The Nuclear Fusion Bubble Is Going to Burst

A *New Energy Times* White Paper

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"There is no other endeavor or project undertaken by mankind on which energy and money have been spent for close to a hundred years without any tangible results. ... The reason must be that there is a lot at stake, or perceived to be." — Author L.J. Reinders

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1. Introduction

In recent years, public attention and private investment in nuclear fusion research have reached an unprecedented level in its 70-year history.

This activity, however, does not represent real advances or developments. It is a bubble, and it is going to burst. Here are the primary factors:

> 1. Fusion representatives have claimed for half a century that the achievement of practical fusion power is close. The most prominent of those claims have been consistently inflated and in some cases falsified. Not one Watt of potentially usable power has ever been produced by an experimental fusion reactor. [1]
>
> 2. Fusion representatives have claimed that the fuel for deuterium-tritium fusion reactors is abundant, virtually inexhaustible, and equally accessible to everyone. [2] Directly contradicting this claim is the fact that the tritium fuel component required for commercial fusion reactors doesn't exist in nature. [3]
>
> 3. Fusion representatives have claimed that they can make tritium by breeding it from enriched lithium. Although this process can produce man-made tritium, peer-reviewed literature states that there is no known way to breed tritium faster than it will be burned up and lost in fusion reactors. [3]
>
> 4. Even if the tritium breeding-rate issue can be solved, there is no legal, non-toxic way to produce industrial quantities of enriched lithium needed for breeding tritium, according to peer-reviewed literature and U.S. government documents. [5]

2. Hydrogen Fusion in the Sun

Life on Earth would not exist were it not for the fusion of hydrogen nuclei in our sun. The dream of harnessing this natural mechanism and emulating it here on Earth is indeed a noble quest. We owe a debt of gratitude to the honest students and scientists who have devoted their time and, in many cases, their entire careers to this endeavor.

But much in the business of fusion has not exemplified this altruism. Fusion has been overhyped and oversold with scant basis or scientific credibility as a practical energy source. An objective understanding of the state of fusion is crucial because the world has never been in greater need of new approaches to clean, carbon-free energy.

One of the *New Energy Times* editors identified the existence of the bubble. In response, this author performed an analysis of the circumstances, as contained in this paper.

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3. Emulate the Sun, Not Replicate It
We cannot, unfortunately, replicate what happens on the sun because, on the sun, gravity does the hard work of forcing hydrogen nuclei to overcome their repulsion from one another. For terrestrial fusion research, we can only attempt to emulate solar fusion.

On Earth, we can create laboratory fusion with a relatively simple tabletop Farnsworth-Hirsch fusor device. But any prospect of creating fusion to produce useful energy requires machines encumbered with immeasurable complexity.

To compensate for the lack of gravitational force on Earth, fusion scientists need to use extremely high temperatures and magnetic fields to achieve the same kinetic energies that allow atomic nuclei to fuse in the sun. Although the sun has no moving parts, a device like the International Thermonuclear Experimental Reactor, ITER — if and when it is finished — will have 10 million parts. But high temperatures or magnetic fields are not silver bullets to fusion; they are among several fundamental, required operational parameters.

Although the sun uses ordinary hydrogen for its fusion fuel — the most abundant element in the universe — scientists know that, here on Earth, using ordinary hydrogen is out of the question. Because of the physics, ordinary hydrogen nuclei require far too much energy to fuse on Earth.

Although creating fusion on Earth using helium-3 is possible, we would have to go to the moon, mine it from the moon's surface, and carry it back here. So far, nobody's figured out a cost-effective way to do that. Some people claim to have figured out a way to make helium-3 cost-effectively on Earth. If they have really done so, faith in press releases will not suffice. To be taken seriously, they must deliver such world-shattering technology.

For all other fusion endeavors on Earth, we are left with the necessity of using isotopes of hydrogen. The first is called deuterium. Like normal hydrogen, deuterium has one proton in its nucleus. But deuterium also has a neutron. It's a stable element and is abundant in ocean water. The second isotope is called tritium. Instead of one neutron, it has two neutrons in its nucleus and is radioactive.

As a result of these differences, fusion scientists cannot attempt to replicate fusion as it occurs on the sun; they can only attempt to emulate the process.

4. Double Meanings in the Fusion Lexicon
Although the vast majority of fusion researchers have approached their work with integrity, their representatives who had communicated with the public, elected officials,

and news media did not. Instead, they engaged in systemic misleading information campaigns for decades. [6]

