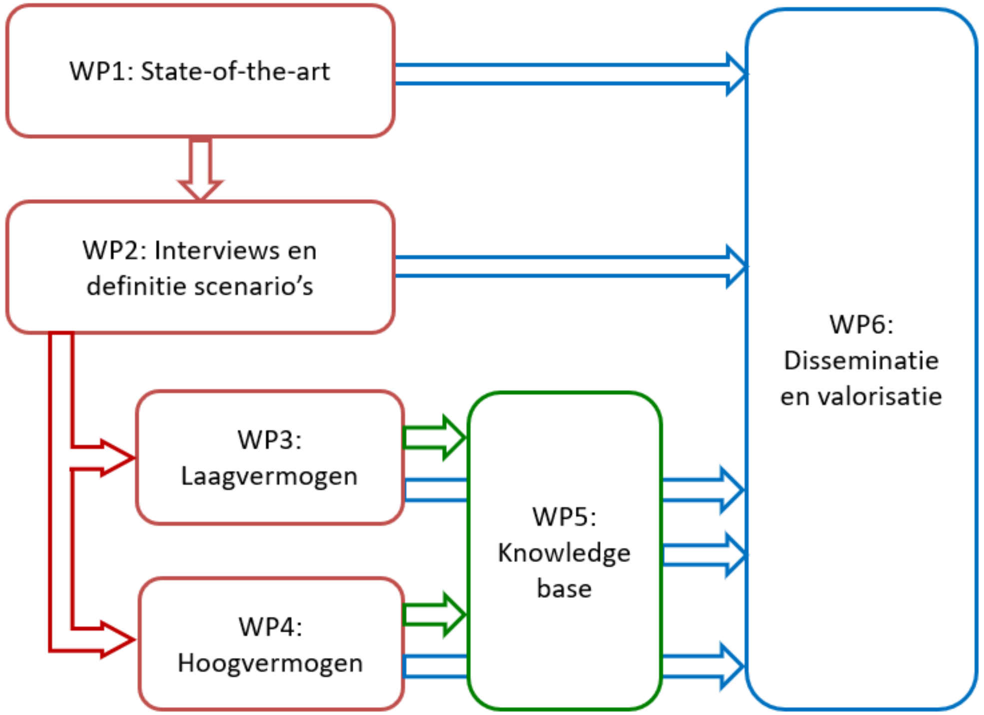
1) Define use-case requirements:

- Power, distance, size, efficiency,…
- Measure dielectric properties of materials using ELECTA's testbench and perform simulations to evaluate system performance.
- Assess each use-case for technological feasibility, scalability, and cost

2) Build a high-power demonstrator

- to validate the performance for a selected use-case and test feasibility

WP4: High power

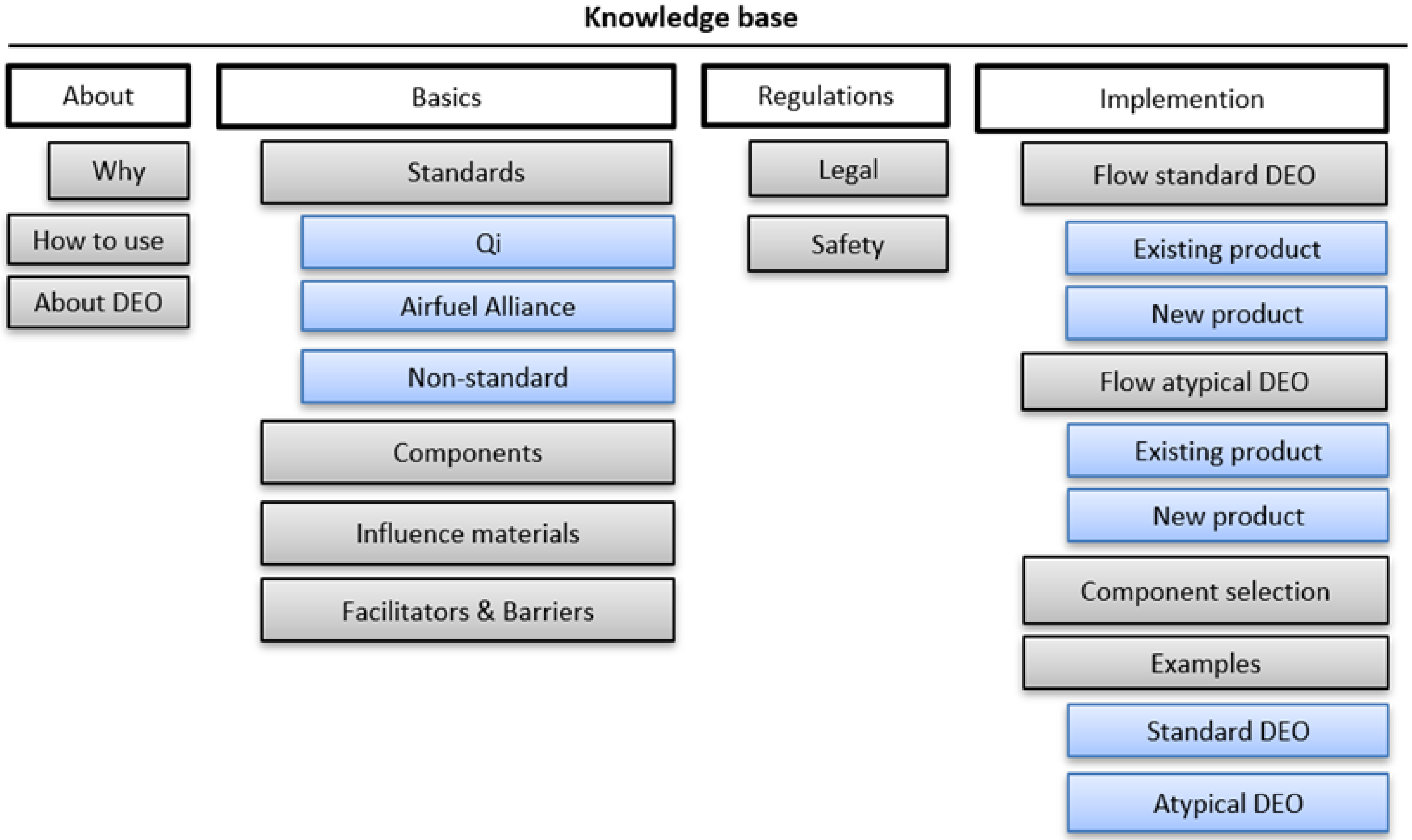


3) Educational setup:

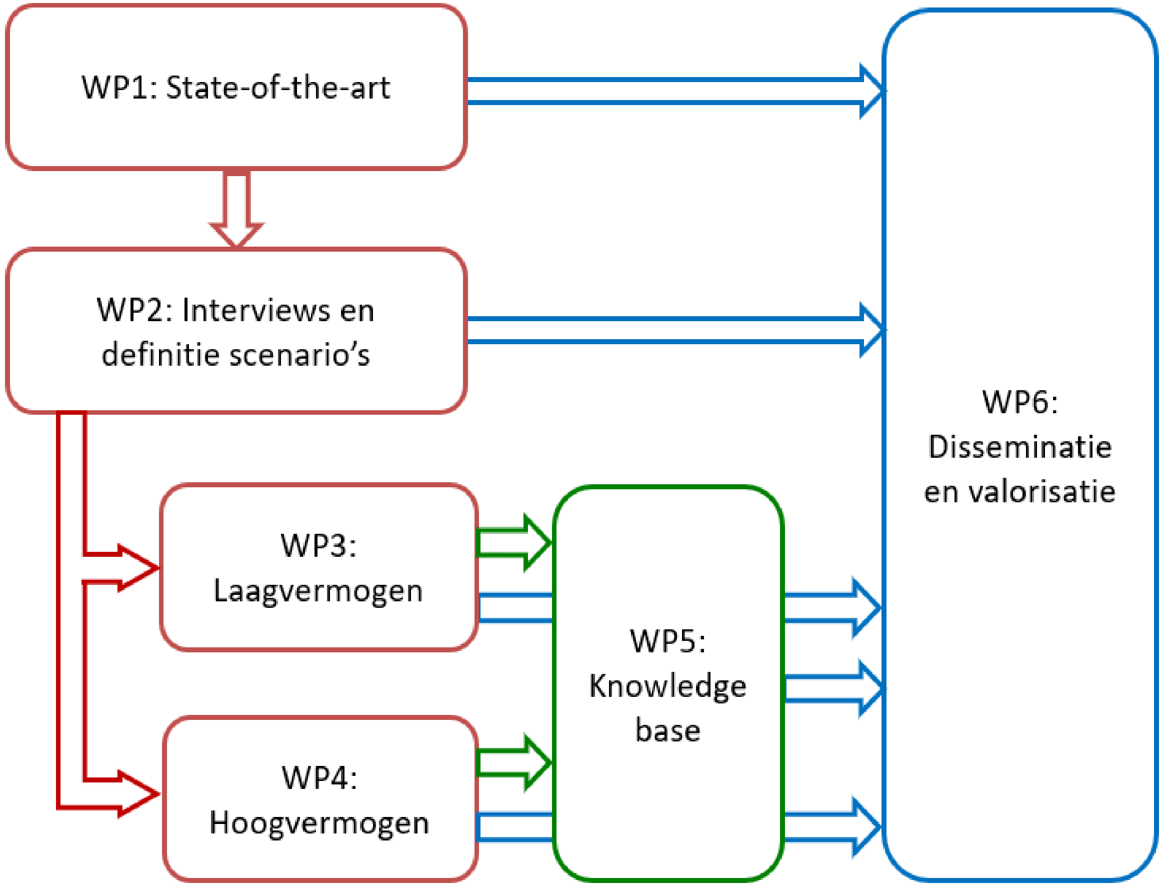
- A high-power inductive WPT system for practical training and data collection
- Power: 500 W
- Distance: 5 cm
- Efficiency: 90%
- Off the shelf components

WP5: Knowledge base

- An online, easily accessible knowledge database
- Practical, user-friendly access, updated throughout the project



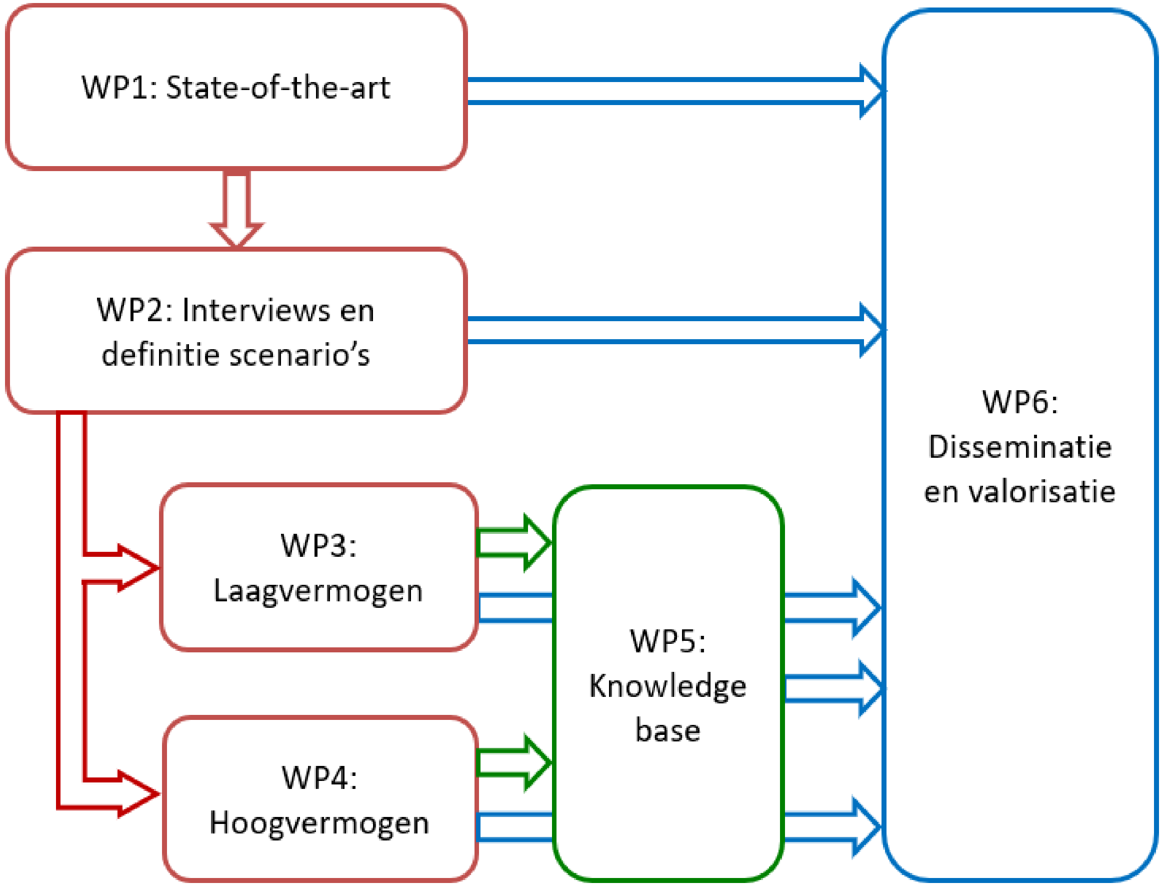
WP6: Dissemination and valorization



- Throughout the project duration, not only at the end!

