Wireless Power Transfer (WPT)

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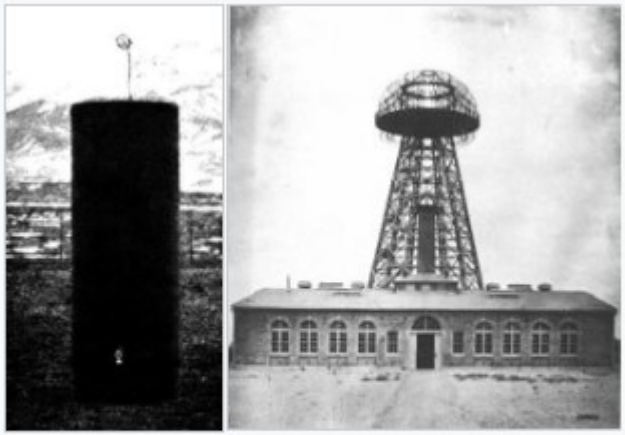
R2

Cleaned up hyperlinks



(left) Experiment in resonant inductive transfer by Tesla at Colorado Springs 1899. The coil is in resonance with Tesla's magnifying transmitter nearby, powering the light bulb at bottom. *(right)* Tesla's unsuccessful Wardenclyffe power station.

Today' Discussion

- What is Wireless Power Transfer (WPT)?
- History
- Examples of WPT (existing)
- Examples of WPT (future)
- WiTricity
- Wi-charge
- Videos
- Discussion

Included some additional information

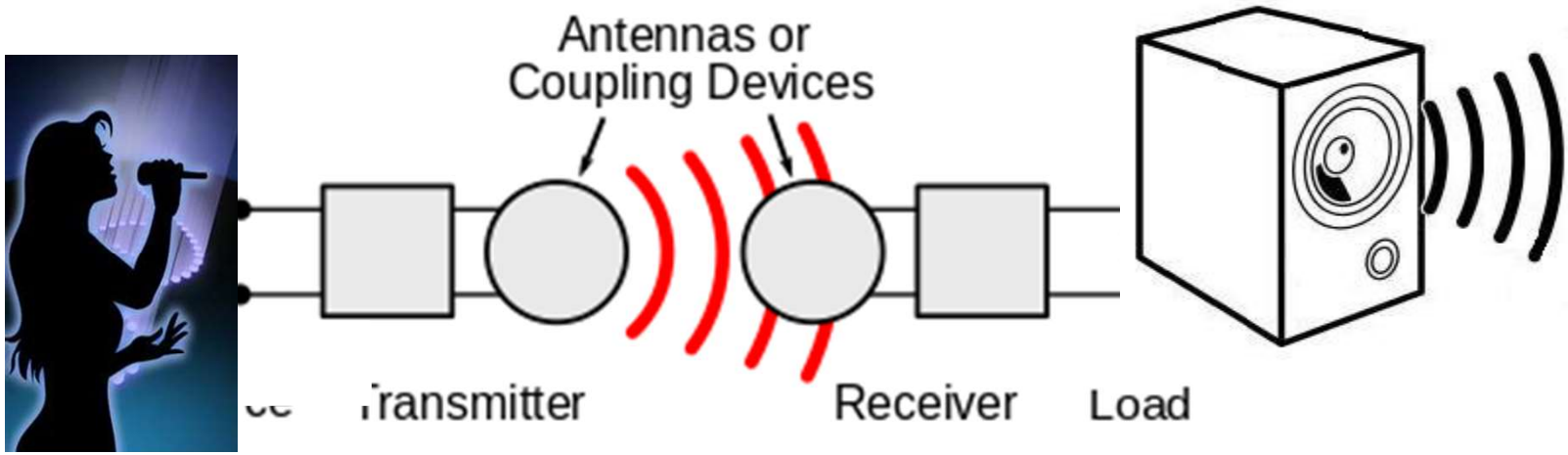
But First

- We need an understanding of Maxwell's equations. As shown below. ;-)

