

How a Particle Physics Prediction Became the Core of a New Energy Equation



Why a single term in the Schubart Master Formula carries five decades of particle physics inside it

In 1974, a theoretical physicist named Daniel Freedman sat with a calculation that was, by any measure, remarkable. He had worked out that neutrinos, particles famous for passing through planets without noticing, would under specific conditions interact with entire atomic nuclei as coherent units. Not with individual protons or neutrons, but with the whole nucleus simultaneously, like a sound wave hitting a wall rather than striking individual bricks.

The mathematical consequence of this coherence was significant. The cross-section for the process, the measure of how likely the interaction is, would scale not with the number of nucleons but with the square of the neutron number. For heavy nuclei, that meant amplification by factors of hundreds compared to incoherent single-particle scattering. The interaction would still be weak. But it would be orders of magnitude less weak than anyone had assumed.

Freedman published his prediction and waited. The detectors of 1974 were not sensitive enough to confirm it. Neither were those of 1984, or 1994, or 2004. The prediction sat in the literature, mathematically sound, experimentally untested, for forty-three years.

During those decades, while institutional physics waited for detector technology to catch up, a mathematician named Holger Thorsten Schubart was asking a different question entirely. Not how to observe the interaction, but how to engineer a material system that could aggregate millions of such interactions into usable electrical output.

The Assembler

Schubart's contribution to physics is not a discovery. It is an assembly. While particle physicists were focused on detection for astrophysical purposes, he was working from a mathematician's vantage point, looking at the full landscape of what was already known about ambient particle flux, electromagnetic background fields, thermal fluctuations, and nanomaterial behaviour, and asking whether the pieces, correctly combined, described a viable energy conversion architecture.

The answer he formalised is the [Schubart Master Formula](#):

$$P(t) = \eta \cdot \int V \Phi_{\text{eff}}(r,t) \cdot \sigma_{\text{eff}}(E) dV$$

Every term corresponds to something measurable or engineerable. $P(t)$ is instantaneous electrical output. η is total conversion efficiency. $\Phi_{\text{eff}}(r,t)$ is the effective ambient flux at a given position and time, combining contributions from neutrinos, cosmic muons, electromagnetic fields, and thermal fluctuations. The volume integral sums the conversion across the entire active material. And $\sigma_{\text{eff}}(E)$ is the effective interaction cross-section: the term that carries the most scientific history, attracts the most scepticism, and does the most work.

The [Neutrino® Energy Group](#), the globally distributed innovation ecosystem that grew around Schubart's framework, incorporating an international network of scientists, engineers, and research institutions with connections spanning CERN, Fermilab, the Max Planck Society, MIT, and IIT, treated $\sigma_{\text{eff}}(E)$ not as a borrowed particle physics parameter but as an engineered quantity. Understanding why requires understanding what the standard dismissal gets right, and what it misses.

The Objection, Taken Seriously

The standard criticism is not wrong about the numbers it cites. At solar energies, the cross-section for neutrino interactions with individual nucleons runs around 10^{-44} square centimetres. That figure is real. Anyone who uses it to dismiss neutrino-voltaic conversion is citing a genuine physical quantity.

The error is not in the number. It is in which number is relevant.

$\sigma_{\text{eff}}(E)$ in the Master Formula is not the single-nucleon cross-section. It encodes a different physical process operating through a different material architecture. The distinction is the rest of this article.

The N^2 Amplification

Return to Freedman's 1974 prediction. The process he described is now called coherent elastic neutrino-nucleus scattering, or CEvNS. When a neutrino's de Broglie wavelength is large relative to the target nucleus, all the nucleons contribute to the scattering simultaneously and in phase. In acoustic terms, it is the difference between random noise and a coherent signal. The cross-section for this process scales as N^2 , where N is the neutron number.

For silicon, the primary material in the Neutrino® Energy Group's graphene-silicon heterostructures, the neutron number is 14. The N^2 factor is 196. For heavier nuclei, the amplification is substantially larger. The interaction remains weak in absolute terms. In relative terms, it is orders of magnitude stronger than incoherent single-particle estimates suggest.

In 2017, a team at Oak Ridge National Laboratory called COHERENT finally built a detector sensitive enough to see what Freedman had predicted. They confirmed CEvNS. Four years later, in 2021, they confirmed it again using different target materials. In 2025, the CONUS+ collaboration published results in Nature confirming the interaction in a reactor environment at energies directly relevant to the solar neutrino range, precisely the energies that matter for neutrino-voltaic materials.

Schubart and the Neutrino® Energy Group had incorporated CEvNS into the theoretical basis of the Master Formula before COHERENT's 2017 confirmation. The experimental result did not create their framework. It validated one of its core physical assumptions. That distinction matters: the Group was not waiting for institutional physics to tell it what to build. It was already building, and the physics kept arriving to confirm what it had assumed.