- Meetings with advisory board
- Seminars & workshops
- Regular (short) newsletters
- Website & knowledge base
- Knowledge transfer via sector organisations
- (!) Individual meetings with you

WP6: Dissemination and valorization



- Student involvement
  - At this moment on this TETRA project:
    - 2 master thesis students
    - 8 bachelor thesis students
  - We welcome cooperation for theses with companies!
  - We welcome guest lectures!
- The advisory board helps shape the project!

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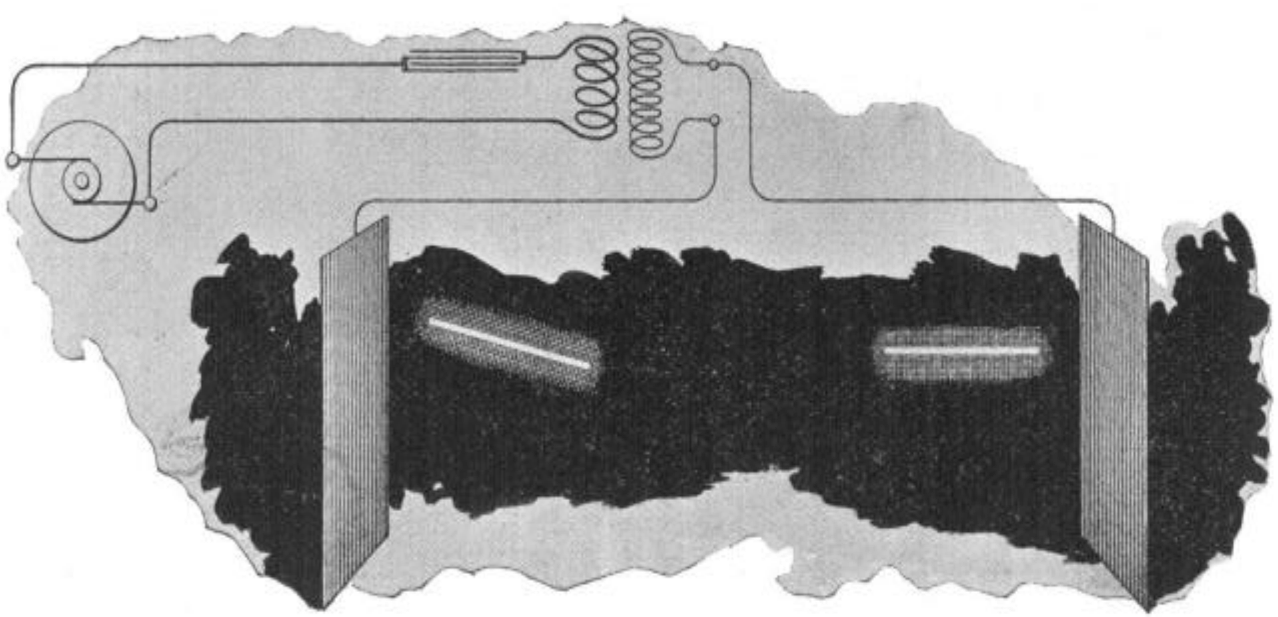
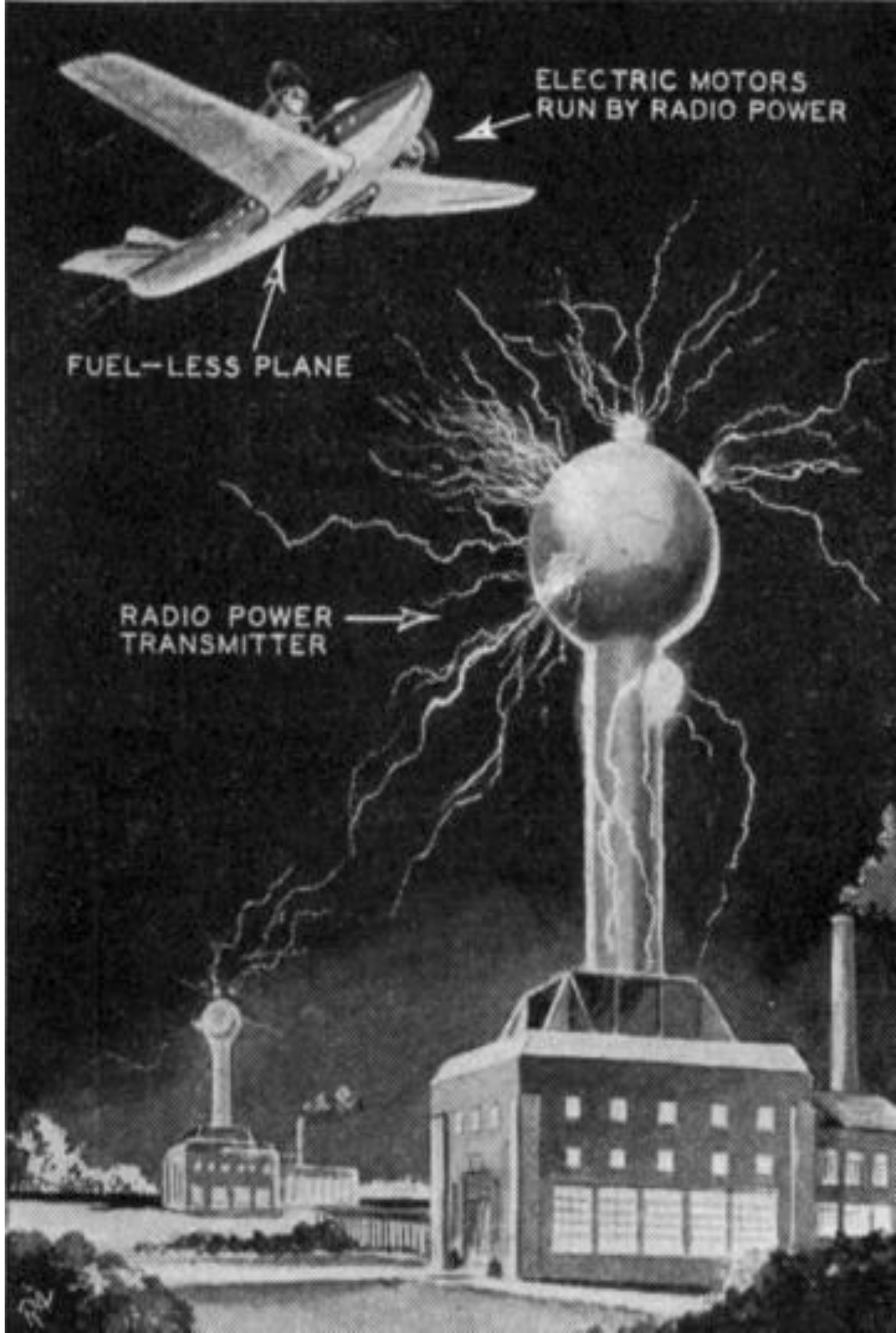
Next steps

Q&A

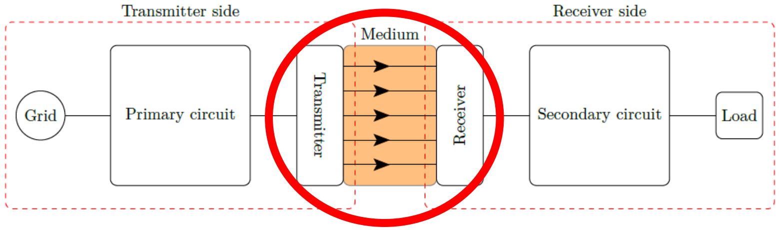
In 1891 …

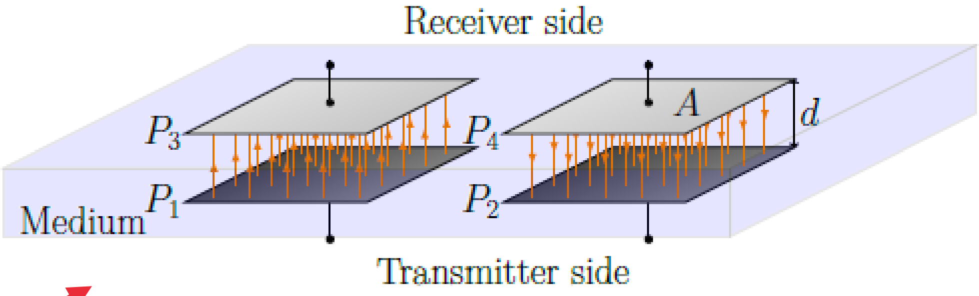
- First described wireless power transfer system by Nikola Tesla



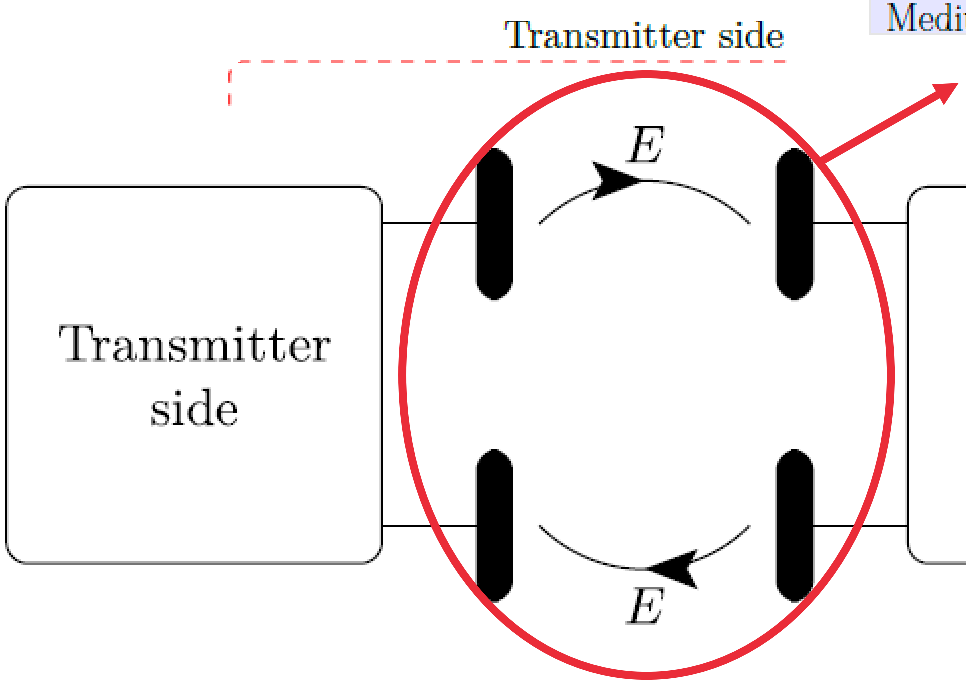


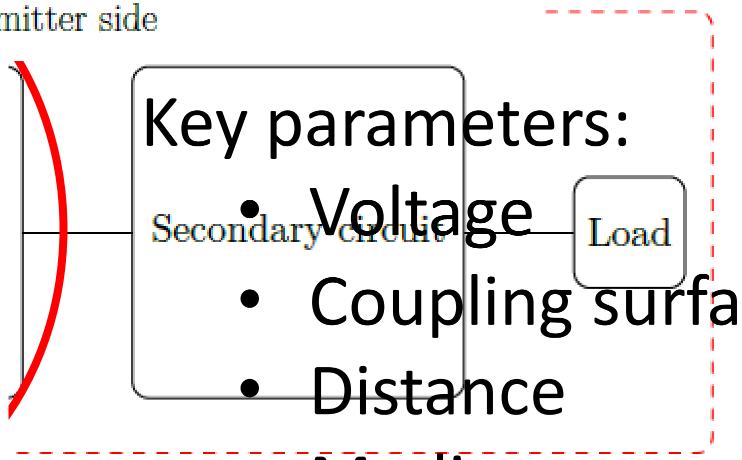
What is capacitive wireless power transfer?





