ISSN: 2834-4928

Research Article

Journal of Electrical Electronics Engineering

Pulse-Induced Electrochemical Phenomena: Proposed Mechanisms using Extended Electrodynamic Theories

Julian Andrew Perry*

Kerrow Energetics, UK

***Corresponding Author**
Julian Andrew Perry, Kerrow Energetics, UK.

Submitted: 2025, Mar 12; **Accepted:** 2025, Apr 02; **Published:** 2025, Apr 08

Citation: Perry, J. A. (2025). Pulse-Induced Electrochemical Phenomena: Proposed mechanisms using extended electrodynamic theories. *J Electrical Electron Eng, 4*(2), 01-20.

Abstract

Prior studies have shown that energy gains can result from the application of inductively generated high voltage pulses to the cathode of both Lead-Acid (Pb-A) and Lithium Iron Phosphate (LFP) batteries using specific operational parameters, including pulse repetition rate and peak pulse voltage. It has also been shown that internal enthalpy cannot be the cause of the energy gains due to a lack of correlation between measured charge capacities and those predicted from a thermodynamic analysis of the electrochemical changes occurring when measured energy releases occur, together with battery behaviour over long-term pulse delivery.

The binary option of the source of energy gains being either inside or outside of the battery carries with it various implications for both the energetics of pulse induced responses of the electrochemistry and, perhaps more importantly, the inclusion of the local environment of the battery as part of an open and interactive system. With the latter having been demonstrated, the question remains as to what mechanisms, processes and energetic pathways might be involved that can result in a coefficient of performance >1 and how any that are proposed relate to currently accepted electrodynamic and field theories, classical and quantum. To this end, classical electrodynamic (CED) theory is compared with extended electrodynamic theory (EED) which is a logical and proven derivative based on decades of work by relevant parties. This work has revealed the presence of longitudinal and scalar field components that can contribute to inductive pulse charging (IPC) effects. Evidence for EED is given, along with various applications, to illustrate its potential role in signal detection, information and power transmission.

Furthermore, experimental work on the extraction of energy from the quantum vacuum is considered in the context of stochastic electrodynamics (SED), which provides a bridge between classical and quantum descriptions of Nature. From these frameworks, various mechanisms are proposed that can explain the evidence obtained from IPC and with a view to adding further weight to these extended electrodynamic theories.

Keywords: Classical Electrodynamics, Extended Electrodynamics, Stochastic Electrodynamics, Quantum Vacuum, Flyback Pulses

1. Introduction

Studies into the effects of inductive pulse charging (IPC) on secondary cells used inductively generated reverse voltage flyback (kickback) pulses that are delivered to an electrochemical system, such as a battery. There is a long history of related systems and patents employing short-duration DC pulses which originally derived from the work and observations of Daniel Cook and Nikola Tesla towards the end of the 19th century, who coined the term 'radiant' effects. Further developments throughout the 20th century by such pioneers as Carlos Benitez, Robert Adams, Raymond Kromrey, Edwin Gray, John Bedini, Peter Lindemann, and others into the 21st century, paved the way for many replications by amateur and professionals alike in the domains of physics, electronics and electrical engineering [1 - 9].

Developments by independent parties continue to the present day but generally fall outside of regular peer review and mainstream publications due to the unconventional, and so far unexplained, nature of the results. Despite this, there have been ongoing proposals for generator designs using, for example, an AI and 'Internet of Things' based control system, or seeking to optimise earlier design parameters [10-14]. These seek to both engineer around the effects of Lenz's Law upon rotor/stator dynamics and, more particularly, to utilise the energy available from the inductively generated high-voltage flyback pulses. This is done to both recycle some of the electrostatic energy available in the pulses and, more importantly, to elicit specific effects upon the battery and the local environment which has been shown to give rise to an energetic phenomenon not currently explainable by conventional electrodynamic theory.

Two recent transparent and publicly accessible studies, undertaken using the Open Science Framework (OSF)[1] and accom-

[1]The first OSF study is at: https://osf.io/ztfub/ and the second at: https://osf.io/bpxg6/

panied by detailed replication materials [9,15], have reported that inductively generated HV pulses can induce energy gains in various secondary cells when the pulses are delivered with specific operational parameters, and that the observed energy gains derive from the local environment rather than from a response of the electrochemistry to the electrostatic pulses; in other words not from internal enthalpy. Specifically, the first study demonstrated energy gains resulting in Coefficient of Performance values of between 1.5 and 2.6 with an 80Ah AGM Lead Acid battery and between 6 and 12 with an 18Ah Lithium Iron Phosphate (LFP) battery. These results are not currently explained by standard classical electrodynamic theory and suggest that an additional energy influx is occurring by as yet unrecognised means, either from internal enthalpy, whereby the electrochemistry responds to the pulses with a release of chemical energy, thereby reducing the battery's capacity over time, or from the local environment through undefined energetic processes and pathways.

The second study explored these two source options by examining the long-term effects of IPC on various batteries and with a detailed analysis of the thermodynamics involved in the potential release of chemical energy using a 'chemical deficit model'. From this analysis, predictions of changes in battery capacity were made after continued IPC and associated energy gains. The predicted capacity values were compared with the measured values when the battery was subsequently discharged through an electronic load down to a repeatable and acceptable 'Depth of Discharge' typically approximately 25% of the battery's capacity remained so as not to cause irreversible damage. The data was analysed to determine the degree of correlation between measured and predicated capacities which would support either the null (enthalpic) or alternate (environmental) hypothesis. The results clearly showed that internal enthalpy could not be the source of the observed energy influx and that the battery and pulse generation system was behaving as an open system, allowing an influx of energy from the local environment.

The processes and pathways for this energy influx cannot currently be accounted for by a classical electrodynamic model (CED), however, in the context of an extended electrodynamic theoretical model (EED) and the stochastic electrodynamic model (SED), various plausible mechanisms arise which are here explored and suggest that these models can play an increasing role in various technologies across many scientific disciplines. This paper will first examine classic electrodynamic theory in section 2 before looking at the derivation of extended electrodynamic theory in section 3. Section 4 will explore the evidence for electroscalar waves and their applications across diverse scientific disciplines. Section 5 will examine the vacuum and the potential for energy extraction, while section 6 considers stochastic electrodynamics with its classical vacuum. Section 7 presents various plausible mechanisms for the observed energy gains in IPC using the extended and stochastic electrodynamic frameworks and how it may contribute to evidence for such. This is followed by the discussion and conclusions.

2. Classical Electrodynamic Theory

Classical electrodynamics is a fundamental pillar of physics in that it unifies electromagnetism with light in a systemic mathematical structure that allows for the design of, and prediction of the behaviour of, nearly all electrical and electronic systems to date with persistent accuracy. It is based upon empirical findings rather than derived axiomatically from first principles and is therefore always one experiment away from falsification and needing revision [16]. It addresses not only conduction electrons but also virtual (non-inertial) charges along the surfaces of metals [17]. However, despite the success of classical electrodynamics (CED), and its quantum counterpart quantum electrodynamics (QED), which could explain the photoelectric effect and absorption spectroscopy which CED could not, there have been longstanding arguments that CED is incomplete from both an experimental and theoretical point of view [18].

Maxwell expressed his original equations as 20 partial differential equations in Cartesian coordinates based on the experimental work of Faraday on induction, and in particular the observations of what he called the 'electrotonic state', which later became known as the magnetic vector potential 'A' [19, 20]. Faraday saw the electrotonic state as a 'store of potential dynamism' in the field surrounding an electrical conductor, the source of the 'electric momentum' in a circuit. This he saw as a precursor to the action of magnetic fields on secondary conductors and fundamental to any electrodynamic theory. It was Maxwell

	Standard vector form	*Using the scalar and vector potentials*
Gauss's Law	$\nabla \bullet \vec{E} = \frac{\rho}{\epsilon}$	* $\nabla^2\Phi - \frac{\partial^2\Phi}{\partial c^2 t^2} = -\frac{\rho}{\epsilon}$
Gauss's Law for Magnetics	$\nabla \bullet \vec{B} = 0$	$\vec{B} = \nabla \times \vec{A}$
Faraday's Law	$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$	$\vec{E} = -\nabla\Phi - \frac{\partial \vec{A}}{\partial t}$
Ampere-Maxwell Law	$\nabla \times \vec{B} = \mu\epsilon\frac{\partial \vec{E}}{\partial t} + \mu\vec{J}$	* $\nabla^2\vec{A} - \frac{\partial^2\vec{A}}{\partial c^2 t^2} = -\mu\vec{J}$
		* Φ *and A wave equations*

Table 1: Maxwell's equations in vector form and expressed in terms of the scalar and vector potentials. Those marked with an * are the derived wave equations [18].

[2]CoP is the ratio of the net efficiency moderated output energy divided by the input energy supplied by the user.

who later, in close association with Faraday, mathematically formalised this appreciation as the magnetic field vector potential A [21]. Heaviside, Hertz and Gibbs later rewrote them as only 4 equations in vector calculus form and also with solutions in terms of the electric scalar potential (**Φ**, equivalent to **V**) and the magnetic vector (A) potential as shown in **Table 1**. Historically, the original architects of what became known as classic electrodynamics considered the electric scalar potential (**Φ**) and the magnetic vector potential (A) to be mere mathematical entities to facilitate the computation of various solutions to Maxwell's equations. One of the predictions was the transverse electromagnetic (TEM) wave which Hertz was the first to detect, but he did not publish details of his other observations of what were considered by Tesla to be longitudinal waves akin to the cathode rays produced in an evacuated tube [22]. This started a bias towards TEM at the expense of longitudinal components that persists to the present day.

Maxwell's original form for the B-field was $\vec{B} = \nabla\times \vec{A}$ which Heaviside re-wrote as $\nabla \bullet \vec{B} = 0$ and that has $B = \nabla\times A$ as a solution. However, the vector potential version of $\nabla\cdot B = 0$, as $B = \nabla\times A$, allows the addition of $\nabla\Lambda$ to A, where Λ is any of an infinitude of scalar functions of space-time. The Maxwell-Heaviside form then paved the way to gauge theory which improperly treated the irrotational (zero-curl) component of A. Lorenz later recognised that wave equations for Φ and A can only be obtained via an additional constraint known as the Lorenz gauge. However, the Lorenz gauge does not eliminate the arbitrariness in CED and allows an infinitude of gauge transformations. Also, it is applied in an ad hoc fashion with no justification from first principles [18]. It was primarily Heaviside, with his background in engineering and telegraphy, and also independently Hertz, who argued that the electric and magnetic potentials had no physical significance, were unmanageable and unnecessary and that the 'duplex' field equations were the sole foundation of electromagnetism [21]. Furthermore, according to classical field theory, EM potentials can only be real if they are gauge-invariant and so for the potential to have 'real' physical meaning, they would have to become either gauge-invariant or part of a gauge-free theory.

It has been argued that the magnetic vector potential A and the electric scalar potential **Φ** (or **V**) can be derived from superpotentials and, for some, are considered to form part of a triad with the gravitational scalar potential and where all three are themselves derived from a scalar superpotential. Indeed, in QED we may write A as the gradient of the superpotential χ and **Φ** as the rate of change of χ with respect to time. Derivation of the gravitational potential using a superpotential has been applied in cosmological models and therefore it may be reasonable to argue that χ is the same in both cases, as depicted in **Figure 1**, and which would be a valuable contribution to the unification of electrodynamics and general relativity [23]. Work to confirm the interrelationship between these potentials, and therefore the plausibility of an overarching superpotential that would contribute to a theory of everything, is still in its early stages and not yet bridging the disciplines in a manner consistent with its implications.

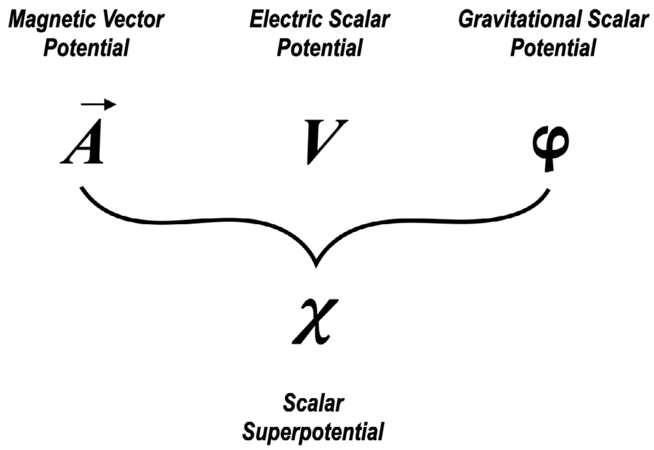

Figure 1: Magnetic vector, electric scalar, and possibly gravitational, potentials derived from a superpotential.