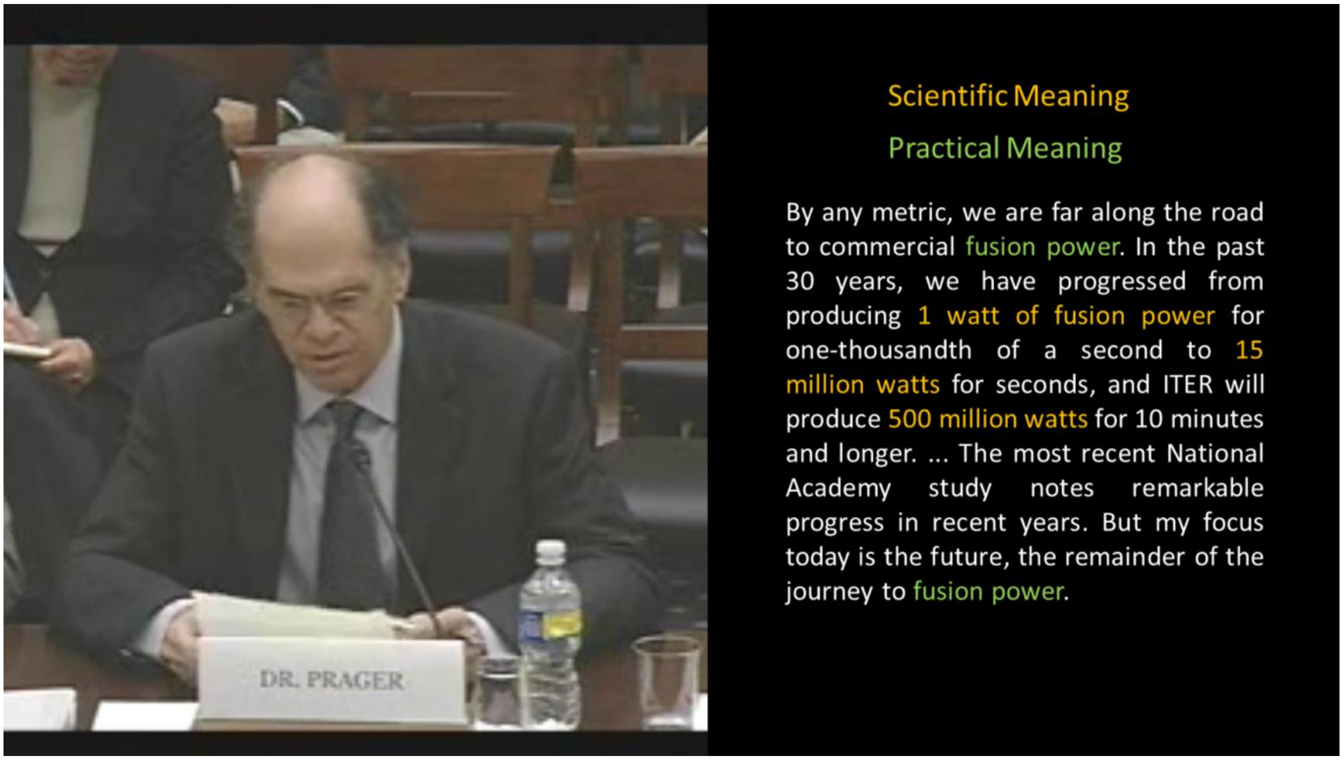
Fundamental to these campaigns was their use of phrases and arcane terminology that have double meanings. More significantly, they didn't disclose the existence of those double meanings to non-experts. [7]

The key phrase was and still is "fusion power." Its practical meaning is the *net power that would be produced by a fusion reactor.* It might seem obvious to a lay person. But no fusion reactor has ever produced net power. On the other hand, the scientific meaning of "fusion power" is the *gross thermal power produced by fusion physics reactions*.

The practical meaning of "fusion power" accounts for the power required to operate a fusion reactor, whereas the scientific meaning excludes the required operating power. It's strictly concerned with the physics rather than the engineering.

In 2009, when Stewart Prager, the seventh director of the Department of Energy's Princeton Plasma Physics Laboratory, testified before members of Congress, he switched between the two meanings without disclosing what he was doing. [8]

He began with the practical meaning, switched to the scientific meaning, then finished with the practical meaning. No member of Congress would have realized what he did.



5. Undisclosed Input Power

Furthermore, no member of Congress would have realized, when Prager said the Joint European Torus (JET) reactor produced "15 million Watts," that the JET reactor actually lost 685 million Watts of electrical power.

Why not? Because a) Prager didn't disclose the double meaning of "fusion power," b) Prager didn't disclose the 700 million Watts JET needed to operate and, c) the 700 MW input was not publicly known at the time.

The 700 MW electrical input required for JET was deeply buried until the *New Energy Times* team unexpectedly learned about it in 2014. [9] Until that time, the nearly universal understanding was that JET needed only 24 MW to operate. [10]

Prager's testimony is just one example. This practice, deliberately implying that ***reaction*** power values were ***reactor*** power values, has been commonplace among fusion representatives.

When fusion scientists testified before Congress about ITER, they consistently implied that the project was designed for net ***reactor*** power gain when it is designed for only net ***reaction*** power gain. Footage from a congressional hearing shows Bernard Bigot, the director-general of the ITER organization, testifying that "ITER will have delivered the full demonstration that we could have 500 megawatts coming out of the 50 megawatts we will put in." [6] He implied that the ITER ***reactor*** would need only 50 megawatts to produce 500 megawatts.

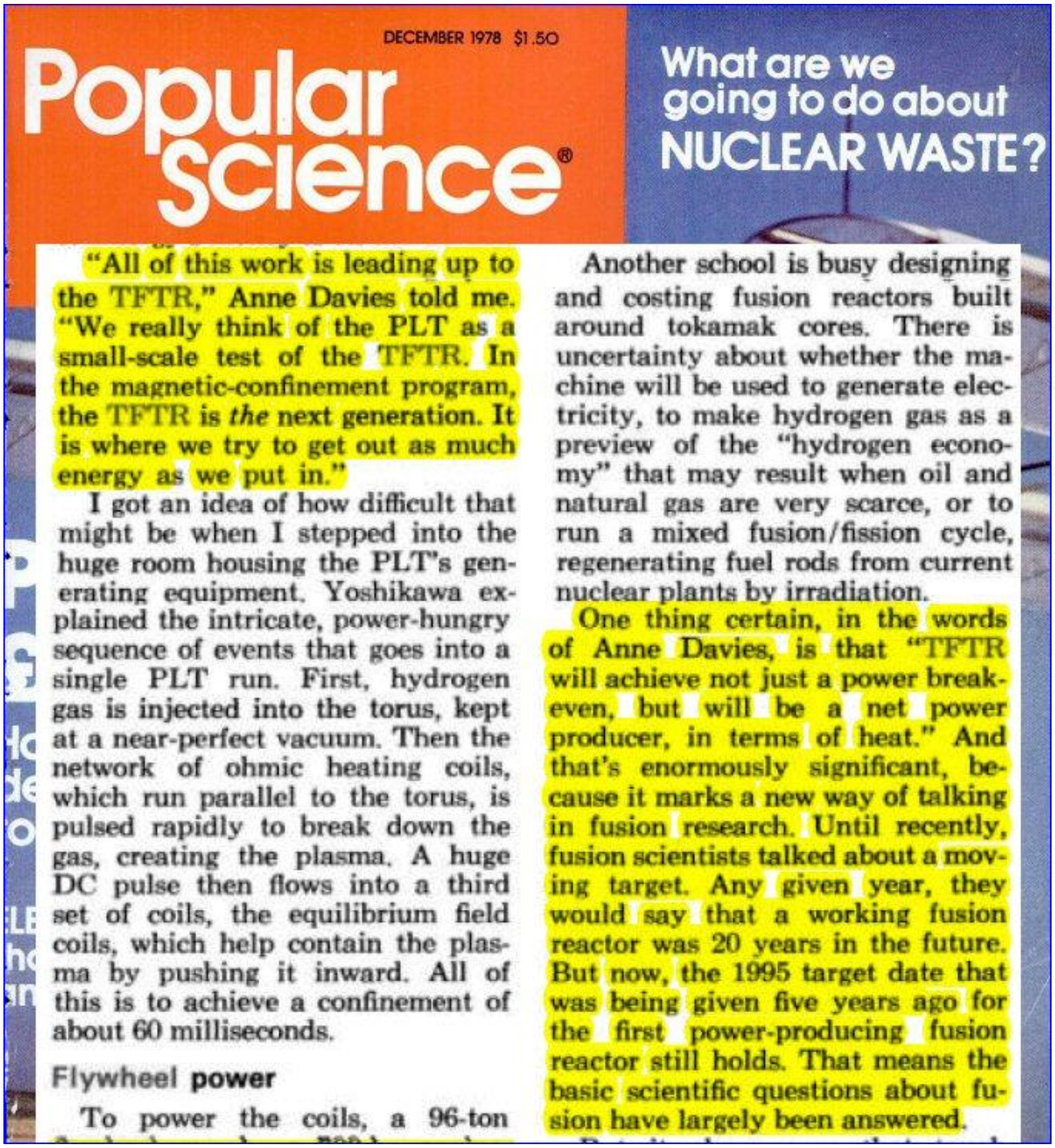
But, as reported by *New Energy Times* in 2017, the ITER ***reactor*** will need 300 to 400 megawatts of input electricity to operate. [1]

