

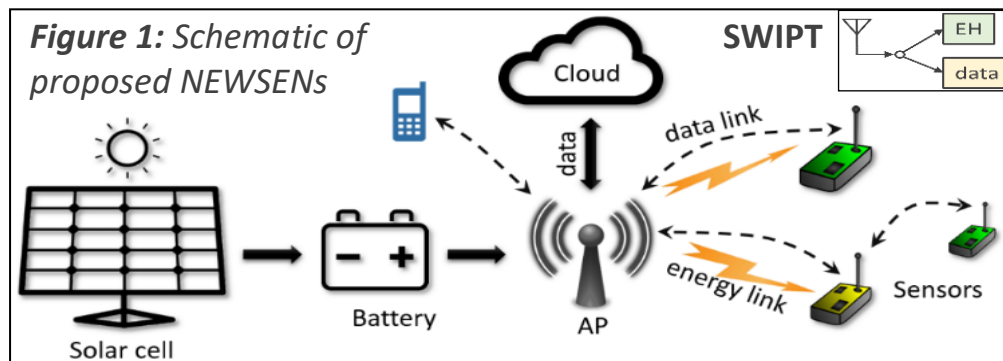


## eNergy nEutral Wireless Sensor Networks

### NEWSENS

**About the Project:** Urbanisation is a significant worldwide trend that Smart City technologies aim to address through prolific smart sensing and intelligent actuation and control. However, the high battery replacement costs of wireless sensors impede innovation and long-term deployments. This project aims to alleviate this problem through a novel system architecture that is powered by cheap, renewable solar energy and that uses state-of-the-art radio frequency (RF) wireless power transfer (WPT) technologies. More specifically, this project will study the technical, practical, and economic aspects of eNergy nEutral Wireless Sensor Networks (NEWSENSs) that comprise of solar-powered central access points acting as RF-energy and information hubs serving a collection of RF-powered wireless sensor devices.

The electromagnetic waves used to wirelessly communicate data information with the small electronic devices and sensors will therefore also be used to power them up through a rectification circuitry. When inter-connected, these wireless devices form networks capable of supporting various Smart City applications. This interdisciplinary effort will utilise advanced mathematical models, multi-objective optimisation algorithms, and renewable energy economics.



**About the Marie Curie Fellow:** Dr Orestis Georgiou has a PhD in Applied Mathematics from the University of Bristol, UK. He has published over 70 articles in leading journals and conferences of Mathematics, Physics, Computer Science, Engineering and Medicine, two of which received Best Paper Awards. Orestis is passionate about innovation, impact, and collaboration, and is currently a Marie Curie Fellow at the IRIDA research centre for communications. Previously, he was Director of Research at Ultrahaptics where he was co-PI of the FET Open projects Levitate and H-Reality, and Senior Research Engineer at Toshiba TRL. Orestis was recently awarded the 2019 IEEE Heinrich Hertz Award for his contributions towards enlarging the field of communications engineering through the analysis of LoRa networks.





## The ‘Singing Arc’

William Duddell, UK, 1899

Carbon Arc Lamps were commonly used for **street lighting** and industrial applications in the late 1880s. The Carbon Arc Lamp generated light by creating a bright spark between two carbon nodes. The problem with this method of lighting, apart from the dullness of the light and inefficient use of electricity was a constant humming, shrieking or **hissing noise** emitted by the electric arc.

The British physicist and electrical engineer William Duddell was appointed to solve the problem in London in 1899. During his experiments Duddell found that by varying the voltage supplied to the lamps he could create controllable audible frequencies from a resonant circuit caused by the rate of pulsation of exposed electrical arcs.

Duddell’s investigations revealed that the cause of the arc-lamp noise was the **nonlinear nature** of the arc that resulted in a negative resistance. This phenomenon had already been recorded in 1898 by a Dr. Simon (Frankfurt, Germany) who had noticed that the electric arc could be made to “sing” by means of modulating the voltage to an electric arc supply. Dr. Simon showed that the electric arc made an effective loudspeaker which he demonstrated in public. Dr. Simon’s experiments also showed that the modulated arc produced not only sound but a **modulated light beam** by means of which the German Navy managed to make telephone calls between ships using a modulated arc searchlight and a photosensitive selenium cell.

Duddell, who may have been aware of Simon’s work, tried to solve the noise by adding a **resonant circuit across the arc** and in doing so he created a **tuneable oscillator**. By attaching a keyboard that varied the voltage input to the circuit, Duddell created one of the **first electronic musical instruments**.

