Chapter 3

Essential Public Policy Changes for the Development and Deployment of Solid-State Fusion Energy

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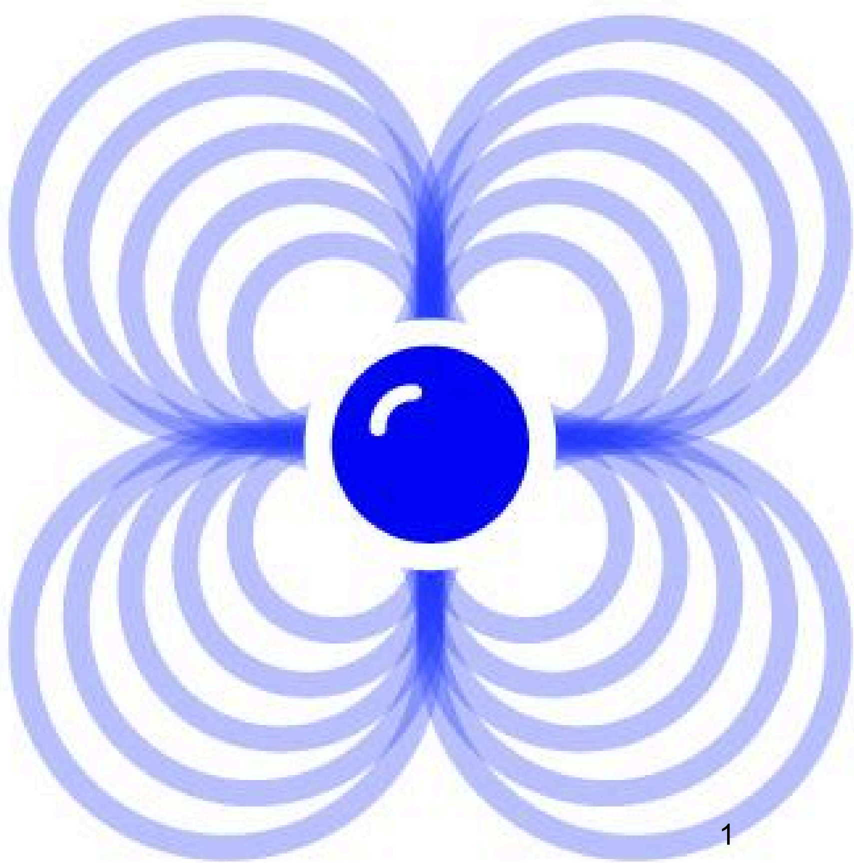

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1. Introduction

Martin Fleischmann and Stanley Pons announced cold fusion at the University of Utah in March 1989. The energy production potential of cold fusion (now frequently referred to as Low Energy Nuclear Reactions, LENR, or Solid-State Fusion, SSF) was clearly realized at the time[1]. As a potential new source of energy, SSF offers many advantages[2]:

- Virtually unlimited energy source
- Environmentally secure (no emissions or effluents)
- No harmful radiation or radioactive waste
- Possibly deployable in centralized or dispersed configurations
- Low cost of materials
- Operational advantages (low maintenance)
- High energy return (output vs input)
- Energy source available everywhere without transport or restriction

When it was announced, memories of the oil embargoes and long lines at gas stations of the 1970s were still fresh. The main emphasis at the time was on SSF's potential as an additional energy supply. The situation has shifted dramatically with the emergence of global climate change (GCC) as a principal issue. GCC, which is caused (or at least initiated) primarily by greenhouse gases from fossil fuels, threatens the very habitability of the earth. The urgency is now for SSF to replace or displace fossil fuels and their greenhouse gas emissions.

Notwithstanding its potential advantages, SSF was rejected by mainstream science within a year or so[3],[4]. The reasons for the rejection are rooted in how science is conducted – the sociology of science[5],[6]. Incremental science is readily accepted, whereas revolutionary discoveries are not[7]. SSF is undoubtedly a revolutionary discovery and requires that current scientific understanding be significantly changed or extended. In retrospect, SSF rejection was a failure in the sociology of science. The error has been compounded by the failure of self-correction of science in the decades since. SSF's primary issues continue to be insufficient reproducibility and inadequate understanding.