Bigot did not start this deceptive practice. He was doing the same thing that his predecessors did when they sold the ITER concept to Congress and to the public three decades ago. The statement from Rep. Eric Swalwell provides an example of the elected officials who were misled. Swalwell enthusiastically supported ITER because he thought, based on what fusion promoters told him, that "ITER is designed to produce at least 10 times the energy it consumes." [11]

Statements in *Science* magazine from 2003 to 2022 by journalist Daniel Clery, who describes himself as someone with "a long pedigree in science journalism," provide an example of the journalists who were misled. In an Oct. 13, 2006, article, Clery wrote that "ITER aims to produce 500 megawatts of power, 10 times the amount needed to keep it running." [12]

6. The Inflated Appearance of Progress

For 50 years, fusion scientists have been artificially inflating the appearance of fusion progress, creating the false impression that fusion reactors are coming close to producing net energy. We've traced it back to at least a 1978 *Popular Science* article about the Princeton laboratory's tokamak fusion test reactor (TFTR).



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What are we going to do about NUCLEAR WASTE?

"All of this work is leading up to the TFTR," Anne Davies told me. "We really think of the PLT as a small-scale test of the TFTR. In the magnetic-confinement program, the TFTR is *the* next generation. It is where we try to get out as much energy as we put in."

I got an idea of how difficult that might be when I stepped into the huge room housing the PLT's generating equipment. Yoshikawa explained the intricate, power-hungry sequence of events that goes into a single PLT run. First, hydrogen gas is injected into the torus, kept at a near-perfect vacuum. Then the network of ohmic heating coils, which run parallel to the torus, is pulsed rapidly to break down the gas, creating the plasma. A huge DC pulse then flows into a third set of coils, the equilibrium field coils, which help contain the plasma by pushing it inward. All of this is to achieve a confinement of about 60 milliseconds.

Flywheel **power**

To power the coils, a 96-ton

Another school is busy designing and costing fusion reactors built around tokamak cores. There is uncertainty about whether the machine will be used to generate electricity, to make hydrogen gas as a preview of the "hydrogen economy" that may result when oil and natural gas are very scarce, or to run a mixed fusion/fission cycle, regenerating fuel rods from current nuclear plants by irradiation.

One thing certain, in the words of Anne Davies, is that "TFTR will achieve not just a power break-even, but will be a net power producer, in terms of heat." And that's enormously significant, because it marks a new way of talking in fusion research. Until recently, fusion scientists talked about a moving target. Any given year, they would say that a working fusion reactor was 20 years in the future. But now, the 1995 target date that was being given five years ago for the first power-producing fusion reactor still holds. That means the basic scientific questions about fusion have largely been answered.

The TFTR reactor could not possibly have come close to producing net power: It produced fusion reactions with 10 MW of thermal power from an electrical input of 950 MW. [13] *Popular Science* quoted Anne Davies, a Department of Energy fusion program manager, who did not explain that the power values applied strictly to the fusion <u>*reaction*</u> rather than the fusion <u>*reactor*</u>. The misleading claims of presenting fusion <u>*reaction*</u> power values as if they are fusion <u>*reactor*</u> power values continues to this day.

In the process of promoting ITER, fusion scientists falsified the power gain of its predecessor, JET, the Joint European Torus. They claimed that JET had produced fusion reactions with 16 megawatts of thermal power from a "total input power" of only 24 megawatts. This created the foundation for the false claim that the ITER fusion device would produce 500 megawatts of thermal power from an input power rate of only 50 megawatts. On this basis, the scientists claimed that the device would demonstrate a power amplification of 10 and, therefore, that ITER would be the first fusion device in history to create net energy.

> **What will ITER do ?**
>
> **1) Produce 500 MW of fusion power for pulses of 400 s**
>
> The world record for fusion power is held by the European tokamak JET. In 1997, JET produced 16 MW of fusion power from a total input power of 24 MW (Q=0.67). ITER is designed to produce a ten-fold return on energy (**Q=10**), or 500 MW of fusion power from 50 MW of input power. for long pulses (400-600 s). ITER will not capture the energy it produces as electricity, but as the first of all fusion experiments in history to produce net energy ... it will prepare the way for the machine that can.

