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

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Electromobility: a market readiness study – Preliminary findings

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Electromobility benefits for grid

- Utilization of the vehicles as distributed energy storage, opening new horizons in decentralized energy storage and management;
- Renewable energy sources integration to the transportation and greater penetration limits since EVs may provide a huge energy buffer > increased grid stability;
- Bi-directional power transfer making the operation of the smart grid more secure and flexible. Each EV can be considered as a decentralized energy storage system;
- Reduction of energy market costs via supply/load shaping.

Strategic investments in electromobility

- **ASIA**
  - China, Japan, Korea: government incentives, regulations promoting awareness and adoption of EVs.
  - Toyota, Nissan, Honda, Mitsubishi joint development of charging infrastructure. Target: 8000 new normal chargers, 4000 new fast chargers.

- **NORTH AMERICA**
  - The US Transportation Electrification Program represents the world's largest EV demonstration project. $400 million funding. Target: 1 million plug-in EVs by 2015.

- **EUROPE**
  - 2013 European Parliament resolution requiring member states to install a specified number of EV charging stations and hydrogen and natural gas stations by 2020. Targets: Germany 86000, Italy 72000, UK minimum of 70000.
  - Several national projects: Fastned (NL), ELMO (EE), CLEVER (DK)…

EV charging modes - Static

Parameter	Range	Comments
Vehicle speed (km/h)	0	Mode applicable if stationary for longer than 5 minutes
Vehicle acceleration (m/s^2)	N/A	
Transmitted power level range (kW)	3 to 120	
Power transmitted to which component	N/A	Power transmitted to the vehicle on-board energy storage system only
Charging time (minutes)	>5	Upper limit of charging time is subject to use, power rating and vehicle on-board energy storage system capacity
Vehicle status	N/A	Vehicle engine / power will generally be off during charging (but may be on for a short time while initiating coupling / charging process)
Technology	Plug-in and wireless (inductive)	

EV charging modes - Stationary

Parameter	Range	Comments
Vehicle speed (km/h)	0	Mode applicable if stationary for less than 5 minutes.
Vehicle acceleration (m/s^2)	N/A	
Transmitted power level range (kW)	20 to 200	
Power transmitted to which component	N/A	Power transmitted to the vehicle on-board energy storage system only.
Charging time (minutes)	<5	Depends on the use scenario (e.g. Charging at traffic lights, or taxi ranks, or bus stops).
Vehicle status	N/A	Vehicle engine / power can be on or off during charging depending on the vehicle powertrain control.
Technology	Wireless (inductive) and conductive	

EV charging modes - Dynamic

Parameter	Range	Comments
Vehicle speed (km/h)	0 < v < 130	Limited by speed limits and technical restrictions.
Vehicle acceleration (m/s^2)	-	Range covers possible accelerations of vehicles ranging from cars to trucks.
Transmitted power level range (kW)	20 to 360	
Power transmitted to which component	N/A	Power transmitted either to the vehicle electric drive or to the on-board energy storage system or both.
Charging time (minutes)	<5	Depends on vehicle speed and dimensions of the primary charging infrastructure.
Vehicle status	N/A	Vehicle engine / power is on during the power transfer process.
Technology	Wireless (inductive) and conductive.	

Market status – static plugin

Full charge (>450km range) in 1 hour, Half charge ~ 30’ at 120kW

Market status – static wireless

QUALCOMM HALO WEVC trials in London 2013

EVATRAN Plugless power US installations

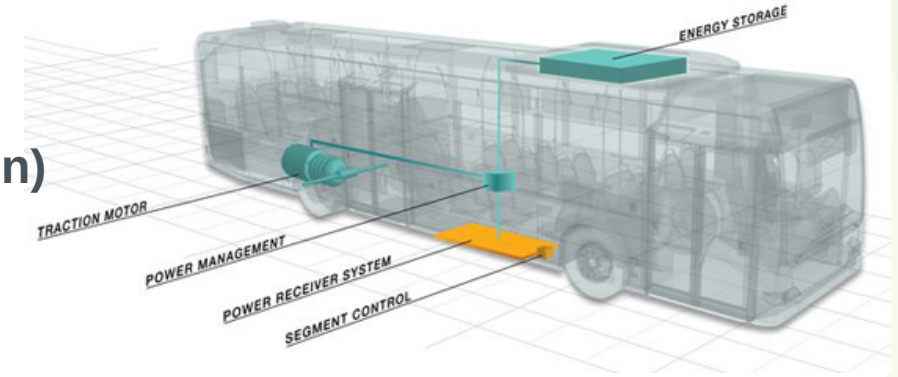
WiTricity partnership with Toyota and AUDI

Major vehicle manufactures announced models with wireless charging capability

Market status – stationary

- **Bombardier Primove: Operational in Braunschweig, Germany since 2013, 200kW inductive stationary charging**

- **Capabus (China)**
- **Conductix-Wampfler (Genoa-Turin)**
- **WAVE (US)**



Market status – dynamic conductive

Siemens eHighway – California tests

Elways electric road prototype - Arlanda

Volvo/Alstom conductive road prototype

Market status – dynamic wireless

In 2009, KAIST installed a system on its own campus and was able to charge vehicles inductively with 60 percent efficiency over a gap of 12 cm.

