Vol. 46, No. 4 October 2017

PHYSICS & SOCIETY

A Publication of The Forum on Physics and Society A Forum of The American Physical Society

Note from the Editor

This October 2017 issue contains several articles intended to commemorate the 150th birthday of Marie Curie. These articles are versions of invited talks given at the corresponding commemorative section at the New Orleans APS March meeting. I am very happy and grateful to the speakers for having been so cooperative in creating this issue. Letters and counter-letters referring to the July issue show the advantages of publishing controversial articles. And this time we have three book reviews.

Other good news: I am very pleased to announce that we have a new Media Editor, a position which had been vacant for nine months. She is Tabitha Colter, a recent graduate in Physics and Philosophy from Furman University, and a former AIP Science Policy intern. Send your suggestions to her at tabithacolter@gmail.com.

I remind you all that the contents of the newsletter are very largely determined by submissions from the readers. We accept articles on any topic broadly relevant to Physics and Society, and do not shy away from controversy. Please see the October 2016 issue for details.

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IN THIS ISSUE

Five years ago Wallace Mannheimer published a somewhat misleading article in Physics & Society disparaging renewable sources of energy for the world and urging continued reliance on fossil fuels(1, 2). In the July 2017 issue (3) he reprises his advocacy for fossil fuels with even less convincing arguments (almost nothing quantitative at all this time, with still no accounting for real economics) and mixes it with a toxic brew of climate misinformation. I feel reluctantly compelled to respond rather than to leave this mess unaddressed on these pages.

A substantial part of Mannheimer's claims (aside from the extensive polemics) rest on using outdated figures. The year is 2017, so why is he illustrating his article with figures published years ago? The most egregious example is his figure on sea level rise, for which he cites the widely-respected Intergovernmental Panel on Climate Change (IPCC), but uses an image from their 4th assessment report (published in 2007). The 5th Assessment Report was published in 2014, based on research from 2013 and earlier, and so is already several years out of date. Figure 1 is directly taken from Figure 3d of the Summary for Policy Makers of the 5th assessment report. Mannheimer's assertion that there has been no recent increase in the rate of sea-level rise is directly contradicted by the analysis presented by the IPCC concerning this figure: "It is very likely that the mean rate of global averaged sea level rise was 1.7 [1.5 to 1.9] mm yr–1 between 1901 and 2010, 2.0 [1.7 to 2.3] mm yr–1 between 1971 and 2010, and 3.2 [2.8 to 3.6] mm yr–1 between 1993 and 2010. Tide-gauge and satellite altimeter data are consistent regarding the higher rate of the latter period."(4) The IPCC also notes these increases are consistent with calculations of increased sea level expected from ocean warming and glacial melting, both of which have been accelerating.

Mannheimer's figures on energy use are similarly several years out of date. This matters the most for solar photovoltaics, which have been doubling about every 2 1/2 years(5) with over 300 GW capacity in use by the end of 2016. Wind power has not been growing as quickly, but was still slightly larger than solar PV at close to 500 GW capacity by the end of 2016(6). Given that total world electricity generation is roughly 2850 GW(7) year-round and given the roughly 30% typical capacity factor for wind and solar installations, these new renewable sources are already approaching 10% of world annual electricity generation, and still growing exponentially.

Mannheimer's figure 3 and caption argue that "Clearly it is extremely unlikely that solar power can replace fossil fuel in 20 years". In addition to being out of date, this conceals something else - in fact the exact same issue that I raised in my response to his 2012 article (2). Mannheimer shows a plot of "energy consumption", not production of useful energy like electricity. In these graphs, electric production from renewables is counted at par value (1:1), but fossil fuels (which at least for coal and oil are typically burned in thermal generating plants that lose roughly 2/3 of their energy to heat) are counted effectively at 3:1. Put back in that factor of 3 for hydro and "other renew", note that the exponential growth is already evident even at the edge of this graph which is 4 years in the past, and Mannheimer's qualitative "clearly extremely unlikely" becomes instead rather plausible indeed. 20 years is 8 times the 2.5 year doubling time we have recently seen for solar PV capacity, or (if growth could continue at that rate) a factor of 256 - there is plenty of room for "solar" to replace fossil fuels and go far beyond that in the next twenty years.

Mannheimer's only cost analysis in the article seems to confuse the money for "American Federal support for climate change research" with money to "support renewable solar power". Those are two very different things - which are his numbers actually for? At any rate, if $15 B gets us the 15 GW of solar capacity that was installed in the US in 2016, getting to the 500 GW (year-round) production level to replace all fossil electricity in the US should cost less than 2 trillion dollars, not even counting the steady cost reductions that have been experienced from improved production processes (of course there are electricity storage and transmission issues that would also need to be addressed). This is only 1/10 of our annual economy, so spread over 20 years would it even be very noticeable? The scale of the effort needed in the US is clearly well within our capacity. The fact that China and India are also forging ahead on solar and wind (China now has the largest installed solar capacity of any country(5)) suggests the price is also not too high for those Mannheimer classifies as "developing". Note that replacing fossil fuels also means we no longer have to pay for those fuels - a savings of at least hundreds of billions of dollars a year in the US - nor for their ancillary costs in illness and war which may be comparable in scale.