When Duddell exhibited his invention to the London Institution of Electrical Engineers (IEE) it was noticed that arc lamps on the same circuit in other buildings also played music from Duddell’s machine. This led to speculation that **music delivered over the lighting network** could be created.

Duddell didn’t capitalise on his discovery and didn’t even file a patent for his instrument. In 1902 Danish electrical engineers Valdemar Poulsen and Peder Pedersen realised that Duddell’s singing arc would function as a **radio transmitter** if the circuit was tuned to radio, rather than audio, frequencies.

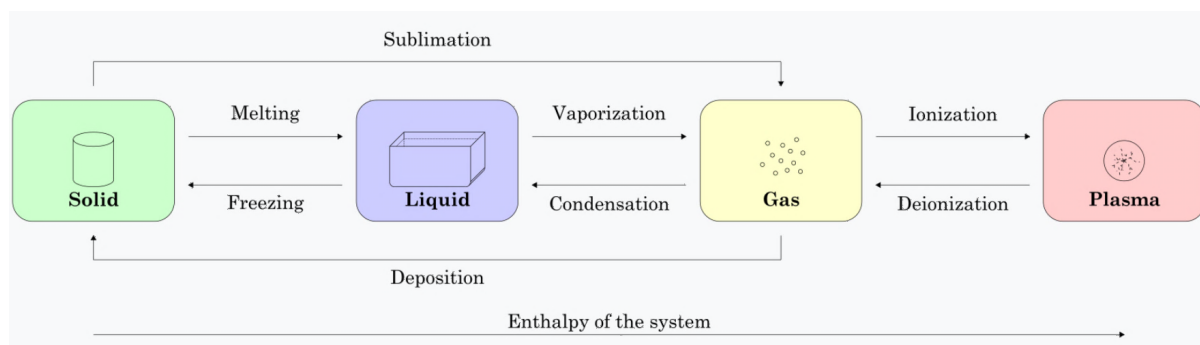
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## What is Plasma?

Plasma (from Ancient Greek πλάσμα, meaning 'moldable substance') is one of the four fundamental states of matter (solid, liquid, gas, plasma), and was first described by chemist Irving Langmuir in the 1920s. It consists of a gas of ions (atoms which have some of their electrons removed), and free electrons. Plasma can be artificially generated by heating or subjecting a neutral gas to a strong electromagnetic field to the point where an ionized gaseous substance becomes increasingly electrically conductive. In fact, for many purposes, the conductivity of a plasma may be treated as infinite. Plasmas are also by far the most common phase of ordinary matter in the universe, both by mass and by volume.



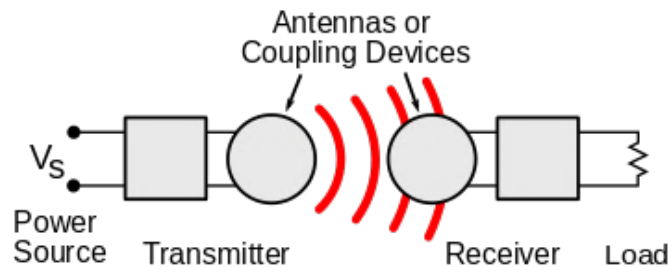
Lightning is an example of plasma present at Earth's surface: Typically, lightning discharges 30 kiloamperes at up to 100 megavolts, and emits radio waves, light, X- and even gamma rays.





## What is Wireless Power Transfer (WPT)?

Wireless power transfer (WPT), is the transmission of electrical energy without wires. In a WPT system, a transmitter device, driven by electric power source, generates a time-varying electromagnetic field, which transmits power across space to a receiver device, which extracts power from the field and supplies it to an electrical load.



Technology	Range	Frequency	Antenna devices	Current and/or possible future applications
Inductive coupling	Short	Hz – MHz	Wire coils	Electric tooth brush and razor battery charging, induction stovetops and industrial heaters.
Resonant inductive coupling	Mid	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	kHz – MHz	Metal plate electrodes	Charging portable devices, power routing in large-scale integrated circuits, Smartcards, biomedical implants.
Magnetodynamic coupling	Short	Hz	Rotating magnets	Charging electric vehicles, biomedical implants.
Microwaves	Long	GHz	Parabolic dishes, phased arrays, rectennas	Solar power satellite, powering drone aircraft, charging wireless devices
Light waves	Long	$\geq$ THz	Lasers, photocells, lenses	Charging portable devices, powering drone aircraft, powering space elevators.