*False claims made by the ITER organization, as published on its Web site, before Oct. 6, 2017 (**Click here** to see ITER organization's correction soon after Oct. 5, 2017)*

Screenshot from the home page of the ITER organization. Date retrieved May 10, 2017

The ITER organization did not begin to explain that the "50 MW of input power" was limited to only the injected heating power until December 2017. That was a month after *New Energy Times* revealed that the reactor would require at least 300 MW of electricity for its input power. [1]

Although the matter of the deceptive power claims about JET and ITER is, effectively, an open secret now, few people have been willing to talk about it and call the fusion community out. But there have been a few physicists who have been willing to speak out. One was Japanese Nobel laureate Masatoshi Koshiba, who wrote that "ITER is like what is said in ancient China: 'Sheep head and dog meat'."

“This implies that the shop says it is selling sheep meat but actually they are selling dog meat,” Koshiba said.

One is L.J. Reinders, now retired, who had a career in high-energy physics. He is the author of two critical books on fusion. [14, 15]

Another is Daniel Jassby, a plasma physicist retired from the Princeton Plasma Physics Laboratory. Jassby is the author of critical articles on fusion published by the Bulletin of the Atomic Scientists and an article published by the American Physical Society and reprinted in *New Energy Times*. [15, 16, 17]

Another is Thiéry Pierre, a plasma physicist with the French Centre National de la Recherche Scientifique who has written directly to Director-General Bigot.

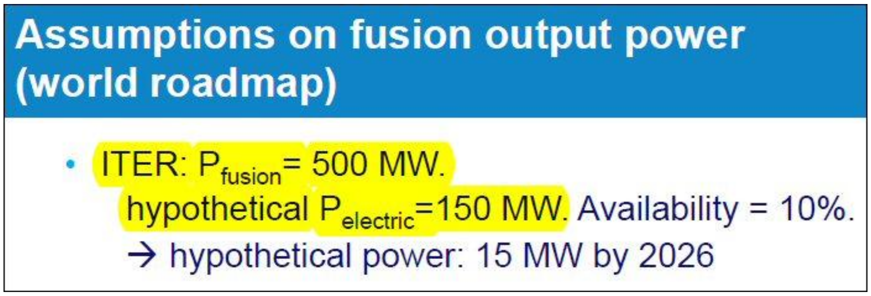
7. Misleading the Next Generation

One of the most concerning consequences of the inflated claims is the potential effect on students. It is impossible to know how many young scientists made a career choice of fusion based on false expectations, thinking that ITER would demonstrate net energy.

Luca Comisso, for example, a postdoctoral researcher at Princeton University, was misled about his expectations of the power gain intended for ITER. Comisso's professors taught him that ITER would need 50 MW of electricity to produce 500 MW of thermal power from fusion. [6] We also know that the Massachusetts Institute of Technology misled students, telling them that "ITER is designed to produce output of 500 MW from an input of 50 MW, and prove fusion power’s feasibility." [19]

FuseNet, the largest fusion educational organization in Europe, misled students from 2011 to 2019 about ITER’s purpose and output, telling them that the ITER "fusion reactor itself has been designed to produce 500 MW of output power, or ten times the amount of power put in." [20] FuseNet was founded by Eindhoven University professors Roger Jaspers and Niek Lopes Cardozo.

Cardozo is the former leader of the Dutch fusion research program (2001-2009) and served on top-level European fusion governance committees. He was also the vice-chair of the governing board of the ITER European domestic agency. In his presentations, he said that ITER would demonstrate a "10-fold power multiplication" from a 50 MW input. He said that thermal power produced by ITER would be enough, if converted to electricity at a 30% rate of efficiency, for a net positive yield of 150 megawatts of electric power. He neglected to account for the reactor operating power. [21]



With an operating power requirement of at least 300 MW of input electricity, the hypothetical electrical power balance from ITER, if connected to turbines, would be negative. Rather than a gain of 150 MW, it would be a loss of 80 MW. [22]

Three years after Bigot and Laban Coblentz, his head of communications, were fully aware of the power requirements for ITER, they made the same type of false claim. In a July 28, 2020, press release, they said that, if ITER were configured with turbines, it would produce "200 megawatts of electric power, enough for about 200,000 homes." Again, they neglected to account for the reactor operating power. [23] The Princeton Plasma Physics Laboratory made the same false claim in a 2012 brochure. [24]

How the fusion representatives managed to falsely report the objective and design parameters of ITER for so long, to create the illusion that it is a reactor designed to produce net energy, is explained in the documentary film "ITER, The Grand Illusion: A Forensic Investigation of Power Claims." [6]

8. The Fall of ITER

As *New Energy Times* reported on Feb. 21, 2022, construction of the ITER reactor has come to a halt because the first two of nine sectors that compose the reactor core were delivered in early 2021 with damage. [25] Two days ago, we learned that two more sectors also have damaged components.

The ITER organization kept all of this secret. Last fall, staff members leaked the news to us and we located the respective reports on the Web site of Autorité de Sûreté Nucléaire (ASN), a French nuclear safety regulator. When we were tipped off that ASN had ordered a halt to the reactor assembly this year, we pushed ASN to release the stop-work order to the ITER organization.

All of this speaks to the opacity of the ITER organization’s management as well as its tight control of information. Judging by its actions, the ITER organization never intended to disclose the reactor assembly shutdown publicly.

ASN has also identified other construction and design issues. Some of them involve unfixable design flaws in the walls of the buildings that will result in reduced radiological protection from neutron emission and gamma-ray radiation. This information comes from another French nuclear regulator, IRSN, l'Institut de Radioprotection et de Sûreté Nucléaire, in its report No. 2021-00195, Dec. 8, 2021. [27]

ASN has also identified deviations in the design, manufacturing, and installation of fuel circuit pipes that, as it wrote in its report No. INSSN-MRS-2022-0627, "appears unsatisfactory." [26]

In sum, ASN has written that the issues "characterize a lack of safety culture, defined as the set of characteristics and attitudes which, in organizations and in people, ensure that matters of protection and safety receive, as an absolute priority, the attention they deserve because of their importance." [26]

The cumulative result, as we reported on Feb. 21, 2022, is that the regulator has demanded the ITER organization provide comprehensive updated design specifications to verify compliance with all safety and radiological protection criteria before ASN will allow the reactor assembly to continue.