Along with the out-of-date graphs and numbers, Mannheimer's article is full of stale anti-climate-science talking points. Rather than discuss them all, I would point readers to the excellent compilation of answers to these dated claims at skepticalscience.com(8) and note on their list of "MOST USED Climate Myths", Mannheimer used #3 ("It's not bad"), #4 ("There is no consensus"), #6 ("Models are unreliable"), #7 ("Temp record is unreliable"), and several more. Just to address the most scurrilous of these in Mannheimer's article, the "97%" claim clearly refers to "climate scientists", not to scientists (and engineers and other PhD's) in general - yet it is the latter who signed the "Oregon petition", there are almost no "climate scientists" who are signatories. Does Mannheimer seriously think there are a million climate scientists out there? But there are many millions of PhD's in the US, so 32,000 is well below 3%. Also note this petition was circulated 20 years ago, before the science was as clearly conclusive as it is now. The truth is that many independent studies have found a strong consensus among qualified scientists of generally well over 90% - the Skeptical Science discussion of this is a good review.

Worse is Mannheimer's accusation against NOAA: "NOAA has seriously damaged its credibility by publishing such changes, changes that please their political bosses; and then refusing to publicize their new methodology." NOAA's methodology was published in the peer-reviewed literature, it agrees to within hundredths of a degree with every other surface temperature compilation from a variety of independent groups, and the main recent change that has been touted involved the calibration of sea surface temperatures made using different methodologies that had a primary effect on the temperature assessment for the middle of the 20th century.(9). Mannheimer makes no mention of the Berkeley Earth project, which was started by a skeptical group in 2010 (funded by the Koch's!) and ended up reproducing the land surface temperature record completely independently and transparently and found that if anything that previous analyses might have slightly underestimated surface warming of the Earth.(10)

Each of Mannheimer's three "not such well-known aspects of solar power and climate change" are "not well-known" for a good reason: they are simply not true. This entire article seems aimed mainly at advertising his rather odd article from a year ago in the "International Journal of Advanced Research", which even includes the same Tom Lehrer quote (with the same missing word in the lyrics). Ironically, it is not climate scientists, nor climate activists, who have been ignoring the consequences of their advocacy. The lyrics much more directly apply to those who think the continued rise of fossil carbon in the atmosphere is not their "department". It is unfortunate that their voices seem too frequently to outweigh the truth.

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1. *Wallace M. Mannheimer, "American Physics, Climate Change, and Energy", Physics & Society, April 2012 - https://www.aps.org/units/fps/newsletters/201204/manheimer.cfm*
2. *Arthur P. Smith, "Letters On "American Physics, Climate Change, and Energy,",* Physics & Society, *July 2012 - https://www.aps.org/units/fps/newsletters/201207/smith.cfm*
3. *Wallace Manheimer, "Three Not Such Well-known Aspects of Solar Power and Climate Change",* Physics & Society, *July 2017 - https://www.aps.org/units/fps/newsletters/201707/climate.cfm*
4. *Intergovernmental Panel on Climate Change, Assessment Report 5, Working Group 1, Summary for Policy Makers, Section B.4, p. 11 - http://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_SPM_FINAL.pdf*
5. *Wikipedia has an excellent, well-referenced page on the growth of solar photovoltaic capacity worldwide: https://en.wikipedia.org/wiki/Growth_of_photovoltaics*
6. *Global Wind Energy Council, Global Statistics 2016: http://www.gwec.net/global-figures/graphs/*
7. *Energy Information Administration, "International Energy Outlook 2016" - https://www.eia.gov/outlooks/ieo/electricity.php*
8. *"Skeptical Science" - https://skepticalscience.com*
9. *Gavin Schmidt, "NOAA temperature record updates and the 'hiatus'", http://www.realclimate.org/index.php/archives/2015/06/noaa-temperature-record-updates-and-the-hiatus/*
10. *See the project website at http://berkeleyearth.org/*

Manheimer replies:

Arthur Smith and I have crossed swords 5 years ago, as he correctly points out. While I would never describe his assertions as 'polemics', or 'a toxic brew of misinformation', I do still appreciate his interest and comment. But he is incorrect in virtually all of his assertions, and as the editor has allowed, I will comment briefly.

Regarding information on things like sea level rise, anyone who looks at the Internet data as much as I have, can see that things do not change very much from year to year. Hence my goal was never to use the absolute most up to date information; rather it was use information easily available on the Internet, so that anyone can check up on what I presented anywhere, anytime. This avoids the need to go to a large university library, or the library of congress to scour a bunch of obscure, dusty journals. The data speaks for itself; there is no need for any expert to interpret it. The linked paper in my Forum article gave various assertions by alarmists, and then checked them out with an Internet search. (See https://www.ijeas.org/download_data/IJEAS0407025.pdf for a more up to date version) The unmistakable conclusion is that the claims of the alarmists simply do not stand up to serious scrutiny. For instance take the sea level rise, which Mr. Smith mentions. My claim was 20-25 cm/century. His numbers vary between 15 to 36 cm/century; not such a big difference, considering that at the December 2015 Paris meeting, some people were talking, with absolute certainty, about a 4-6 meter rise, by century's end. Actually it is likely that Mr. Smith's upper estimate is too high. In an April 17, 2017 (is this recent enough for him?) op ed in the *Wall Street Journal*, Steven Koonin, a very reliable authority, said that the rise in sea level has slowed down. See his quote in my Forum article. This is made much more credible by the recent NASA measurements that over the entire continent, ice in Antarctica is forming, not melting (see https://www.nasa.gov/feature/goddard/nasa-study-mass-gains-of-antarctic-ice-sheet-greater-than-losses)

Regarding NOAA, there is no question that it damaged its credibility by suddenly changing its figures to those more pleasing to its political bosses at the time. If on an issue this important, which could affect the lives of billions of people, NOAA felt that its earlier figures were in error, its proper course would have been to invite several major labs and universities, in the USA and abroad, to go over the figures and methodology with them, and come out with some sort of joint statement. I am reasonably sure that my lab, the Naval Research Lab, would have been happy to help if asked. Instead NOAA played its cards very close to the vest. Who knows what to believe now?