However, since QED now recognises the magnetic vector potential (A) as one of the four fundamental forces in Nature, alongside the electro-weak, the strong force and gravity, it has once again risen to its correct place and, in the spirit of Faraday's 'store of field momentum', can be exchanged with the kinetic energy and momentum of charged particles in a conductive medium.

3. Extended Electrodynamic Theory

The journey to an extended electrodynamic theory began back in 1889 when Sir Oliver Lodge made observations of what is now termed the 'Maxwell-Lodge' effect (MLE) depicted in **Figure 2A.** Here a long solenoid was supplied with an alternating signal, which produced a measurable magnetic field inside the solenoid, but not outside it. Despite the absence of an external B-field, a secondary voltage is measurable in a wire loop arranged radially to the coil [21, 16]. The observations were put down to inaccurate 19th century equipment and the possibility of extraneous magnetic fields, so the effects were not included in Maxwell's theoretical developments and formalisation and therefore those that followed from Heaviside, Gibbs, Hertz and others.

[3]Typically approximately 25% of the battery's capacity remained so as not to cause irreversible damage.

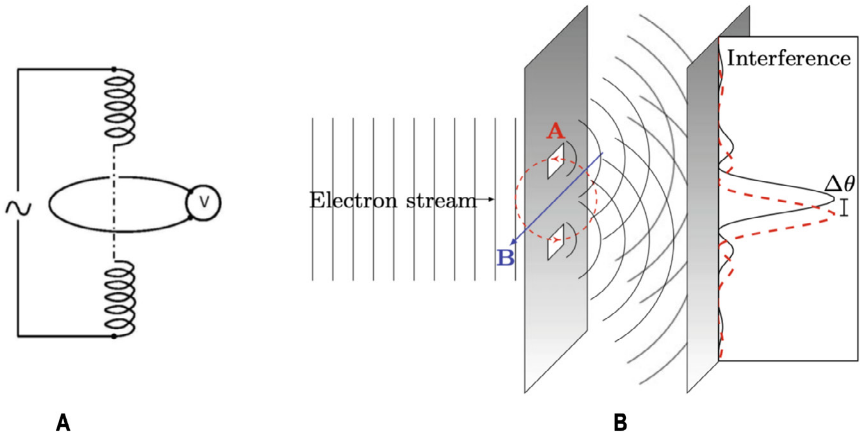

Figure 2: The two effects that demonstrated the physical reality of the magnetic vector potential, (A) the 'Maxwell-Lodge' effect and (B) the 'Aharonov-Bohm' effect [27]. (Full sized versions of all figures and tables can be viewed at: https://osf.io/ebc2k/files/osfstorage)

Additionally, in classical mechanics and field theory, the equations of motion are derived solely from the field values where the potentials (Φ and A) are seen as purely mathematical auxiliaries and devoid of any real physical meaning. Therefore the fields, and not the potentials, were viewed as the fundamental reality. The so-called Aharonov-Bohm effect (ABE), depicted in **Figure 2B**, demonstrated how a stream of electrons can produce an interference pattern after experiencing a phase shift from the magnetic vector potential even in the absence of a magnetic field. It was predicted in 1959 [27] and experimentally verified in 1986 [24] and which has been variously repeated and these experiments have demonstrated the physical significance of A. It is this result in particular that has instilled QED with the validity of the field vector A as a real physical entity, as expounded by Richard Feynman in his lectures [25]. In a similar fashion, an electric equivalent of the ABE exists where a variation in **Φ** along two different paths with zero electric field produces a phase shift in the wave function [26].

Therefore, contrary to the conclusion of classical electrodynamics, there exist effects on charged particles due to the presence of the potentials, even in regions where all the fields (and therefore the Lorentz forces on the particles) are zero and where an electromagnetic effect can be propagated without any magnetic component and at all scales. As such the MLE is now seen as the classical equivalent of the ABE, although its significance was not appreciated at the time.

Rousseaux et al. demonstrated theoretically, experimentally and numerically that the ABE effect can be understood using the vector potential while it cannot be when using only the B and E-fields, and others have done likewise [28, 29, 30].

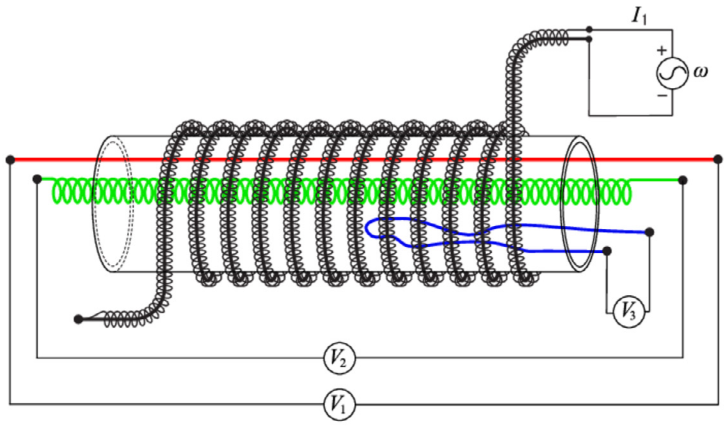

Figure 3: A Vector Potential transformer (VPT) [31].

Daibo et al. further demonstrated the creation of a curl-free vector potential inside a hollow cylinder, referred to as a vector potential transformer (VPT), without a magnetic field and where the potential generates a secondary voltage across a secondary conductor with a time-varying primary current [31]. Daibo went on to demonstrate a version of the MLE where the secondary coil was shielded by a high-temperature superconducting cylinder, demonstrating a phase shift in the wave function with zero electric field and, as a consequence, the valuable penetrating capabilities of vector potentials in, for example, non-destructive testing and medical equipment [32].

Besides the early gauging away of the vector potentials and their later re-introduction as independent physical realities, various inconsistencies have been recorded over decades that have not been resolved in CED. Hively & Loebl identified three main issues [18]. Firstly, there is an overdetermination in CED that has been unsatisfactorily resolved by circular logic and unwarranted assumptions. Secondly, there are disparities in the matching conditions for a surface charge between differing conductive media from Φ and Gauss's law. Thirdly, the interdependence of the magnetic vector potential A and the scalar electric field potential Φ when the arbitrary Lorenz gauge is applied.

According to the Helmholtz theorem, a three-vector field can be uniquely decomposed into irrotational and solenoidal parts. Woodside has also shown that smooth Minkowski four-vector fields also can be uniquely decomposed into a four-solenoidal (divergent-free) part and a four-irrotational (curl-free) part with tangential and normal components on the bounding three-surface [33]. He subsequently used the Stueckelberg-Lagrangian density (*Eqn. 1*), written by Dirac, Fock and Poldolsky, to express it in terms of the standard scalar (Φ) and magnetic vector potentials (A) for a massless 4-vector field [34]. It is the relationship between the potentials that underscores the disclosure of the missing electroscalar field and its otherwise unsuspected role in electrodynamics [21].

$$L = \frac{\epsilon c^2}{4} F_{\mu\nu}F^{\mu\nu} + J_\mu A^\mu - \frac{\gamma \epsilon c^2}{2}(\partial_\mu A^\mu)^2 - \frac{\epsilon c^2 k^2}{2}(A_\mu A^\mu)$$

Eqn. 1

For $\boldsymbol{\gamma} = 1$ and m = 0 (where *m = k h/2π and h is Plank's constant*) the Lagrangian density in CED becomes:

$$L = \frac{\epsilon c^2}{2}\left[\frac{1}{c^2}\left(\nabla\Phi + \frac{\partial \vec{A}}{\partial t}\right)^2 - (\nabla \times \vec{A})^2\right] - \rho\Phi + \vec{J} \bullet \vec{A} - \frac{\epsilon c^2}{2}\left(\nabla \bullet \vec{A} + \frac{1}{c^2}\frac{\partial \Phi}{\partial t}\right)^2$$

Eqn. 2

This has two solutions, the first has zero four-curl $A^\mu = \partial^\mu \Lambda$ together with a non-zero dynamic scalar field:

$C = \partial_\mu A^\mu = \partial_\mu \partial^\mu \Lambda$ where Λ is a scalar function of space-time.

Eqn. 3

The second has a zero four-divergence A_μ, $C = \partial_\mu \partial^\mu \Lambda = 0$ (the Lorenz gauge) and is consistent with CED.

3.1. Wave Equations

Detailed analysis by Hively and Loebl (p113 & 115) shows that the CED wave equations based on E, B, A and **Φ** are still derived using EED and without a gauge condition [18].

$$\nabla^2 \vec{E} - \frac{\partial^2 \vec{E}}{\partial c^2 t^2} = \frac{\nabla \rho}{\epsilon} + \mu \frac{\partial \vec{J}}{\partial t} \qquad \nabla^2 \vec{B} - \frac{\partial^2 \vec{B}}{\partial c^2 t^2} \equiv \Box^2 \vec{B} = -\mu \nabla \times \vec{J}$$

$$\nabla^2 \vec{A} - \frac{\partial^2 \vec{A}}{\partial c^2 t^2} = -\mu \vec{J} \qquad \nabla^2 \Phi - \frac{\partial^2 \Phi}{\partial c^2 t^2} = -\frac{\rho}{\epsilon}$$

Eqn. 4

	CED	EED
Gauss's Law	$\nabla \bullet \vec{E} = \frac{\rho}{\epsilon}$	$\nabla \bullet \vec{E} + \frac{\partial C}{\partial t} = \frac{\rho}{\epsilon}$
Gauss's Law for Magnetics	$\nabla \bullet \vec{B} = 0$	$\vec{B} = \nabla \times \vec{A}$
Faraday's Law	$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$	$\vec{E} = -\nabla\Phi - \frac{\partial \vec{A}}{\partial t}$
Ampere-Maxwell Law	$\nabla \times \vec{B} = \mu\epsilon \frac{\partial \vec{E}}{\partial t} + \mu \vec{J}$	$\nabla \times \vec{B} - \frac{1}{c^2}\frac{\partial \vec{E}}{\partial t} - \nabla C = \mu \vec{J}$
$C = \nabla \bullet \vec{A} + \frac{1}{c^2}\frac{\partial \Phi}{\partial t}$	$Lorenz\ gauge\ (C) = 0$	$C = Scalar\ field$

Table 2: Comparison of equations for CED and EED (***Derived from*** **[16]).**

The wave equation for C can also be determined without the ad hoc assumptions used to avoid the overdetermination of Maxwell's equations [35, 18].

$$\nabla^2 C - \frac{\partial^2 C}{\partial c^2 t^2} = -\left(\frac{\partial \rho}{\partial t} + \nabla \bullet \vec{J}\right)$$

Eqn. 5

The dynamical equations were derived by Ohmura in 1956 [36] and the Lagrangian and Hamiltonian were updated by Aharonov and Bohm in 1956. The Lagrangian allows only two classes of four-vector fields [18]. One class has zero four-divergence and is consistent with CED, the other has zero four-curl and includes a non-zero scalar field [37]. This gives rise to a set of equations for EED as shown in **Table 2,** including a longitudinal scalar field where the new scalar-valued component (C) is a dynamic function of spacetime and no longer a zero gauge condition for the solenoidal fields as described in CED [16, 21].

3.2. Electroscalar Waves

EED also predicts the presence of longitudinal electroscalar waves, commonly referred to as scalar longitudinal waves (SLW). Conventionally, the four-gradient component of A is gauged away in CED which is inconsistent with experiments [29, 31]. Gauge-free EED eliminates this disparity by explicitly including solenoidal (transverse) and irrotational (longitudinal) components.

