

FARRINGTON DANIELS, SOLAR PROPHET AND PIONEER IN THE USE OF SOLAR ENERGY AS APPROPRIATE TECHNOLOGY

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ABSTRACT

I never had a conversation with Farrington Daniels (1889-1972), I wish I had. Fortunately, after working for several years as archivist for the Daniels' papers at the University of Wisconsin-Madison and assisting his widow, Olive Bell Daniels (1891-1984) in writing his biography, I learned enough about Daniels to comment on his life and scientific career.

As most of you know Daniels was a founding member of the Solar Energy Society and the first to propose that the society publish a journal, which when volume one appeared in 1957 had the title *Journal of Solar Science and Engineering*. I am therefore extremely pleased on the fiftieth anniversary of the society's first meeting in Arizona to have the opportunity to speak on Daniels and thank the organizers of the Solar History Symposium, Renate Boer and Cesare Silvi, for inviting me to participate. My commentary on Daniels addresses three questions about his life and science: (1) who was Daniels the person and the scientist, (2) what was his solar research program, and (3) what is his legacy?

1. WHO WAS DANIELS - THE PERSON AND THE SCIENTIST?

Daniels was an idea man, a man of many ideas. During his lifetime he kept a log book in which he regularly recorded ideas for new research projects, new ideas about old research investigations, general ideas and specific ideas, but always ideas on what he planned to do next. He never retired his mind despite officially retiring from the University of Wisconsin in 1959.

Friendliness was another Daniels quality. Despite not being a tall man, a physical characteristic that sometimes leads a shorter person to adopt an aggressive behavior, such as an extremely firm handshake, to compensate for a lack of height, Daniels was always the first to extend his hand in a friendly greeting (except when custom dictated otherwise). He did not project himself in an aggressive way because Daniels was not a flashy or aggressive person. In fact his friendliness was the quality that his colleagues found most attractive about him. Once you became his friend, you were always his friend, and because he valued friendship highly, he carried on a voluminous lifelong correspondence with his graduate students, many of whom came from different parts of the world, and with fellow scientists, such as Linus Pauling and G.N. Lewis. All of his correspondence is in the university's archives and leads a reasonable person to conclude that Daniels never threw away a single letter. Their sheer number made their cataloging a really formidable job.

A final quality about Daniels was his unbending commitment to a just cause and his respect for scientific truth which he demonstrated most clearly in the Allen Astin (1904-84) incident of 1953, the year Daniels was president of the American Chemical Society (ACS). Jesse Ritcher, a tractor operator in Oakland, California, and his partner, had developed a battery additive ADX-2 that they claimed would prolong battery life. Astin, a physicist and longtime Bureau of Standards employee (1932-69) and since 1952 its director and in charge of testing ADX-2's effectiveness, showed that ADX-2 was useless. The Eisenhower administration's incoming secretary of commerce, Sinclair Weeks (1893-1992), nevertheless, challenged the Bureau's report claiming that the Bureau had not allowed *the market* to decide the effectiveness of ADX-2, and consequently

fired Astin. Weeks' action marked the return of *laissez-faire* policy under Eisenhower and an acceptance of scientific fraud for a political objective. Daniels strongly criticized Astin's firing and galvanized the ACS to act. His opposition, along with strong opposition from other scientists, forced Sinclair to back off and reinstate Astin who remained the Bureau's director until his retirement in 1969. This largely forgotten incident is worth mentioning because it represents an earlier example of a problem that has re-emerged quite forcefully today, particularly with respect to environmental pollution and genetic engineering, where the manipulating of scientific data for political purposes has become almost routine despite the seriousness of the issue.

Daniels was not a good joke or story teller, but a gaff before 20,000 people at the University's College of Letters and Science 1957 graduation ceremony, where he was a last-minute substitute for the dean, was likely the funniest story he ever told. Daniels' assignment was to inform the sitting graduates, at the appropriate time, that they were to stand and then remain standing. This is what came out instead: Will everyone please rise and continue to rise. The class of 1957 later adopted the *rise and keep on rising* as its motto.