9. Objections From ITER Staff Members

New Energy Times has received information from several former senior ITER organization staff members, and their personal accounts mirror ASN's description.

Two of them are American beryllium toxicology experts Kathryn Creek and Robert Winkel. French journalist Celia Izoard reported what Creek told her about a presentation she was about to give to senior management:

> In February 2020, just before a security assessment meeting, I was taken into an office where three engineers and two executives tried to force me to modify my presentation to conceal the serious safety problems in the design of the hot-cell building [where the irradiated materials will be treated] that I denounced. I refused to comply and resigned the next day. [28]

Beryllium has been part of the ITER design specification for at least 20 years and JET was specifically retrofitted with beryllium to perform tests with its "ITER-like wall."

One former high-level staff member who was not willing to speak with us is Joelle Elbez-Uzan, the former head of Safety and Environment at the ITER organization.

MAILING ADDRESS: ITER ORGANIZATION

ITER Organization Headquarters
Building / Office Number / Department / Division (of the addressee, if known)
Route de Vinon-sur-Verdon, CS 90 046
13067 St. Paul-lez-Durance (France)

Tel: +33 4 42 17 68 88

A map and directions are available here...

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For ITER site visits, please follow this link:
http://www.iter.org/visiting

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In early 2021, she was assigned to provide a tour to and answer questions from Izoard. In a series of three articles, published June 16-18, 2021, Izoard quoted Elbez-Uzan making honest statements and transparently expressing safety concerns. [29, 30, 31]

A few days later, this author spoke with Izoard on the phone about, among other things, the revelation that someone at such a high level in the ITER organization as Elbez-Uzan had been misled to believe that the overall ITER reactor was designed to produce a tenfold power gain. This author was shocked to hear Izoard say, "Joelle will probably get fired for being so honest with me."

A few weeks later, on July 29, 2021, the ITER organization began advertising for Elbez-Uzan's replacement. (Archival copy)

Career Opportunities: Head of the Environmental Protection & Nuclear Safety Division IO0168 (4420)

Requisition ID **4420** - Posted **29/07/2021** - **France, 13067 St Paul Lez Durance Cedex** - **Managerial** - **New Posting**

Job Description Print Pre

Then there is the Dec. 1, 2021, e-mail provided to us that was written by Charles Lyraud, a man with a lifetime of experience in nuclear science. He and two other scientists were dismissed by the ITER organization, as he explained, translated from French:

> — the waves of many dismissals, which I paid for because we did not accept (group of 3 people) to install parts without being tested which presented mortal risks for the maintenance personnel.
> — unfortunately, we have been fighting for a long time to correct these anomalies
> ... but the order was "let's look at it later — let's move on."

Topping things off, Bigot testified falsely before members of the French Senate in 2021 about the power values expected from ITER. [32] In practice, ITER is far from the magnificent international science collaboration as it was envisioned and promoted.

10. ITER Extra-Legal
Unlike any national nuclear or science project, there is no nation that has overall authority or oversight of the ITER project. As a result, and to a large degree, the organization is an autonomous, independent entity, generally operating with impunity from the ordinary laws and oversight of all its sponsoring governments — and taxpayers.

The cases where the director-general been compelled to answer for his and his organization's actions are rare. ASN is one case. Another is the International Labour Organization. Several years ago, Bigot illegally fired Françoise Cazenave-Pendariès, the head of the human resources department. ILO ruled in her favor and awarded her damages. [33] He fired Michel Claessens, the former spokesman, for no stated cause.

The U.S. Government Accounting Office, which is aware of our long-running investigation, knows that ITER was founded and funded based on false power claims. But according to an e-mail from Frank Rusco, a director in GAO's Natural Resources and Environment team, the GAO will not initiate an inquiry:

> We are aware of the potentially misleading language that has been used to describe energy in versus energy out for fusion reactors. We do not have a Congressional request to look into ITER at present, but we think that a good line of inquiry would be to evaluate, among other things, how much progress has been made over the years in getting to a net positive energy output.

The progress is very simple to evaluate: ***In 70 years, fusion scientists have gone from losing 100 percent of the power used by an experimental fusion reactor to losing 98 percent of the power fed into a reactor.*** [34]

11. Inflated Private-Sector Power Claims
Until ITER began to hit rough waters, it appeared to be the model to emulate, so promoters of private fusion projects did so with their power claims. They used the same dual meanings of "fusion power," and they relied on the dual meanings of "breakeven" and "Q-value." (See article "Fusion Q-Values and Breakeven Explained.")

For example, fusion scientists at the Massachusetts Institute of Technology misled their own news writer, David Chandler, who wrote that, for MIT's new SPARC reactor concept, "the whole fusion system should indeed produce net power output, for the first time in decades of fusion research." [35] In fact, the SPARC reactor is not designed to produce net power output for the whole system. Only the physics reaction, which excludes the power required to operate the reactor, is designed for net power output. [36]

In 2016, after 43 years of receiving federal public funding for MIT's fusion reactor program, Congress finally pulled the plug. Instead of giving up, several MIT fusion professors and some of their graduate students decided to solicit private investors to continue fusion research. They incorporated a private company called Commonwealth Fusion Systems, made bold claims, attracted their first investor, then another, and eventually more than 72 investors contributing, in total, more than $2 billion. [37]

Commonwealth's chief executive officer, Bob Mumgaard, regularly made false claims on his company's ramp-up to acquiring those investments, for example in the Nov. 17, 2021, issue of *Nature* magazine:

> MIT and CFS together are preparing to build what Mumgaard calls “the first fusion machine that makes net energy” — producing more energy than goes into it. Named SPARC, it is being constructed in Devens, Massachusetts. Mumgaard says it will be running by the end of 2025 and will be “**commercially relevant**” because it will generate around 100 MW of power. [38]

It will do no such thing. If SPARC works as designed, it will have an equivalent net loss of about 20 megawatts of electricity. Mumgaard did what everybody else had done: He conflated ***reaction*** power with ***reactor*** power and omitted all the power required to operate the reactor. Thus, here's what we already know:

**If SPARC accomplishes its scientific design objective,
it will be *commercially irrelevant*.**

12. Inflated Claims About Recent Developments
In recent years, there have been many claims of technical achievements in fusion.