Using the identity $\vec{A_L} = \nabla\alpha$ (where α is a scalar function of space-time) and using $B = \nabla \times \vec{A}$

$$\vec{B} = \nabla \times \nabla\alpha = 0,\ or\ \vec{A_L} = \nabla\alpha \Longrightarrow \vec{B} = 0$$

Eqn. 6

It can then be shown that: $\vec{A_L} = \nabla\alpha \Leftrightarrow \vec{B^T} = 0 \Leftrightarrow \vec{J^L} = \nabla\kappa$ ([18], *pp*115-116)

This equation drives the 'scalar-longitudinal' wave (SLW), also known as an 'electro-scalar' wave, since $\vec{E}_L = \frac{\vec{J}}{\sigma} = \frac{\nabla\kappa}{\sigma}$ where $\vec{E}_L$ and $\vec{J}_L$ are longitudinal (irrotational, curl-free and gradient-driven) vectors. Faraday's Law can then be written as:

$$\nabla \times \vec{E}_L = -\frac{\partial \vec{B}}{\partial t} = \nabla \times \frac{\nabla\kappa}{\sigma} = 0 \qquad \textit{Eqn. 7}$$

With no B field, there are no eddy currents formed so the SLW is unimpeded by the skin effect in linear conductive media. From the SLW impedance, it can be shown that the radiation pattern is isotropic with a $1/r^2$ attenuation [18].

The time-averaged power output can also be shown to be [18, 37]:

$$P_{out} = \frac{1}{2}\left(\frac{I^2\hat{r}}{(4\pi r)^2}\sqrt{\frac{\mu}{\epsilon}}\right) \qquad \textit{Eqn. 8}$$

where μ and ε are the magnetic permeability and electric permittivity respectively of the propagating medium and not necessarily a vacuum.

3.3. Scalar Waves

EED also predicts a scalar wave (SW) that has a scalar component and an associated longitudinal component. Hively and Loebl ([18], p115-117) show that:

Using $\vec{A}_L = \nabla\alpha$ and the condition that $\vec{E} = 0$ (meaning that a scalar field is generated by a current that is not driven by an electric field) then $\Phi = -\frac{\partial\alpha}{\partial t}$ and $C = \nabla \bullet \vec{A} + \frac{1}{c^2}\frac{\partial\Phi}{\partial t}$ can be written as:

$C = \nabla^2\alpha - \frac{1}{c^2}\frac{\partial^2\alpha}{\partial t} = \Box^2\alpha$ and that C has the same 1/r dependence in free space and that the scalar wave has a pressure of $\frac{\nabla C^2}{2\mu}$ but no momentum density.

Also that EED further predicts a revised energy balance equation:

$$\frac{\partial}{\partial t}\left(\frac{\vec{B}^2}{2\mu} + \frac{C^2}{2\mu} + \frac{\epsilon\vec{E}^2}{2}\right) + \nabla \bullet \left(\frac{\vec{E}\times\vec{B}}{\mu} + \frac{C\vec{E}}{\mu}\right) + \vec{J}\bullet\vec{E} = \frac{\rho C}{\epsilon\mu} \qquad \textit{Eqn. 9}$$

and which includes new terms $\frac{C^2}{2\mu}$, SLW energy $\frac{C\vec{E}}{\mu}$ and a power source $\frac{\rho C}{\epsilon\mu}$ and a new momentum balance equation:

$$\epsilon\mu\frac{\partial}{\partial t}\left(\frac{\vec{E}\times\vec{B}}{2\mu} - \frac{C\vec{E}}{\mu}\right) + \rho\vec{E} + \vec{J}\times\vec{B} + \frac{\nabla\times\vec{B}C}{\mu} = \vec{J}C + \frac{\nabla C^2}{2\mu} + \nabla\bullet\overleftrightarrow{T} \qquad \textit{Eqn. 10}$$

indicating that a power gain $+\frac{C\vec{E}}{\mu}$ in *Eqn. 9* translates to a momentum loss $-\frac{C\vec{E}}{\mu}$ in *Eqn. 10* in accordance with Newton's Third Law of Motion.

Contrary to the assumption of no 'four-gradient' in the vector potential A, experiments have measured irrotational current densities arising from irrotational vector potentials, as in arc-discharges, gradientdriven currents across cell membranes and EEG measurements in humans [18].

Occam's razor, together with Popper's principle of falsification, mean that, despite the long-standing success of Maxwell's theory, just as with any theory, CED can be disproved by only one 'reliable failure'. However, this does not mean that it is wrong but rather that, as with, for example, Newton's Laws of Motion, it is incomplete and there are theoretical and experimental contexts that are not fully described by it. As Buchanan put it, models can lure us into a misplaced confidence in their ability to make accurate predictions and an assumption that it is an accurate description of Nature rather than a stage in a developmental process [38]. Extending CED brings it into line with ongoing theoretical and experimental developments, as well as resolving the result of early historical decisions and events, thereby dramatically increasing the reach of electrodynamic theory. As a result of addressing these issues, EED is a gauge-free theory that is relativistically covariant, and produces the same wave solutions for A, B, E and **Φ** as those produced by CED. The EED theory reveals a SLW comprised of a scalar field C and a corresponding longitudinal electric field vector E having energy and momentum [39]. When these interact with distant conductive objects they induce both an electric current density (J) and potentially also a force (JC) on the object [21].

The absence of a magnetic field B, in the 4-irrotational vector field of A, means that there will be no circulating eddy currents that can give rise to a reactive force as described by Lenz's Law. This in turn means that the skin effect does not apply at any alternating frequency and SLWs can penetrate much deeper than TEM waves. The lack of observation of SLW is due primarily to the dipole design of most antennas which only responds to TEM waves and produces circulating (closed-loop) and solenoidal currents with an attendant magnetic field so that C = 0 and $E^L = 0$ with no SLW power output or reception [39].

Some of the main differences between the features of CED and EED are shown in **Table 3** and which hint at possible areas of further research as well as applications.

CED	***EED***
Solenoidal (zero) divergence of potentials	Non-zero divergence of potentials
Scalar-Vector potentials dependent (subject to Lorenz condition)	Scalar-Vector potentials independent (Not subject to Lorenz condition)
Magnetic fields exist with current subject to Lenz's Law, eddy currents and frequency dependent skin effect	Magnetic field zero - Current not subject to Lenz's Law ($\nabla \times A = 0$)
Solenoidal (circulating) currents	Gradient driven current with zero curl ($\nabla \times J = 0$)
Transverse electromagnetic (TEM) waves	Scalar Longitudinal Waves (SLW)
TEM has no scalar field	SLW has a scalar field: $C = \nabla \bullet \vec{A} + \frac{1}{c^2}\frac{\partial \Phi}{\partial t}$
Free space attenuation $1/r^2$	Free space attenuation $1/r^2$

Table 3: Comparison of the the main features of CED and EED [18].

4. Evidence and Applications

Evidence for the existence of scalar longitudinal waves (SLW) and scalar waves (SW), as predicted by EED, derives from a wide range of sources both inorganic and biological systems. This suggests a need for an interdisciplinary approach to understanding their full implications in Science and technology and some examples will be explored here.

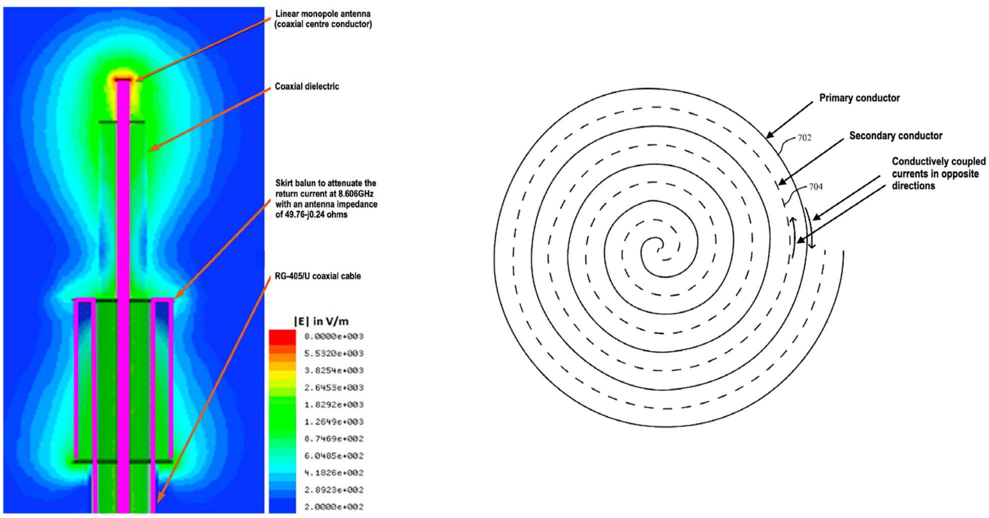

Figure 4: A) A monopole antenna and B) a bifilar coil used to produce SLWs [40].

4.1. Monopole Antenna

Hively's patent for generating and utilising SLWs employs two methods of producing them. The first is a monopole antenna **(Figure 4A)** where a second tubular conductor is aligned with the primary conductor to cancel most or all of the return current in the second conductor. In this way all of the electrical irrotational current goes into charging and discharging the antenna to drive the SLW. Power propagation (see Pout in *Eqn. 8*) is isotropic in free space with an inverse square law attenuation [40].

The second method uses a bifilar coil **(Figure 4B)**, commonly used in experiments with Tesla coils and transformers. In the specific configuration used, the two coplanar windings are such that the current flows in opposite directions in adjacent windings thereby cancelling the magnetic field associated with each one. The net neutralisation of the magnetic field is a requirement for the production of scalar-longitudinal waves from the gradient-driven current. The bifilar coil's inductance and capacitance are also zero due to the opposing current flow and the same charge density in each winding.

4.2. Solar Observations

SLWs have also been observed in connection with solar observations during a solar eclipse in August 2008. Since the Sun is a large plasma body with large irrotational currents within its mass, EED predicts that it should emit large quantities of SLW from radial plasma oscillations. During the eclipse, the Moon shields conventional TEM radiation from reaching the Earth while the longitudinal waves, with their greater penetration, can reach terrestrial detectors.

In this case, the detector used an array of copper spheres, each connected to each others' centres, and placed in a Faraday cage. **Figure 5** shows the peak response during the eclipse without the presence of any transverse waves. It is the longitudinal electroscalar mode of wave that performs relativistic transport of the Coulomb field and which is absent in the classical Maxwell theory [41].

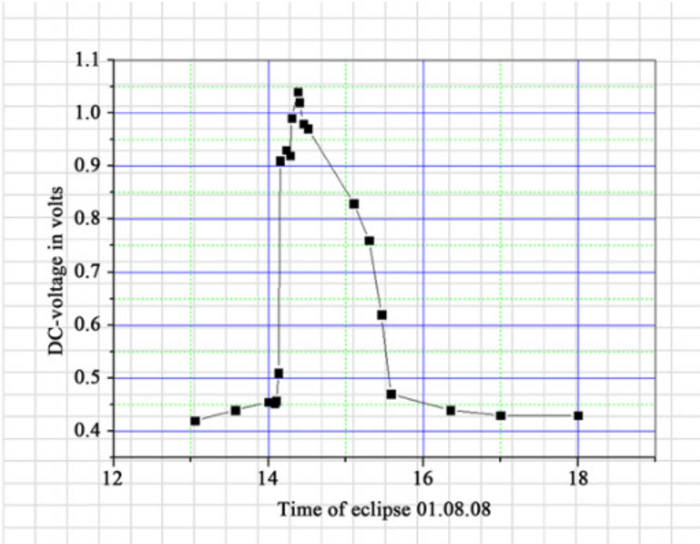

Figure 5: Scalar waves detection during a solar eclipse

The detection was also possible during a new Moon where the Earth is similarly shielded from regular TEM. However, further replication has yet to be done to confirm and to explore the deeper implications of solar SLWs for energy detection and generation. Towards these goals, a flat plate capacitor can be charged which then responds to the solar SLW emissions and generates force variations across the capacitor plates via the CE/μ term in *Eqn 9*, corresponding to a voltage yielding a power-producing current. Such power production would be available independent of day-night cycles since, with the Earth behaving as a spherical conductor and monopole antenna, local astronomical regions are constantly bathed in SLW Emissions [21, 40, and 41].