Who was Daniels the scientist? Daniels received his BS and MS degrees in chemistry from the University of Minnesota in 1910 and 1911, respectively, and the PhD in physical chemistry from Harvard University in 1914 where he studied under Theodore W. Richards (1868-1928), the second American to receive a Nobel Prize in science. Richards received the prize for his accurate determination of atomic weights. Albert Michelson (1852-1931), the first American prize winner, received his award for measuring the speed of light. Harvard awarded Daniels a traveling scholarship for study with Fritz Haber (1868-1934) in Berlin, but when the outbreak of World War I prevented his acceptance he took a position at Worcester Polytechnic Institute in Massachusetts, remaining there until 1918.

With the United States's entrance in the war, Daniels saw duty in 1918 as a first lieutenant in the Chemical Warfare Service working on nitrogen fixation and the problem of fogging in gas masks. From 1919 to the fall of 1920 he was at the Fixed Nitrogen Research Laboratory in Washington, DC, leaving there to join the chemistry department at the University of Wisconsin in Madison. Daniels rose through the ranks at Wisconsin serving as chairman from 1952 until his retirement in 1959. He continued to maintain an active research program until his death from liver cancer, directing most of his later efforts to solar research and the promotion of solar energy.

The three following research areas are most representative of his career: (1) chemical kinetics, particularly of the nitrogen oxides (2) the applications of appropriate technology, and (3) the development of alternative energies, particularly solar energy. He was a dedicated teacher and had a strong commitment to improving education in both the sciences and humanities. Daniels wrote his first book because he saw that chemistry students were seriously deficient in mathematical preparation, and as the author or co-author of two widely used physical chemistry textbooks that went through many editions, he was a major force in the scientific education of thousands of students. Daniels had a genuine concern for the social implications of science and was a well known spokesman for the promotion of science, both of which he did effectively through the offices he held in scientific organizations, such as the ACS and the National Academy of Sciences.

2. WHY DID DANIELS UNDERTAKE SOLAR RESEARCH AND WHAT WAS HIS SOLAR PROGRAM?

Daniels' longtime interest in the nitrogen oxides led to his pioneering work in the development of appropriate technologies, such as his development of a high-temperature pebble bed furnace for the synthesis of nitric acid. His continued interest in promoting appropriate technologies led to work on the design of a gas-cooled nuclear fission reactor for peacetime energy production in the United States and in nonindustrialized countries. He had served as director of the Manhattan Project's Metallurgical Laboratory at the University of Chicago from 1945 to mid-1946 and while there designed a small (5-50 megawatt), helium gas-cooled reactor. The Manhattan Project awarded Daniels \$3 million to construct an experimental reactor at Oak Ridge, Tennessee, but the Cold War was just beginning, and in 1947, shortly after giving the go-ahead, the recently-established Atomic Energy Commission (AEC) canceled Daniels' proposed reactor. Its action, Daniels believed, effectively ended the United State's opportunity to construct the world's first peacetime atomic power plant. The United States wanted nuclear weapons not nuclear reactors.

The cancellation of the reactor project was the first event that led to Daniels' abandoning nuclear research and to renew his interest in the direct use of the Sun's energy. The second event that launched Daniels's solar research program occurred in September 1948 when he discussed new energy sources in an invited address at the American Association for the Advancement of Science (AAAS)

centennial in Washington, DC. Even before his wartime call to Chicago, Daniels strongly believed in scientific accountability and the scientists' responsibility to explain to the public the actual or possible social impact of their research. This was a significant departure from the widely accepted scientific code of neutrality or non-accountability regarding the social impact of science and largely a reaction to the dropping of atomic bombs on Japan in August 1945. Daniels therefore welcomed the opportunity to discuss the future of not only nuclear energy but his renewed interest in the future of solar energy. The government had canceled his nuclear reactor for peacetime energy production, and in considering alternatives Daniels turned to the Sun, which he called the poor man's nuclear reactor, to provide an unlimited and safe source of energy.

For the next twenty-five years Daniels became a foremost advocate of solar energy. Like nuclear energy, solar energy was little developed in 1947, and to Daniels it had a much greater potential as an appropriate technology, especially in nonindustrialized countries that received ample amounts of sunlight such as Mexico, India, and many of the Pacific Ocean Islands. His numerous and longtime contacts with his graduate students, the research and lecture trips for the university, the ACS, and the National Academy of Sciences made Daniels quite familiar with living conditions in many of these countries. His experiences convinced him that the introduction of technologies that these societies seemed to need and could easily adopt was the best way to increase their self reliance and improve their well-being. Daniels's goal of finding the technology that best fit the situation without causing environmental and social problems, and which he now found in the direct use of the Sun's energy, was similar in spirit to the later, and independently developed, intermediate (appropriate) technology movement that arose in England in 1963.