OLEV's system can now charge with 85 percent efficiency at 100 kW over a gap of 20 cm. And vehicles can charge while in motion.

Market readiness survey - methodology

- Organization
- Name and position in organization
- Name of system/website
- Type of system
- Current TRL, MRL
- Projected TRL, MRL (1 year)
- Current TRL, MRL (components)
- Projected TRL, MRL (components)

Technology Readiness Levels		
Research	TRL 1	Paper studies and scientific experiments have taken place; Performance has been predicted;
	TRL 2	Application specific simulations or experiments have been undertaken; Performance predictions have been refined;
	TRL 3	Performance investigation using analytical experimentation and/or simulations is underway;
tion	TRL 4	The technology component and/or basic subsystem have been validated in a laboratory or test house environment;
	TRL 5	The component and/or basic subsystem have been validated in a relevant environment, e.g. via a mule or adapted current vehicle;
	TRL 6	A prototype of the system or subsystem has been demonstrated within a test house, test track or similar operational environment;
	TRL 7	Multiple prototypes have been demonstrated in an operational, on-vehicle environment;
	TRL 8	The technology has been proven to work in its final form and under expected conditions;
	TRL 9	The technology has been successfully applied in its final form and under real-world conditions;
	TRL 10	The technology is successfully in service in multiple application forms, vehicle platforms and regions;

Manufacturing Readiness Levels		
Proof of concept	MRL 1	Basic manufacturing implications have been identified;
	MRL 2	Manufacturing concepts and feasibility have been determined and processes have been identified;
	MRL 3	Experimental hardware has been created, but is not yet integrated or representative; Supply chain requirements determined;
Prototypes	MRL 4	Capability exists to produce the technology in a laboratory or prototype environment; Design optimised for production;
	MRL 5	Capability to produce prototype components in a production relevant environment;
	MRL 6	Capability to produce integrated system or subsystem in a production relevant environment;
	MRL 7	Capability to produce systems, subsystems or components in a production representative environment; Procurement plans made;
Low & high volume production	MRL 8	Initial production is underway; An early supply chain is established and stable; Manufacturing processes have been validated;
	MRL 9	Full/volume rate production capability has been demonstrated; Major system design features are stable and proven;
	MRL 10	Full Rate Production is demonstrated; Lean production practices are in place and continuous process improvements are on-going; The manufacturing capability is globally deployable;

