

Special Section: Memorial Festschrift for the Late Professor Frank Kreith

*Sunrise Delayed but the Sun Shines Brightly: The Energy-Sustainability
Quandary and Legacy of Professor Frank Kreith*

The imperative of conserving energy resources, acerbated by the ever-rising global demand and consumption, has been acutely underscored by many global events in the last two decades. The cause of *energy security* that has engendered worldwide conflicts has been recognized and debated ever since the oil embargo of early 1970s (Merrill, K. R., 2007, *The Oil Crisis of 1973-1974: A Brief History With Documents*, Bedford/St. Martin's, Boston, MA; Jacobs, M., 2016, *Panic at the Pump: The Energy Crisis and the Transformation of American Politics in the 1970s*, Hill and Wang, New York). This has been further interlaced with multifaceted issues relating to climate change, including environmental degradation and the inherent energy-water nexus that pose additional entanglements in our insatiably energy-centric world. This has enormous economic, social, and political implications, and there is a compelling need to organize our resource consumption in a sustainable manner. Sustainable development warrants novel solutions and strategies for mitigation and abatement of all interconnected issues.

One of the earliest advocates, articulators, and policy influencers in the efforts to achieve sustainability goals was the Late Professor Frank Kreith (1922–2018; Fig. 1). In fact, it was his pioneering work and efforts in the 1960s that led to the development and deployment of much of the initial solar energy systems in the U.S. [1–6]. His own personal hands-on experience with renewable energy was to install a retrofit solar hot water system in his own home in the 1960s. This experience was then extended to several commercial properties owned by him, and the activity was pursued into the 1980s, albeit with a brief interruption in the mid-1970s due to a very tragic event in his family. In the 1960s, with funding from the space program of the time, he also presented a short course on radiation to NASA engineers that led to his first book on solar radiation heat transfer for applications in spacecrafts as well as solar power plants [3]. Frank subsequently collaborated with his long-time colleague and friend, Jan F. Kreider, to publish the first of its kind book in 1975: *Solar Heating and Cooling* [7]. This scholarly and professional partnership continued to produce some of the finest books and references in solar energy [4,5], as well as other engineering application engagements.

Perhaps *the shining example*, if one may use this solar metaphor, of his drive, initiative, and foresight is his role in the establishment of the Solar Energy Research Institute (SERI) in 1977 in Golden, CO. The idea, first conceived in 1974, was motivated by the experiences and outcomes of the 1973–1974 oil embargo [8], and the push to move away from oil-dependence as a major energy resource. This effort was further driven by Frank's own passionate commitment to solar and alternate energy, and the definitive call made in early 1977 by President James E. Carter, Jr.: "With the exception of preventing war, this [energy crisis] is the greatest challenge our country will face during our lifetimes.

The energy crisis has not yet overwhelmed us, but it will if we do not act quickly. . . .” SERI functionally came into existence in July 1977 and a little less than a year later, as shown in the photograph in Fig. 2, President Carter visited Golden, CO, to dedicate a permanent site. Unfortunately, the country and much of the world has yet not entirely heeded the warnings of 1977 and an extended energy crisis, compounded with the energy–water nexus and climate change, is upon us that demands urgent action.

In September 1991, SERI was renamed as the National Renewable Energy Laboratory (NREL) and designated a national laboratory of the U.S. Department of Energy (DOE) by President George H.W. Bush. Frank had contributed immensely to the work and mission of SERI and had worked there, prior to the transition to the new DOE laboratory, in various capacities for a decade from 1977 to 1987. His work at SERI included numerous seminal and path-breaking initiatives in solar energy, ranging from developments in liquid fuels, design of economical concentrating collectors, efficient domestic hot water heaters, high-temperature receivers for solar-thermal electric systems, ocean thermal energy conversion systems, thermal energy storage, and industrial process



Fig. 1 Professor Frank Kreith, Ph.D.: Dec. 15, 1922 (Vienna, Austria)–Jan. 8, 2018 (Boulder, CO)



Fig. 2 Photo taken in May 1978 at the Solar Energy Research Center (SERI) in Golden, CO, during the permanent site dedication: L to R—Dr. Frank Kreith, President Jimmy Carter, and Dr. Paul Rappaport (then SERI Director); note SERI was renamed in 1991 and is now the National Renewable Energy Laboratory (NREL) of the U.S. Department of Energy (DOE).