Regarding energy use, I stand by my figures 3 and 4. Mr. Smith and I could quibble over whether the electricity production from solar and wind is 17% of capacity (the figure I have usually seen) or 30%, his figure. But take 20% of his 800 gigawatts installed, and the power delivered is in the neighborhood of 160 GW, just about 1% of the 14 TW the world uses, just as my article claims. This is after $140 billion was spent in the USA alone to develop solar power. Germany has decided to go to solar power for electricity, and has succeeded producing ~25% of its electric power with solar and wind. However their power is strongly subsidized by the government, and yet customers pay triple what we pay for a kilowatt hour, and double what the mostly nuclear French pay. In addition, they still emit more CO_2 into the atmosphere per capita than their European neighbors. This is carefully documented in my papers linked here and in Forum article. The data up to now is unambiguous; sunlight is free, but solar produced electricity is *very, very* expensive.

I have several friends who would be only too happy to sell Mr. Smith their solar and wind stock for half of what they paid for it.

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ARTICLES

Marie Curie and Mildred Dresselhaus, Inspirations to Women in Science

Summary of a talk given by Cherry Murray, Harvard University at the APS March Meeting, New Orleans, LA, March 16, 2017

My talk is dedicated to Mildred (Millie) Dresselhaus, (born November 11, 1930, and passed away February 20, 2017,) who was scheduled to give the talk in this time slot at the 2017 March Meeting session celebrating the 150th anniversary of Marie Curie's birth entitled "*How Marie Curie got me into Condensed Matter Physics*." There are many parallels in life and impact on physics between Millie and Marie Curie (1867-1934.) Millie was an inspiration to all and especially to women in physics, just as Marie Curie was an inspiration to Millie. I will cover the parallels I find between Marie Curie and Millie since Ruth Howes will cover Marie Curie's career in full detail later in the session. I will then give a brief summary of Millie's life and career and note a few of her accomplishments.

Marie Slowdowska Curie was named the most famous scientist of her time in 1903, the year she won her first Nobel Prize, the first woman ever to do so. Earlier, she was one of two women graduate students in Europe, the first woman to earn a doctoral science degree in France, the first female professor in France, and the first person to win two Nobel Prizes (in Physics for the discovery of Radioactivity in 1903 and in Chemistry for the discovery of the element Radium in 1911.) She was certainly the "Queen of Radioactivity," having discovered and named the spontaneous decay of elements completely unexpected by the scientific community at the time - and as a result, between Marie and her immediate family members there were four Nobel Prize winners.

Mildred "Millie" Dresselhaus was called the "Queen of Carbon" in 2013, having made a career studying semi-metals and, indeed, lowly carbon - both considered uninteresting to the scientific community when she began her research on them. Millie also had a number of firsts: the first woman professor of electrical engineering at MIT, the first woman Institute Professor at MIT, the first person to win a solo Kavli Prize, the first woman to win an IEEE Medal of Honor. She had a prolific career with many other awards, authored over 1700 scientific papers, 8+ books, and mentored over 60 graduate students.

The young Marie Curie, Marya Sklodowska, was born in 1867 in Russian-controlled Warsaw, the youngest of five children, into a family of teachers with challenging finances. She lost both a sister and her mother to disease early in her life. She excelled in studies as a child, supported by her widowed father; was active in her teens in the underground counter–Russian-culture "Floating University," learning physics in various soirees. After taking a job for 6 years as a governess in order to help earn money to help a sister through medical school in Paris, Marie (as she then called herself) enrolled in the Sorbonne at the University of Paris, the only university that allowed women. There, Marie met Pierre Curie, and they married in 1895. Pierre was especially supportive of Marie, left a promising line of his own research to collaborate on Marie's radioactivity project and was her closest collaborator until his death in 1906. They had two daughters while Marie continued her research.

The young Millie Dresselhaus, Mildred Spiewak, was born in Brooklyn, NY in 1930, the younger child of Polish émigré parents in a low-income neighborhood. Millie excelled in her studies but attended poor schools. While in grade school Millie read the biography of Marie Curie and dreamed of being a scientist. Her brother Irving was a violin prodigy, and the family moved to Bronx for his lessons. Millie also took violin lessons from age 4-13, traveling alone by subway to Greenwich House School, where she heard about Hunter College High School, a public school for "intellectually gifted young ladies". Millie studied hard and aced the entrance exam, attended Hunter High, learning physics from boys at Stuyvesant High, graduated top of her class in 1948, and then enrolled in Hunter College, the City College of New York (CCNY). Millie met Gene Dresselhaus in graduate school at the University of Chicago and married him in 1958, the year she defended her thesis on magnetism in superconductors. Gene, a theorist, was especially supportive of Millie's research and her constant collaborator after 1960. They had one daughter and three sons while Millie continued her research.

When Millie was attending Hunter College, CCNY from 1948-1950, she overlapped for a year with Rosalyn Yalow, who taught her elementary physics and became a lifelong friend and mentor. Millie did experimental work at CCNY on metals. Rosalyn told Millie that she MUST become a researcher and go to a top graduate school, and wrote letters of recommendation for her. Rosalyn went on to win the Nobel Prize in Physiology or Medicine in 1977.

Millie spent 1950 as a Fulbright Fellow at the University of Cambridge. She then enrolled at Radcliffe to study physics but left in 1952 after a Master's Degree to enroll at the University of Chicago at the age of 22, one of 11 entering graduate students – the only woman. Gene Dresselhaus was a fellow graduate student there.

At Chicago, Millie met and got to know Enrico Fermi, her hero, who taught her how to think like a physicist; and spent a year visiting with his family and walking each day to the University together with him in the early mornings, before he passed away suddenly in 1953.

