Exciting New Science and Potential Clean Energy

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The essay below was submitted to an American Physical Society contest in May 2018. It did not get recognized. The updated essay is offered here in case such a short summary of the status of LENR would be of interest or use to anyone.

New science, even if it is understood, can be difficult to develop into commercial products. Much more challenging are established effects that are not understood, but have commercial promise. This is the story of a solid empirical scientific effect that is still not understood, but might be very important commercially, and could be developed into clean energy generators within several years.

Three decades of global experimental research have shown that it is possible to stimulate nuclear reactions with chemical energies. The ability to release energies on a MeV scale with stimuli on an eV scale indicates the possibility of high energy gains. The gain is defined as the ratio of thermal energy out of an experiment divided by the electrical energy put into the experiment. Significant energy gains have already been demonstrated in many experiments. Substantial work in a few countries has produced gains in the range of 5 to 30. The highest reported gain is 800.

The experiments that produced high gains are not yet reproducible nor controllable. They are like the situation in the early days of semiconductor devices, when impurities gave highly variable performance. Now, after many decades of research and development, we have profitable chips with well over ten billion transistors. Issues of reproducibility, controllability and reliability are vanquished, and unit prices are remarkably low. The imager in a cell phone camera costs only about $20. Semiconductor successes lead to a question: will high energy gains indicated by many good experiments ever be engineered into reliable commercial generators for production of nuclear energy?

There is ample motivation for that possibility. The hundreds of available reports of experimental results from thousands of experiments show that energy gains are not the only attractive feature of the new science. There is very little prompt radiation emitted during the experiments, and they produce essentially no radioactive waste. Like other forms of nuclear energy, the experiments do not emit greenhouse gases. These remarkable characteristics point to an important potential new source of clean energy.

These attractive features have emerged at a time when the world needs other clean energy sources for three reasons: the growing global population, the increasing per capita energy use as nations develop, and the urgency of slowing climate change. This combination of push by the new science and pull by global needs could be expected to attract both great scientific attention and major investments in research, development and commercialization. However, that is decidedly not the case in the U.S. and many other countries. China is the exception, and has long invested in this new energy science.

By this point in the essay, many readers will have recognized what is being discussed. The topic was initially termed "cold fusion," a name that some still use for the field. However, the most popular name for the topic is now low energy nuclear reactions (LENR).

How is it that the strong results from about a third of a century of laboratory research on LENR are being generally ignored? The answer to the question is quite clear. The field started with a press conference early in 1989 by Martin Fleischmann and Stanley Pons of the University of Utah. They almost simultaneously submitted a paper to a refereed journal, which was published soon after. However, the hyped announcement to the press generated unusual worldwide attention. Many scientists tried immediately to reproduce the reported results, and failed. Experimental success depended on having the right materials. Further, the reported ability to produce nuclear reactions in electrochemical cells was at odds with available theory in 1989. There was also active opposition to "cold fusion" by some scientists and others. In short, the field got a bad name, which is still remembered. And, lacking funding, there is little motivation on the part of most scientists to pay attention to the field, even though the many reports of strong results are readily available.

Despite problems on many levels—scientific, technical, financial and even political—work on LENR has continued since 1989. The field is now part of what is termed Condensed Matter Nuclear Science. It has a refereed electronic journal, the *Journal of Condensed Matter Nuclear Science*. One U.S. laboratory has published 48 papers on LENR in refereed journals.[1] There are thousands of papers and reports on LENR available on the internet. The primary source is lenr.org. Sessions on LENR have been held during conferences on physics and chemistry in the U.S. and abroad. There have been many conferences entirely devoted to LENR—24 in Russia, 18 in Japan and 18 in Europe. The main series of international conferences has rotated from North America to Europe to Asia every year or two since 1990. The 22nd International Conference on Condensed Matter Nuclear Science (ICCF22) was held in the fall of 2019 in Italy. ICCF23 is planned during the spring of 2021 in China. The series continues to employ the abbreviation ICCF for the International Conference on Cold Fusion, which was used for the conferences in 1990 and several following years.

Much was learned experimentally about LENR during the 1990s. Since 2000, a large number of experiments and the resulting publications have made the database for LENR essentially impregnable. Critics have been challenged to find fault with the experiments that report results which can only be explained by nuclear reactions. No one has been able to explain away all the data indicating LENR can occur at low temperatures, and produce nuclear products.

The current situation regarding LENR can be summarized. Scientifically, there is a robust data base behind the earlier statement about the ability to produce nuclear reactions with chemical energies. The generation of heat that cannot be explained by chemistry is well established experimentally. Competent scientists have used adequate equipment with proper calibrations to measure heat production with good signal-to-noise ratios. In addition, many papers have reported the generation of tritium, helium and other elements, the production of which cannot be explained by chemical reactions. Again, the experiments from which nuclear products were found were performed competently. Over a dozen papers have reported on the correlation of heat generation and helium production during the same experiments.