Despite the rejection by mainstream science, SSF has continued to be pursued by many highly qualified scientists worldwide. Continued research, experimental results,[8] and progress in theory development indicate that SSF may yet realize its potential as a new energy source. Mainly because of the existential threat of GCC, policy changes for research support for SSF are essential. And because its deployment as an energy source will almost certainly disrupt the current energy infrastructure and associated elements of society, new policies are also needed to mitigate these effects.

The case is made here for SSF policy changes by describing the current situation, advocating policy changes for SSF research, delineating the policies needed to deal with its disruptive impacts, and setting forth important corollary policy considerations.

2. Cold Fusion Policies: Where Do We Stand?

The public interest ingovernment support for scientific R&D has long been recognized. Salient historical examples are the Manhattan Project, which ended World War II, and the U.S. space program, whose research has led to many benefits beyond the program's immediate goals. In the early stages of technology development, government support is critical when risks are high, and research costs may not be justified for private sector investment.

Because of its potential as a new energy source, SSF development is very much in the public interest. When it was rejected, however, public policies for research support generally followed suit. After the rejection, the public withdrew its support, amplifying the damaging support policies. Because SSF's energy prospects were negated, preparation for its potential disruptive effects was also minimal.

The US Department of Energy (DoE) led in SSF rejection in two significant events. First, through its Energy Research Advisory Board (ERAB), the agency investigated SSF and issued its final report in 1989[9]. It recommended no special funding for SSF research. In practice this recommendation resulted in no funding of any consequence at all.

Second, in 2004, the DoE underwent another process involving two groups of perceived experts[10]. The conclusion was that no change from the 1989 recommendations was needed. Critiques of the effort[11],[12] found several deficiencies in how the review was conducted and the conclusions drawn. For example, a close examination of the input received from the participants indicates that the final report recommendations are inconsistent with the input received.

In a recent (February 2023) apparent policy reversal, The DOE's Advanced Research Projects Agency-Energy (ARPA-E) funded eight projects to investigate SSF[13] for a total of about $10 million.

However, the DOE's historical negative stance influenced the policies of agencies and entities not only in the U.S. but also around the world. For example, the US Patent and Trade Office has refused to grant patents for SSF devices[14]. The National Science Foundation has not considered SSF a legitimate science nor supported research in the field.

Despite DoE's long-standing policy example, other federal agencies have supported SSF research on and off in the decades since 1989. These agencies have vital interests in energy development and may serve as examples for future SSF research support. For example, components of the US Navy conducted internally funded research on the phenomenon at no fewer than three locations – Space and Naval Warfare Systems Command (SPAWAR), San Diego; Naval Air Weapons Center, China Lake, CA; and Naval Research Laboratory, Washington, DC[15]. The US NASA has periodically conducted and supported research starting soon after the announcement[16]. Research has been done at the Glenn Research Center, Cleveland, OH, and Langley Research Center, Hampton, VA. Two relevant publications describe recent NASA research on lattice-confined fusion[17],[18]

3. Policy Changes for SSF Development

Public support for a scientific claim must be based on the evidence that it is a real phenomenon. Evidence-based policymaking[19],[20] for proposed new energy sources like SSF ensures that the public interest is served for realizing the benefits while avoiding undeserved support for false claims.

The free market is well established as a force for the public interest. Discoveries like SSF often lead to new technologies that quickly enter the market. Marketable technologies did not happen for SSF because of its rejection and continuing issues of inadequate explanation and lack of reproducibility. Some aspects of the market that are not central to its function – called "market externalities," or "market failures" – may not serve the public interest. They may require government intervention to protect the public interest. A prime example is the plethora of laws and regulations that governments worldwide issued, particularly in the 1970s, in response to air, water, and land pollution from energy and other industries.