ve coupling
ive coupling

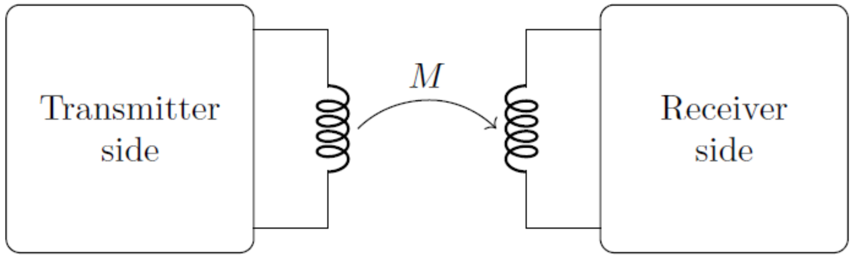


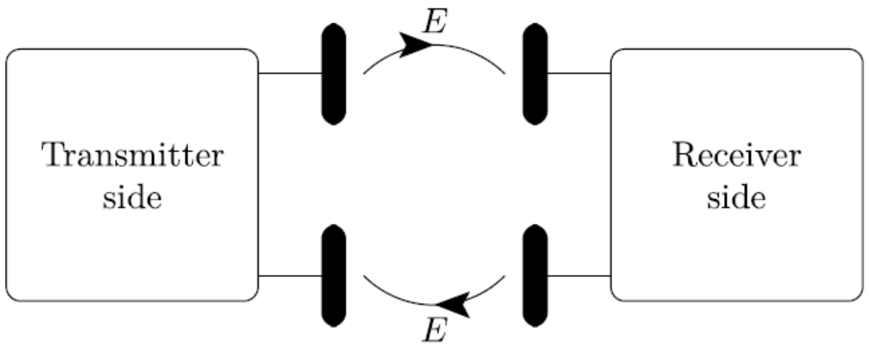


Key parameters:

- Voltage
- Coupling surface
- Distance
- Medium

State of the art





	INDUCTIVE	CAPACITIVE
Coupling type	Magnetic	Electric
Transferable power	50 kW	6 kW
Distance	mm - 5m	mm – tens of mm
Power density	27.5 – 780 kW/m²	24.3 kW/m²

Applications of CPT

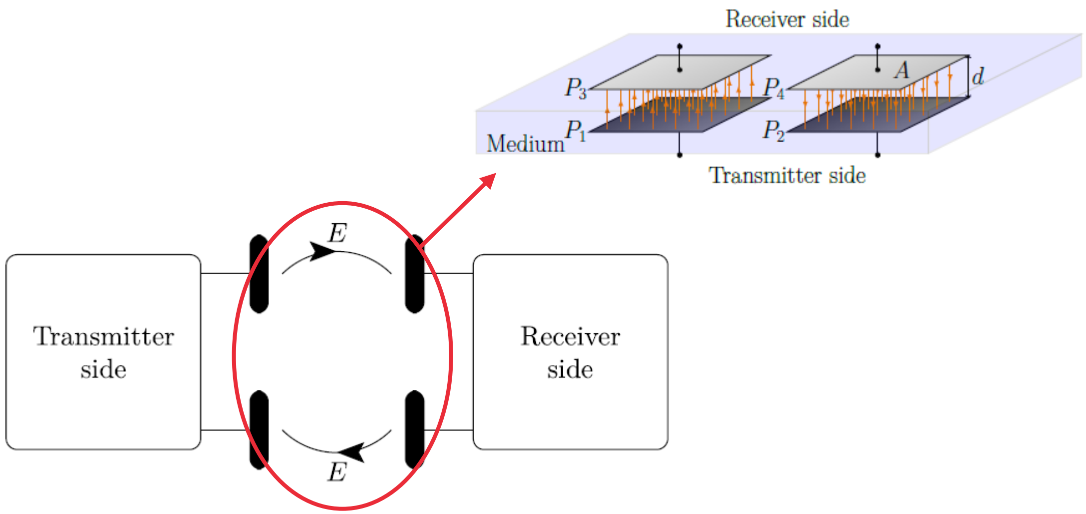
Automated guided vehicles

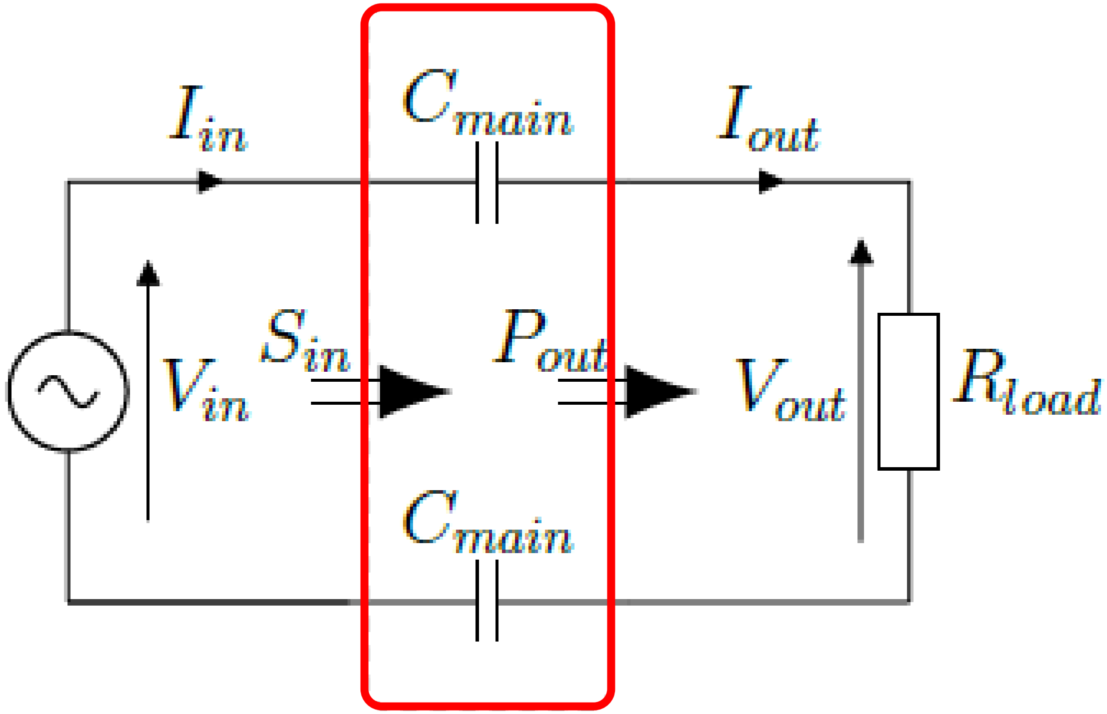
Medical implants

Unmanned water vessels

Start-up AWL-e

Problem statement





=> Low resulting coupling capacitance

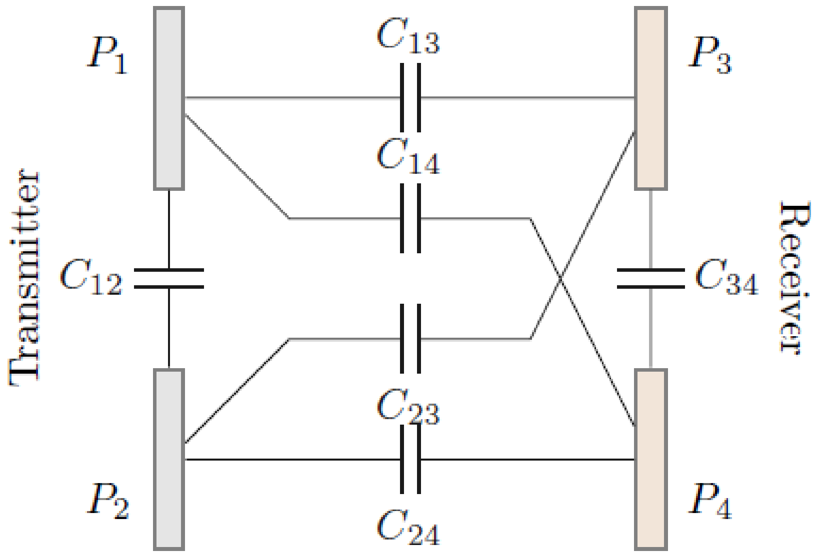
- High frequencies needed
- High input voltage needed
- Low power density

=> No standards available

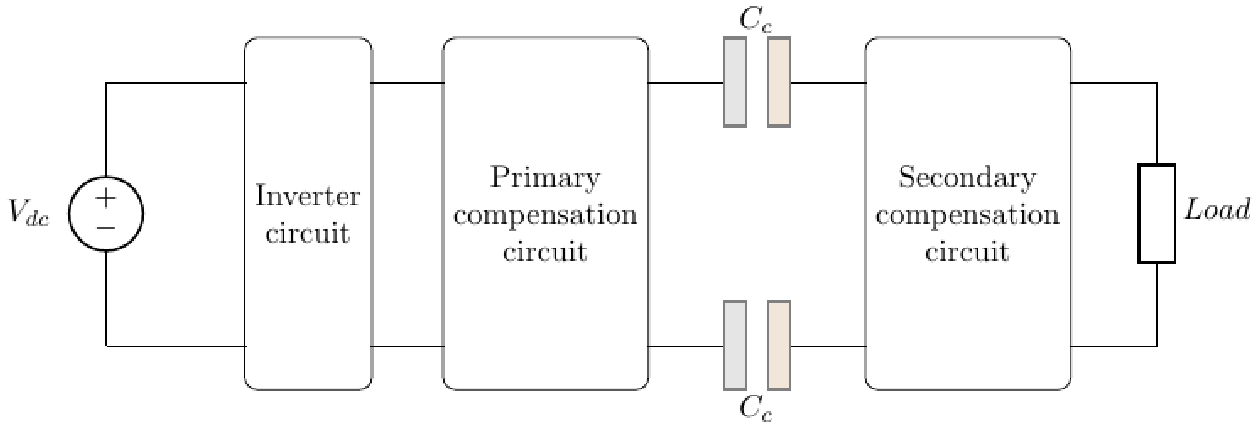
Past research at KUL

What is the impact of solid media on 100 W CPT system?

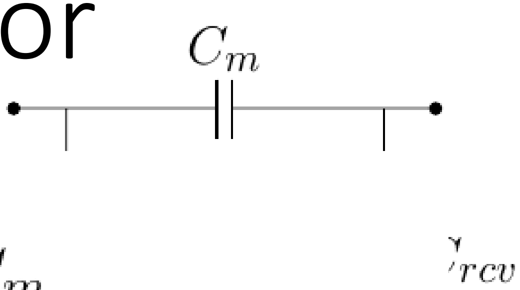
Coupler modelling:



System design



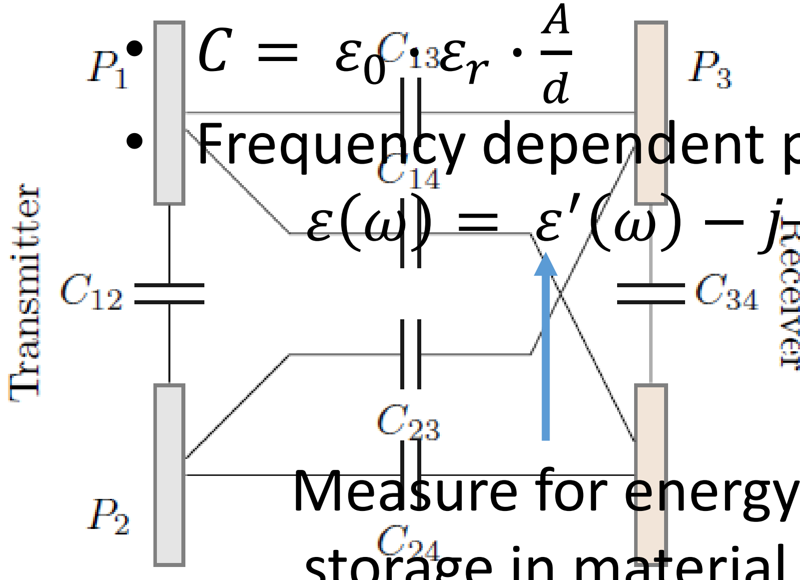
Behavior of the material in the capacitor



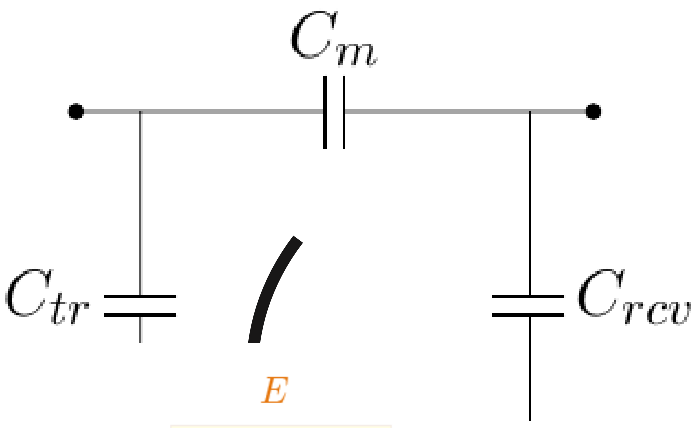
What about the losses?