4.3. Seismic Signals

The need for warning of impending earthquakes is of clear value to protect life and indicate trends in seismically active areas. Park developed a system to detect precursor earthquake signals earlier than other types of detectors **(Figure 6)** [42]. The two types of waves, primary (P) and secondary (S), that propagate within the Earth's crust, behave differently in that P waves are longitudinal and push (compress) and pull (dilate) the ground in the direction of propagation. The breaking of chemical bonds as rocks fracture leaves positive and negative charges on opposite sides of the fault thereby setting up gradient-driven currents when arcing occurs across it. The gradient-driven current generates an SLW and are saturated over the frequency spectrum.

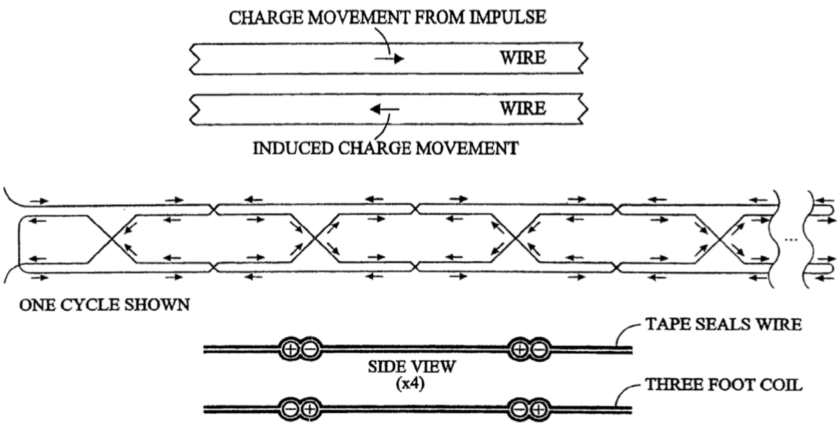

Figure 6: Bifilar coil used in seismic precursor signal detection [42].

This fact, and the use of a flat bifilar (pancake) coil in the detector, are designed to eliminate inductance and capacitance to create the gradient-driven current, thereby enabling this detector to be sensitive to scalar longitudinal seismic wave precursor signals from Earth movement [21].

4.4. Triboelectric Effect

It has been previously observed and reported that when an adhesive tape is peeled from a surface in a vacuum, visible light (triboluminescence), radio waves and x-rays are emitted due to charge separation and the breaking of chemical bonds within the adhesive [43]. When electrons are accelerated and then strike the opposite side of the tape, to conserve momentum bremsstrahlung X-rays (braking radiation) are emitted in the same way that diagnostic X-ray machines generate bremsstrahlung X-rays when accelerated electrons, from a heated filament, impact a tungsten target and are accelerated within the electric and magnetic fields of the target nuclei.

The number and angular distribution of photons emitted has been recorded by Constable et al. at various gas pressures and found to possess a pressure-independent peak 20° wide in the direction perpendicular to the electron movement [44]. The thick black line in **Figure 7** is the expected distribution from the ordinary bremsstrahlung process and the recorded distribution, with its peak, is not explainable by the ordinary bremsstrahlung model.

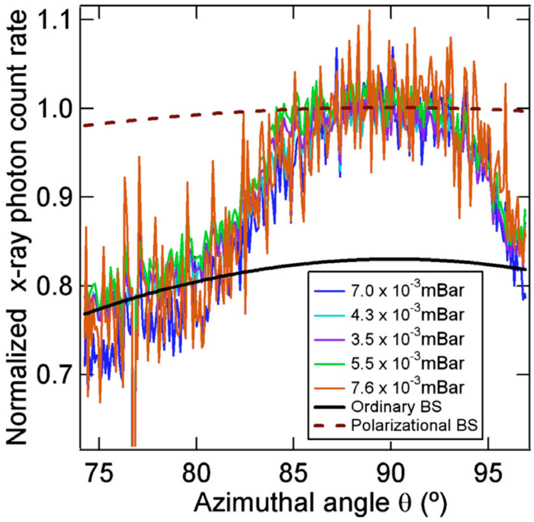

Figure 7: Tribo-electric Bremstrahlung radiation emission distribution [44].

Additionally, the measured charge densities of 10^{12} electrons/cm2 are an order of magnitude larger than commonly measured in tribo-charging systems. Specifically, ordinary Bremsstrahlung peeling bounds the angular distribution from below, while polarised Bremsstrahlung bounds the angular distribution from above. The peak between 80° and 100°, and the EED prediction that SLW are unconstrained by the skin effect, may provide a revised model to explain these findings [39]. Similarly, Camara noted that triboelectric events can be achieved with recorded limits and distributions of energies and flash widths that are beyond current theories of tribology [43].

4.5. Biological and Chemical Effects

Since all living processes involve the movement of ions across cell membranes, the ion concentration is responsible for gradient-driven currents in all biological systems. On that basis, SLWs will have a direct effect on cell processes by modifying the membrane gradients and ion transport. This may serve as a basis for some therapeutic interventions and is certainly the driving force behind ongoing experimentation with various types of scalar wave generators in the context of biological systems and clinical interventions [45].

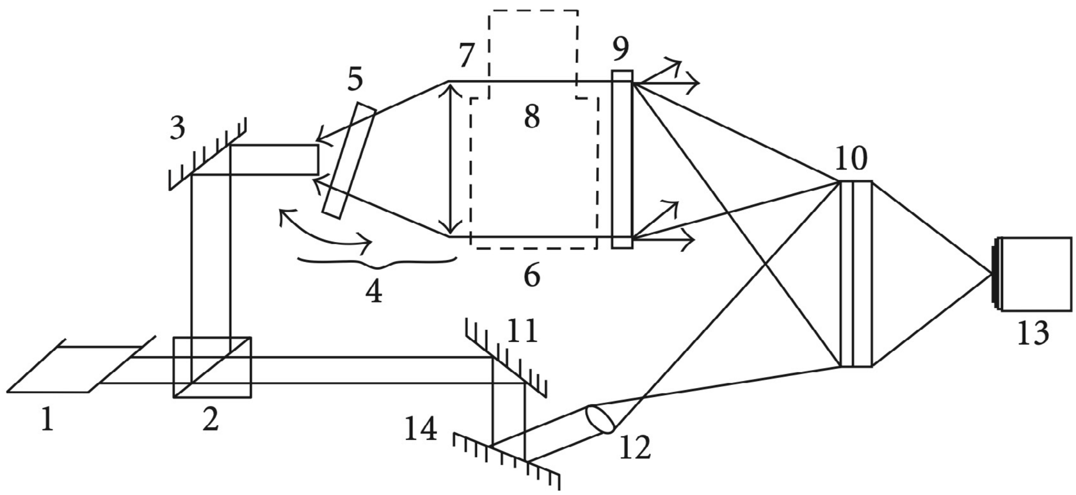

Figure 8: Experimental holographic setup: (from 1 to 13) He-Ne laser; (2) Beam splitter cube; (3) Mirror; (4) Collimator; (5) Plane parallel plate; (6) Quartz flask (cuvette) with the solution; (7) Teslar bracelet (chip); (8) Filter that divides two flasks; (9) Scattering layer; (10) Thermoplastic recording plate; (11) Reference beam mirror; (12) Reference beam lens; (13) TV camera [46].

Using a TESLAR chip (TC), from inside a particular type of quartz watch, and which its inventors claim emits SLW at low frequencies, Andreev used holographic interferometry, as shown in **Figure 8,** and showed that the refractive index of distilled water and aqueous solutions of L-tyrosine and b-alanine did not change in 10 minutes of exposure to the TC. In contrast, a 1% aqueous solution of plasma, extracted from the blood of a patient with heart vascular disease, changes its refractive index in under 2 minutes when exposed to the TC [46]. This is claimed to be due to an inertial field emitted by the chip (see EED *Eqn. 10*) similar in magnitude to that resulting from the action of a constant magnetic field of intensity 1.1 mT.

The inertial field transfers local deformations of space, which appear in physical terms as changes in mass and subsequently of physical and chemical systems. Therefore, the inertial field transfers mass-changing potential properties of the environment to a localised space. The findings so far support the suggestion that SLW can offer certain forms of clinical benefit in respect of the immune system, but to date, there has been little focused work in the clinical area.

Using Helmholtz decomposition, Menendez has shown that, in EEG measurements of the brain, the irrotational part of the primary current is physiologically meaningful and extends outside the region of the primary source currents [47]. Also, it is only the divergence of the irrotational signal that corresponds to the specific locations of the generators of the EEG signal. This does not mean that sources inside the brain are solely irrotational, but rather that EEG measurements are insensitive to the solenoidal part of the primary current and consequently, that the irrotational source model is physiologically meaningful as long as its divergence remains confined to the brain volume.

4.6. Power transmission

In the last decade of the nineteenth century, Nikola Tesla was engaged in the systematic research of high frequency electric waves with the specific aim of developing a method of transmission and reception of electric energy without the use of connecting wires, as depicted in **Figure 9** [48]. Having been inspired by the experimental work of Hertz, to verify Maxwell's developing theory of electro-magnetism, it was when he developed an oscillating current transformer that he was able to make observations that did not match the transverse wave emanations theorised by Maxwell and that Hertz attempted to verify. Tesla identified the waves from his system to be of a longitudinal-dielectric waveform, and he considered the transverse format as ineffective in delivering wireless power on an industrial scale [49]. Tesla was in the process of experimenting with long-distance transmission, in particular with his Wardenclyffe Tower installation in New York State, before the loss of his funding prevented him from completing the work.

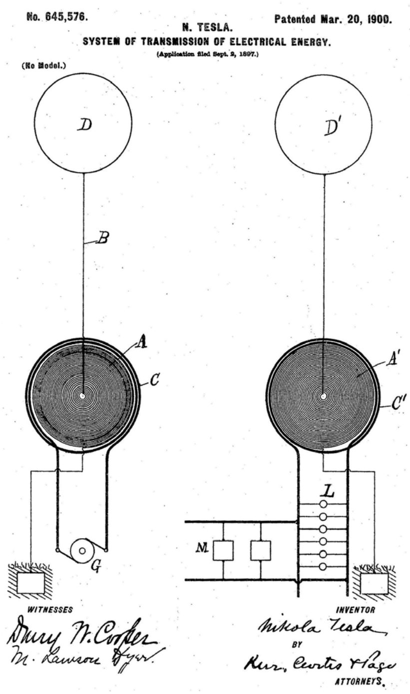

Figure 9: Tesla's apparatus for the wireless transmission of power [48].

Various replications of Tesla's work have been undertaken by Dollard in conjunction with Marsh et al. with attempts to transmit power wirelessly using longitudinal-dielectric waves, another term for the E^L component of SLW [50]. Marsh, amongst others, also proposes that in a coil a 'Longitudinal Magneto Dielectric' standing wave can be established which is a precursor to a displacement event and a wireless transmission of power triggered by a non-linear event introduced into the electrical system [51].

However, there are differences between this mechanism of transmission and that using SLW in that the former proposes a coherent relationship between the electric and magnetic fields of induction and their working together to establish a displacement event. In contrast, with SLW there is no magnetic component, in keeping with EED, and from where the term (CE/μ) in *Eqn. 9* is an additional term that forms a generalised Poynting vector, corresponding to the magnitude and direction of power density transmission by the SLW. This new term implies that SLW power can be transmitted wirelessly over large distances in a directed fashion, for example to power satellites or aircraft from the ground, electrical power transmission and advanced forms of directed beams [40].

5. The Vacuum

Maxwell devised his mathematical formulations of Faraday's experimental observations within a milieu, an assumption, that free space was filled with some form of substance, an aether, which was required for propagation of electric and magnetic fields. It was Einstein and the observations of Michelson and Morley that eventually dismissed this form of aether as not being required for TEM. However, in the decades since, mainly due to the formulation of quantum theory since the beginning of the twentieth century and quantum electrodynamics (QED) from the 1920s onwards, a modern-day and more nuanced form of 'aether' has returned with profound implications for physics and our view of the universe. Indeed, the so called inflationary model of the cosmos proposes the existence of a 'false' vacuum that decayed into the vacuum we see today, producing all the observable mass and energy in the process.