A rational and straightforward way to apply evidence-based policymaking to the SSF case is to borrow terminology and levels of evidence from the legal field[21]. Public support decisions can then be made based on the probability that the claim is valid. Because of the importance of SSF to the future of humanity, the following are proposed as conservative but reasonable policy responses based on levels of evidence.

Level of Evidence (LOE)	Probability	Policy Response
Lower Probability (LPR)	<50%	Reinstate; support like other emerging technologies
Preponderance of Evidence (POE)	>50%	Support at a level equivalent to hot fusion
Clear and Convincing Evidence (CCE)	>70%	Support at a higher level than hot fusion
Beyond a Reasonable Doubt (BRD)	>90%	Crash program (like the Manhattan Project)

As noted, these estimates are for a conservative scenario. For a more urgent scenario, including the GCC crisis, the policy response would be to implement a crash program for both the CCE and BRD levels of evidence. If the level of evidence is POE, SSF should be pursued at a higher level than hot fusion in the past.

What, then, is the level of evidence for SSF, and what is the corresponding research support to best serve the public interest?

Reinstatement is essential to correct the sociology of science error that occurred with SSF's rejection. Beyond that, the scientific evidence for SSF and the corresponding level of evidence (LPR, POE, CCE, BRD) are a matter of opinion. Rationally, a valid opinion must be informed and based on facts. The following observations suggest levels of evidence for SSF and the corresponding policy responses.

3.1 Preponderance of Evidence: Fleischmann and Pons Credentials

The first consideration is the scientific qualifications of the chemists Martin Fleischmann and Stanley Pons, who made the startling claim in 1989[22]. Both had outstanding reputations in electrochemistry, the method they used to achieve SSF. Dr. Pons had been promoted to the chairmanship of the chemistry department at the University of Utah. Dr. Fleischmann was visiting Dr. Pons at that university after retiring from the University of Hampton in England.

Dr. Fleischmann was recognized at the time as one of the world's foremost researchers in the electrochemistry field. He was elected to the Royal Society, the top scientific honor in England, in 1986 based on his contributions to that field[23]. Fleischmann and Pons were exceptionally well qualified for the work they were doing. They knew how to perform electrochemical experiments and associated calorimetry to measure excess heat as the primary signature. They conducted these experiments for more than five years to be sure of the results before announcing them in 1989.

Based on Fleischmann and Pons' qualifications, there is a POE for SSF's existence. The conservative policy response would be, at a minimum, to support SSF development at a level that hot fusion has been supported for the past 50 years. A more liberal response would be to provide even more support than hot fusion has received in the past.

3.2. Clear and Convincing Evidence: Early Verifications.

Charles Beaudette in 2002 and Ed Storms in 2007 authored books describing early experimental verifications of Fleischman and Pons' claims. Bayesian network analysis of early experiment results further supports the original claim.

Beaudette Assertions. In Dr. Charles Beaudette's book,[24] he made the point that in normal scientific investigation, confirmation of a new claim leads quickly to widespread acceptance of the discovery. He then described four early and compelling experiments that showed excess heat using electrochemical methods similar to the Fleischmann and Pons design.

- Richard Oriani[25], Professor Emeritus, University of Minnesota, performed electrolytic cell experiments in the summer of 1989. Two of the cells produced excess power as shown on a plot of power output as a function of power input. The excess power is indicated on the plot by significant departures of the output above from the straight line depicting output equals input power. According to Beaudette, during the 150 minutes of the experiment, about 3.6 watts of excess power were produced.

- Robert Huggins[26], Professor at Stanford University, California, began experiments in 1989. He measured excess power in terms of percent of input power. In an experiment that lasted 120 minutes, he observed anomalous power from the 40th to the 100th minute. It increased rapidly to a maximum of 56% and then decreased rapidly. The cell's temperature rose from 11°C to 18°C and then fell back to 11°C during excess power production.