- $C = \varepsilon_0 \cdot \varepsilon_r \cdot \frac{A}{d}$
- Frequency dependent permittivity:

$$\varepsilon(\omega) = \varepsilon'(\omega) - j \cdot \varepsilon"(\omega)$$

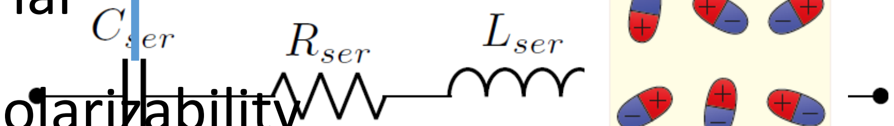


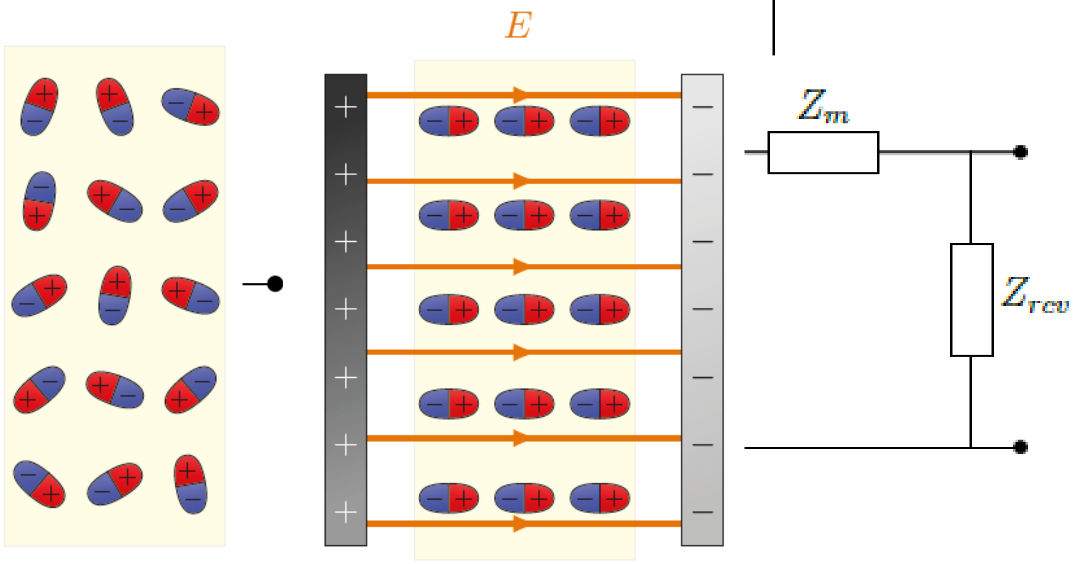
Four plate coupler
(6 capacitances)



Measure for energy storage in material

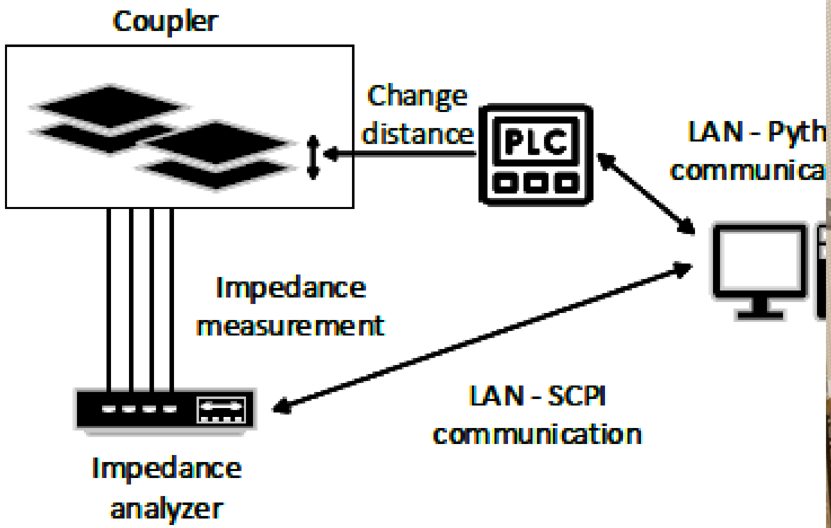
polarizability

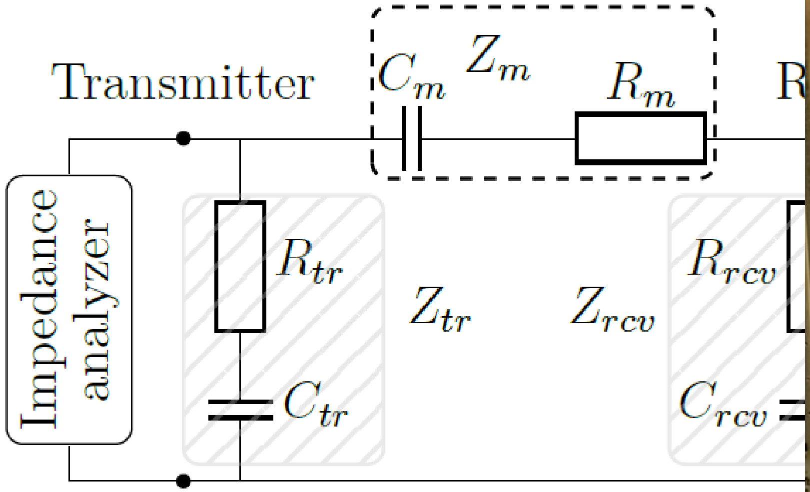


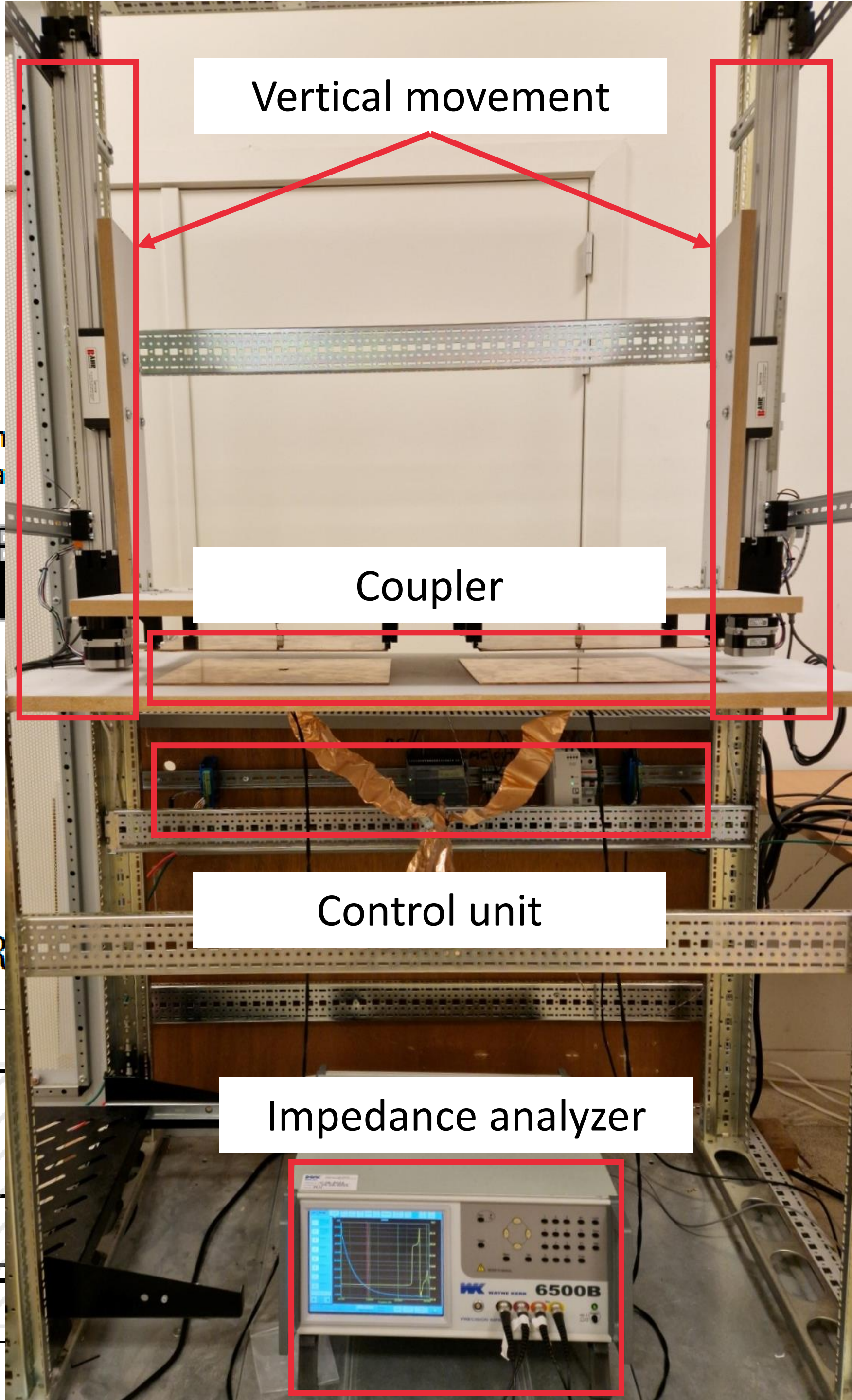


$$\rightarrow \quad Z_c = \frac{1}{j \cdot \omega \cdot (\varepsilon' - j\varepsilon") \cdot C_0}$$