Just Kidding

Name	Integral equations	Differential equations	Meaning
Gauss's law	$\oiint_{\partial\Omega} \mathbf{E} \cdot \mathrm{d}\mathbf{S} = 4\pi \iiint_{\Omega} \rho \, \mathrm{d}$	$\nabla \cdot \mathbf{E} = 4\pi\rho$	The electric flux leaving a volume is proportional to the charge inside.
Gauss's law for magnetism	$\oiint_{\partial\Omega} \mathbf{B} \cdot \mathrm{d}\mathbf{S} =$	$\nabla \cdot \mathbf{B}$	There are no magnetic monopoles; the total magnetic flux through a closed surface is zero.
Maxwell–Faraday equation (Faraday's law of induction)	$\oint_{\partial\Sigma} \mathbf{E} \cdot \mathrm{d}\boldsymbol{\ell} = -\frac{1}{c}\frac{d}{dt} \iint_{\Sigma} \mathbf{B} \cdot \mathrm{d}\mathbf{S}$	$\nabla \times \mathbf{E} = -\frac{1}{c}\frac{\partial \mathbf{B}}{\partial t}$	The voltage induced in a closed loop is proportional to the rate of change of the magnetic flux that the loop encloses.
Ampère's circuital law (with Maxwell's addition)	$\oint_{\partial\Sigma} \mathbf{B} \cdot \mathrm{d}\boldsymbol{\ell} = \frac{1}{c}\left(4\pi \iint_{\Sigma} \mathbf{J} \cdot \mathrm{d}\mathbf{S} + \frac{d}{dt} \iint_{\Sigma} \mathbf{E} \cdot \mathrm{d}\mathbf{S}\right)$	$\nabla \times \mathbf{B} = \frac{1}{c}\left(4\pi\mathbf{J} + \frac{\partial \mathbf{E}}{\partial t}\right)$	The field integrated around a closed loop is proportional to the electric current plus the displacement current (rate of change of electric flux) through the loop encloses.