In following the line of causation backwards to enquire what initially produced the false vacuum, and similarly, what sustains the present quantum vacuum in its incessant interactions with the macroscopic world, we venture into areas where human observation cannot directly follow but instead, we must resort to logic and the extrapolation of our more immediate experience and observations. The overall picture that emerges is that the electromagnetic zero point field (ZPF) spectrum is generated by the motion of charged particles throughout the universe which are themselves undergoing ZPF-induced motion, in a form of self-regenerating grand ground state of the universe [52]. The value for the zero point energy state was derived by Max Plank in 1900 after he had determined the energy emitted by a single atomic oscillator as a function of absolute temperature as:

$$\epsilon = \frac{h\nu}{e^{h\nu/kT} - 1} \qquad \textit{Eqn. 11}$$

In his later description of the continuous emission of radiation as discrete packets of energy, he added a multiple of *hv* (Plank's constant x frequency) resulting in:

$$\epsilon = \frac{h\nu}{e^{h\nu/kT} - 1} + \frac{h\nu}{2} \qquad \textit{Eqn. 12}$$

where the *hv*/2 constitutes the minimum possible value and a 'jiggle' in the ground state according to QM and QED. Einstein was initially in disagreement but, in 1920, he finally upheld the validity of the ZPF when it supported general relativity and the use of his cosmological constant in finding solutions to his wave equation. The energy density for the zero point energy (ZPE) is derived to be very large or very small depending on whether you approach the subject from the view of quantum theory or relativity. In the former case, the precise figures depend upon the maximum value of frequency used.

$$\rho(h\nu) = \frac{h\pi\nu^2}{c^3}\left(\frac{h\nu}{exp(h\nu/kT) - 1} + \frac{h\nu}{2}\right) \qquad \textit{Eqn. 13}$$

However, in quantum field theory (QFT) renormalisation is usually applied such that whatever the actual value of the energy density, it is set to zero for mathematical purposes so that meaningful quantities can be measured in physical space. This is akin to sitting in isolation on a high tension wire with no other relative potential nearby. It can go unnoticed and all transactions and calculations can be conducted with reference to the high tension. While Feynman notoriously said that such mathematical renormalisation was 'a dippy process', it is standard practice and therefore circumvents the need to obtain a precise value but leaves an unresolved problem in physics known as the 'vacuum catastrophe' and with a disparity between the two approaches of as much as 10^{120} [53].

The modern quantum vacuum then is seen as a 'material' medium, if not a physical one, that is neither particle nor field-free but a seething flux of virtual particles[4] and electromagnetic waves that pop in and out of the vacuum field and there is no doubt that fluctuations in the zero point field (ZPF) lead to real physical effects upon matter. If the vacuum is a 'nothing', then it is a special kind of nothing and more of a something. Indeed, it is the incessant interactions between the vacuum and observable particles that result in quantisation and, for example, sustains electrons in their stable orbits around the nuclei of atoms. Without the impulses from the ZPF then the ground state energy of atomic orbital electrons would dissipate their energy as Larmor radiation as they spiralled into the nucleus [54].

The Lamb shift, an anomalous difference between the theoretical and measurable energies of two orbital levels in a hydrogen atom, is also caused by interactions between the electrons and the ZPF and was the prelude to modern QED. Similarly, the liquid state of Helium at near absolute zero is due to the input of ZPE to its molecular structure.

5.1. Energy Extraction

It was an effect first proposed by Hendrik Casimir in 1948, subsequently accurately experimental measured in 1997, that has solidly confirmed the physical effects of the ZPF.

In the Casimir effect, a cavity is established between two bounding surfaces that might take the form of adjacent spheres, but more commonly two conducting plates that are positioned less than $1\mu m$ apart, and where limits are placed on the ZPF modes that can exist between the two plates (see **Figure 10**) [55]. The longer wavelengths are suppressed and excluded within the gap whereas outside they are not, resulting in a pressure differential. The force between the plates depends upon the geometry and with the parallel plate configuration is:

$$F(d) = \frac{\pi^2 \hbar c}{240 d^4} \qquad \textit{Eqn. 14}$$

The negative energy density within the Casimir cavity would appear to contradict the QED definition of the vacuum as the lowest energy state. With a negative energy density, an energy differential can exist locally with implications for energy flow,

[4]The notion of particles here is considered by many to be a misnomer. Rather the virtual 'particles' constitute stochastic and disordered disturbances in the quantum field that is the basis of all particles and fields in QM.

even if, in the case of the Casimir effect, the force is conservative and therefore would require as much energy to reset the plates as was initially extracted. Since in this case, the Casimir energy derives from the vacuum, the process constitutes the conversion of vacuum energy into heat and is no more mysterious than in the analogous gravitational case. In such fashion, we see that the conversion of vacuum energy into heat, rather than violating the conservation of energy, is in fact required by it [54]. Despite the calculated force of attraction between the two plates, cycling the process to withdraw power would require as much work to reset the plates as was made available to withdraw on account of the conservative nature of the Casimir force. Other approaches to extracting ZPE include taking advantage of the step in the ZPE parallel at the boundary of the Casimir cavity, where the reduced ZPE would result in reduced support for the maintenance of electron orbitals within the cavity [56].

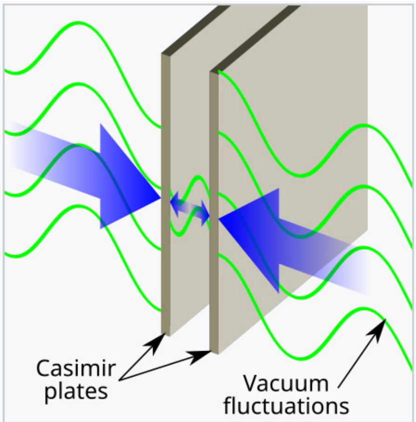

Figure 10: Casimir force between two parallel plates Casimir effect. (2024, November 4). In Wikipedia. https://en.wikipedia.org/wiki/Casimir_effect

In **Figure 11** a gas, such as Argon or Xenon, is pumped around the system comprising gold-coated cavity membranes and, as the gas molecules enter the Casimir cavity, the atoms lose energy as radiation and absorb it again on the other side of the cavity. Measurements of the radiation emissions detected have been recorded but to date the possibility of emissions from other sources, for example, frictional heating and gas turbulence, has not been ruled out so this is still an unconfirmed process but worthy of continued experimentation. Errors and possible violation of the second law of thermodynamics aside, it was not clear if equilibrium considerations render it incapable of providing harvestable energy [56].

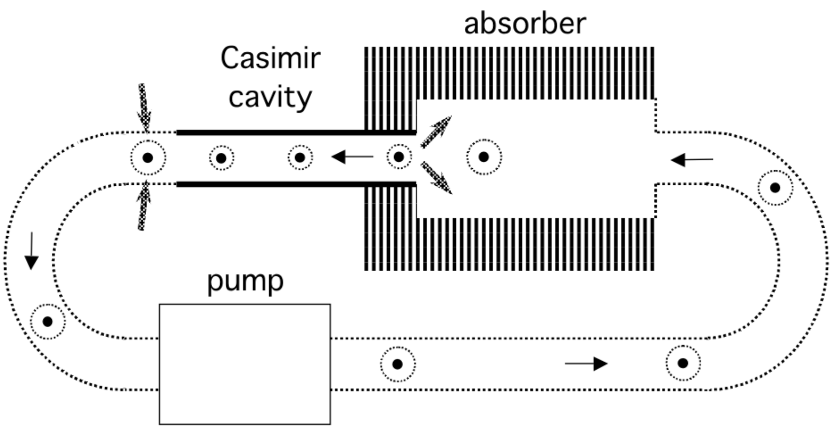

Figure 11: Patented proposal to extract ZPE using a pumped gas (Puthoff et al., 2002 reported in [56])

The ZPF is normally in a state of equilibrium, as are the elements of most non-linear systems that might be used to extract ZPE. Where asymmetry naturally occurs, the balance argument still applies and the energy in matches the energy out. However, there may still be situations where an unnatural and forced asymmetry and non-equilibrium state could be created which might circumvent this limitation.

Calculations indicate that the ZPF drives particle motion and that the total of all the particle motions in the universe dynamically generates the ZPF in a self-generating feedback cycle [52]. This caused Archibald Wheeler to remark that ”elementary particles represent a percentage-wise almost completely negligible change in the locally violent conditions that characterise the vacuum”. In other words, elementary particles do not form a fundamental starting point for a description of Nature. Instead, they represent a first-order correction to vacuum physics” [57].

The application of even small forces, based on the Casimir principle and derived from using modifications to the vacuum energy density to push against, have been explored by NASA as part of its ‘Q thruster’ programme [58]. The requirements for space travel are such as to make such propositions workable when, in this case, amplification to 0.1N/kW of supplied power is validated. Here the vacuum is recognised as a tangible medium, amenable to modification and where the reactive thruster force is against the quantum vacuum itself and considered as a sea of virtual particles and with regions where there is a higher virtual particles density than in others. Despite the prospect of an enormous energy density, the isotropic and homogeneous nature of the vacuum means that only departures from that uniformity will produce observable effects. On the other hand, accelerated motion through the vacuum can in principle reveal the presence of the ZPF energy density directly.

6. Stochastic Electrodynamics

It was the treatment of the stability of the ground states of matter that gave rise to stochastic electrodynamics (SED), another derivation from CED that includes a random classical Lorentz invariant radiation field, akin to the ZPF, and inferred from observations of the Casimir effect. Since its inception in the 1960s, SED has sought to provide a deeper and more realistic understanding of QM once the interaction between classical charges and electromagnetic radiation has been properly explained [59]. For some it is a good approximation to non-relativistic QED but with a narrow range of validity [60].

Whereas in QM the vacuum represents the lowest possible energy or ground state, and the zero-point field (ZPF) is comprised of virtual particles, in SED the ZPF comprises electromagnetic radiation that is 'real' in the classical sense of EM radiations and one that still radiates at absolute zero and therefore mimics the statistical properties of quantum measurements. SED theory involves only classical physics, in the sense of the electrodynamics described by classical Maxwell's equations, plus the Lorentz–Dirac equation, the relativistic version of Newton's equation of motion for a charged particle.

Experimental evidence and theoretical development have shown that SED can explain a wide variety of physical phenomena previously assumed to be only describable by QM [61 - 65]. These include blackbody radiation, electric dipole harmonic oscillators, Casimir forces, diamagnetism and the effects of acceleration of electrodynamic systems in the vacuum. As such, SED can explain much of the atomic realm, certainly the configuration and spectra of the Hydrogen atom through the coupling between charged particles and radiation, whereas more complex atoms have proven mathematically challenging to model in this way [59].

This model includes a classical electromagnetic zero-point radiation, that is part of the theory of random electrodynamics and which serves as a boundary condition on Maxwell's equations. The ZPF possesses a Lorentz-invariant spectrum with a scale set by Plank's constant and where in the limit $\hbar \rightarrow 0$, the theory of random electrodynamics becomes Lorentz's theory of electrons [61]. Within this model, the spectrum of the classical zero point radiation is inferred from measurements of the Casimir effect and accounts completely for the measured forces.

Therefore from the SED viewpoint, the fluctuations of the ZPF, in conjunction with any thermal and applied fields, result in fluctuating particle motions and provide the statistical equilibrium behaviour of both fields and particles. All of these changes involve energy exchanges between the fields and the kinetic energy of the varying electron motion, plus the binding potential energy between electrons and nuclei. While the changes in energy are not necessarily large, they are real and are involved in all chemical reactions [60]. Similarly, with the Casimir phenomenon, when energy and electron densities are changed, energy is transferred between them and the vacuum via the ZPF.

SED is therefore a realistic and hybrid approach to the worlds of the macroscopic, described by classic physics, and the microscopic described by quantum theory where EM radiation acts on charged particles and charged particles release EM radiation when accelerated, and these two functions maintain an equilibrium [59]. In essence, it is a classical theory but one that incorporates Plank's constant that is so central to the description of quantised states and the quantum model expressed by QED. As such SED involves a boundary, set by energy scales, between macroscopic phenomena, where the contributions of zero-point radiation are generally so small as to be irrelevant, and microscopic phenomena where the contributions of zero-point radiation are essential and may be vital.