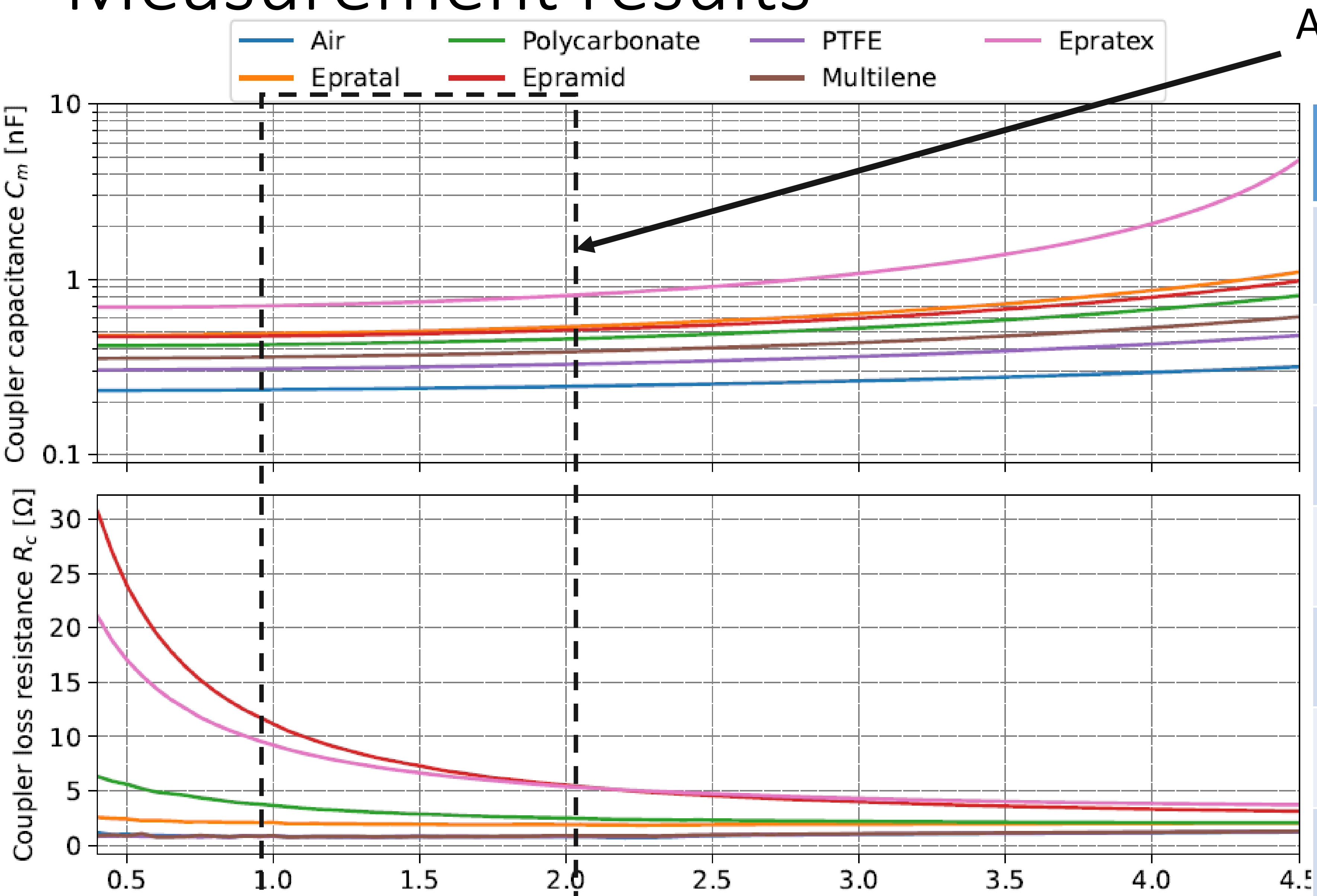
KUL testbench





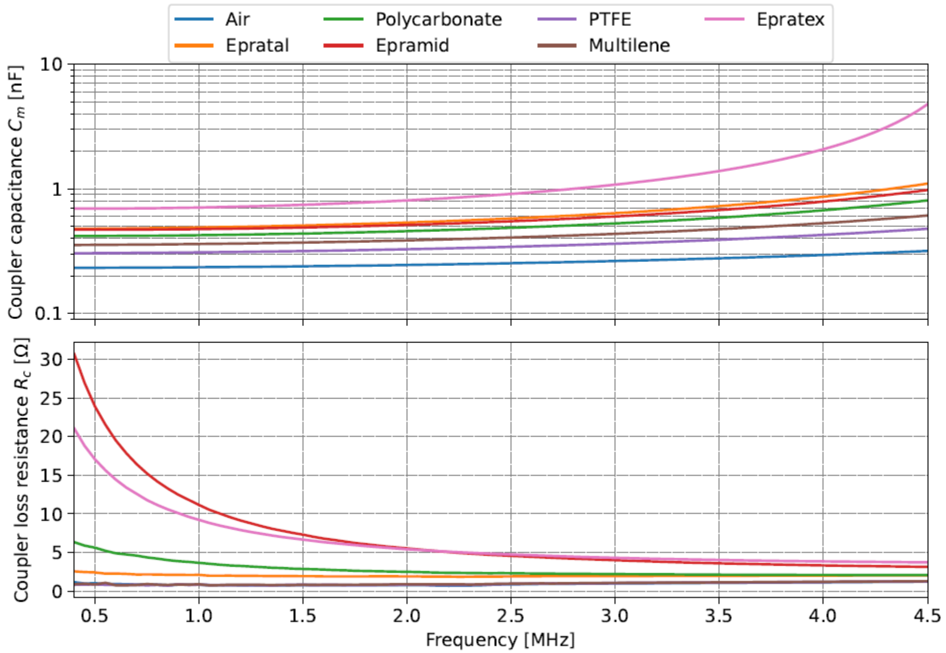


Measurement results



Material	C [pF]	R [Ω]
Air	**235**	**0.84**
PTFE	309	0.85
Multilene	360	0.89
PC	424	3.66
Epramid	474	11.1
Epratal	489	2.1
Epratex	707	9.23

System design



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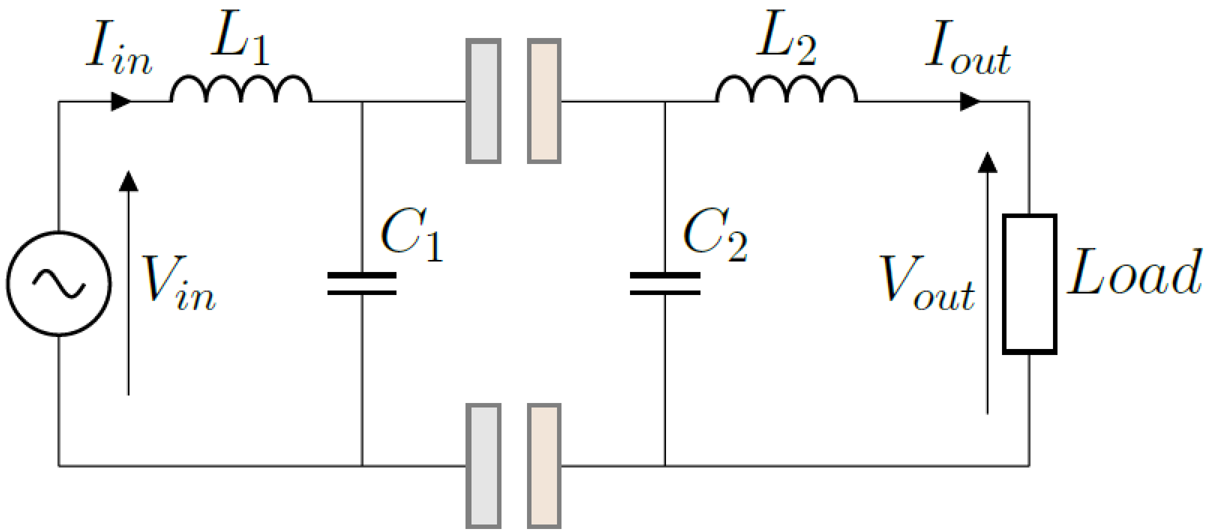
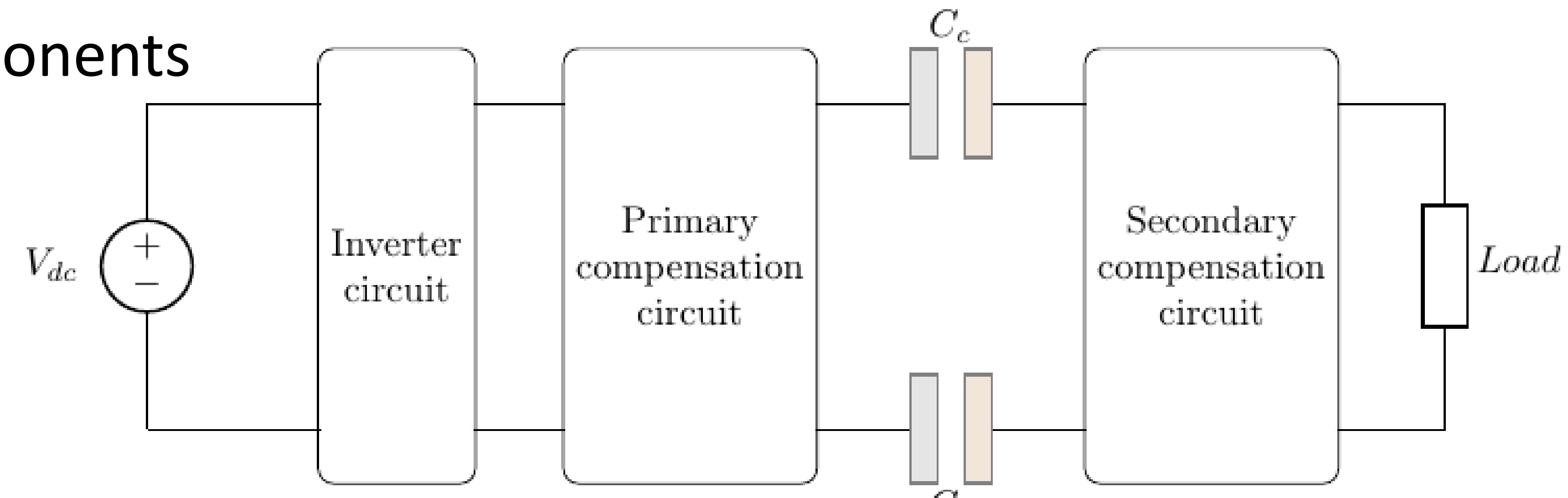


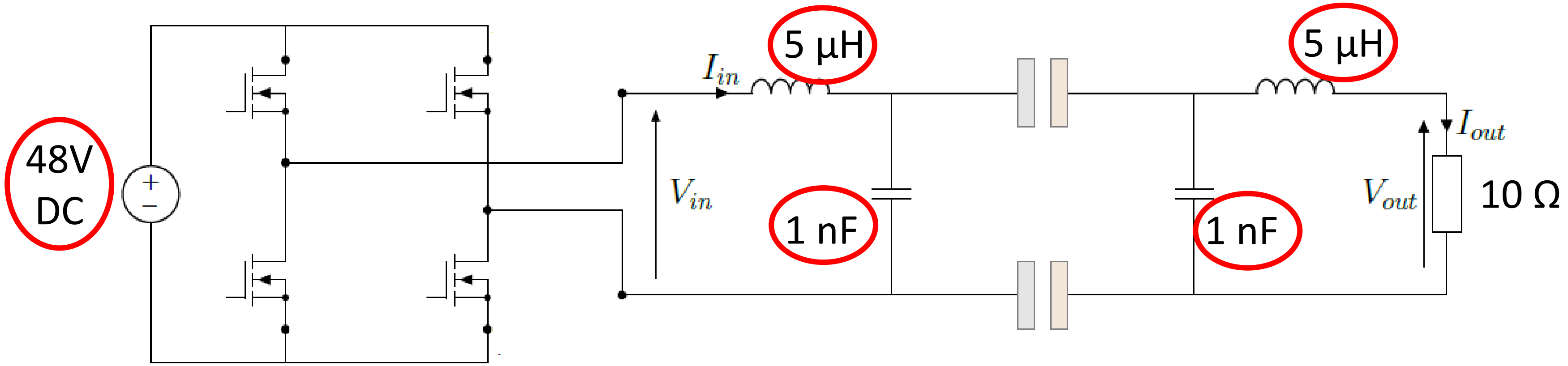
Specification

- Power output: 100 W
- DC input voltage: 48V
- Plate distance: 2 mm
- Off-the-shelf components