Millie's thesis advisor, Andrew Lawson, believed women had no place in science and told Millie this. Millie had to cobble together her apparatus out of old parts lying around. At the 1958 APS March Meeting, Millie presented experimental results from her thesis work on the microwave properties of a superconductor in a magnetic field inconsistent with the 1957 Bardeen-Cooper-Schrieffer theory. This attracted the interest of both John Bardeen and Bob Schrieffer, who later on was instrumental in getting Millie's career started.

After Gene and Millie married in 1958, Gene accepted an offer as an assistant professor at Cornell University, and Millie was offered a National Science Foundation postdoctoral fellowship there and joined Gene. Millie continued to work on the magnetic properties of superconductors and got to know Richard Feynman. A Cornell faculty member told Millie that no woman would ever be permitted to lecture to his engineering students. Gene and Millie's daughter Marianne (MIT '81) was born in 1959.

At the end of Millie's postdoc, Millie and Gene searched for jobs where there were no nepotism rules, and could find offers at only two places: IBM and the Massachusetts Institute of Technology (MIT) Lincoln Lab. In 1960, they accepted offers in the Solid State Division at MIT Lincoln Lab headed at the time by Benjamin Lax. At the time Millie joined, there were 1000 men and two women employed as scientists and engineers by MIT Lincoln Lab. Millie was told to switch fields to the magneto-optical properties of materials, and chose to work in semimetals. The big excitement at the time was semiconductors, but Millie recalled in her later years that "there were advantages working in a less competitive research area while we had our babies." They had another three children, all sons, from 1961 to 1964, for whom Millie took five days total off from work for their deliveries. Millie measured the magneto-optical properties of bismuth, graphite, and the group V semimetals; Gene did the electronic band structure calculations. In all they spent seven years laying the

Physics and Society is the non-peer-reviewed quarterly newsletter of the Forum on Physics and Society, a division of the American Physical Society. It presents letters, commentary, book reviews and articles on the relations of physics and the physics community to government and society. It also carries news of the Forum and provides a medium for Forum members to exchange ideas. ***Opinions expressed are those of the authors alone and do not necessarily reflect the views of the APS or of the Forum. Articles are not peer reviewed.*** Contributed articles (up to 2500 words), letters (500 words), commentary (1000 words), reviews (1000 words) and brief news articles are welcome. Send them to the relevant editor by e-mail (preferred) or regular mail.

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foundation of the physics of semimetals.

In 1967, Millie accepted the offer of an Abby Rockefeller Mauzé visiting professorship in electrical engineering at MIT. In 1968, she accepted the offer of a permanent professorship in electrical engineering – the first to a woman. In 1969, I was an entering freshman at MIT interested in physics and met Millie for the first time. She was an incredible inspiration and role model for me!

In 1973, Millie and Gene began to work on intercalation compounds in graphite, and noticed that stage 1 and stage 2 intercalation compounds have vastly different electronic properties – setting the stage for the physical understanding of graphene.

In 1980, Millie and Gene started a collaboration with Morinobu Endo on carbon fibers, and began experiments using laser ablation and carbon clusters – setting the stage for discovery of nanotubes and the fullerenes.

In 1983, Millie was offered a joint professorship in the MIT physics department, and in 1984 she became president of the American Physical Society (APS). In that year she discussed C_{60} with Richard Smalley, and began research on C_{60}'s 200 infrared and Raman active vibrational modes.

In the 1990's she began spectroscopy of single walled carbon nanotubes, and in 1991 she wrote an influential paper jointly with Fujita and Saito (controversial at the time) predicting the properties of single walled nanotubes depending on the orientation of the hexagons with respect to the nanotube axis, showing that the electronic properties could vary between semiconducting and metallic.

In 1992, Millie began research on thermoelectricity for energy harvesting, and in 1996 launched the field of low dimensional nanostructured semimetals. Millie became emerita, but maintained an active research program until her death.

Millie's research career in semimetals and the intercalation of graphite laid the foundations for carbon as the miracle material of the 2000's, as well as the foundations of nanoscience with fullerenes, nanotubes and graphene as examples. Semimetals, low dimensional semimetals in particular are now a burgeoning area of science and its applications.

Millie's service to the science community was extensive: in 1984 she served as APS president, in 1998, as American Association for the Advancement of Science president, from 1996-2000 she was treasurer of the National Academy of Sciences, in 2000 she served as Director of the Department of Energy's Office of Science, in 2003-2008 she served on the governing board of the American Institute of Physics. Millie was a mentor to all, especially to her 60+ graduate students, and she worked tirelessly to support women in science.

I'll end with a partial listing of Millie's accolades. In 1985, she was named Institute Professor at MIT. In 1990, she won the National Medal of Science, in 2004, the Institute of Electrical and Electronics Engineers (IEEE) Founder's Medal, in 2005 the Heinz Award, in 2008 the Oersted Medal, in 2009 the Vannevar Bush Award, in 2012 the Kavli Prize in Nanoscience, in 2012 the Enrico Fermi Award, in 2013 the Materials Research Society Von Hippel Award, in 2014 the National Inventors Hall of Fame, in 2014 the Presidential Medal of Freedom, and in 2015 the IEEE Medal of Honor. In addition Millie was awarded over 30 honorary degrees.

We will miss Millie, an inspiration to us all.

The growth of nuclear daughters

Sherry J. Yennello, Texas A&M University

Often people think of radioactivity as the disappearance of a nucleus through decay, but equally true is the appearance of a new nucleus – the daughter. In the same way that a relatively pure sample of Uranium develops over time to have many different components, the relatively homogeneous field of physics that Marie Curie lived in has transformed in the last 150 years to have much greater representation. The birth of daughters enables the transformation of a field from being very male dominated to having more diverse representation.