The energy of the oscillator changes continuously as it absorbs energy upon acceleration from the random ZP radiation and at the same time radiates it away according the the rules of Newton's laws and Maxwell's equations [66]. So SED can provide a classical description of events that would otherwise require a quantum description. This is of value because a theory that can explain and describe events across all scales is simpler and more embracing than one requiring different models at different scales. While in QED fluctuations in the vacuum are an intrinsic property of the quantum field, in SED the random EM field is also seen as a fundamental feature of the vacuum but is not derived from the uncertainty principle central to QM.

Within the context of SED, energy extraction from the vacuum can therefore be seen as a more realistic possibility since the ZPF is made up of real EM radiation which can allow for the creation of an energy gradient when stimulated in a specific way, in particular, when 'far from equilibrium' conditions exist. Furthermore, based on the classical exchanges taking place between the ZPF and charged particles, disruptive changes to equilibrium can result in energy gradients and precursors to energy flows. It becomes clearer and more tangible to see how boundary conditions, asymmetry and far-from-equilibrium states can be a dynamic driver for an EM influx in open systems where such interactions are a fundamental part of their constitution.

7. Pulse-Induced Energy Mechanisms

In considering various plausible mechanisms for the effect of IPC on secondary cells and how energy gains with a CoP>1 might occur, the predictions and observations of EED, and similarly the development of SED, provide various mechanisms that can help explain the energetic processes involved.

7.1. Creation of a Divergent E-Field

Firstly, the use of short HV pulses, with dt<20μs and $dV/dt > 10^8$ V/s, minimises the formation of eddy currents that produce a magnetic field and which would oppose the current driving the magnetic field formation in accordance with Lenz's Law. The rapid radial movement of electrons due to the HV pulse creates a divergent A-field and then a divergent E-field in line with the EED version of Faraday's Law:

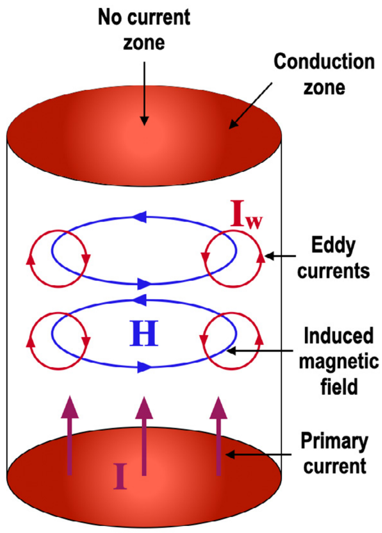

Figure 12: The skin effect (*derived from* [67]).

In more detail, the skin effect results from the formation of an induced magnetic field in response to a time-varying current, either alternating current or pulsed DC, as a function of dI/dt. The induced magnetic field creates an EMF with a polarity such as to impede the primary current. This EMF results in the formation of induced eddy currents that resist the primary current towards the centre of the conductor and support it towards the edges, as depicted in **Figure 12**. The skin effect is therefore a function of AC frequency, or DC pulse rise and fall times, and also the conductivity of the material.

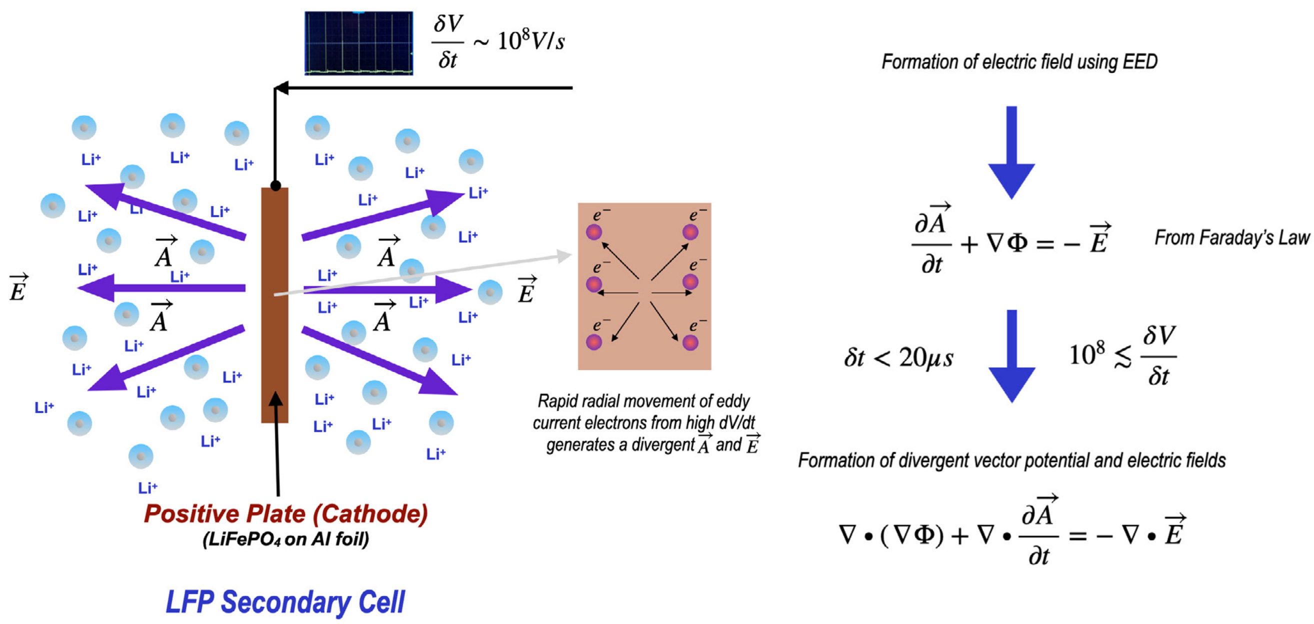

Figure 13: The creation of a divergent E-field using the skin effect (*derived from* [68]).

Kapcia describes how high values of pulse slew rate cause a high dI/dt and, in turn, a high dH/dt and induced eddy current where electrons are driven radially towards the conductor's surface [68]. Furthermore, a high dI/dt can be obtained using minimal primary current, using MOSFET Gate switching with a low duty cycle, and with short duration pulses. This serves to minimise the conventional current demand, input energy and the creation of magnetic fields that would impede the creation of SLW.

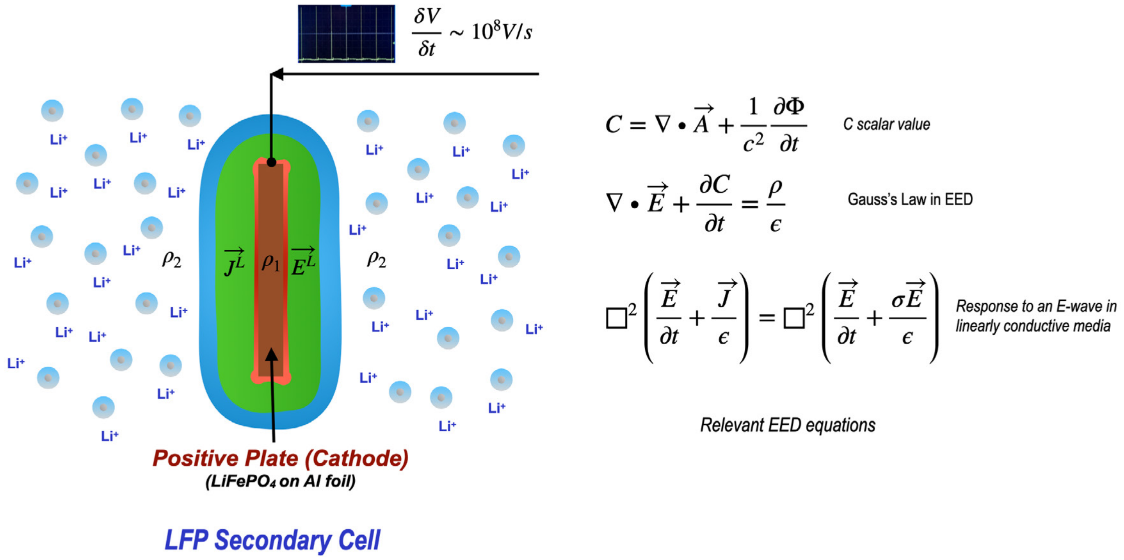

Figure 14: A monopole antenna used to produce SLWs (*derived from* [40])

The radial movement of electrons towards the surface, as if from a central point inside the wire, results in a divergent A-field and, from the rate of change of A, a divergent electric field, as depicted in **Figure 13**, where:

$$\frac{\partial \vec{A}}{\partial t} + \nabla\Phi = -\vec{E} \qquad \textit{Eqn. 15}$$

This divergent E-field then transfers energy to the mobile Li+ charge carriers as expressed via the EED version of Gauss's Law:

$$\nabla \bullet \vec{E} + \frac{\partial C}{\partial t} = \frac{\rho}{\epsilon} \qquad \textit{Eqn. 16}$$

which results in a current density $\vec{J} = \sigma\vec{E}$.

The longitudinal E-field vectors will radiate out perpendicularly from the direction of current flow caused by the incoming pulses such that many of the E-field vectors are directed away from the anode position. The energised charge carriers will then take additional time to reorientate themselves and migrate towards the anode under the influence of its negative polarity and attraction.

7.2. Cathode as a Monopole Antenna

The second proposed energetic mechanism, that will operate simultaneously with the first, involves the behaviour of the cathode electrode as a monopole antenna due to the interface between it and the electrolyte on account of their different volumetric charge densities. Here $\rho_v 1 > \rho_{v2}$ where ρ_{v1} is that of the electrode and ρ_{v2} that of the electrolyte as illustrated in **Figure 14.**

The wave equation for the scalar potential C is:

$$\nabla^2 C - \frac{\partial^2 C}{\partial c^2 t^2} = -\left(\frac{\partial \rho}{\partial t} + \nabla \bullet \vec{J}\right) \qquad \textit{Eqn. 17}$$

which equates charge separation with the scalar field C, therefore with non-local charge conservation as is well known in electric arcs, homopolar generators and charge separation in living cells amongst others.

The time-varying scalar field drives a longitudinal E-field to generate the SLW as described by:

$$\nabla \times \vec{B} - \frac{1}{c^2}\frac{\partial \vec{E}}{\partial t} - \nabla C = \mu \vec{J} \quad \text{(EED revised Ampere's Law)} \qquad \textit{Eqn. 18}$$

In the process of energy being transferred to the charge carriers, energy is extracted from both irrotational components of the SLW.

These processes have been confirmed by experiments [18] together with the EED predictions that SLW is unconstrained by the skin effect and that the attenuation in free space obeys the inverse square law.

7.3. Combined Cathode Energetics

Combining these two effects, the delivery of HV transients of sufficiently high slew rate and short rise and fall duration, typically FWHM 20μs, to the positive cathode of the battery, results in the creation of both longitudinal E-fields and SLW which incorporate the scalar component. As shown in **Figure 15**, the longitudinal E-fields radiate out in all directions and with a current density J^L (via the EED Gauss's Law) delivering energy to the Li^+ charge carriers.

Down to the value of a minimum supply current, the ratio of the energy delivered via SLW and SWs to the electrical supply to the generator, measured as a CoP value, increases as the input is reduced. Once a critical minimum supply current and energy is reached, then there is insufficient pulse energy to radially accelerate electrons to create a longitudinal E-field to mobilise the charge carriers and for the cathode to act as an antenna. At this point, the ratio of J^L / J^T starts to fall from its peak and the CoP approaches 1 and below.