Communications



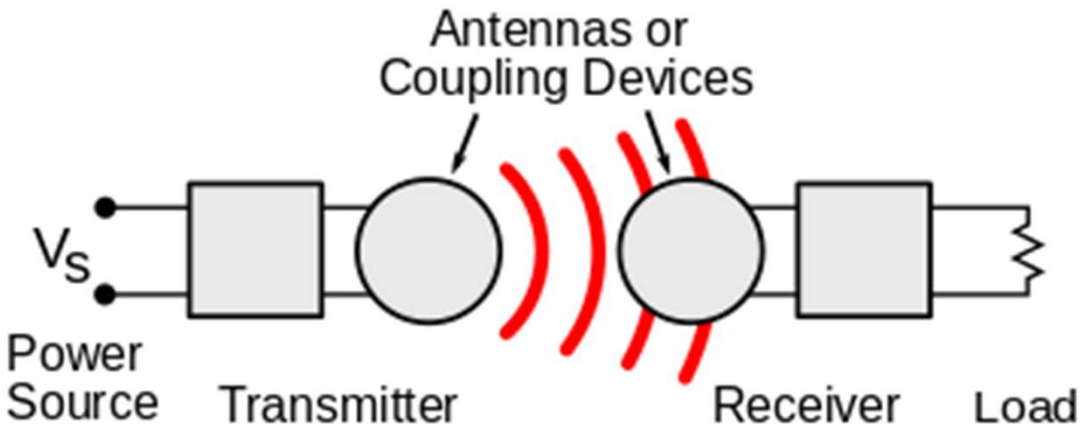
Communications well known applications

Cell Phone
Wi-Fi
Blue Tooth
Broadcast Radio
Broadcast TV

Garage Remote
GPS
RFID Power/Comm.
Micro Wave

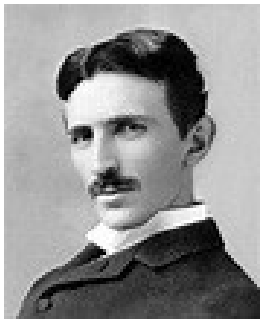
Use This
every day

What is WPT

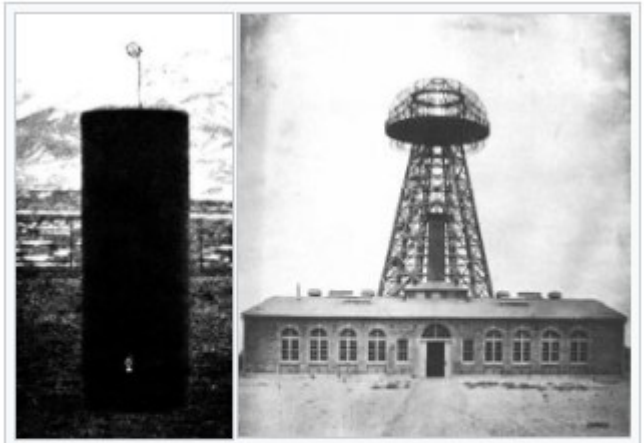


In general a wireless power system consists of a "transmitter" connected to a source of power such as mains power line, which converts the power to a time-varying electromagnetic field, and one or more "receiver" devices which receive the power and convert it back to DC or AC electric current which is used by an electrical.

History



- 19th century developments in electromagnetism by
  - Ampere
  - Faraday
  - Hertz
  - Maxwell
  - Marconi
  - Tesla (AC Generation, distribution, motor)
- At this time there was interest in both wireless communications and wireless power transfer
- Marconi made the first long distance wireless communication in 1901
- Tesla made attempts to demonstrate WPT 1900 – 1906 with very limited success.
- Developments in wireless communications increased exponentially
- While there have been some developments in wireless power in the last century they are far and in between
  - **This may be Changing**



(left) Experiment in resonant inductive transfer by Tesla at Colorado Springs 1899. The coil is in resonance with Tesla's magnifying transmitter nearby, powering the light bulb at bottom. *(right)* Tesla's unsuccessful Wardenclyffe power station.

Power Applications lagging by over 100 years

Further reading

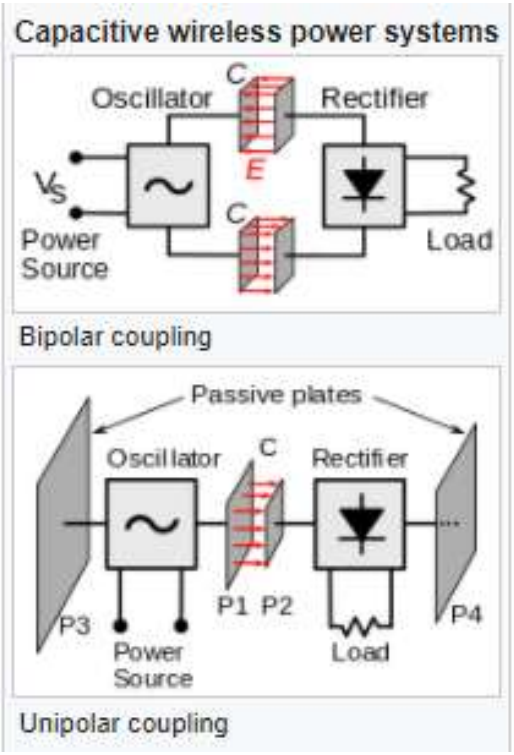
Nikola Tesla's Free Electricity Project

Having become obsessed with the wireless transmission of energy, around 1900 Nikola set to work on his boldest project yet: to build a global, wireless communication system — to be transmitted through a large electrical tower — for sharing information and providing free electricity throughout the world. With funding from a group of investors that included financial giant J.P. Morgan in 1901 Tesla began work on the project in earnest, designing and building a lab with a power plant and a massive transmission tower on a site on Long Island, New York, that became known as Wardenclyffe.

However, doubts arose among his investors about the plausibility of Tesla's system. As his rival, Guglielmo Marconi ---with the financial support of Andrew Carnegie and Thomas Edison — continued to make great advances with his own radio technologies, Tesla had no choice but to abandon the project. The Wardenclyffe staff was laid off in 1906, and by 1915 the site had fallen into foreclosure. Two years later Tesla declared bankruptcy and the tower was dismantled and sold for scrap to help pay the debts he had accrued.