heat conservation, among others. A key innovation of Frank's work was the development of advanced direct-contact condensers that gave a viability fillip to ocean thermal energy conversion, and also subsequently led to the publication of an authoritative monograph on the broader subject [9]. While at SERI, Frank was also instrumental in proposing and then initiating the launch in 1980 of the first of its kind solar energy research archival journal: the *ASME Journal of Solar Energy Engineering*. This, incidentally, coincided with the centennial celebration of ASME (1880–1980), and he served as its founding senior technical editor from 1979 to 1989. His farewell editorial [10] is instructive of both the historical context and persisting issues in alternate (nonfossil-fuel based) energy and sustainability. Later in 2014, and to celebrate Frank's 91st birthday, a *festschrift* issue of the *Journal of Solar Energy Engineering* was published.

Frank Kreith not only influenced public policy vis-à-vis energy and sustainability with his scholarship, research, and engineering innovation, but actively worked to do so. In this context, he served as a legislative fellow at the National Conference of State Legislatures (NCSL) for four years (1987–2001) postleaving SERI. By participating in a plethora of testimonies, scientific reviews, and other such engagements he was able to persuade the outcomes of some legislations. During such interactions with various stakeholders from different US States, he began investigating solid-waste management. This work was further spurred by the unusual news headlines of that time (1987) of a barge named *Mobro 4000*, which was loaded with heaps of trash and it sailed from New York City along the east coast to Belize and back seeking a port to dump its load.¹ This led NCSL to ask Frank to organize a two-day conference dealing with this issue at Breckenridge, CO, in 1988. Based on the papers and presentations at this event, and other testimonies during his tenure at NCSL, Frank edited and published the first handbook on solid waste management in 1993–1994. The subsequent second edition was co-edited and published in 2002 [11], was later translated in Chinese, and the compendium has served as a critical input in formulating waste-management policies worldwide.

This work segued to integrated waste management and waste-to-energy for combined heat and power. Use of biomass and landfill waste in combustion systems for producing steam for district heating and power began to gain traction in Europe, and Frank traveled across the globe, consulting, advising, giving seminars, and much more. In the following years, his work expanded to include energy conservation, alternative fuels, utility restructuring, environmental pollution, and viable transportation, all

evolving cornerstones of seeking sustainable energy usage and management. His expertise in sustainability [12] in its multifaceted issues [11,13–16] became renowned internationally, and Frank was sought out through several groups, organizations, and agencies (ICHMT, NATO—Scientific Affairs Division, UN, etc.). With that his globe-trotting took him to the former Yugoslavia (the part that is Serbia now), Japan, Russia, Turkey, India, Nepal, China, and Cuba.

Of course, Cuba had a special meaning to the professional visit, as Frank's wife Marion had lived there for many years. She had traveled with other Jewish refugees from WWII Nazi Germany and had worked in diamond cutting and polishing, an industry that had been established in Cuba by Belgian refugees. In fact, Frank and Marion Kreith's daughter, Judy Kreith, in collaboration with Robin Truesdale, has made an acclaimed documentary film based on their lives: "Cuba's Forgotten Jewels, a Haven in Havana".² My own assessment of this film is best summarized in the following note that I had written³ to Judy, Marion, and Frank:

"... [it is] the story of perhaps the most extraordinary journey in modern Jewish history. One that is at once very sad and uplifting, and full of hopeful warmth. Sad, because of the extremely painful circumstances and events of that time and the reminder of how human history has many a times displayed unimaginable violence. Yet the narrative is uplifting and inspirational in the remarkable strength of Jewish people who came to Cuba as refugees during WWII; of their grit and fortitude in creating a space for meaningful lives beyond and above the exceptional hardships of the time. And it is a warm, hopeful story as it chronicles the exemplary Jewish lives that evolved in the accommodating space in Cuba ... of those days. The remarkable human spirit this story depicts is indeed the true Jewel of human history!"

As the quirks of history would have it, Frank and Marion were in Havana, Cuba, on Sept. 11, 2001, when the world saw another horrid example of unimaginable violence when Al-Qaida terrorists struck the World Trade Center in New York City.