On March 17, 2022, fusion advocates in the White House Office of Science and Technology Policy (OSTP) and the U.S. Department of Energy (DOE) held a one-day discussion to encourage elected officials to support fusion research. The OSTP issued a press release and said that, "just in the past year, there have been many technical achievements reported in the media." [39] The press release gave these five examples:

> 1. A privately funded U.S. fusion company [Commonwealth Fusion Systems] demonstrated its prototype 20-tesla high-temperature superconducting magnet,

opening up an exciting new high-field, compact approach to commercial fusion energy.

2. The first central-solenoid magnet was delivered for ITER, illustrating fusion-scale manufacturing capability of U.S. industry.

3. The Joint European Torus (JET) in the UK doubled its 24-year-old record with a five-second, high-power pulse, limited only by the experimental hardware, not the plasma stability.

4. Lawrence Livermore National Laboratory's National Ignition Facility (NIF) in California achieved an energy yield eight times higher than its previous record and reached the cusp of ignition, providing us a second fusion approach with similar physics performance as the tokamak.

5. China's Experimental Advanced Superconducting Tokamak (EAST) sustained fusion reactions for 17 minutes at 126 million degrees Fahrenheit – five times hotter than the sun.

Let's examine each of those for any relevance to fusion as an energy source.

1. The demonstration of Commonwealth's high-field magnet was not intended to produce and did not produce nuclear fusion reactions.

2. The delivery of the central-solenoid to ITER did not produce nuclear fusion reactions.

3. In 1997, JET produced a 5-second pulse of 22 megajoules. Now, 25 years later, it produced another 5-second pulse, but this time reaching 59 megajoules. But JET consumes 3,500 megajoules of input energy. ***Therefore, in 1997, JET lost 99.4 percent of the energy it used. In 2021, JET lost 98.3 percent of the energy it used. That's one-tenth of one percent better after 25 years. This is the world's most powerful fusion result.*** [34]

4. The NIF experiment did achieve a record output of 1.3 megajoules in 2021. ***When we account for the 400 megajoules needed to operate NIF, it lost 99.7 of the energy the device consumed***. [40]

5. The duration of fusion pulses in the EAST reactor have shown the effectiveness of superconducting magnets. The experiments in EAST, however, are irrelevant to the potential ability of a fusion reactor to produce energy because EAST does not use nuclear fuel. It is only a deuterium-deuterium reactor, not a deuterium-tritium reactor.

Not one of these technical achievements provides evidence that fusion is a potential energy source. To the contrary, this list, provided by OSTP and DOE, tells us the opposite:

There have been no achievements that show fusion as a potential energy source.

13. Inflated Significance of Plasma Temperature

A recent claim from a private-sector fusion project, Tokamak Energy, shows an example of how fusion promoters are using temperature measurements to create a misleading appearance of progress. Here's what the company said in a March 10, 2022, press release:

> Tokamak Energy has demonstrated a world-first with its privately funded ST40 spherical tokamak, achieving a plasma temperature of 100 million degrees Celsius, the threshold required for commercial fusion energy. [41]

First, there is no such "threshold" of 100 million degrees in fusion science. That value is arbitrary; it's just an even, nicely rounded number that the company achieved.

Second, temperature is one of three parameters that, when optimized, bring a fusion reactor to the state where practical fusion energy ***begins to be possible***.

These parameters were initially developed by fusion pioneer John D. Lawson and later expanded into the concept known as the fusion "triple-product," which measures plasma density, plasma confinement time, and temperature. As Lawson explained in 1957, these criteria "are certainly necessary, ***though by no means sufficient***, for the successful operation of a thermonuclear reactor." [42]

Thus, even if the three parameters are optimized perfectly, that doesn’t mean that a fusion reactor can produce net energy, let alone do so cost-effectively. The reason is that fusion triple-product values do not account for reactor operating power. Fusion triple-product values also do not measure output power. [43] That's why the company's claim of being on "the threshold required for commercial fusion energy" is nonsense.

The third point to consider with the Tokamak Energy temperature claim is that, in 1995, the TFTR reactor had attained 510 million degrees centigrade. [44] With this in mind, Tokamak Energy's 100 million-degree achievement is a step backward.

14. Inflated Claims of Fuel Availability
Even if fusion someday achieves the three required breakeven levels — scientific, engineering, and commercial — which are all prerequisites for a useful source of energy, those breakthroughs will be irrelevant unless two fuel miracles occur.

Last year, plasma physicist Thiery Pierre informed *New Energy Times* that the fuel for future fusion reactors — amazingly — doesn't exist.

But he showed us the peer-reviewed scientific literature. Between the issues with tritium and lithium, Pierre is right. That's what the latest science shows, the fuel doesn't exist. We examined these issues and reported them in three articles. [45, 46, 47] The best place to start is the Jan. 12, 2022, article "The Fuel for Nuclear Fusion Doesn’t Exist," but we will provide a summary here. (The references and sources for the fuel issues are not listed in this white paper but are provided in that set of articles.)

The peer-reviewed scientific literature shows that, after 2060, tritium, which does not exist as a natural resource, is no longer planned to be produced. It is true that in a laboratory, lithium can breed tritium. But natural lithium, as found in nature, won't work well for fusion reactors. Fusion scientists have known this for at least 45 years. [48]

Instead, enriched lithium, which concentrates the percentage of the lithium-6 isotope, is required for fusion reactors. In nature, natural lithium is composed primarily of the other stable isotope, lithium-7. The reason lithium enriched in the lithium-6 isotope is necessary is that, when it is used to breed tritium, it produces energy. Alternatively, when lithium-7 is used to breed tritium, it consumes energy, which is counterproductive for a device intended to produce practical energy.