Market readiness survey - participants

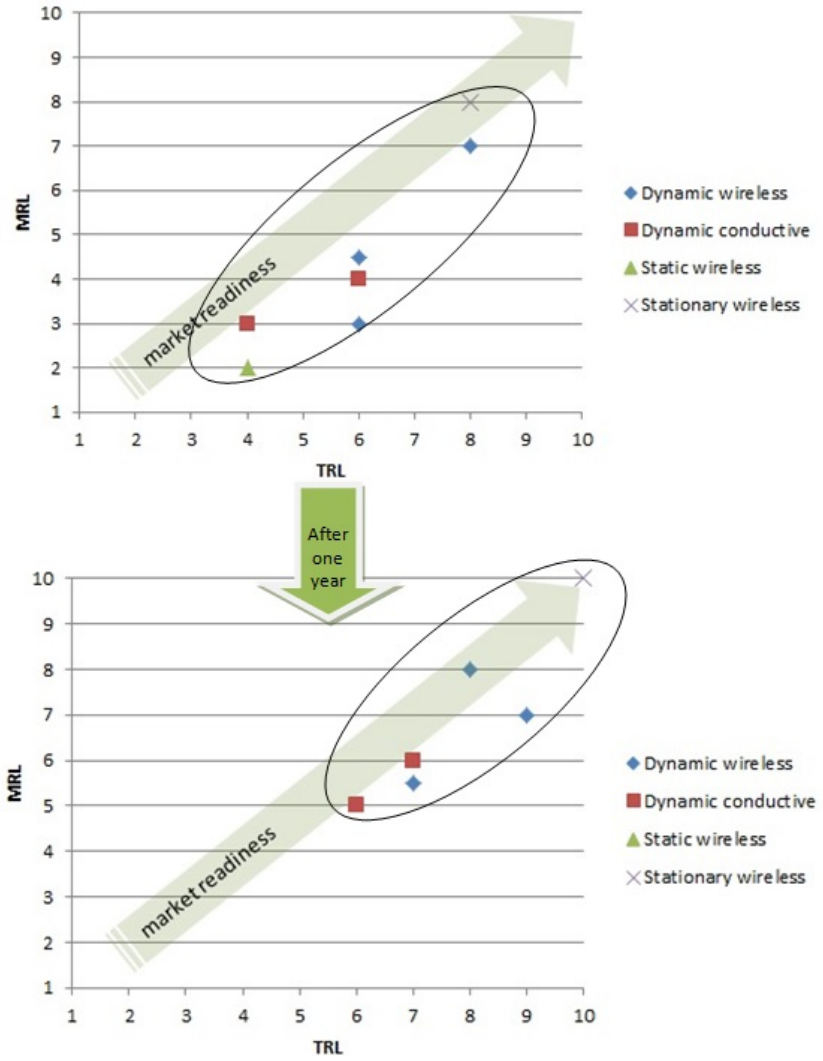
- Replied

Companies and institutes contacted to participate in ommunications SotA survey	Solution	Charging mode
Conductix-Wapfer	IPT	Static wireless
EVATRAN	Plugless power	Static wireless
HELLA		Static wireless
QUALCOMM	HALO	Static wireless
WiTricity		Static wireless
Bombardier	Primove	Stationary wireless
Sinautec Automobile Technologies	Capabus	Stationary wireless
Utah State University	WAVE electric buses	Stationary wireless
Elways	Electric road	Dynamic conductive
Siemens	eHighway	Dynamic conductive
Alstom	Slide-in ERS	Dynamic conductive
INTIS	INTIC	Static/dynamic wireless
KAIST	OLEV	Dynamic wireless
Oak Ridge National Laboratory	ORNL dynamic charging	Dynamic wireless

Market readiness survey – results I

Subjective assessments of product maturity were a bit different from the internet-based market survey.

Significant improvement for systems as a whole are expected next year. Some products are expected to be market ready.

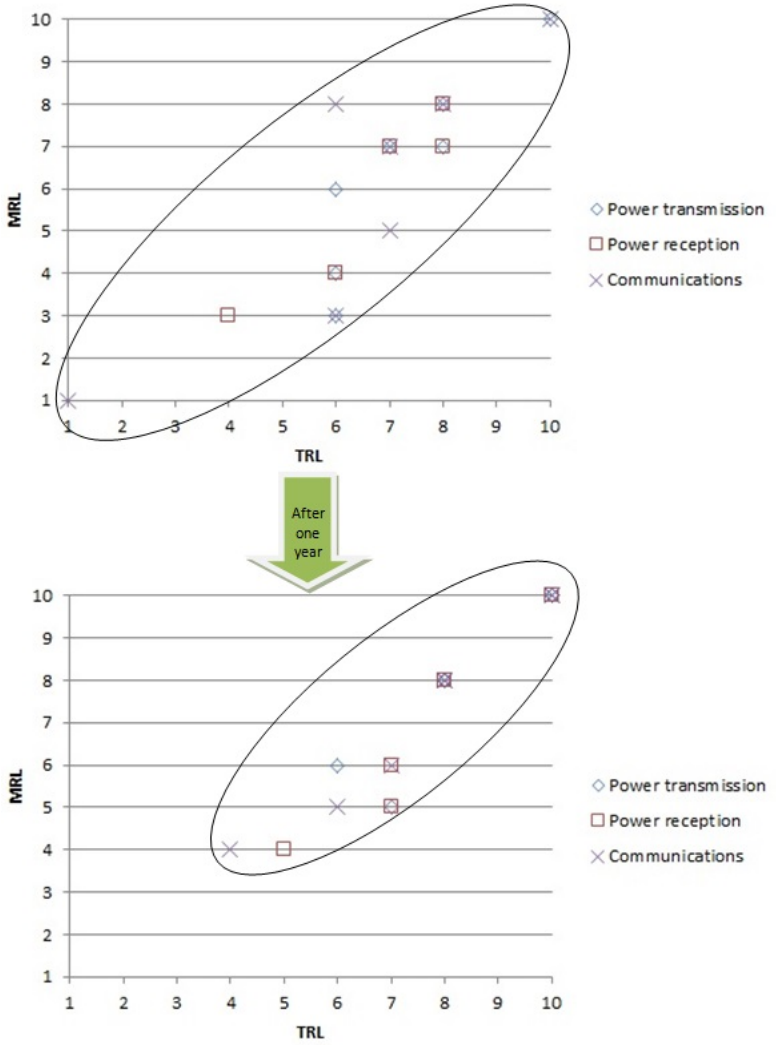


Market readiness survey – results II

Power transmission components more mature than power reception ones

Power reception components have many vehicle-specific restrictions.

Significant improvement is expected next year.



Market readiness study - Conclusions

- Fast static plugin charging is commercially available.
- Static wireless charging is a technologically mature solution which has been tested extensively and the related products are ready to reach the market. Major vehicle manufacturers and OEMs are expected to provide wireless charging stations and EVs within the next year.
- Stationary wireless charging is a technologically mature solution which has been extensively tested for buses. The EVs and infrastructure products are already marketable and their commercial exploitation has begun.
- With the exception of KAIST OLEV, the dynamic charging technology is still in R&D or pre-protopying phase.
- Conductive dynamic charging has been out of the lab environment and is being tested on regular roads. However commercialization is expected to take more time due to the significant investments required to transform normal roads to electric roads.
- Power transmission components are slightly more mature than power reception components. Regarding communications, most manufacturers focus on the power transmission side rather than communications.

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Thank you!

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