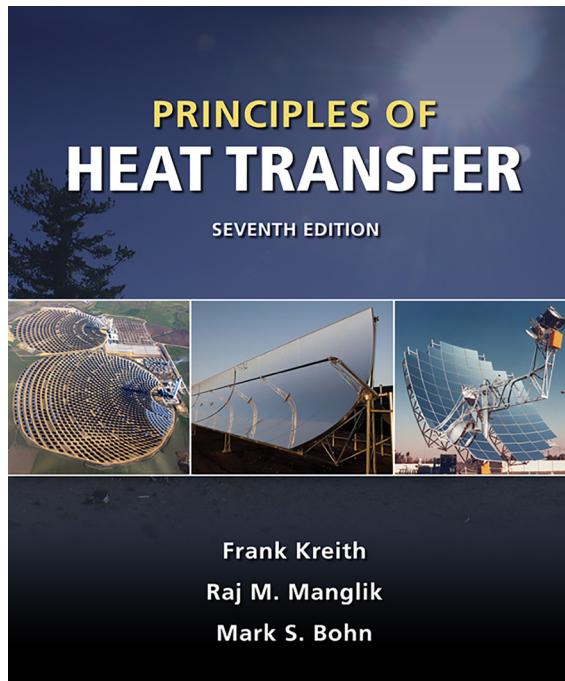
My own personal, more intimate collegial journey with Frank began when he invited me to join him and Mark Bohn to co-author the seventh edition of his classic text book: *Principles of Heat Transfer* [17]. This invitation was at the suggestion of my own mentor, the Late Professor Arthur E. Bergles [18–20], who had been approached by Frank for ideas of revising and updating the book to meet evolving engineering design and educational needs. Was this fortuitous destiny, or a fateful realignment of stars (or mentors, in this case)? For it was the second edition of this book that I had studied heat transfer from in my own undergraduate education at the Indian Institute of Technology—Madras, Chennai, India; I still have my well-preserved copy of this 1965 print of the book. Needless to say that I enthusiastically accepted the invitation, and thus began not only my own collaboration with the textbook but the expansion of my work on energy conservation and sustainability [21,22]. The seventh edition of this classic textbook was published in 2011 (Fig. 3(a)), and this was followed up in 2018 with the eighth edition (Fig. 3(b)); in the interim, sadly, Mark Bohn passed away. Again, as fortunate circumstances of life would have it, the printed copy of the latter edition of the book was released in late 2017 well before the passing of Frank Kreith in early 2018. I surely do not have enough words to express my deep gratitude for this collaborative opportunity, and perhaps the celebratory photo in Fig. 4, taken at the publicity launch of the seventh edition during the ASME IMECE 2011 in Denver, CO, says it all. Frank was indeed a mentor, friend, and sage, who is and will be missed in these trying times as we attempt to come to grips with goals of energy conservation and sustainability.

The wisdom, novel insights, and experience of Frank Kreith was admired and respected by colleagues and friends worldwide.

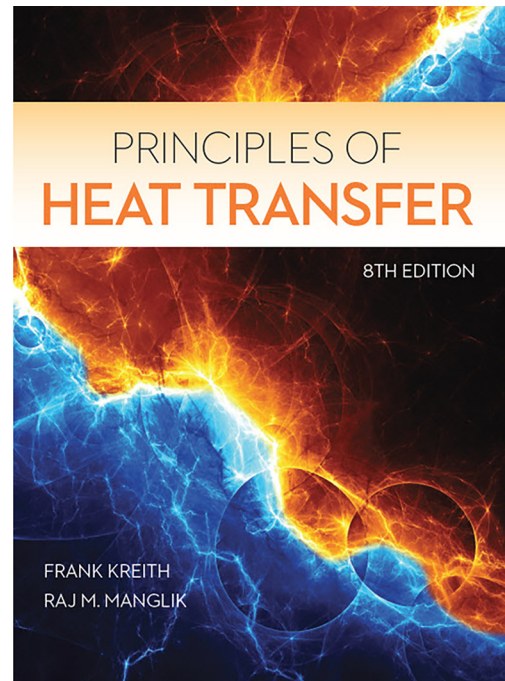
¹<https://projects.newsday.com/long-island/long-island-garbage-barge-left-islip-30-years-ago/>

²<https://forgottenjewelsfilm.com>

³<https://forgottenjewelsfilm.com/trailer>



(a)



(b)

Fig. 3 Co-authored editions of the classic textbook, *Principles of Heat Transfer*, which was first published in 1958 as the first comprehensive book on the subject: (a) seventh edition, 2011, and (b) eighth edition, 2018; all published by Cengage Learning



Fig. 4 The author (Raj M. Manglik) with Professor Frank Kreith in Denver, CO, during the ASME International Mechanical Engineering Congress and Exposition (IMECE), November 2011, at the exhibition booth of the publisher Cengage Learning, and the launch of their co-authored book, *Principles of Heat Transfer 7e*.