Daniels' early solar research was both theoretical and applied. Later, in the 1950s he dealt more and more with the practical applications of solar energy, particularly solar cooling, cooking, and distillation. Each had comparatively low research and development costs and its solar units were relatively easy to construct and apply. Daniels always tried to construct the solar unit from locally obtained materials and with the assistance of local inhabitants and to test it at the intended place of application. He was sensitive to the local traditions and cultures and recognized that the acceptance and implementation of solar apparatus depended on the inhabitants' perceiving it as appropriate to meeting their needs or improving their lifestyle. Both user and inventor had to value the technology as appropriate, which sometimes was a problem because of unforeseen technological difficulties and unsuspected sociological misunderstandings.

The invention and development of appropriate technology, nevertheless, remained the motivating force behind Daniels' solar program and his commitment to the future of solar energy. In a 1954 paper he pointed out that the study of solar energy drew upon the expertise of researchers from several sciences, including chemistry, meteorology, and climatology, yet its development still faced formidable technical problems and its adoption serious social barriers. Solar energy remained largely a neglected field of study, and Daniels urged solar researchers to consider five important questions before initiating programs of solar research and development: (1) is it theoretically possible, (2) is it technically feasible, (3) is it economically sound, (4) is it socially useful, and (5) is it politically wise? He believed that solar energy though not initially economically self-supporting, had now become socially useful and technically feasible. Its research and development was, therefore, politically wise and should proceed first in those regions that needed small isolated units for the production of electrical and mechanical power. Daniels urged that the solar scientists stimulate interest and encourage new scientific and inventive talent to investigate the problems of solar energy. They should identify the most promising directions of research or the different ways of using solar energy in nonindustrial countries and study the cost limitations that solar-powered units had to meet because of the special conditions required for their implementation

3. WHAT IS DANIELS' LEGACY?

Daniels was a tireless promoter of solar energy, promoting its development throughout the 1950s and 1960s in presentations and publications, especially in his 1964 book *Direct Use of the Sun's Energy*. He even served as chief science adviser for the 1956 film *Our Mr. Sun*, one of the Bell Telephone Company's Science Series films. The series, which Bell started in 1952 and provided for free use in schools nationwide, was a tremendous success. It received the 1957 Thomas Alva Edison award for the best youth-category science television program and remained available for viewing twenty years later.

Although idealism drove Daniels' promotion of solar energy, he was, at the same time, a realist and risk taker and readily accepted that widespread use of solar energy remained far in the future. His twenty-five years of solar research had witnessed little success in cooking but increasing success in water heating and distillation and in home heating and cooling. The solar heated homes of Maria Telkes in Massachusetts, George Löff in Colorado, and at MIT were clearly the result of increasingly promising research on solar heating and cooling. Yet solar researchers could claim practical success in only one field,

the development of solar cells for use in space vehicles. These were significant advances, but they represented progress in solar research and development quite different from Daniels's solar interests. In 1971, one year before his death, Daniels conceded the obvious, that government and industry had not acknowledged a large market for solar energy as either an alternative or an appropriate technology and had dismissed it as either too expensive to develop, or too impractical to use, or both. The universities' lack of interest in solar research, mainly because it cut across so many branches of science and engineering, also troubled him. Solar research, Daniels one lamented, seemed to fit everywhere, but unfortunately it belonged nowhere. Where, he asked, were the departments of solar science and engineering? Who was teaching the solar science and engineering courses so crucial to the success of a nationwide solar energy program and to the future development of solar energy? Any large-scale commitment to solar energy research, Daniels said, probably had to wait another twenty-five years.

We have now waited more than twenty-five years. How should we in 2005 judge Daniels' prediction regarding solar energy development as either alternative or appropriate technology? In the mid-1970s active solar energy programs were underway in Germany, France, Japan, Russia, and Australia. Solar researchers in India claimed they had overcome conceptual difficulties in solar refrigeration, solar pump design, solar desalination, and other areas, but low technological input, heavy initial costs, and sociological barriers delayed significant solar energy use. In the United States total spending on solar research and development in 1976 was \$110 million, far more than in any nation, but solar energy provided only one-half of one percent of the United States's total energy requirements. The two most active areas of research were solar heating and cooling of homes and buildings and photovoltaic conversion. By the 1980s research spending had increased significantly, and during the last decade private industry and the federal government poured several billion dollars into solar research. Most of the spending, \$3 billion, went into photovoltaic research, which continues to be the area of greatest success.