- Melvin Miles[27],[28], Research Scientist, US Naval Weapons Center, China Lake, California, conducted an electrolytic cell experiment in late 1989. He measured excess power as a ratio of output power to input power. Anomalous power started on day seven and reached a ratio of 1.30 from day 10 to day 15. The average excess power ratio over 11 days was 1.145.

- Michael McKubre[29], Experimentalist, SRI International, Menlo Park, California, performed longer-term electrochemical cell experiments from 1990 to 1991. One of the cells showed excess heat after 53 days and continued for 11 days. During that time, the maximum output to input power ratio was 1.3.

Storms Findings. Dr. Edmund Storms, who is retired from Los Alamos National Laboratory and is one of the earliest and most prominent SSF researchers, has written two books on the topic, published in 2007[30] and 2014[31]. In the first book, based on a thorough review of papers in the field from 1989 to 2004, he presented experimental results for three types of SSF signatures (Tables 2, 8, 11). He reported a total of 319 experimental successes using excess heat (184), elemental transmutation (80), and anomalous radiation (55) as the signatures.

Bayesian Network Analysis (BNA). Johnson and Melich used Bayesian network analysis (BNA) to evaluate the weight of evidence for SSF[32]. They used the results of previous work by Cravens and Letts, who surveyed 167 papers that reported results of electrolytic cell experiments[33]. The survey spanned the years 1989 to 2007. From the results of their study, Cravens and Letts recommended eight papers for applying BNA. Johnson and Melich added the original Fleischmann and Pons report[34] and three arbitrarily selected later papers. Their BNA of the 12 papers resulted in a likelihood ratio of 28 to 1 in favor of SSF. The ratio grew rapidly as more papers were added to the analysis.

Based on the early verifications documented by Beaudette and Storms, and by Johnson and Melich (using BNA), there is a CCE level of evidence that SSF is a real phenomenon. In a conservative scenario, the appropriate policy response is to support its research at a higher level than has historically been received by hot fusion. In a more liberal scenario, a crash program should be instituted for SSF development.

3.3 Beyond a Reasonable Doubt?

The above analysis for the POE and CCE levels of evidence includes experiments conducted up to about 2012. Many experiments have been performed in the years since. An essential measure of SSF evidence is the level of continuing interest, indicating success in the field. Strong continuing interest means that SSF's level of evidence is beyond a reasonable doubt (BRD).

A prominent example of continued interest is the number of downloads from the LENR-CANR.org website, an online library maintained by Jed Rothwell[35]. It includes 2100 scientific papers and a bibliography of over 4700 books, journal papers, and news articles about SSF. Ongoing interest in SSF is indicated by an average of more than 17,000 monthly downloads from October 2002 to October 2023. The total visits were more than 7.2 million, and the total downloads were 4.5 million, which is remarkable considering SSF's rejected status.

Another example of continued interest is LENRIA, formed in 2015 as an embryo industrial association[36]. LENRIA (LENR Industrial Association) was formed in response to growing interest in the practical possibilities of SSF. In a recent update[37], LENRIA displayed a LENR "ecosystem" with almost 60 entities and organizations in categories as shown below.

Core Entities (Long Standing)	10
Organizations	7
Government	9
Academia	9
Businesses	16
Publications	7
Total	58

Still another example of ongoing SSF interest is the Anthropocene Institute's "Solid-State Fusion[38] during 2023"[39]. It explores several questions, including who is involved in the field, what is known about the science, the patent landscape is, what can be learned from previous breakthroughs, and what the socioeconomic impacts of SSF will be. Chapter 1 of the document, "Who's Involved in SSF?" references the LENRIA ecosystem and then describes 67 entities and organizations involved in SSF in five categories:

Basic Research Efforts	
Privately Funded Projects	4
Publicly Funded Research	
Multi-Nation	4
U.S.	2
EU	7
Japan	6
Commercial Entities	24
Professional Organizations	5
Investors	3

Media and News Websites	12
Total	67

The substantial continued interest in SSF is mainly because of continued success with the phenomenon. This indirect evidence – on top of the POE and CCE levels up to 2012 described previously – may well indicate that SSF is a real phenomenon beyond a reasonable doubt (BRD).