Backup

Types of WPT



- There are many types of WRT
- Just like there are many types of wireless communications
  - Inductive
  - Bipolar or capacitive coupled
  - Unipolar
  - Resonant
  - Microwave
  - Magnetodynamic coupling
    - rotating armatures and permanent magnets
  - Atmospheric plasma channel coupling
  - Far-field (radiative) techniques
  - IR

Energy Harvesting

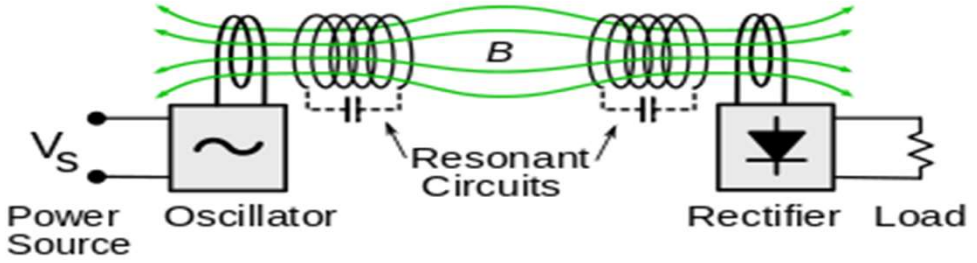


Diagram of the resonant inductive wireless power system demonstrated by Marin Soljačić's MIT team in 2007. The resonant circuits were coils of copper wire which resonated with their internal capacitance (dotted capacitors) at 10 MHz. Power was coupled into the transmitter resonator, and out of the receiver resonator into the rectifier, by small coils which also served for impedance matching

Many Technologies can support WPT

Additional Info.

Technology	Range[18]	Directivity[11]	Frequency	Antenna devices	Current and/or possible future applications
Inductive coupling	Short	Low	Hz – MHz	Wire coils	Electric tooth brush and razor battery charging, induction stovetops and industrial heaters.
Resonant inductive coupling	Mid-	Low	kHz – GHz	Tuned wire coils, lumped element resonators	Charging portable devices (Qi), biomedical implants, electric vehicles, powering buses, trains, MAGLEV, RFID, smartcards.
Capacitive coupling	Short	Low	kHz – MHz	Metal plate electrodes	Charging portable devices, power routing in large-scale integrated circuits, Smartcards.
Magnetodynamic coupling[16]	Short	N.A.	Hz	Rotating magnets	Charging electric vehicles, buses, biomedical implants.
Microwaves	Long	High	GHz	Parabolic dishes, phased arrays, rectennas	Solar power satellite, powering drone aircraft, charging wireless devices
Light waves	Long	High	≥THz	Lasers, photocells, lenses	Charging portable devices,[19] powering drone aircraft, powering space elevator climbers.

Examples of WPT(existing)

- Cell phone charge pad
- Phillips Tooth Brush

Needs precise alignment and very close proximity for power transfer

- RFID
  - Very small amount of power taken from the communications signal it self is used to send the tags ID to receiver.