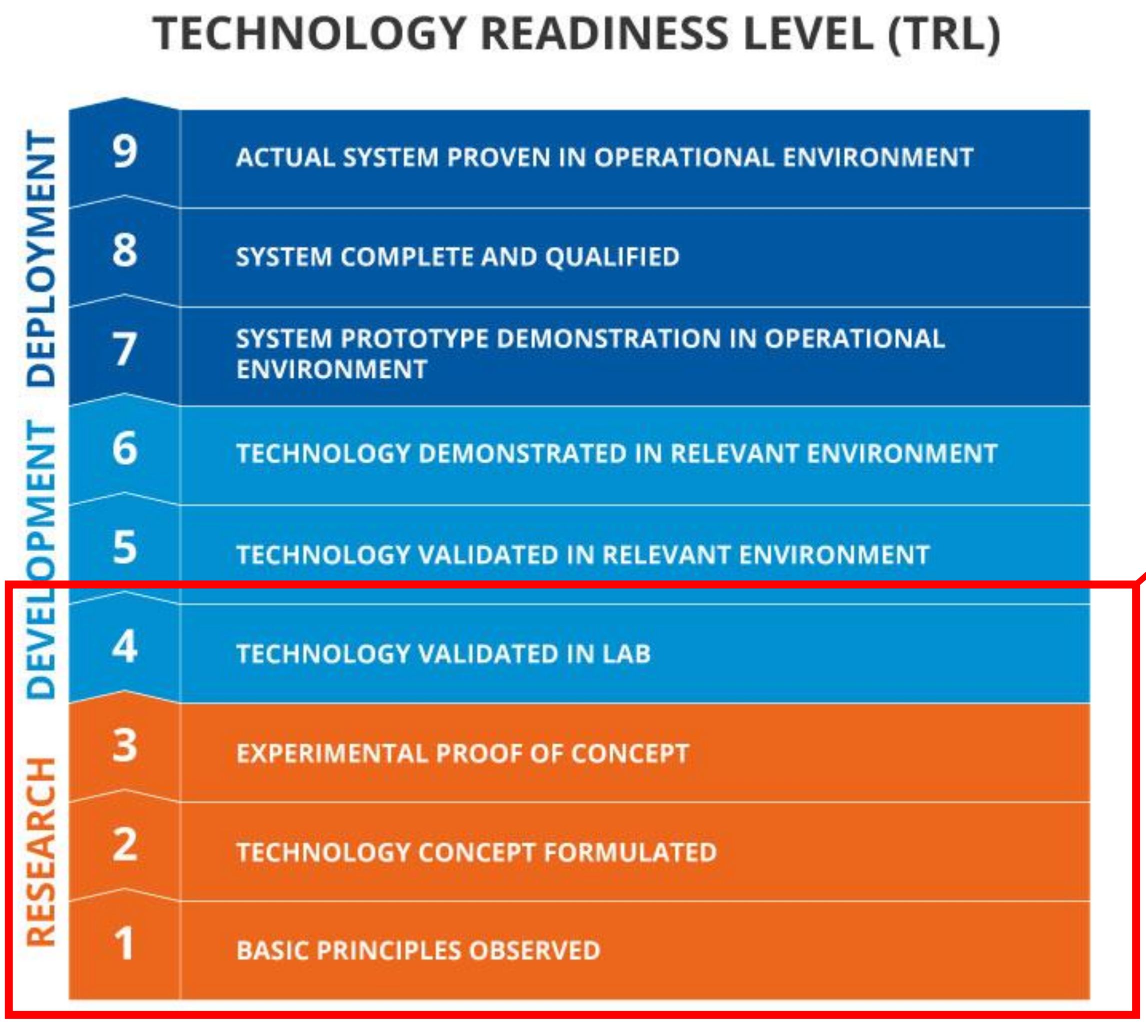
CPT system

- Component selection via Python toolbox

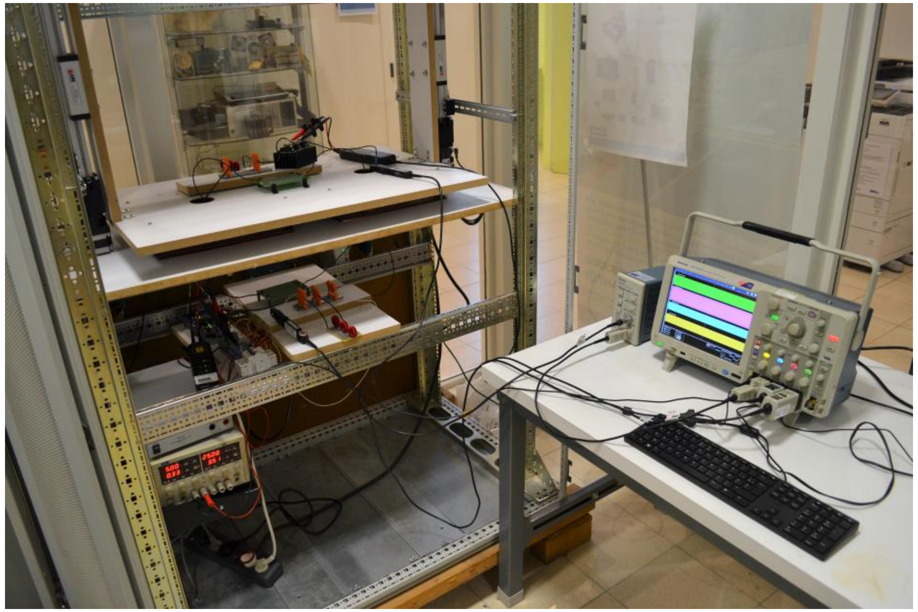


	Air	Epratal
Resonance frequency [MHz]	1.54	1.36
Power output P_{out} [W]	180	160
Efficiency $\eta_{DC\text{-}AC}$ [%]	61.7	75.7

State of research



180 W Demonstrator



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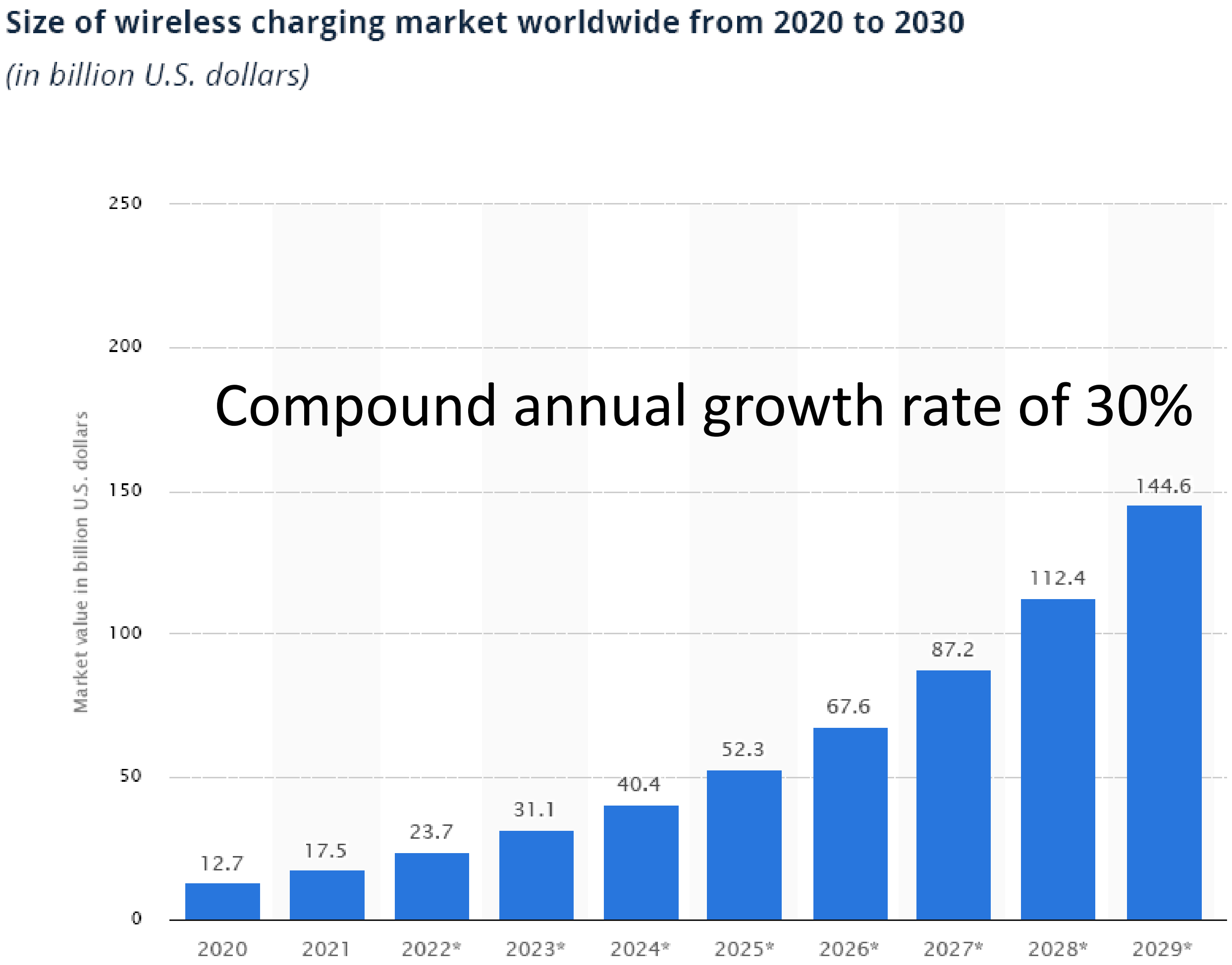
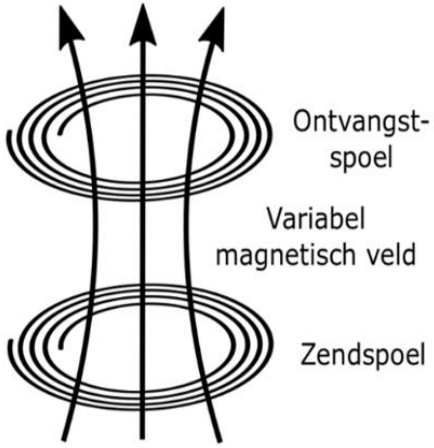
Inductive wireless power transfer

- Sold units WPT:
  - 2018: 541 million
  - 2024: 2200 million
- Mainly Qi standard



Wireless Power Consortium

- Global standard Qi, focus on hand-held consumer electronics
  - Desktop chargers (charging pad or stand)
  - Power banks (designed for travel, contain batteries)
  - Embedded chargers (built in furniture, cars, public locations,…)
- Supported by > 600 companies
- > 8000's of certified products
- Magnetic induction from Tx to Rx

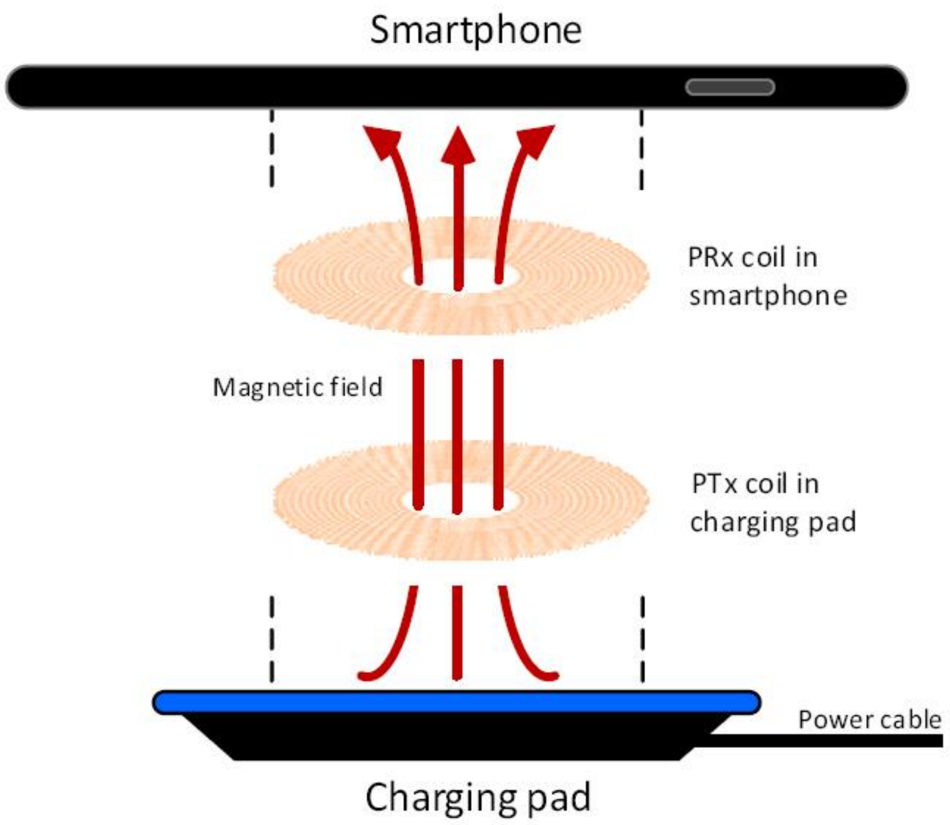


Wireless Power Consortium

- Restrictions Qi:
  - Flat surface devices
  - Up to 15 W
- Under development
  - Ki standard (Ki Cordless Kitchen): 100 W – 2.2 kW
  - Qi Medium power: 30-65 W
  - Light Electric Vehicle (eBikes & scooters)
- Other standards
  - AirFuel Resonant
  - SAEJ2954 (EV’s, up to 11 kW)

How Qi wireless power transfer works

- Principle of transformer, but lower coupling coefficient, typically <0.5
- Before charging begins: communication to
  - establish that Rx is capable of being charged
  - whether it needs to be charged
  - how much power is required
  - …



- Magnetic field can transfer through any non-metallic, non-ferrous materials (plastics, glass, water, wood, air).