3.4. Summary: SSF Evidence and Policy Response

Evidence-based policymaking has long best served the public interest. Based on the level of evidence for SSF, the proposed policy responses are summarized as follows:

		Policy Response	
LOE	Prob	Conservative	Urgent (GCC Crisis)
LPR	<50%	Reinstate, like other emerging energies	Equivalent to hot fusion
POE	>50%	Equivalent to hot fusion	Higher level than hot fusion
CCE	>70%	Higher level than hot fusion	Crash program
BRD	>90%	Crash program	Crash program

The levels of evidence asserted here, particularly considering the emerging GCC crisis, show that a crash program is the most appropriate policy response.

4. Policies Required for SSF Deployment

When SSF becomes widely utilized it will undoubtedly be a disruptive technology. Its profound effects will be both direct on the current energy supply chain and indirect on entities closely related to energy[40]. Suppose SSF energy proves to be deployable in a centralized configuration (like existing power plants) and a distributed manner (like local generators). In that case, the entire energy supply chain will be affected. Government may need to intervene to ease the burden of these impacts on elements of the energy industry.

Many elements of society are closely tied to – and dependent upon – the current energy infrastructure. Examples are coal mine and oilfield communities and government entities that rely on taxes on energy facilities. In addition to supporting energy development, governments may assist private sector and public entities experiencing indirect impacts caused by SSF deployment. Such impacts are not accounted for in market forces and are another type of market failure. Government intervention to assist is a response to this market failure, similar to laws and regulations for environmental protection and cleanup described above.

Technology assessment (TA)[41],[42] is an example methodology for determining the social impacts of new technologies that may be used to identify and mitigate the disruptive impacts of SSF energy deployment. TA generally comprises the following elements.

- Development of the Team. Includes a multidisciplinary technical team and an overarching advisory group whose members represent various categories of affected parties.
- Statement of the Market Failure Problem. Provides a description of the new energy technology and the limitations of market force and characterizes SSF as a disruptive technology.
- Identification of Potential Direct Impacts. Encompasses impacts on the components of the energy system – supply, transport, storage, and consumption.
- Delineation of Potential Indirect Impacts. Inventories various categories of impacted social entities, such as taxing authorities, local governments, and workforces.
- Determination of Policy Options for Impact Mitigation. Includes existing agencies for services and support and identifies any gaps and coverage and sets forth what's needed.
- Mitigation Plan Development and Implementation. Defines the roles and responsibilities of existing (and newly formed, if necessary) agencies. A management structure may be required to deal with gaps and overlaps, as well as to develop additional entities that may be needed.

The TA methodology addresses the consequences of market failure. It was developed concurrently with the many laws and regulations for environmental protection and cleanup in the 1970s. It has been applied successfully to several energy-related issues, including coal-slurry pipelines[43] and large-scale energy development in the western United States[44].

5. Corollary Policy Considerations

Policymakers must consider several factors must in SSF policymaking for research support and mitigation of adverse secondary impacts. These factors include the role of federal agencies, opportunities for the private sector, the problem of inertia of SSF rejection and negative policies, and integration of policy changes.

Agency Opportunities – and Responsibilities. Nearly all agencies dealing with energy issues have mission statements for discharging their duties. The agencies are different, of course, for SSF support and mitigation of its disruptive impacts. For example, in the US, the Departments of Energy and Defense have interests in energy development and supply. Examples of government entities that are responsible for impact mitigation are the Environmental Protection Agency and the Department of Health and Human Services. Changes in SSF policies represent significant opportunities for both types of agencies to fulfill their missions. It may also be argued that these agencies are responsible for incorporating SSF in accomplishing their missions[45].