The observation of an alternative charging dynamic for the influx, in contrast to the conventional one (see **Figure 16**), supports the hypothesis of energy delivery from the migration of ions that are kinetically energised by E-field vectors but which are not aligned with the cathode-anode orientation. This results in a

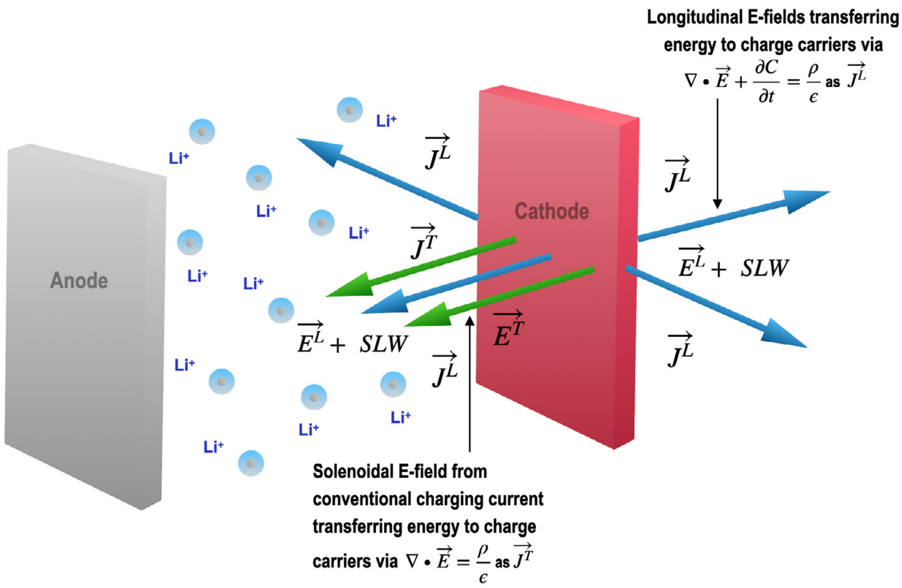

Figure 15: The combined energetics of IPC in a Lithium Iron Phosphate battery

delay in their migration towards the anode before they experience its attraction. This shows as a build-up to a peak response at a specific time that is dependent on the battery chemistry, design and type.

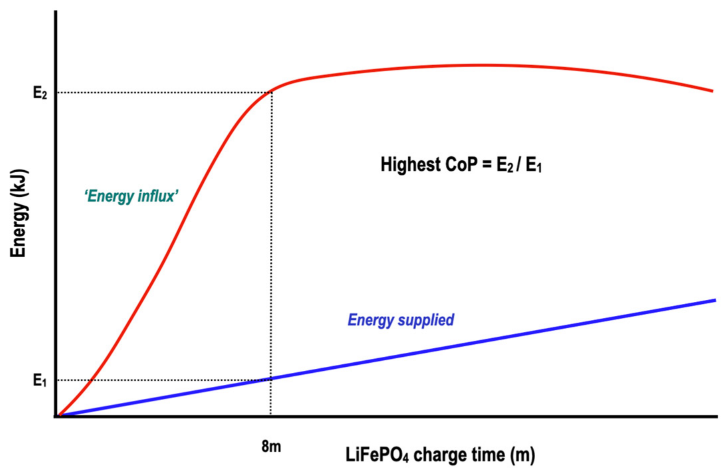

Figure 16: The supply and suggested 'influx' energetics from IPC in a Lithium Iron Phosphate battery [9]

The identification of an optimum battery-specific pulse repetition frequency (PRF) also indicates the ideal delivery rate of pulses that matches the chemical reaction-diffusion model for the Lithium battery. Pulses delivered too fast cannot translate to an increased energy flow from the cathode due to the limitations of Li^+ ion movement and the rate of interstitial lithiation at the carbon-based anode. Analogous processes will be involved in a Pb-Acid battery where the lower diffusion rate of heavier SO_4 ions results in a generally lower optimum PRF and a lower receptivity to the pulses.

Besides the creation of scalar and longitudinal field components within the battery, it must be acknowledged that conventional metering systems, such as voltmeters, are designed to operate with and measure solenoidal currents only as part of 'closed-loop' systems. Based on this type of design, all conventional metering will necessarily only record solenoidal components and under-record longitudinal components of voltage and amperage. As indicated in **Figure 16**, longitudinal E fields will also be transferring energy to the Li^+ mobile charge carriers yet the supply to the pulse-generating device will only be recording the solenoidal input. This element alone will tend towards higher CoP values as any longitudinal components of the supply will not be recorded as part of the supply energy and contribute to the denominator in the CoP calculation. However, this can only account for a part of the energetics since the 'closed-loop' tests reported in the first OSF study indicated that an additional energy influx was occurring, one that allowed the battery to maintain its load voltage while still supplying the input energy to run the system.

8. Discussion

While history has provided an incomplete record of the full findings of Faraday, in respect of longitudinal and scalar components of EM emanations from his experiments with magnetism, coils, and electrical circuits, in recent times there has been a considerable effort to uncover these components through logical and rigorous derivation supported by experimental evidence. Similarly, in QED and elsewhere the primacy of the magnetic vector and scalar potentials has finally been restored, returning them to their rightful place as physical, and not just mathematical, precursors of magnetic and electric fields that are fundamental to all electronic and electrical systems.

A substantial amount of evidence has been gathered from a range of disciplines in support of EED and the SLW that emerge, enough to warrant further developments in those areas. In the process, Maxwell's equations have been expanded to give a fuller picture of the energetics occurring in and around electrical systems. The limited interest to date is mainly due to the lack of general awareness of how longitudinal and scalar components would improve present-day systems, yet that is part of the process of developing a paradigm, especially when substantially updating one. Technical benefits need to accrue alongside pure research for traction to gain momentum.

Alongside SLW, efforts to extract energy from the vacuum are linked to the mode of vacuum envisaged. In QED the concept of the vacuum differs in a vital respect from that in SED. Creating an energy gradient in QED, when the vacuum is already at its lowest possible energy state, must either involve creating a negative energy state at a specific 'location' or raising the energy level everywhere else; both are implausible by the very definition of the vacuum. However, in SED we have a different situation where this ubiquitous and classical background EM energy and flux is open to gradients, asymmetries and boundary conditions that render energy flows possible and which also appear to provide the basis for chemical and atomic processes and reactions that underpin all physical and biological processes. On this basis then, SED provides a framework for an energy influx to occur, driven by far-from-equilibrium events, such that additional energy is drawn in at the cathode and translates to the mobile charge carriers in the conventional manner. While the exact mechanisms occurring at a quantum scale are not yet known, via a classical ZPF, energy may be transferred to charged particles and hence contribute to the overall energy dynamic of battery charging. The measured 'closed-loop' energy gains, together with the experimentally determined fact that the gains do not result from internal enthalpy, as a response of the electrochemistry to electrostatic pulses, can only be explained by an additional energetic component being realised within an open system [9, 15].

It is often argued that it is unrealistic to suggest that activity at the quantum level can have a direct impact on macroscopic processes, however, alongside evidence such as the Casimir effect, it must be recognised that if there was a discontinuity in the line of causation from the quantum realm to that of everyday objects, then our macroscopic world would not exist. Since all atomic processes have the quantum domain and the ZPF, of whatever perceived type, at their foundation, then these dynamic exchanges lead to macroscopic processes through various interactive stages. If all charged particles are rooted in the ZPF then all their interactions with other charged particles and electrodynamic forces must, indirectly, involve quantum-level activity and also lead to macroscopic effects. An example is with low energy nuclear reactions (LENR) that are also proposed to draw upon the ZPF for their activity and properties. This is an area of intense activity and a scalable E-Cat generator has been bench-tested and also run in a commercial EV in Latina, Italy where it was driven 600 miles during which its battery's state of charge rose from 62% to 82% [69, 70]. However, as yet insufficient details have been provided to fully evaluate the validity of these claims.

Besides the main energetic mechanisms proposed in this paper, others may also have a tangential relevance. When Maxwell was building a model of electromagnetic induction, based on the experimental findings of Faraday, he employed a hydrodynamics model to make sense of the 'electrotonic state' and subsequently the magnetic vector potential [20]. More recent researchers have noted the 'fluid dynamic' behaviour of electrostatic pulses. In a similar way to which a ram pump works, when a magnetic field is developed in a coil and the supply currently is abruptly shut off by the switch, then the magnetic field tries to keep the 'momentum' going (Lenz's Law) and, in so doing, results in a high potential that is utilised as the flyback pulse, which is analogous to the increased pressure in the ram pump. This inertial tendency may have effects at boundaries that are not yet fully appreciated and it was Tesla who remarked, towards the end of the 19th century, that electricity follows a fluid dynamic model more closely than a thermodynamic one. In addition, electrostatic pulses are also proposed to create cavitation phenomena at the electrode interface and which have been linked to the formation of exotic vacuum objects (EVOs) which possess unique energetic properties [71].

Experimentally testing the mechanisms proposed in this paper is a complicated and involved task that would require considerable investment and commitment to perceived goals. An example of such a goal is that of the unification of QM and Relativity, one of science's greatest challenges, where each holds dominion in its respective corner but which so far has failed to come together under Quantum Gravity. Yet a new approach, referred to as a 'post-quantum theory of classical gravity', is looking at the problem from a different direction [72]. This is what may be required in electrodynamics; not to disregard what is already evident and effective but rather to expand it to embrace additional aspects revealed by experiment and theoretical derivation, such as the role of the environment, the 'far-field' and the role of open thermodynamics, which recognises that the only systems that are truly closed are those that are specifically engineered that way by us.

Whether or not this is proven at some stage, with ramifications for our models of particle physics, cosmology, space and energy, the application of scalar and stochastic models will play a significant role in developing technologies, particularly in the domains of sensors, signal and power transmission. With the latter, its functionality using a 'one wire' topology, allowing the Earth effectively to function as the 'return wire', provides significant advantages besides permitting and taking advantage of multi-body interactivity as part of a thermodynamically open system [48].

As is often the case, research and applications by certain governmental sectors often get a foot-hold before general civilian applications and benefits are realised. This is no less the case with scalar technologies where various agencies have historically considered the validity of scalar waves and their applications but without establishing a clear scientific and public position or the results of their ongoing investigations [73]. It is evident that scientific progress is a process of 'punctuated evolution' subject to being tempered and moderated by those that seek to maintain the status quo, however that position is justified.

IPC, and the voltage transients it employs has, perhaps inevitably, found its way into this area of enquiry. Energy gains that are currently being replicated by others indicate that treating all electrical systems as closed systems, together with the lumped element model, only works when all components operate in that fashion and when they function close to, or in, equilibrium conditions. Far-from-equilibrium states are normally seen as problematic and to be avoided, but evidence has been presented that shows how asymmetry and nonequilibrium states can be utilised as part of a larger dynamic, one that can be specifically engineered and utilised for the benefit and advancement of various facets of society.

9. Conclusions

The extension of classical electrodynamics (CED) into extended electrodynamics (EED) has been shown to be logically and provably derived and, in the process, has reinstated previously obscured and ignored longitudinal and scalar components that possess their distinct properties and dynamics. Various applications and technologies have been identified that both add further weight to the expanded model but which also offer unique properties and possibilities within a range of important disciplines including power and signal transmission. Similarly, SED has provided a theoretical framework for realistic energy extraction from the vacuum with the work done to date by others requiring the elimination of all possible alternative explanations, as with any novel findings. For IPC, these longitudinal and scalar components provide plausible, if yet currently untested, mechanisms and energetic pathways for the observed energy gains and hint at future possibilities. In so doing, they suggest an untapped potential for energy extraction and charged particle interactions in addition to a set of new approaches to, and aspects of, classical electrodynamics which would expand its already enormous reach into all areas of electrical and electronic design as well as power systems. Additionally, other developments, such as in LENR, may already be demonstrably utilising vacuum energy with tangible applications in transport and clean power.

Furthermore, EED and SED provide elements of a pathway towards the bridging of such disciplines as cosmology and physics in the search for a unified field theory and the updating of both the standard cosmological and particle models that are already requiring modification in the light of recent findings. Updating these and related models does not necessarily undermine the status quo but rather draws upon the intrinsic nature of Science in calling us to revise our models of the world based on evidence and logic rather than upon what is familiar and maintains a particular paradigm. In that process, we will perceive every stage as a stepping stone to a larger perspective rather than as a failure of a particular way of thinking and functioning. In so doing we will see that to understand the world more fully, we do not need to travel to other places but instead see the world through different eyes.

Acknowledgements

The author wishes to gratefully acknowledge the contributions of Dr Lee Hively regarding EED and for proof-reading the manuscript, Prof. Garret Moddel for his input on vacuum energy extraction, and Dr Glenn Ramsey and Stuart O'Connor for also proof-reading.