This is amply reflected in the many awards and honors bestowed upon him. He was a life Fellow of ASME, was elected Honorary Member in 2004, and had been active in its Solar Energy Division since 1955. He was also a Fellow of the American Association for the Advancement of Science (AAAS) and the American Solar Energy Society (ASES), and a member of the International Solar Energy Society, Sigma Xi, and Pi Tau Sigma. Some of his honors included: ASME Heat Transfer Memorial Award (1972), ASME Worcester Reed Warner Medal (1981), ASME-AIChE Max Jakob Memorial Award (1986), ASES Charles Greeley Abbot Award (1988), ASME Ralph Coates Roe Medal (1992), WSE Washington Award (1997), ASME Medal (1998), and ASME Edwin

Church Medal (2001), among many others. In 2006, the Solar Energy Division and the Advanced Energy Division of ASME established the *Frank Kreith Energy Award*⁴ in recognition of his contributions to heat transfer and solar energy.

With the global leveling of our energy-centric economy [23], the goals of sustainability are perhaps most acutely underscored by the need for not only conservation of primary energy resources, but also their conversion, utilization, and recovery in every industrial, commercial, and domestic application. The concomitant engineering problems have a variety of viable solutions, particularly with the use of *heat and mass transfer enhancement techniques* [24–26]. Several others are outlined by the ensuing papers in this memorial section of the *Journal of Heat Transfer*, dedicated to the life and engineering legacy of Professor Frank Kreith. They include consideration of low-temperature salt hydrates by Professor Van P. Carey and co-workers (L. Gagnon and D. Helms) for developing thermal energy storage systems for power plants. Professor Gershon Grossman and co-workers describe some intricacies and technical challenges of building a type of absorption heat pump for recovering low-grade heat energy (typically waste heat). A computational technique that allows a more effective and precise estimation of local heat transfer coefficients has been outlined by Professor Srinath Ekkad and colleagues. The use of compound enhancement, where two or more techniques are used together [25], has been addressed by Professor Roop Mahajan and co-investigators in their paper on the enhanced heat transfer performance of metallic foams under jet impingement. To develop adaptive vent systems for heating, ventilation and air-conditioning (HVAC), Dr. Keskin and Dr. Menguç have employed a complex system approach that combines cyber infrastructure, physical dynamics, and social/human interactions in the analysis. Another paper by Dr. Müller and Dr. Steinfeld evaluates the performance of concentrated solar energy-driven pressurized reactor for thermochemical gasification of carbonaceous particles. And finally,

⁴<https://www.asme.org/about-asme/honors-awards/achievement-awards/frank-kreith-energy-award>

for another use of thermal energy storage in a power plant, Professor Jane Davidson and colleague (F. Carlson) evaluate its integration for increasing plant operational flexibility, thereby incentivizing renewable energy and decarbonizing the grid. It is self-evident that the gamut of engineering science explorations represented by these papers are indeed a fitting tribute to Frank Kreith's legacy.

The exceptional life journey of Professor Frank Kreith, so eloquently and endearingly narrated in his memoir [27], was one of joyful celebration and unwavering grit in the face of tribulations. It traversed an extraordinary path from escaping the violence of Nazi Germany during WWII, as a 15-year-old child, aboard a train from Vienna, Austria, to England, and subsequently to the shores of USA, to the ensuing legacy of the immense body of scientific explorations and technological innovations. *The title of my editorial and eulogy is affectionately adapted from that of his autobiography as a tribute to all that he did and shared.* In closing, and on behalf of his many friends and colleagues, we honor his memory with this special issue and panegyric: Frank lived a long, eventful, and momentous life with an undaunted assiduous and a highly magnanimous spirit, and made a transformative difference toward achieving the ideal of sustainable wellbeing of our world!

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