Private Sector Opportunities. The main SSF focus of the private sector is on development and deployment rather than dealing with secondary impacts. Because of its lack of acceptable reproducibility, SSF continues to be a high risk for private investment. As noted, this risk necessitates public research support in the current early development stage. When SSF becomes viable as an energy source, the private sector can step in for applications and product development. The power of market forces will then ensure broad deployment of SSF – and the displacement of fossil energy. Private sector investment will be significantly enhanced when negative intellectual property protection policies, particularly those of the US Patent and Trade Office, are corrected.

Several startups and other small firms are pursuing SSF using empirical approaches because of the need for an adequate explanation. Large companies, particularly energy consumers (such as firms having large digital server farms), are also supporting SSF R&D. For example, investigations at Texas Tech University, under the leadership of Rob Duncan, are being supported by a confidential sponsor who is prominent in the production of both software and hardware. Google is another firm that has supported SSF research[46].
Research is also being funded substantially by "angel" investors who don't require a reasonable return on investment but are interested in human welfare and maintaining the earth's habitability. In recent years, the Anthropocene Institute, located in Palo Alto, CA, has supported the SSF field in many ways. The Institute hosted and organized the 24th International Conference on Cold Fusion (ICCF-24) in Mountain View, CA, in 2022. They have also engaged with various start-ups and research groups in the SSF community, including the International Society of Condensed Matter Nuclear Science.

Overcoming Rejection Inertia. Undoubtedly, restoring the legitimacy of SSF and reversing irrational past policies is very challenging.A large inertia of negative perception plagues SSF. Despite the rational advantages of interpreting scientific evidence in terms of levels of evidence (POE, CCE, BRD), reversing negative policies is difficult – even in the face of the emerging GCC crisis. It is apparent that SSF's rejection was a failure of the sociology of science to function in the public interest[48],[49],[50]. So, too, is its continuing failure to correct the problem despite increasingly compelling evidence since the 1989 announcement. Nobel laureate Brian Josephson has noted the irrationality of continued SSF rejection, branding it as "pathological disbelief"[51].

Integration of Policy Changes. In the interest of efficiency and cost-effectiveness, SSF-related public policies may be integrated at the national and international levels[52],[53].

- Development and Mitigation. As support increases and SSF deployment prospects improve, mitigation planning can proceed with the rate of development.
- National and International Agency Coordination. Given the worldwide public interest in realizing the energy benefits of SSF, international agencies and their counterparts in individual nations must communicate and coordinate efforts to avoid overlap and gaps in coverage.
- Government and Private Sector Policy Coordination. As noted, the government intervenes for the private sector by sponsoring R&D in the early phases when market forces cannot yet be brought to bear. Many companies complement government efforts with their research programs where, despite the risks, their interest in SSF energy is sufficiently high. Companies and government entities must coordinate their efforts to reduce costs and avoid gaps and overlap in research.

6. Summary and Conclusions

Three centuries of humankind's dependence on fossil fuels for energy threatens the very habitability of the earth. SSF is perhaps the only energy candidate available to displace fossil fuels and their carbon dioxide emissions to deal with the GCC crisis. Government intervention in the development of SSF is essential for the public interest. Based on its level of evidence, a crash program is the most reasonable policy response, particularly with the GCC crisis, for developing and deploying SSF for the future of humankind.

Market forces will eventually become the primary impetus for deploying cold fusion. Before then, government support is necessary to realize SSF and secure its benefits. The economic hardships on the energy industry and closely related entities may also need be mitigated with government assistance. Both cases of government intervention are in recognition of the power and the weakness of market forces.

7. References

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[1] For example, during the press conference for the announcement, Pons answered a question with the following: “Well we’ve been concerned primarily with the effect – the observation of the – fusion event. I would think that it would be reasonable within a short number of years to build a fully operational device that could drive – produce electric power or to drive a steam generator or a steam turbine, for instance.”

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