Marie Curie has given us nuclear daughters in multiple senses of the word. By her discovery of radioactive decay she showed us the first daughter nuclei. Marie also gave birth to Irene, who was both biologically and scientifically a nuclear daughter. But Marie's early accomplishments also paved the way for many other women to become nuclear scientists. A picture from the nuclear chemistry Gordon conference from

Figure 1 Nuclear Chemistry Gordon Conference 1966.

1966 shows vividly how the field was virtually all men just 50 years ago. So there was not much progress in the first 100 years.

In contrast a picture of the author's research group today is overwhelmingly female.

In 2015 white women made up 31% of the population and 18% of the employed scientists and engineers – so the glass is half full. If one looks specifically at physics women make up 20% of the graduate student population. We have come a long way since the days of Marie – even if we got a slow start.

There are now a number of programs with the intention to increase women either in STEM or specifically in physics. The NSF signature program for increasing women in STEM faculty positions is ADVANCE. (https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5383) The National Science Foundation ADVANCE program began in 2001, and has awarded 300 grants to over 200 institutions. The goal of the ADVANCE program is to develop systemic approaches to increase the representation and advancement of women in academic science and engineering careers, thereby contributing to the development of a more diverse science and engineering workforce. Under the Obama administration there was a White House Council on Women and Girls. The office was tasked with reviewing policy proposals to ensure gender equality, sponsoring public forums on women's issues and coordinating with outside groups among federal agencies.

There has been a series of international conferences on women in physics sponsored by the International Union of Pure and Applied Physics (IUPAP) and there is an IUPAP working group on women. (http://iupap.org/working-groups/wg5-women-in-physics/)

Figure 2 SJY research group 2017.

Within the APS there is a committee on the status of women in physics (http://www.aps.org/programs/women/index.cfm) that sponsors a number of programs to promote women, from Gender EQUITY site visits to professional development workshops. In 2006 a group of senior women hosted the first conference for undergraduate women in physics. This effort grew rapidly and in 2018 there will be a dozen concurrent conferences throughout the country.

While the field of physics has gotten a slow start at diversifying, and the glass is now half full, we have come a long way and I'm sure Marie is smiling down upon us.

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Figure 3 5th International Conference on Women in Physics.

Figure 4 Conference for Undergraduate Women in Physics: Brownsville, TX, 2015.

Marie Curie: The Curie Institute in Senegal to Nuclear Physics

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Celebrating a double Nobel Laureate personated by Marie Curie seemed to be more challenging than anything I have been involved in my short lifetime. The non-trivial piece was to tell my story, something that I often found awkward as I usually do not talk about myself and certainly not about my accomplishments. Being in the background doing research and teaching is what I enjoy. But … when Ruth Howes reached out, I could not say no!

This talk was a dedication to my grandmother and my family! It spans from me growing-up in Senegal (West Africa) learning about nuclear physics to now being involved at two major national laboratories in the United States: Thomas Jefferson National Accelerator Facility (Newport News, Virginia) and the National Superconducting Cyclotron Facility/ Facility for Rare Isotope Beams (Lansing, Michigan).

Elders are highly respected and revered in Africa: they are the source of wisdom! This role was personified by my grandmother (Mame as we called her), along with my entire immediate (father, mother, siblings, aunts, uncles, cousins) and distant families. And yes: it takes a village to raise a child! My cultural and educational foundations were defined by the numerous discussions and lessons learnt with members of my family, even the skills of cooking (which turned out to be a tremendous asset when I headed overseas for my PhD). This type of foundation is also the symbol of Senegal that can be found in the baobab, one of (if not) the largest trees on this planet that can also live in very arid areas.

With a population of about sixteen million people, Senegal is a rich and multi-cultural country where one can find modern and traditional cultures together in one place. This symbiosis is a unique environment to keep its tradition rooted within its population while at the same time opening its door to future technology and businesses. Children growing up in such an environment are exposed to a variety of opportunities, understanding of differences (cultural, religious …) along with unique challenges and engagements that can only benefit mankind if viewed as a way to embrace our diversity on this planet.

My twin brother, René, and I shared many memories and other unique experiences such as the names of our first child (Yannick for my daughter and Yoann for his son, without consulting each others) … and the same birthdate of his daughter (Maeva) and mine! We always read and heard about stories of twins but living it is a totally different experience.

After a review of my early education (from elementary to high-school), one of the first testimony during my presentation was about role models. Naturally, we think of Einstein as one of the greatest scientists. However, there are many hidden heroes. For Senegal, and Africa in general, Cheikh Anta Diop (1923-1986) was a phenomenon and The Greatest Scientist. He owns seven PhDs ranging from linguistic to fundamental science. Carbon 14 dating was introduced to many of us growing up as The Tool attached forever to him. Quantum mechanics teaches us about relativity and this is a powerful example on how relative great scientists are to different people from different origins.

Like many, I was curious about the (inner) workings of our universe drawn mainly by the fascination about the inter- and intra-relationships between various fields: what is the world beyond the stars that we can see with our naked eyes at night? Is there any analogy between the waves created from an object dropped in water and drawing mountains on a 2D map since they look the same? How do fundamental particles "talk" to each other to make atoms and molecules so unique that we and objects around us look (and are fundamentally) different? … why, how, what: all the questions that most scientists try to answer. Where are the solutions and how can we ensure they are correct? I used to be labeled "Mr. Questions" while going through my education in Senegal (until my MS) and in France (for my PhD).