The only application closer in spirit to Daniels' vision of solar energy as appropriate technology is the recently developed small solar-power systems (SSPS) that presently bring electric lighting and communication to about 200,000 families in the nonindustrial countries of Central America, Asia, and Africa. At the end of the twentieth century, when seventy percent of the nonindustrialized world's population remains without electricity and has to rely on nineteenth-century light sources, such as smoky kerosene lamps or wood fires, photovoltaic SSPS provide a clean and

inexhaustible source of electricity to individual households.

Despite advances made in photovoltaic and other branches of solar research, Daniels' concern about the indifference and lack of solar programs remains somewhat unheeded and solar energy's development as either an alternative or an appropriate technology, therefore, has remained an unfulfilled promise. A breakthrough appeared close at hand in the mid- and later nineteenth century with the solar engine researches of scientists and engineers that included Augustin Mouchot and Charles Tellier in France and John Ericsson, Aubrey Eneas, and Frank Shuman in the United States. Rapid consumption of the conventional fuels wood and coal in the industrializing countries, contrasted with the scarcity and expense of these fuels in many nonindustrializing countries had seriously concerned and strongly motivated these nineteenth-century solar researchers. But two events quickly changed the energy picture and put to rest the most promising solar projects. First, the improvement in coal mining techniques and better railroad transportation, particularly in France, led to increased production and decreased price. Second, the large petroleum discoveries at Titusville, Pennsylvania, in 1859 and then at Spindletop, Texas in 1901, ushered in the era of abundant and cheap liquid fuel. Another solar breakthrough, to which Daniels, Löf, Telkes, and others made major contributions with their research in solar heating and cooling, appeared imminent shortly after World War II ended, but the excitement that nuclear energy generated once again sidetracked solar research. In the 1970s, the Arab Oil Embargo of 1973-74 and the Iranian Hostage Crisis of 1979-81 sparked another renewal of interest in solar energy. The United States Federal Budget in 1974 included \$13 million for solar research, compared to the 1960s nearly zero spending other than for NASA's solar cell research. Funding peaked at \$1.7 billion in 1981 before falling about eighty percent by the end of the 1980s and has since gone through another up in the early 1990s and a down beginning in 1996.

Twenty percent solar in twenty years became a common slogan beginning in 1980, but much of the government-industry hype quickly ended once oil prices collapsed in the early 1980s. Like other alternative energies, such as wind and geothermal energy, solar energy has had to endure a series of starts and stops, experiencing short-lived revivals in times of crises or energy shortages only to suffer from long periods of neglect once the real or imagined threat disappeared. The history of solar energy shows that a long-term government-industry commitment to its development has been missing, and until this occurs the future of solar energy as either an appropriate or an alternative technology will remain clouded.

4. BIOGRAPHICAL ON DANIELS

Daniels was active in a number of societies, serving as president of the American Chemical Society (ACS, 1953), Geochemical Society (1958), Solar Energy Society (1965-67), and Sigma Xi (1965). He was associate director and then director of the Metallurgical Laboratory (1944-46) and chairman of the Board of Governors, Argonne National Laboratory (1945-47).

Daniels was elected to the National Academy of Sciences in 1947 and was vice-president from 1957-61. Throughout his career he gave hundreds of lectures, both in the United States and abroad, on behalf of these societies. Many of his later presentations were in support of solar energy. The ACS awarded him its highest honors: the Willard Gibbs Medal (1955), the Priestley Medal (1957), and the James Flack Norris Award (1957).

Daniels was the author or co-author of several books including *Mathematical Preparations for Physical Chemistry* (1928), the many editions of *Physical Chemistry* (1931-70), *Experimental Physical Chemistry* (1929-70), *Chemical Kinetics* (1937), *Challenge of Our Times* (1953), and the widely acclaimed *Direct Use of the Sun's Energy* (1964). He also published 300 papers, some with his graduate students and colleagues.