How much lithium is needed? Could it be extracted from used-car batteries? Here is what scientists at the U.S. Department of Energy's Pacific Northwest Laboratory wrote in 1977:

> Lithium inventories for a 1,000-gigawatt-generating [fusion reactor] will require from 400,000 to 1,200,000 metric tons of natural lithium for different power plant designs, which is about 50- to 160-years’ worth of current U.S. lithium production or up to one-third of known U.S. lithium resources. [48]

But even if mining capacities have expanded exponentially since 1977, the capacity of lithium inventories is not the problem. The crucial issue is that, according to the peer-reviewed scientific literature, no legal and environmentally benign method exists to process the tons of enriched lithium that would be needed for fusion reactors. Even if a commercial-scale method to extract lithium from seawater is developed, the supply of lithium is not the constraint; the limitation is producing enriched lithium. A fusion reactor on the scale of the EU DEMO design would need tons of enriched lithium.

The second fuel problem is that there is no known method to breed tritium faster than a reactor would lose and consume tritium.

These facts, published in peer-reviewed literature, contrast sharply with the statements provided by fusion representatives. For example, here is what Thomas Klinger, the scientific director of Wendelstein 7-X fusion project at the Max Planck Institute for Plasma Physics in Germany, said at a TEDx conference in Brussels:

> It is abundant, enough fusion fuel for millions of years – and it is accessible to everybody. So nobody owns the fusion fuel. The machines are expensive, but the fuel cost is essentially zero. [49]

So what is the fusion community doing about lack of fusion fuel?

15. No Fuel for EU DEMO Reactor

Tony Donné is the head of the EUROfusion organization. Donné is responsible for the team that is designing the EU DEMO reactor.

Assuming a) ITER works as planned, b) the EU DEMO reactor is built and ready to operate by 2060, and c) no other fusion reactors consume the world's remaining tritium, then there will be enough remaining tritium mid-century to ***start*** the EU DEMO. According to the peer-reviewed scientific literature, there will not be enough tritium to keep the EU DEMO ***running.***

Even if a scientific breakthrough occurs that enables a fusion reactor to breed tritium quickly enough, and a scientific breakthrough occurs to enable a legal, environmentally benign method of enriching tons of lithium, fusion reactors will still need tritium to start operating and begin the breeding cycle.

The start-up tritium requirement is a precarious situation. Either a) the aging tritium-producing fission reactors must be kept online to provide the start-up tritium that will be needed for fusion reactors or b) fusion reactors must come online and produce excess tritium before the fleet of tritium-producing fission reactors is decommissioned.

On Dec. 17, 2021, *New Energy Times* sent Donné an e-mail asking where he expects to obtain the enriched lithium. He wrote back the same day with no explanation, just a link to a peer-reviewed paper in *Fusion Engineering and Design*. The lead author is Thomas

Giegerich, a scientist at the Karlsruhe Institute of Technology in Germany. The paper proposes a new process that the authors believe can replace the old, illegal COLEX process.

“In this paper, we will describe only the development of an analytical method and a first lithium enrichment experiment,” the authors wrote.

The single experiment they performed indicated that their method could work. However, their focus was the development of their analytical methods and a confirmation of their measurement techniques. If their process is scientifically and independently confirmed, the authors explained, developing a suitable industrial-scale lithium enrichment facility would take about *20 years*. That's long past the time that all the private companies are promising to bring "fusion energy to the grid" with deuterium-tritium fusion.

Two years have passed since the Karlsruhe group published its paper. We have been unable to locate a subsequent paper from them reporting even their first group of enrichment experiments. Nobody has informed us of an independent confirmation. We sent e-mails to Giegerich and one of his co-authors, Christian Day, asking for an update, but they did not respond. We placed phone calls to Giegerich and left a voicemail, but he did not respond.

We continued the conversation about lithium with Donné in February 2022. Donné said that lithium could be recycled from used-car batteries. That is certainly possible. But Donné bypassed the matter of enrichment. We asked Donné how he intended to produce the enriched lithium needed to run the EU DEMO. He wrote back saying he believes that, by 2060, a suitable technology will be developed.

"We have enough time until the fusion reactors are rolled out to develop the technology and set up plants to enrich the lithium," Donné wrote.

In the context of Donné's stewardship of the EU DEMO, his optimism that a lithium enrichment breakthrough will occur could be considered wishful thinking. There's nothing wrong with that in the context of Donné's experimental research project. One of the main goals of the EU DEMO is testing whether producing net electricity from a fusion reactor is even possible. Another of its crucial goals is testing whether a fusion reactor can breed enough tritium. These are both sound and scientific goals. Failure to achieve either of these goals, however, will terminate the public quest for fusion.

But for the private-sector fusion businesses, particularly those that claim to be on track to deliver commercial fusion reactors in the next few years, wishful thinking is not going to fly. The lack of a scientifically proven method of breeding tritium fast enough and the lack of a legal method of enriching large quantities of lithium indicate that those companies have promised their investors technology that does not exist.

16. The Silent Spectators

Aside from a few outspoken insiders, the fusion community has remained silent while hundreds, if not thousands, of examples show that false and exaggerated information distributed by their representatives has saturated the public conversation about fusion. [51, 52]

As Henry Fountain told us, no fusion experts objected when he wrote in the *New York Times* that ITER "will produce about 10 times more power than it consumes." [53]

Nature magazine kept publishing the wrong — but favorably exaggerated values — for 16 years. No fusion experts wrote to inform the magazine that they had "misunderstood" the design objectives of ITER. [54]

17. Public Backlash

The falsifications and exaggerations are eventually going to take their toll, causing the bubble to burst. When that happens, not only financial consequences, but also societal consequences will result. A few fusion scientists deserve credit for sounding the alarm.

Robert L. Hirsch began his fusion career at the Atomic Energy Commission. In 1972, he was nominated to be the head of its Controlled Thermonuclear Research Division. Decades later, he gave a presentation titled "*Time to Face Reality*" at a fusion meeting in December 2015. Here's an excerpt:

> • The public has been told that fusion power will be economic, safe, and environmentally attractive.
> • When the public learns that ITER [and] tokamak fusion power is very expensive, not inherently safe, and produces large volumes of [radioactive] waste, the public could feel deceived, and a public backlash would not be surprising. [55]

In his article "Voodoo Fusion Energy," Jassby compares the companies selling fusion reactor designs to Theranos. [17] Jassby told *New Energy Times* that he predicts the bubble will burst around 2025. He says, “That’s the date when everyone is promising fusion energy breakeven." Jassby shows in that article that many of the private fusion companies have already failed to live up to their claims from several years ago.