My decision to pursue nuclear physics stems, in part, from some discussions with one of my late uncle (Prof. René N'Doye); a medical doctor who was also the Dean of the School of Medicine and Pharmacy of UCAD, along with heading the Biophysics and Radiation Physics program at a local hospital (Aristide LeDantec). While I read many textbook about science and physics in particular, one of my very first exposures to the "Curies" was the "Institut Curie" housed in the same hospital where radiation treatments were held to treat diseases. I didn't pay too much attention to what was happening there but I knew something special was being done. I do recall some short visits to the "Institut" and seeing a few patients seated in the waiting room or going into treatment rooms. What I did not realized at that time is that something was slowly growing inside me and pulling me toward the field of nuclear physics.

Through my BS and MS, I got the chance to learn more about the discovery of radioactivity and the amazing life and impact that Pierre and Marie Curie had in the field of nuclear physics. I did not mention this during my talk but I recall saving my earnings from private tutoring sessions to purchase as many physics and chemistry books detailing the earlier experimental work from fascinating scientists, including Röntgen, Becquerel, the Curies, Chadwick, J. J. Thomson, etc., who pioneered what we know today about the atoms and radioactivity. One story stuck with me since that time that I did not understood until recently. It was one of Marie Curie. A reception was organized to honor her work and people were waiting for a while until someone went to her room to find out why she was so late to come out. It turns out she didn't want to leave the room with the light still on in her closet, which will waste energy and money … an attitude from her growing up with little money at home. Her friend told her that the light automatically turns off when the door shuts. Of course she did not believe it and wanted a proof. What she did was stunning: she asked her friend to close the door behind her after she went into the closet. Realizing that the light indeed turns off when the door shuts, she was then ready to go to the reception. Looking back, my journey to becoming a nuclear physicist has been to question every information I obtained, whether from a teacher, peer, friend, colleague and while conducting experiments. The approach is simple if one looks at any sort of radiation: put yourself on top of it and, while riding the wave, question everything you "see".

My earlier interest was to embrace as many topics as possible, scientific or not, since each had its own fascinating facts. This curiosity was nurture with one of my aunts, Marie Guèye. But one was standing above: Quantum Mechanics! One could use it in physics, explain chemistry and even engage in religious discussions (since it is founded on the ideas of probability, "I cannot believe God plays with dices" as Einstein once said). The original plan heading to France was to pursue a PhD in bio-physics; but during my first semester, I was offered the chance to switch to the last experiment comparing unpolarized electron and positron beams scattering off carbon-12 and lead-208 at the former Accélérateur Linéaire de Saclay of the Commissariat à l'Énergie Atomique. My thesis consisted on two experiments to test the validity of the Born approximation, namely dispersive effects (elastic scattering) and Coulomb distortions (quasi-elastic scattering). The latter proved to be one of the foundation to unravel a mystery between unpolarized and polarized electron elastic scattering experiments conducted at Jefferson Lab in the early 2000s that was embedded in high order corrections (e.g., two-photon exchange) between the incoming lepton probe and the nucleus.

My postdoc years were spent with the Nuclear Physics group of Hampton University participating in numerous experiments until today at the Thomas Jefferson National Accelerator Facility (Jefferson Lab for short). This is when my passion for nuclear physics solidified with my involvement in the first sets of experiments (especially this "strange quark" that doesn't want to behave like everyone else) and beamline instrumentation (which sparkled a growing interest in accelerator physics). The beauty of the relatively small but most powerful accelerator at Jefferson Lab has provided me with access from source production to physics experiments and everything in-between. This facility is an awesome source for knowledge that I would recommend to all students.

The years following my postdoc allowed me to delve more into nuclear physics and accelerator physics, although I had the privilege to work in other fields such as ultrafast wakefield accelerators, medical physics and more recently radio-astronomy.

I am currently the Chair of the Physics Department at Hampton University (HU), a Historically Black College (HBCU). It has established itself as the #1 Physics Department across all HBCUs Physics. Its research areas currently include nuclear physics, accelerator physics, medical physics, and optical and material sciences. The nuclear physics group (which is relevant for this article) has been leading major projects at Jefferson Lab and, more recently, its 12 GeV upgrade: building the main tracking systems for two experimental halls and leading the entire hypernuclear physics program. HU Physics is the only HBCU to house a graduate program in nuclear physics. Therefore, there was a natural path for this Department to collaborate with the #1 Physics Department in nuclear physics in the US: Michigan State University. This connection was established through the MoNA Collaboration working at the National Superconducting Cyclotron Facility/Facility for Rare Isotope Beams (NSCL/FRIB). Our involvement focused on the development of an active segmented silicon-beryllium target to study neutron rich nuclei along the dripline and a Geant4 Monte Carlo simulation of one of the experimental halls (the N2 vault); thanks in no small words to Michael Thoennessen for opening a path for me to be involved in this (low energy nuclear physics) community.

The present Dean of the School of Science, Dr. Calvin Lowe, is playing a critical role in my new tenure as an administrator. The focus on this session switched to “Millie” Dresselhaus (1930-2017) who passed just weeks before the APS March meeting and highlighting the parallel between her life and the one of Marie Curie. While she will always be remembered as “The Carbon lady”, in my small world her legacy will live forever since she was also the advisor of my new boss, Dr. Lowe, closing the loop of educating even more physicists through her unconditional love of physics and science.

At the time this article was written, I found myself as the only African American doing experimental nuclear physics at an HBCU. Many have been, are and will be first in many areas, establishing breakthrough in various forms and providing opportunities to many for the good of mankind. Along the way, there will be many challenges. Marie Curie proved to not only be an extremely talented and gifted woman physicist but also unique and surpassing many, while maintaining a compassion and humility as a human being. A plethora of documentaries show many facets of her life. Understanding how she and her husband took of the daunting task to extract radium is astonishing but also at the heart of many physicists: passion is a drive that has no time limit! In many ways, “no” is not in my vocabulary as for every problem (whether scientific or not) there is always a solution: one just need to look in the right direction.