Qi power levels

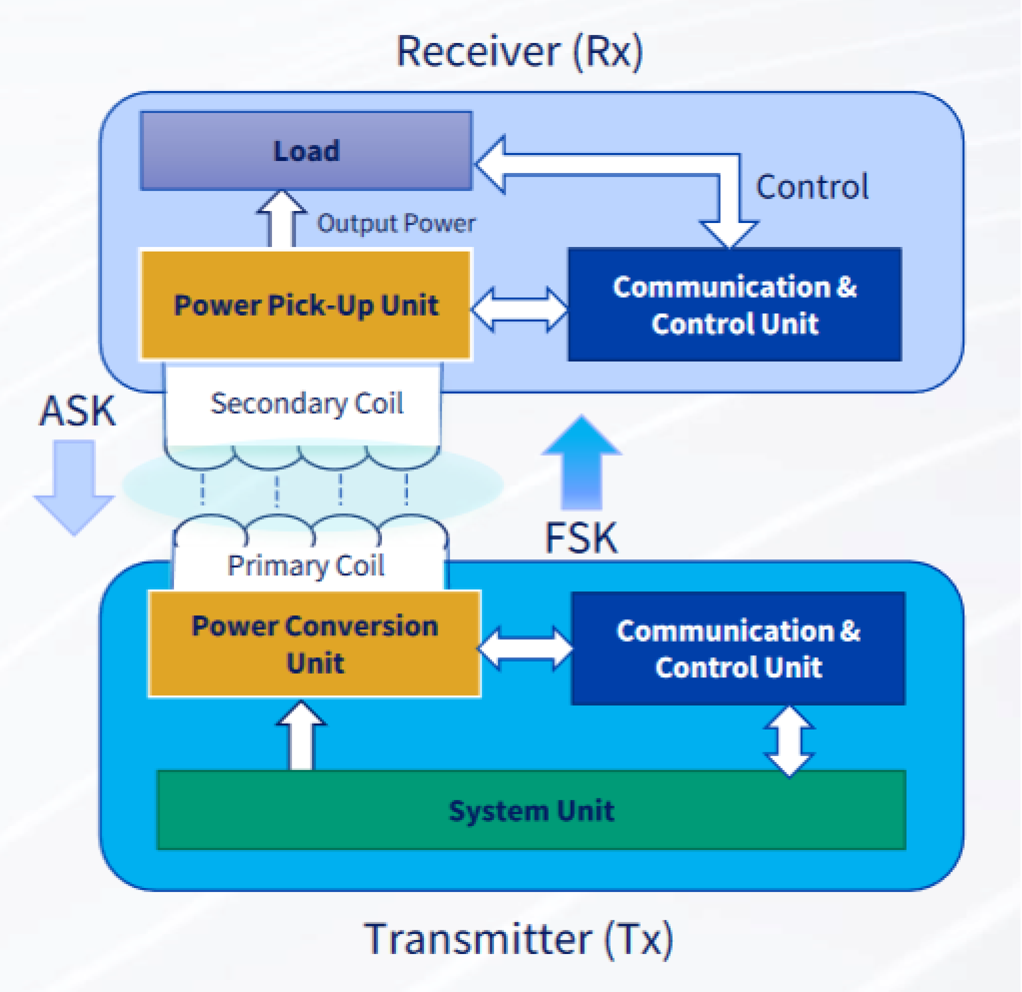
- The actual amount of power that is transferred is subject to negotiation between the communication phases between Tx and Rx
  - Baseline power profile ($\leq$ 5W)
  - Extended power profile (up to 15W)

- Typical efficiencies in commercial products 60-75%

- Frequency 87 to 205 kHz
  - 360 kHz in the new Qi2

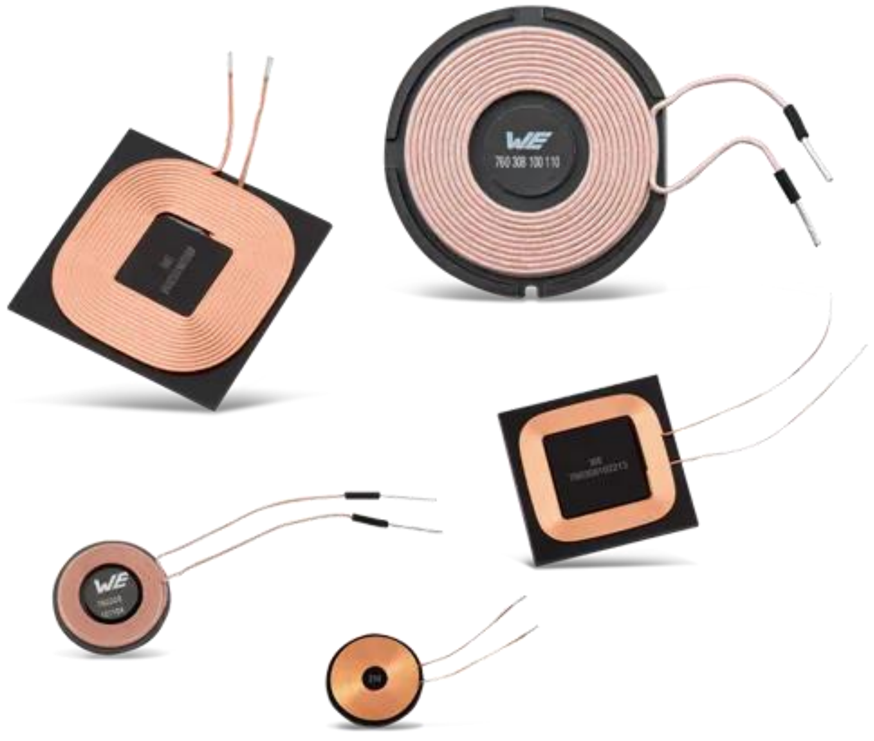
Qi communication

- Communication:
  - First versions: unidirectional from Rx to Tx for power transfer ≤ 5W ("baseline protocol")
  - Later versions: bidirectional communication + enhanced object detection features, for power transfers up to 15 W
- Tx: frequency shift keying
- Rx: amplitude shift keying (ASK) by modulating its reflected impedance



Charging area

- Typical
  - Single coil in the Tx with 50 mm outer diameter
  - Coil in Tx with outer diameter 40 mm
  - Deviations from these dimensions possible as long as they are able to pass all relevant Qi compliance tests
- Misalignment acceptable to (only) about several mm
- The Qi standard allows for multiple coils in Tx as an array

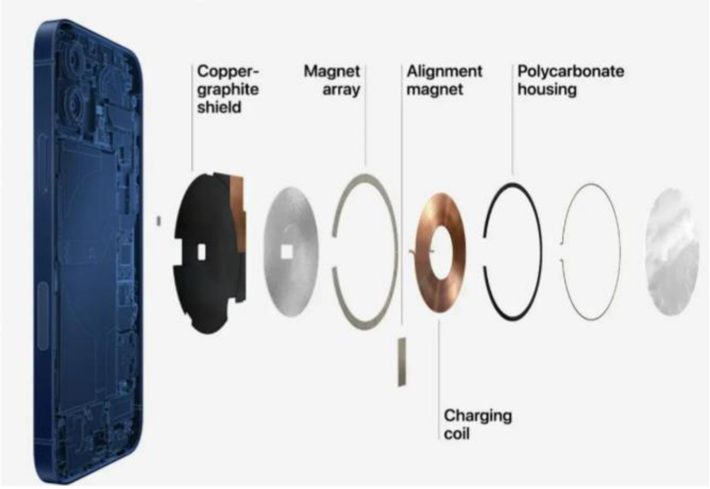


Reference designs

- The Qi specification defines Tx reference designs:

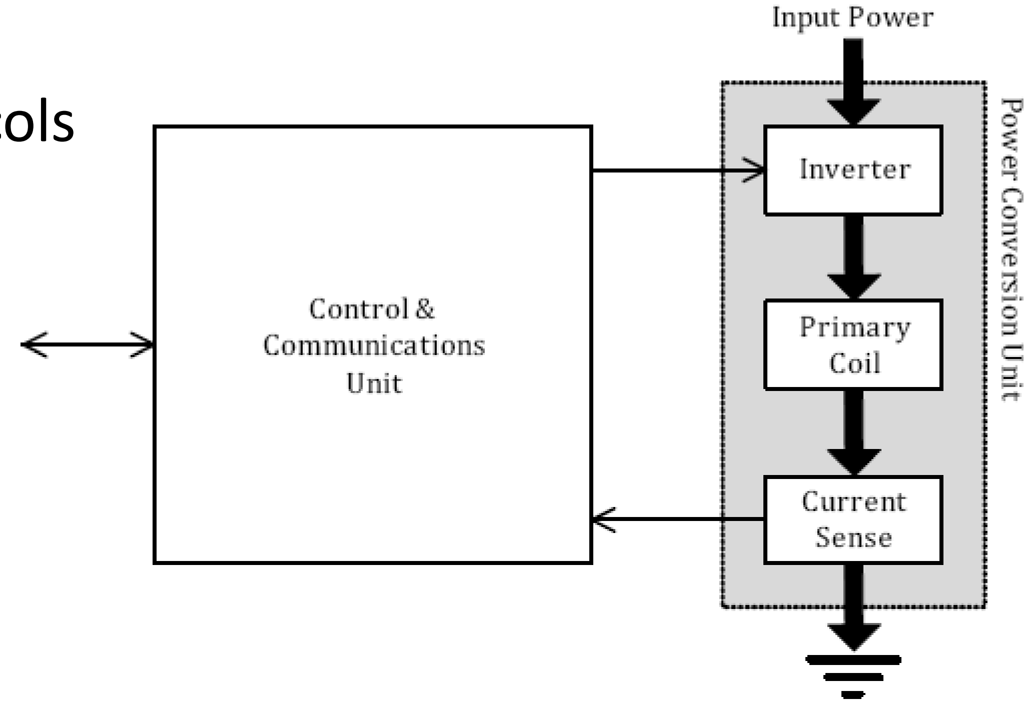
	Up to 5 W	Up to 15 W
Single Tx coil	Type A	Type MP-A
Multiple Tx coils	Type B	Type MP-B

- Depreciated designs throughout the years:
  - Almost all designs with multiple Tx coils
    - Disadvantages: complexity and cost, misalignment, additional power losses from managing multiple magnetic fields
  - Designs with permanent magnet (due to reduced performance)
    - “Magnetic Power Profile” in the new Qi2: magnets to align and tightly couple Tx and Rx coils



Example: “Power Transmitter design A11a”

- Analog parts: Power conversion unit:
  - Inverter: DC => AC
  - Resonant circuit: Primary coil + series capacitor
  - Current sense to monitor the primary coil current
- Digital part: Control & Communications unit
  - Receives and decodes messages from the Rx
  - Executes power control algorithms and protocols
  - Drives the frequency of the AC



Example: “Power Transmitter design A11a”

- Primary coil
  - AWG 17 wire (1.15 mm diameter)
  - Litz wire with 105 seperate AWG 40 (0.08 mm diameter)
  - Circular
  - Two layers