Another retired fusion scientist from the Princeton Plasma Physics Laboratory, Ernesto Mazzucato, said in a letter to *Science* magazine 26 years ago that ITER "is tantamount to a suicidal plan that would discredit nuclear fusion as an economically viable form of energy production." Early indicators suggest the accuracy of Mazzucato's prediction. [50]

Another dissenting fusion scientist was Lawrence Lidsky, an MIT professor of nuclear engineering, the associate director of the MIT Plasma Fusion Center, and the editor of the *Journal of Fusion Energy.*

In 1985, Lidsky published the article "The Trouble With Fusion" in *MIT Technology Review*, revealing the dim prospects for nuclear fusion. Lidsky's message on the cover of the issue was harsh — as was the response from his peers. Soon after, he was forced to resign from his position at the MIT Plasma Fusion Center.

Like ITER, the SPARC reactor, if it accomplishes its scientific objective, will consume more power than it will produce, thus proving Lidsky right again, as he said in 1985: "Even if the fusion program produces a reactor, no one will want it." [56]

18. It's Not a Joke Anymore

Humor can sometimes be a way to poke fun at uncomfortable truths. Fusion has been the brunt of two jokes for at least half a century: "Fusion is the energy source of the future and always will be." "Fusion is just 30 years away and always will be."

As Jassby has pointed out, many of the private fusion attempts have failed to meet their promised timelines. The proponents of the more-credible fusion projects, those in the public sector, continue to speak in multi-decade time scales.

This is no longer a joke. It is an indicator of the long-standing manipulation of public perception to keep the dream of fusion alive and keep the public funding flowing.

Were the fusion scientists who kept promising us the Holy Grail of energy accurate in their projections? No. The more important question is whether they were being honest with themselves. Perhaps they forgot the warning of physicist Richard Feynman, who said, "The first principle is that you must not fool yourself, and you are the easiest person to fool."

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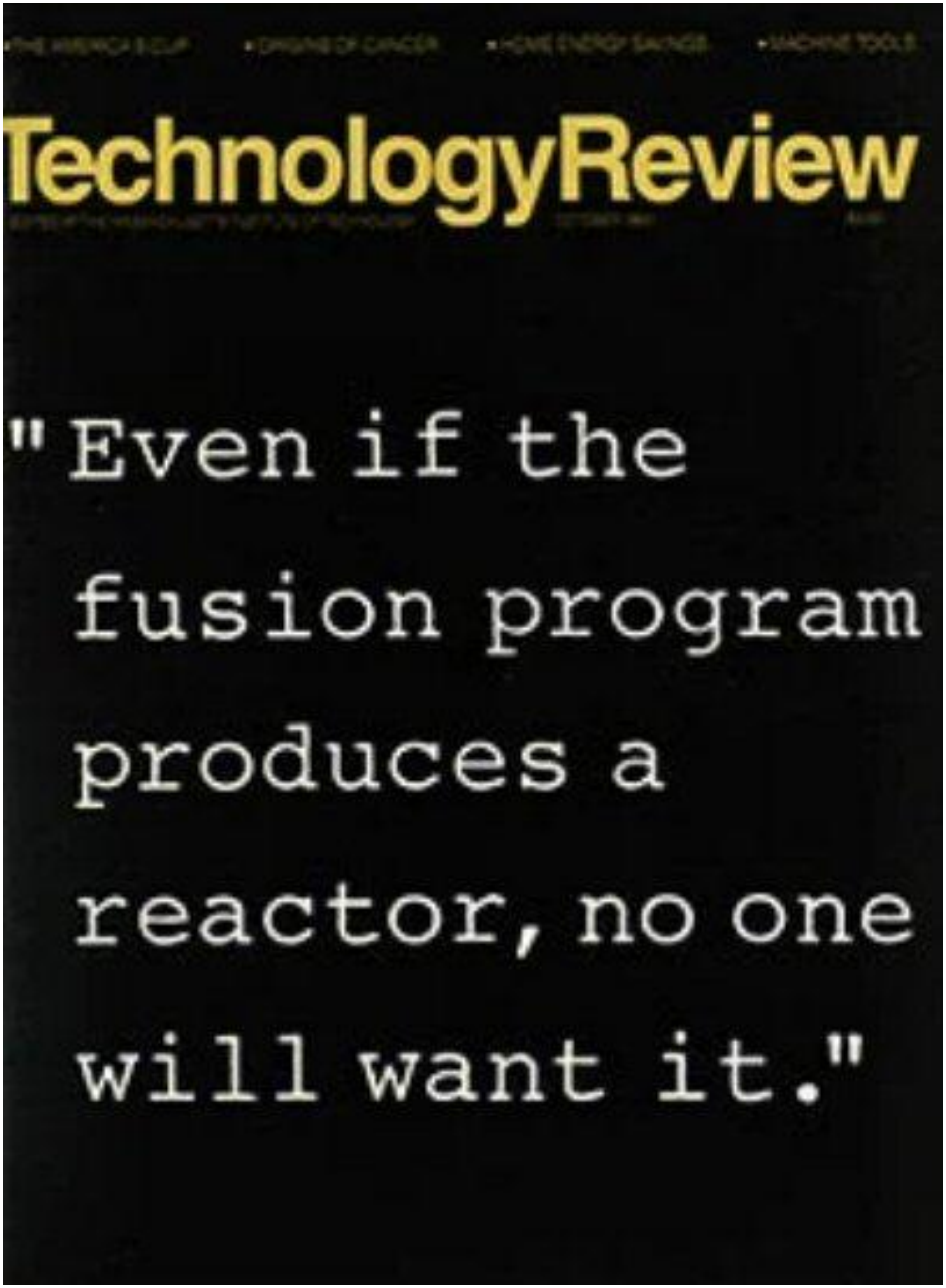
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