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Marie Curie: Physicist and Woman and the Penny Press

By Ruth Howes, rhowes@bsu.edu

Maria Salomea Sklowdowska was born in Warsaw Poland on November 7, 1867. This year we celebrate her 150th birthday.

Most physicists know the outline of Maria’s life. She grew up in a poor Polish family as an academic star. Her mother, who never cuddled her youngest daughter for fear of transmitting tuberculosis to the child, died when Maria was ten. After agreeing with her older sister Bronya to support her medical studies in Paris, Maria took a position as a governess in the country, fell in love with the son of the family, had a wedding called off by his displeased parents, and travelled to Paris to study physical science at the Sorbonne while living with Bronya and her new husband. At the end of a year, she moved out of her sister’s apartment to seek solitude and study time in a series of 6th floor garrets where she nearly starved and froze herself to death before finishing first in her class for the equivalent of a master’s degree in the physical sciences. The next year, she continued her solitary existence studying mathematics with the aid of a scholarship for Polish students and a grant to study the magnetic properties of steels.

She needed laboratory space and asked a talented young physicist, Pierre Curie, if he could provide it. Curie had no space and worked in a corridor at EPCI, a solid but not elite college in Paris. His corridor-based studies of magnetism including the Curie Law and the Curie Temperature would earn him his doctorate. The two young people fell in love and married on June 28, 1895. Afterwards they left for their honeymoon riding bicycles which was very fashionable and rather daring, particularly for women. Their first daughter, Irene was born on September 12, 1897 and Pierre’s mother died on September 27. Pierre’s father, a medical doctor, moved in with the young couple and took care of the baby while Marie attacked the task of investigating the rays recently discovered by Becquerel for her doctoral thesis. She made this choice because she could do laboratory work instead of reading papers on x-rays in the library.

With the help of the piezoelectric electrometer invented and provided by Pierre, Marie confirmed Becquerel's results on potassium uranyl disulphate in only two weeks. She then experimented with samples of many materials and found that thorium also emitted rays. Through her professor, she reported it to the French Academy of Sciences just 19 days after the thorium result was reported by a German chemist. Marie examined a variety of uranium compounds and found that the intensity of the rays a sample emitted was proportional to the amount of uranium in the sample, a clear indication that the rays came from the atoms of uranium. In February 1898, she found that pitchblende, a uranium ore, emitted far more rays than would be expected based on the uranium it contained. Marie realized that pitchblende must contain a very small amount of a new, highly radioactive element.

With the help of Gustave Bémont, a chemist and laboratory chief at EPCI, Marie and Pierre set about isolating the new element. Their strategy was to chemically separate the ore into compounds and then further separate the compounds more active in emitting rays. Rather quickly, they found not one, but two new elements that more actively emitted rays than uranium. One chemically resembled Barium; the other, Bismuth. By May 25, they had found compounds 300 times more active than uranium. But they were not able to spot the spectral lines that would unambiguously identify a new element. On July 13, Pierre wrote in their lab notebook that Bismuth harbored a new element which they labelled Polonium after Marie's native land. By December 26, 1898, the Curies and Bémont reported the barium held another related substance, radium, which actually produced new spectral lines although it was present in very tiny concentrations. Marie would have to process 8 tons of pitchblende to isolate a decigram of pure radium. The only free space they could find for this huge labor was a wooden shed at EPCI with a glass roof that leaked when it rained, and heated only by a small stove and very hot in summer. Both the Curies absorbed huge doses of radiation without knowing they were in danger. Even today, scholars who want to see Marie's notebooks must sign a waiver releasing the Biblioteque Nationale from responsibility for radiation damage.

Pitchblende from which the uranium had been extracted was considered waste and was discarded in a pine forest near the uranium extraction plant in Austria. The company gave the waste to the Curies who were able to pay for transportation of the depleted ore with the help of a donation from Baron Rothschild.

In the spring of 1899, Marie started backbreaking work of boiling more than 80 lbs of pitchblende in a metal kettle while stirring it with an iron rod as tall as she was. Then she invented fractional crystallization to further purify the radium. She chose to work with radium since separating it from barium was easier than separating polonium from bismuth. In March 28, 1902, Marie succeeded in determining the atomic weight of radium: 225.93 amu.

Marie always remembered these years as the happiest of her life. The young couple was deeply in love and had no distractions to keep them from concentrating on experimental science. Their daughter was thriving, and they saw only friends about whom they cared. They were both astonished at the properties of the radium they had discovered. They would walk back to the shed after dinner simply to enjoy the light coming from the flasks of radium solutions.

Marie had begun teaching physics at the Ecole Normale Supérieure at Sèvres, the best school for women teachers in France. After a rough first year, she learned to express her concern for her students who responded by adoring her. She was the first teacher in the school's history to invite students for tea. She added an hour to the physics lectures and introduced hands-on laboratory work, the first time the women had done it.

Marie presented her work on the decigram of radium as her doctoral thesis in June 1903 and invited her female students to attend the defense. She was awarded the doctoral degree with high honors and the thesis was published in at least two journals. There was also tragedy. Marie wrote her father of her discovery of radium on May 8, 1902 and on May 14, he died before Marie could reach his bedside. In August 1903, Marie had a miscarriage in her fifth month of pregnancy and was thrown into a deep depression.