References

1. Cook, D. M. (1871). Improvements in Induction Coils. US Patent 119,825A. *US Patent and Trademark Office*.
2. Tesla, N. (1893). On Light and Other High Frequency Phenomena. *Nature 48*, 136–140.
3. Benitez, C. F. (1918). New Process for the Generation of Electrical Energy, Patent GB121561, *UK Patent Office*
4. Aspden, H & Adams, R. G. (1993). *UK Patent Office*, Patent GB2282708A.
5. Kromrey, R. (1968). Electric Generator, US Patent 3374376A. *US Patent and Trademark Office*.
6. Gray Sr, E. V. (1987). *U.S.* Patent No. 4,661,747. Washington, DC: *U.S. Patent and Trademark Office*.
7. Bedini, J. C. (2004). U.S. Patent No. 6,677,730. Washington, DC: *U.S. Patent and Trademark Office*.
8. Lindemann, P., & Murakami, A. (2013). Bedini SG-The Complete Intermediate Handbook. *Washington: A & P Electronic Media Liberty Lake*.
9. Perry, J.A. (2024). Pulse-Induced Energy Gains in Electrochemical Systems. *J Electrical Electron Eng, 3*(4), 01-15.
10. Sriphan, U., Kerdchang, P., Prommas, R., & Bunnang, T. (2018). Coefficient of performance of battery running and charging by magnet generator Bedini. *Journal of Electrochemical Energy Conversion and Storage, 15*(4), 041002.
11. Chrysocheris, I., Chatzileontaris, A., Papakitsos, C., Papakitsos, E., & Laskaris, N. (2024). Pulse-Charging Techniques for Advanced Charging of Batteries. *Mediterranean Journal of Basic and Applied Sciences (MJBAS), 8*(1), 22-36.
12. Ali, A. H., & Ismail, A. N. C. (2017). Design and simulation of self-running magnetic motor. *J. of Engineering Technology, 5*, 27-31.
13. Murad, P. A. & Brandenburg, J. E. (2020). A Nonlinear Electromagnetic Device and Potential Explanation. *Journal of Multidisciplinary Engineering Science Studies (JMESS)* ISSN: 2458-925X Vol. 6 Issue 12, p3587 - 3600.
14. Inam, H., & Al-Turjman, F. (2021). Intelligent free energy usage through radiant energy space phenomenon: An IoT-powered prototype for modified Bedini generator. *Microprocessors and Microsystems*, 104319.
15. Perry, J. A. (2025). An Investigation into the Origins of Pulse-Induced Energy Gains in Electrochemical Systems. *J Electrical Electron Eng, 4*(1), 01-16.
16. Hively, L. M., & Land, M. (2021, July). Extended electrodynamics and SHP theory. In *Journal of Physics: Conference Series* (Vol. 1956, No. 1, p. 012011). IOP

Publishing.
17. Chubykalo, A & Kuligin, V (2018) The Tesla Currents in Electrodynamics. *Applied Physics Research*, Vol. 10, No. 5; 2018
18. Hively, L. M., & Loebl, A. S. (2019). Classical and extended electrodynamics. *Physics Essays, 32*(1), 112-126.
19. Faraday, M. (1839). Experimental researches in electricity (Vol. 1). *Library of Alexandria*.
20. Klausen, K. O. (2020). A treatise on the magnetic vector potential. *Springer International Publishing*.
21. Reed, D. (2019). Unravelling the potentials puzzle and corresponding case for the scalar longitudinal electrodynamic wave. In *Journal of Physics: Conference Series* (Vol. 1251, No. 1, p. 012043). IOP Publishing.
22. Onoochin, V. (2019). Longitudinal Electric field and the Maxwell equation.
23. Kamenshchik, A. Y., Pozdeeva, E. O., Tribolet, A., Tronconi, A., Venturi, G., & Vernov, S. Y. (2024). Superpotential method and the amplification of inflationary perturbations. *American Physical society 110*(10).
24. Tonomura, A., Osakabe, N., Matsuda, T., Kawasaki, T., Endo, J., Yano, S., & Yamada, H. (1986). Evidence for Aharonov-Bohm effect with magnetic field completely shielded from electron wave. *Physical review letters, 56*(8), 792.
25. Feynman, R. P. (1966). The development of the space-time view of quantum electrodynamics. *Physics Today, 19*(8), 31-44.
26. Ehrenberg, W., & Siday, R. E. (1949). The refractive index in electron optics and the principles of dynamics. Proceedings of the Physical Society. *Section B, 62*(1), 8., B62,
27. Aharonov, Y., & Bohm, D. (1959). Significance of electromagnetic potentials in the quantum theory. *Physical review, 115*(3), 485.
28. Rousseaux, G., Kofman, R., & Minazzoli, O. (2008). The Maxwell-Lodge effect: significance of electromagnetic potentials in the classical theory. *The European Physical Journal D, 49*, 249-256
29. Varma, R. K. (2012). Curl-free vector potential observation on the macro-scale for charged particles in a magnetic field compared with that on the micro-scale: the Aharonov–Bohm effect. *Physica Scripta, 86*(4), 045009.
30. Shukla, P. K. (2012). Curl-free vector potential observed at the macroscale. *Physica Scripta, 86*(4), 048201.
31. Daibo, M., Oshima, S., Sasaki, Y., & Sugiyama, K. (2015). Vector potential coil and transformer. *IEEE Transactions on Magnetics, 51*(11), 1-4.
32. Daibo, M. (2023). Vector Potential Coupling From Outside the Loop Through the Superconducting Shield. *IEEE Transactions on Applied Superconductivity, 33*(5), 1-5.
33. Woodside, D.A. (1999) Uniqueness Theorems for classical four-vector fields in Euclidean and Minkowski spaces. *J. Math. Phys., 40*, 4911–4943
34. Dirac, P.A.M., Fock, V.A., Podolsky, B. (1932) On Quantum Electrodynamics; Faddeev, L.D., Khalfin, L.A., Komarov, I.V., Eds.; 2004. Reprinted in Fock, V.A. Selected Work—Quantum Mechanics and Quantum Field Theory; *Chapman & Hall/CRC: New York, USA*, pp. 243–255
35. Sousa, E. M., & Shumlak, U. (2016). A blended continuous–discontinuous finite element method for solving the multi-fluid plasma model. *Journal of Computational Physics, 326*, 56-75.
36. Ohmura, T. (1956). A new formulation on the electromagnetic field. *Progress of Theoretical Physics, 16*(6), 684-685.
37. Jackson, J.D. (1962) Classical Electrodynamics *Wiley, New York*.
38. Buchanan, M. (2023). Beware the lure of models. *Nature physics, 19*(1), 2-2.
39. Reed, D., & Hively, L. M. (2020). Implications of gauge-free extended electrodynamics. *Symmetry, 12*(12), 2110.
40. Hively, L. M. (2016). Methods and apparatus for generation and detection of a scalar longitudinal electromagnetic wave, Patent 9,306,527, *US Patent Office*.
41. Zaimidoroga, O. (2016) An Electroscalar Energy of the Sun: Observation and Research. *Journal of Modern Physics, 7*, 806-818.
42. Park, L. (2008) Seismic Activity Detector, *US Patent 8,023,360,*
43. Camara, C.G., Escobar, J.V., Hird, J.R. and Putterman, S. J (2008), Correlation between nanosecond X-ray flashes and stick–slip friction in peeling tape. *Nature (London) 455*, 1089.
44. Constable, E.; Horvat, J.; Lewis, R.A. (2010) Mechanisms of X-ray emission from peeling of adhesive tape. *Appl. Phys. Lett., 97*, 131502.
45. Pula, B. (2023) Exploring the Potential of Scalar Waves in Medicine and Healing. *Fluid Mech Open Acc,* Volume 10:05, 2023.
46. Andreev, E., Dovbeshko, G. and Krasnoholovets, V. (2007) The study of the influence of the TESLAR technology on aqueous solution of some bio-molecules. Res. *Lett. Phys. Chem.* 2007, 94286.
47. Grave de Peralta Menendez, R., & Gonzalez Andino, S. (2015). Electrical neuroimaging with irrotational sources. *Computational and Mathematical Methods in Medicine, 2015*(1), 801037.
48. Tesla, N. (1897) System of transmission of electrical energy. *US Patent US645576A US Patent Office*.
49. Dollard, E. (1986) Theory of Wireless Power. https://ericpdollard.com/wp-content/uploads/2018/04/theory_of_wireless_power_eric_dollard.pdf
50. Dollard, E., Marsh, A. & Murakami, A., (2023) *Extended Colorado Springs Tesla Transformer Experiments.* https://www.am-innovations.com/extended-colorado-springs-tesla-transformer-experiments-adrian-marsh-eric-dollard-et-al/.
51. Marsh, A. (2018) *Flat Coil Design - part 1*. https://www.am-innovations.com/category/designs/designs-flat-coil/
52. Puthoff, H. E. (1990). The energetic vacuum: implications for energy research. *Spec. in Sci. & Technology, 13*, 247
53. Feynman, R. P. (1985) QED: The Strange Theory of Light and Matter. *Princeton: Princeton University Press*, p. 128.
54. Puthoff, H. E. (2016). Quantum ground states as equilibrium particle–vacuum interaction states. *Quantum Studies: Mathematics and Foundations, 3*(1), 5-10.
55. Casimir, H. B. (1948). On the attraction between two perfectly conducting plates. In *Proc. Kon. Ned. Akad. Wet*. (Vol. 51, p. 793).
56. Moddel, G., & Dmitriyeva, O. (2019). Extraction of Zero-Point Energy from the Vacuum: Assessment of Stochastic

Electrodynamics-Based Approach as Compared to Other Methods. *Atoms, 7*(2), 51.
57. Macken, J. A. (2013). The Universe Is Only Spacetime. *Santa Rose California*.
58. White, H. (2013). *NASA Brief: Q-Thruster Physics* (No. JSC-CN-28943). *NASA Johnson Space Centre, Houston*
59. Cole, D. C. (2019). Energy considerations of classical electromagnetic zero-point radiation and a specific probability calculation in stochastic electrodynamics. *Atoms, 7*(2), 50.
60. Santos, E. (2022). On the analogy between stochastic electrodynamics and nonrelativistic quantum electrodynamics. *The European Physical Journal Plus, 137*(12), 1302.
61. Boyer, T. H. (1975). Random electrodynamics: The theory of classical electrodynamics with classical electromagnetic zero-point radiation. *Physical Review D, 11*(4), 790.
62. Boyer, T. H. (1985). The classical vacuum. *Scientific American, 253*(2), 70-79.
63. Boyer, T. H. (2012). The blackbody radiation spectrum follows from zero-point radiation and the structure of relativistic spacetime in classical physics. *Foundations of Physics, 42*, 595-614.
64. de la Peña, L.; Cetto, A.M. (1996) The Quantum Dice. An Introduction to Stochastic Electrodynamics; *Kluwer Academic Publishers/Springer Science+Business Media:* Dordrecht, The Netherlands
65. De la Peña, L., Cetto, A. M., & Valdés-Hernandes, A. (2014). The zero-point field and the emergence of the quantum. *International Journal of Modern Physics E, 23*(09), 1450049.
66. Boyer, T. H. (2019). Stochastic electrodynamics: the closest classical approximation to quantum theory. *Atoms, 7*(1), 29.
67. Santoso, S. & Beaty, H. W. (2018). Standard Handbook for Electrical Engineers. McGraw Hill Education
68. Kapcia, J. (2016). U.S. Patent No. 9,385,537. Washington, DC: *U.S. Patent and Trademark Office*.
69. Levi, G. (2021) Performance of SK-Ecat prototype on a six hours period. *University Di Bologna*
70. Leonardo Corporation (2024) Overview of the E-Cat EV Test in Latina, Italy [Video] *YouTube* (Accessed 18th January, 2025).
71. Shoulders, K. R. & Sarfatti, J. (1997). Energy Conversion From The Exotic Vacuum—Revised. *Nanosoft.co.nz*.
72. Oppenheim, J. (2023). A postquantum theory of classical gravity? *Physical Review X, 13*(4), 041040.
73. CIA (1987) Summary statement on scalar waves - CIA-RDP96-00792R000500240001-6 (Accessed 15th February 2025).