The field of LENR now has two main branches. The first is similar to the approach used by Fleischmann and Pons, namely the production of deuterons by electrolysis of heavy water and their interactions with palladium. It has two drawbacks, the first being the expense of D_2O and Pd. More important is the practical fact that the boiling point of water is a temperature too low for efficient production of electricity. The second branch of the field involves the interaction of protons with nickel-based materials. High temperatures, up to around 1000°C, are used to disassociate hydrogen gas to produce the protons. Substantial energy gains have been reported with this approach. It is attractive for commercialization because of the cheaper materials and higher temperatures. The H-Ni experiments still use low powers compared to conventional means of producing nuclear reactions.

While the experimental side of the field has many defensible results, theories of LENR are not as robust. A few dozen ideas have been published, but most of them are incomplete. And, the stronger theories usually have not been carried to the point where their results can be compared to experiments. Many scientists believe that the understanding of the mechanisms behind LENR is a challenging scientific problem. The solution of this problem might bring fame to the scientists who first illuminate what is happening in LENR experiments. The situation is reminiscent of the delay between the laboratory discovery of superconductivity and its understanding more than four decades later. There were also about four decades between the idea of plate tectonics and its adoption.

A remarkable situation has developed. Despite the lack of understanding, over a dozen companies have been formed in several countries to develop commercial energy generators based on LENR. In contrast to current fission power stations and hypothetical hot fusion generators, LENR offers the prospect of small nuclear power sources. They could be used in mobile field units, and also to power homes and other small buildings. Distributed LENR energy would relieve stress on the electrical grid, and also offer protection against blackouts. The combination of the attractive features of LENR, and the global need for clean energy sources, is the reason for the current interest in commercialization of LENR. So also is the opportunity to get into a major new industry early, even as it develops. The level of investment in LENR is only a few tens of millions of dollars during the past decade. That is small compared to the funding put into hot fusion research annually only by and in the U.S. An Industrial Association was founded in 2015 (lenria.org) to advocate for attention to and funding of LENR.

There is a clear need for more experimental work on LENR. It is well known that neither the reproducibility nor the controllability of the energy output of LENR experiments is satisfactory, despite the thousands of experiments. Along with the lack of a basic understanding, those problems contribute to LENR not getting needed attention and support. Two areas attract most interest regarding reproducibility, namely materials and experimental setups. There is an empirical case that can be made for materials being the major unknown in LENR experiments. A few laboratories have found that some batches of materials produce LENR energy, but others used in the same equipment with the same protocols fail to generate power. There are dozens of material parameters, including the composition and structure of the bulk and surfaces, which need to be thoroughly interrogated. Low level impurities, defects in the bulk and the details of surface physics and chemistry all need experimental attention.

Support of scientific research on LENR by the U.S. and other governments would result in substantial publishable work in physics, chemistry, materials and related fields. Such support could have three major impacts on the field. One would be the ability to perform systematic parametric materials and other experiments, which require substantial time and money. Another is the chance to employ modern scientific tools, both experimental and computational, which could contribute substantially to understanding LENR. Techniques from nano-science and nano-technology, and the use of beams of synchrotron radiation for dynamical measurements, are but two examples. The employment of modern computational tools, notably molecular dynamics, is also highly desirable. Finally, experience from the semiconductor industry, and other mass manufacturing markets, could be brought to bear on making LENR reproducible, controllable and reliable. Even today, the yield of new chips is often low. But, there are methods in place within chip producing companies to rapidly improve yield and profitability.

The scientific challenges and commercial opportunities of LENR come at an interesting time in the history of physics. The understanding of LENR might contribute to the trend toward conceptual unification of the basic levels of matter. Currently, there is increasing interaction between high energy physics and nuclear physics, as forces within nucleons are being related to forces between nucleons. In a somewhat similar fashion, understanding of LENR could lead to a closer intellectual relationship between the nuclear and atomic levels of matter. It is appropriate that nuclear physics, with its multiple models, is in the middle of the current attempts to understand LENR. The new subject raises old and unresolved issues in nuclear physics. Could understanding of LENR lead to a more integrated and mature theory of the nucleus?

Whatever impact the study of LENR has on nuclear physics, it has long been clear that the task of understanding LENR is strongly interdisciplinary. Knowledge of several disciplines is needed, including physics, chemistry, materials science, measurement science and both electrical and mechanical engineering. The hundreds of people now studying LENR enjoy the challenges of the learning and work required by such a broad and integrated topic.

For the several reasons noted above, LENR is indeed *Exciting New Science and Potential Clean Energy*. Understanding of the science, and development of clean energy generators, might each prove to be historic.

Reference

1. Mosier-Boss, P.A. and Forsley, L.P. 2015. "Condensed Matter Nuclear Reactions," online at https://www.academia.edu/17964553/Condensed_Matter_Nuclear_Science_October_2015

About the Author

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