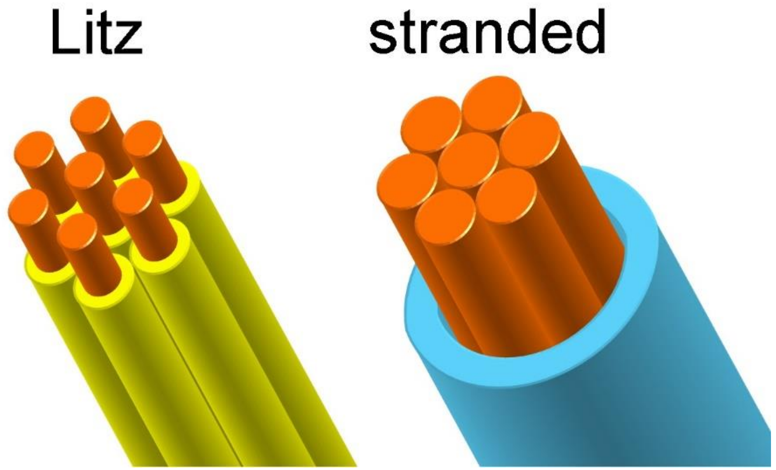


Figure 19. Primary Coil of Power Transmitter design A11a

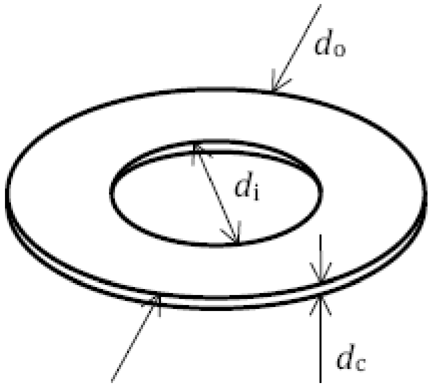
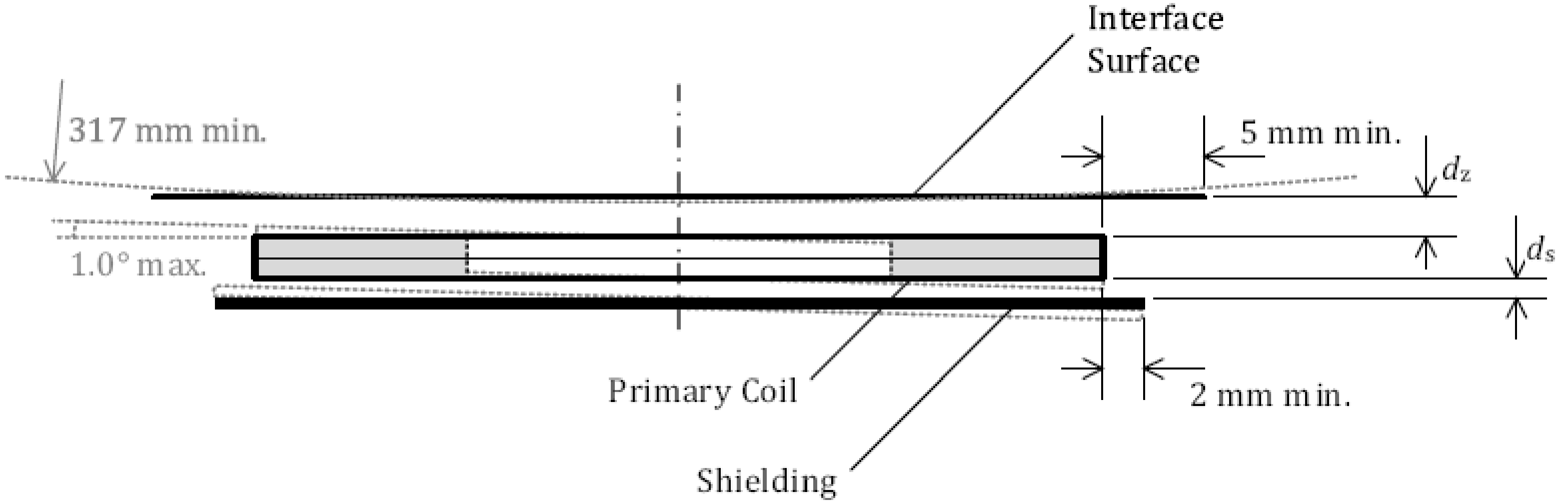


Table 17: Primary Coil parameters of Power Transmitter design A11a

Parameter	Symbol	Value
Outer diameter	d_o	$44^{\pm 1.5}$ mm
Inner diameter	d_i	$20.5^{\pm 0.5}$ mm
Thickness	d_c	$2.1^{+0.5}$ mm
Number of turns per layer	N	10 (5 bifilar turns)
Number of layers	–	1 or 2

Example: “Power Transmitter design A11a”

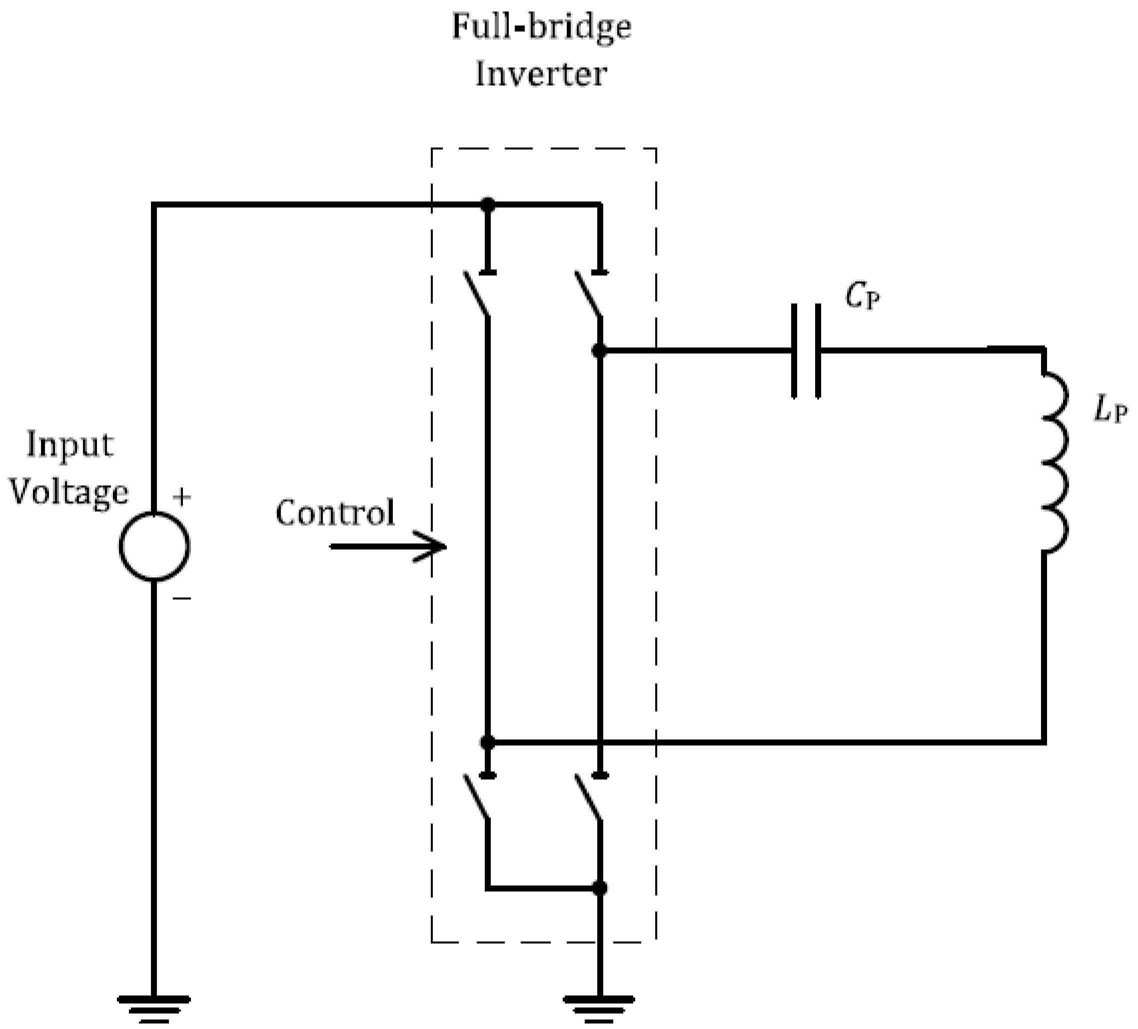
- Shielding
  - Protect the Tx from the magnetic field that is generated by the primary coil
  - Ni-Zn or Mn-Zn ferrite, at least 0.5 mm thick
  - Extends at least 2 mm beyond the primary coil



- “*It is recommended to employ at least one user feedback mechanism to help alignment*”, e.g.
  - A marked interface surface to locate the active area (logo, visual marking…)
  - An LED to indicate proper alignment
  - An audible or haptic feedback mechanism

Example: “Power Transmitter design A11a”

- Electrical details
  - Full-bridge inverter
  - Lp: 6.3 µH (± 10%)
  - Series Cp: 0.4 µF (± 5%)
  - Input voltage: 5 V (± 5%)
    - Near resonance voltages > 100 V peak to peak over capacitance
  - Operating frequency: 110 – 148 kHz (initial 146 kHz)
  - PID algorithm to control power transfer



Agenda

Presentation consortium UAntwerpen & KU Leuven

Introduction to VLAIO-TETRA

DEO project: goal and work-packages

Introduction capacitive power transfer

Coffee break & demo

Introduction inductive power transfer

Interaction with the advisory board

Q&A

Expectations of the advisory board

Cochlear™

ed&a
custom-made electronics

WE
WÜRTH ELEKTRONIK

BEKAERT

FORCEBIT®
measurement made easy

PICANOL

Urban Waterway Logistics

multipowr

flux50
ENERGISING THE FUTURE

FABRIEK LOGISTIEK

ROGERS CORPORATION

How to collaborate?

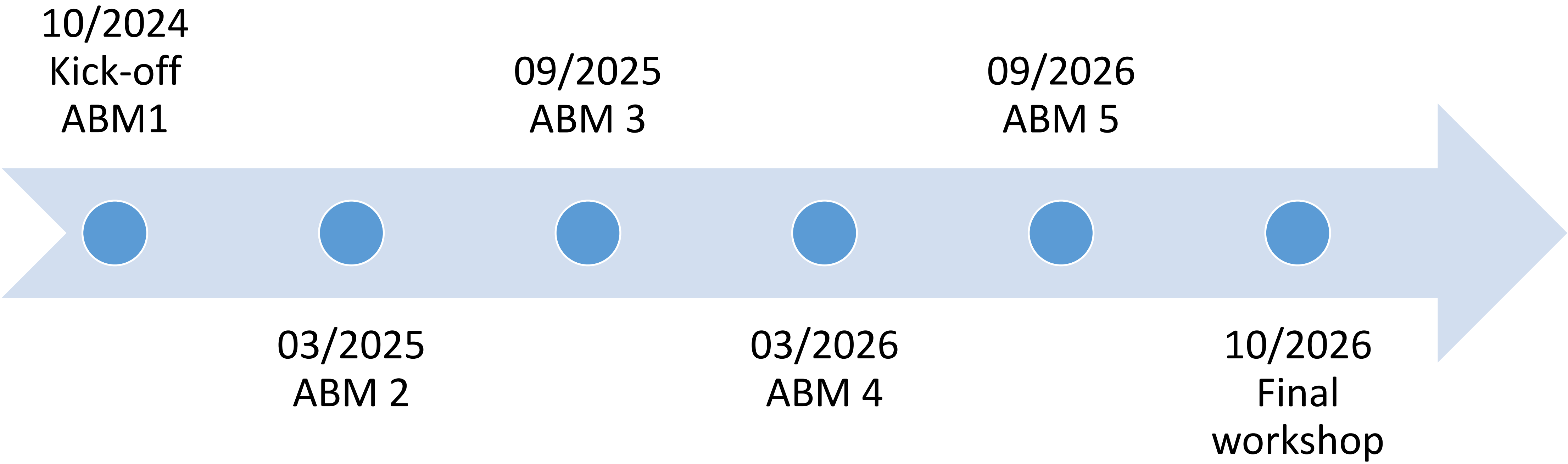
Interaction with the advisory board:

- Newsletter (mail) every two months with short polls
- Five in-person advisory board meetings (ABM)
- Bilateral meetings within the research work

Dissemination to the public:

- 2 public seminars and 2 hands-on workshops
- 1 public final workshop
- A public website
- Publications for the research community, industry and the broader public

Timeline – advisory board interaction



ABM: advisory board meeting

What are the next steps?

1. Each company must sign the contract (reglement van orde) and pay the participation fee
2. Projectteam will start interviews with the AB for WP2
   - Gather requirements for the use-cases
   - Gather information on wireless technology from the
3. On the next AB-meeting, the projectteam will discuss with the AB
   - the results on the state of the art (WP1)
   - the scenarios obtained from the interviews (WP2)

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Companies in the advisory board

Q&A