MIT Spinoff- Witricity

http://witricity.com/

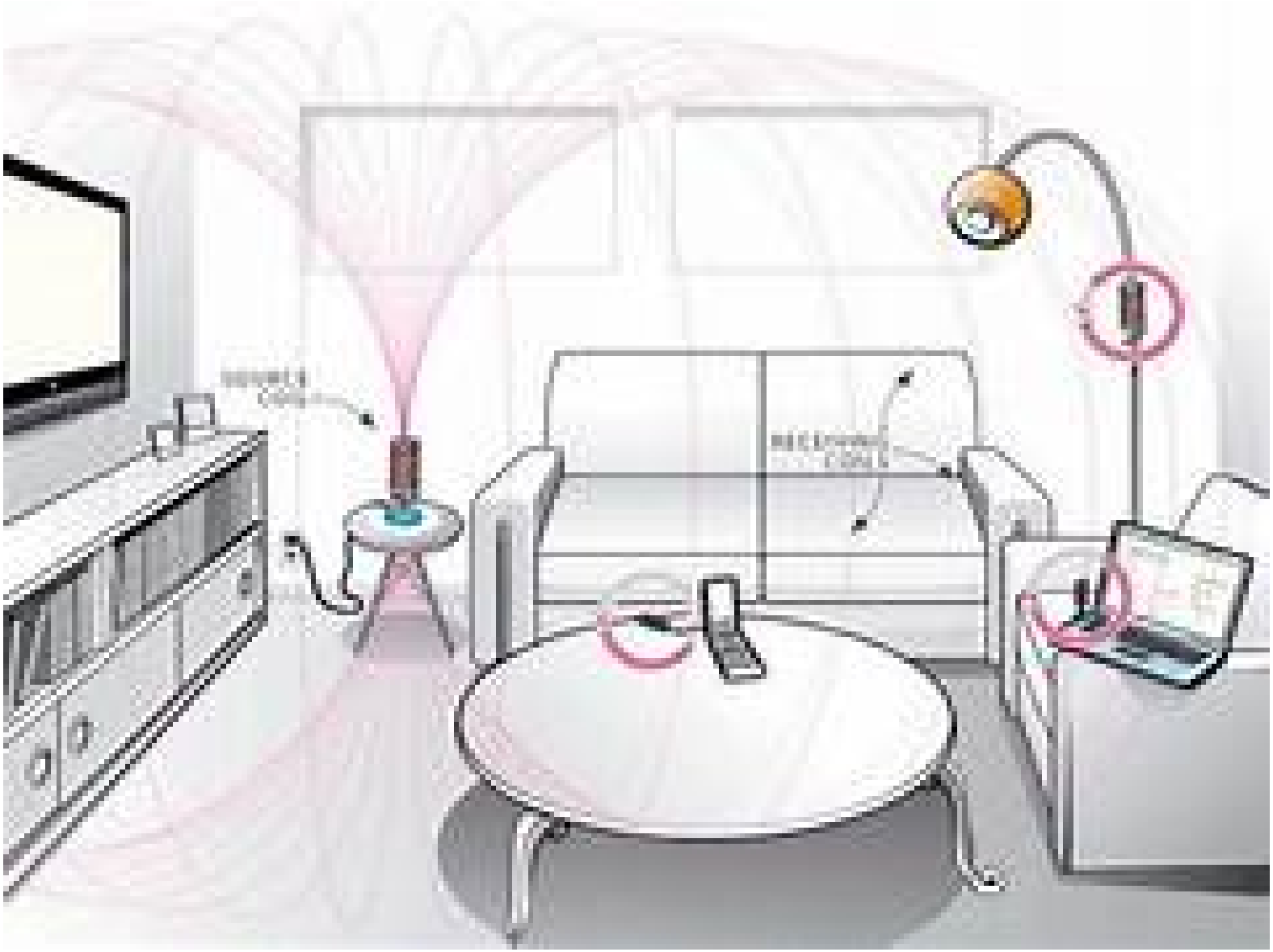
Wireless Power Consortium

Texas Instruments – making compliant silicon

Note:

- Witricity has been at this for several years with very slow progress.
- They did TED talk in 2009 and another very similar one in 2013.

WPT in a Room



Wireless Power Consortium (WPC)

- formed in December 17, 2008
  - based in Piscataway, New Jersey.
- Its mission
  - to create and promote wide market adoption of its interface standard Qi used for wireless charging across a number of products.[
  - It is an open membership of Asian, European, and American companies
  - working toward the global standardization of wireless charging technology As of 2017, the company has over
  - 250 individual companies
  - of which 25 are members of its board of management.