From Nuclear Recoil to Electrical Current

Now pause. The physics above is real and the confirmation is documented. What follows is the engineering step that most critiques never reach.

CEvNS delivers momentum to an atomic nucleus. That nucleus sits inside a graphene-silicon heterostructure. The momentum transfer excites lattice vibrations, phonons, that propagate through the material. In a symmetric system, these vibrations cancel and no net current flows. The asymmetric graphene-silicon interface changes that. Through piezoelectric, flexoelectric, and triboelectric effects operating across the engineered interface, directed lattice vibration converts into a measurable potential difference. The asymmetry is the mechanism.

Professor Paul Thibado at the University of Arkansas provided peer-reviewed experimental confirmation of this transduction pathway. His published research demonstrated that freestanding graphene membranes at room temperature, driven by ambient thermal fluctuations, produce measurable electrical output, up to 10 picowatts per nanomembrane. Not a theoretical prediction. An experimental result published in Physical Review Letters and related journals.

Ten picowatts sounds negligible. The scaling is not. Across 100 to 1,000 stacked layers per centimetre of active material, distributed across 1,500 square metres of internal surface area, individual membrane contributions aggregate into the kilowatt range. The logic is identical to integrated circuit design: individual components contribute almost nothing; scale and architecture produce systems that define modern civilisation.

$\sigma_{\text{eff}}(E)$ therefore encodes this entire chain: the probability of the initial nuclear interaction, scaled by the N^2 coherence factor, combined with the efficiency of phonon generation, and the transduction efficiency of the asymmetric interface. It also incorporates contributions from cosmic muons, which produce stronger per-event momentum transfers than solar

neutrinos and interact via ionization, and from electromagnetic coupling through plasmonic modes in the graphene layers. The parameter is multi-channel by construction.

The experimental lineage behind it runs from Freedman's 1974 prediction through COHERENT 2017, COHERENT 2021 with argon targets, CONUS+ Nature 2025, and the PENG, TENG, and flexoelectric transduction literature in ACS Nano, Nature Communications Engineering, and Physical Review B. Thibado et al. provides the direct experimental bridge to the graphene conversion pathway. None of these experiments were conducted in support of the Neutrino® Energy Group. All of them confirmed physical processes the Master Formula depends on.

What $\sigma_{\text{eff}}(E)$ Is Not

Precisely because the quantity is engineered rather than purely derived, one clarification belongs here.

$\sigma_{\text{eff}}(E)$ is a phenomenological effective parameter. Its precise value depends on material architecture: doping concentration, layer count, interface quality, and the local ambient flux environment. It requires experimental calibration for each specific device configuration. It is not derived from first principles alone and does not pretend to be.

The Neutrino® Energy Group is transparent about this. The Master Formula defines the governing framework and establishes the physical relationships between inputs and output. Laboratory measurement determines the specific value of $\sigma_{\text{eff}}(E)$ for each implementation. This is not a weakness in the framework. It is how serious engineering operates in every field. The Navier-Stokes equations govern fluid dynamics; the viscosity of a specific fluid requires measurement. Maxwell's equations govern electromagnetism; the permittivity of a specific material requires measurement. The Master Formula governs neutrinovoltaic conversion; $\sigma_{\text{eff}}(E)$ for a specific device architecture requires measurement.

What the Derivation Actually Is

Forty-three years passed between Freedman's prediction and COHERENT's confirmation. During those decades the physics was real, mathematically consistent, and experimentally inaccessible. Schubart began assembling the engineering framework during that waiting

period, working from mathematical conviction that the pieces, taken together, described something new.

What $\sigma_{\text{eff}}(E)$ represents is not an invented parameter designed to make inconvenient numbers work. It is the intersection of a fifty-year arc of particle physics, a decade of graphene materials science, and a mathematician's decision to ask whether the accumulated knowledge of those fields, assembled correctly and engineered precisely, could produce something the fields themselves had never considered building.

The derivation of $\sigma_{\text{eff}}(E)$ is, in that sense, less about the formula and more about the decision to ask a question nobody else was asking.

The physics was never hidden. It was simply never assembled for this purpose.

Independent Scientific Commentary

by Specialists in Particle Physics and Advanced Materials Engineering based on publicly documented physics spanning from Freedman's 1974 CEvNS prediction through COHERENT (2017/2021), CONUS+ (2025), and contemporary graphene transduction research.

NEUTRINO ENERGY GROUP

SCIENTIFIC ADVISORY BOARD

-Chairman- Geneva, 17 May 2026