Wireless Power Consortium

WIRELESS POWER CONSORTIUM

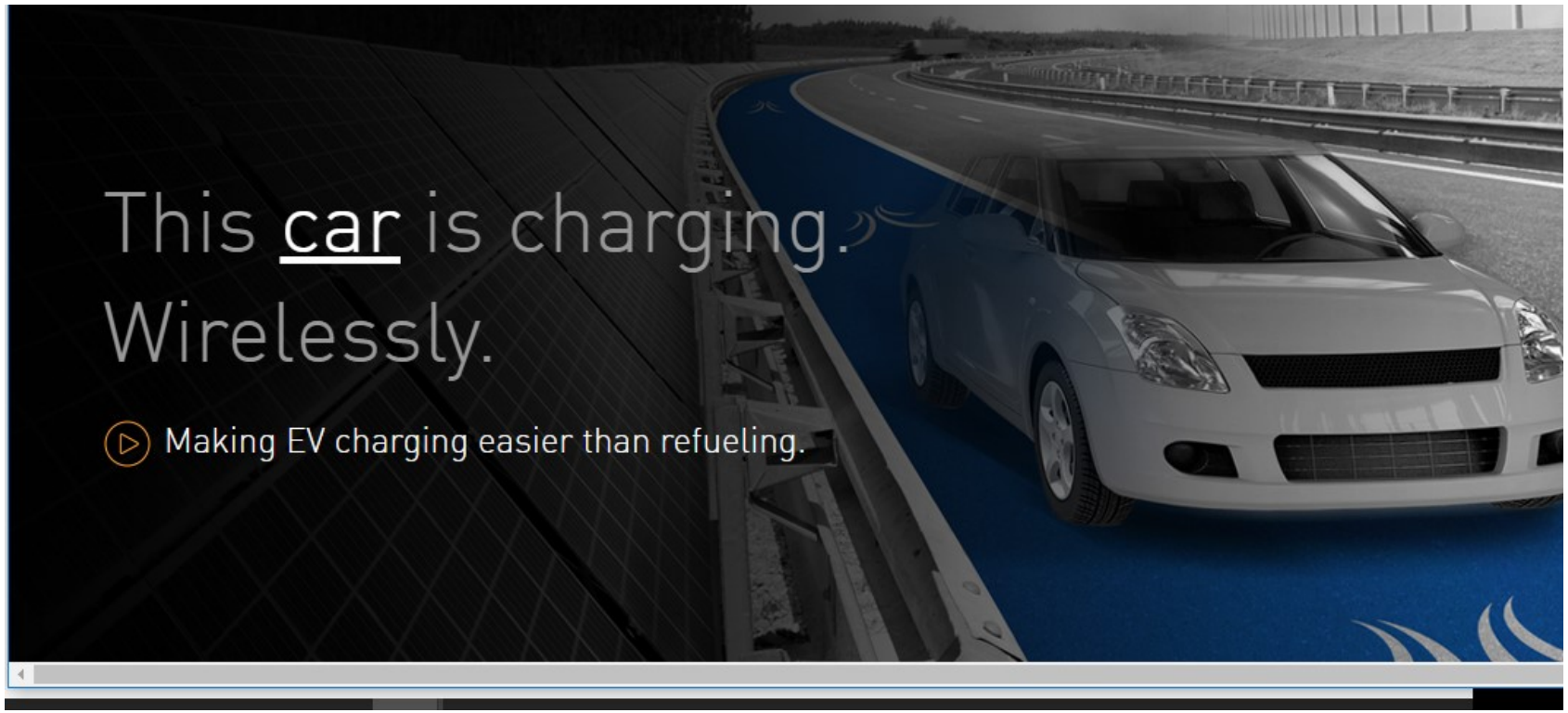
Abbreviation	WPC
Formation	December 17, 2008; 9 years ago[1]
Type	Technology consortium
Headquarters	Piscataway, New Jersey, United States
Region served	Worldwide
Membership	Open

https://www.wirelesspowerconsortium.com/

Wy-charge

- High energy IR
- Sent out in a beam
- Line of sight
- Tracks device movement in room
- https://www.wi-charge.com/

This is a game changer



Videos

Discussion Points

- Brain storm existing applications that may benefit from this
- Unique or new applications
- How pay for power used? Or is it free as Tesla envisioned
- ROI – infrastructure?
- I would like to see solar panels along freeway
  - beam power to electric car for long distance trip
  - You take only the power you need and are billed for what you use.
  - This eliminates the range issues with all electric cars

Other Web Sources

https://www.youtube.com/watch?v=DqQCN-aHYro
young energetic guy

https://www.youtube.com/watch?v=duFL3STguKw
Very good explanation

https://www.youtube.com/watch?v=QSggnJ-JpiA

TEDxRotterdam - Marijn Berk - Wireless power will lead the future.

http://witricity.com/
All videos (plus more) can be found at the above URL

Additional Info.

For further reading

- WPT Description Wikipedia
- Tesla Bio Wikipedia

Backup