Early in 1903, rumors surfaced that Pierre and Becquerel would receive the 1903 Nobel Prize in Physics. Marie was left out until Pierre wrote members of the Nobel Selection Committee pointing out how important her role in the discovery had been. The Committee then reactivated a nomination of Marie from 1902 and awarded half of the 1903 Nobel to both Curies 'for their joint researches on the radiation phenomena', and the other half to Becquerel. The wording of the citation was carefully chosen when the chemists pointed out the possibility of a second Nobel for the discovery of radium. Marie became the first woman ever to be awarded the Nobel Prize in the Sciences and the only one until Irene won in 1935.

At this time, France had a mass circulation penny press which seems to have corresponded closely to our modern blogosphere. The romance of the Curies with one another as well as with radium became fodder for the masses. The shy couple was nearly driven crazy as reporters invaded their quiet shed and even their home where they interviewed Irene's cat.

Marie Curie was everybody's heroine, and did not enjoy the limelight any more than did her very private husband. She received blind praise although many reporters presented her as a privileged assistant to Pierre. She was also attacked. One anonymous writer said, "The woman who works is usually obliged to abandon, to neglect her household, her children…" Neither the praise nor the attacks made life easy for the Curies.

Although radium offered them an opportunity to make significant money, they made it a rule not to patent their discoveries or profit from their research. The money from the

Nobel Prize helped although they gave much of it away to Pierre's brother Jacques and Marie's sister Bronya. The Nobel Prize at last focused the attention of the French scientific establishment on Pierre's excellent work in physics, and by an act of Parliament, a chair was created for him at the Sorbonne. He was also elected to the Academy. On December 6, 1905, Marie gave birth to a baby girl whom they named Eve Denise. In the summer of 1905, the family travelled to Brittany and greatly enjoyed peace and quiet as well as ocean swimming and quiet walks on the beach. The Curies even managed to watch a solar eclipse from Mt. San Michel.

On April 17, 1906, Pierre set out to a meeting of his fellow professors. Pierre invited others to lunch at his apartment. He then left to go to his publisher. It was raining hard. Pierre raised his large umbrella and hurried against the rain. As he crossed a busy road leading from the Pont Neuf, he had his head down and he stepped into the path of a heavy wagon. The driver tried to turn and avoid the body, but the rear wheel rolled over his head and killed him instantly.

The grieving Marie wanted to avoid ceremony at the funeral, and Pierre was buried simply, without religious ceremony and before only family and close friends, in the cemetery alongside his mother. Marie did not grieve publicly, but she closed in on herself and from this time became grim and closed up emotionally.

About a month after Pierre's death, the Faculty of Sciences named Marie to replace him, making her the first woman to teach at the Sorbonne. On November 5, 1906, she gave her first lecture which was mobbed by society ladies showing off their jewels and Marie's class from Sèvres whom she had invited. Marie quietly entered the lecture hall wearing black and began her lecture exactly where Pierre had finished his last lecture.

Lord Kelvin, a friend, picked the summer of 1906 to very publicly declare that radium was not an element but a compound state of lead and helium. Marie rose to Kelvin's challenge to purify enough radium to isolate the metal and prove beyond a doubt that it was an element. It took her and her team of young workers lead by André Debierne until 1910 to isolate radium in the metallic state. Also in 1910, she allowed herself to be nominated for the Academy. To her surprise, her candidacy broke in newspaper headlines first because she was a woman and secondly because she was not Catholic. The Academy election became fodder for the penny press. Marie was rejected and her young staff quickly hid the flowers they had planned to give her in congratulation.

In 1911, Marie was accused in the popular press of having an affair with the physicist Paul Langevin. The scandal broke in the press on November 5, 1911. On November 7, it was announced that Marie Curie had been awarded the 1911 Nobel Prize in chemistry. In a few years, Marie's portrait in the press had gone from heroic French scientist and courageous widow to foreign hussy bent on destroying a proper French marriage. Marie kept her mouth shut, but on December 10 and 11, 1911, Marie went to Stockholm to receive her prize. For once, she underlined her own work both in "private" formal comments and in her formal Nobel lecture although she gave generous credit to Pierre and others. As she left Stockholm, Marie Curie underwent a total physical collapse.

On August 1, 1914, the French Army mobilized for World War I. Marie set out to make x-ray examination available to wounded soldiers at the front. She approached wealthy women asking for donations of cars. She turned the cars into vans to carry x-ray equipment and a dynamo plus everything else needed for an x-ray examination. She eventually equipped 18 vans, popularly called little Curies, obtained her driver's license and learned to make simple mechanical repairs as well as to operate the x-ray equipment. She also established 200 permanent x-ray posts in military hospitals near the front.

Marie and Irene, now her chief assistant, found it hard to deal with pain and death among the wounded as well as with the intransigent arrogance of some of the older doctors who had never used x-rays and felt no need for them now and military officers who tried to deny passage to the Little Curies. Their major problem was a lack of skilled x-ray technicians so they trained women in the field.

After the war, Marie attacked the problems of furnishing the labs in the Curie Institute. One morning in May 1920, a friend introduced her to an American reporter Missy Mattingly. Missy was surprised to learn that France had only one gram of radium and that Marie could not afford the $80,000 needed to purchase another. Missy immediately volunteered to launch a fund-raising effort to buy a gram of radium if Marie would come to the US to be honored and pick it up.

In New York, Marie, Irene and Eve were met at the dock by a brass band switching from the Star-Spangled Banner to the Marseillaise to the Polish national anthem, 300 hundred Polish women waiving red and white roses, hordes of girl scouts and reporters shouting questions. On May 20, 1921, President Harding hung around Marie's neck the key to the lead box containing the precious radium for which she had worked so hard.

After this tour, Marie's health declined. In January 1934, Marie held a flask of an artificially produced radioactive element and realized that her daughter and her colleague husband would win the Nobel Prize for it. On July 3, 1934 Marie died, probably of anemia.

SELECTED RESOURCES:

Eve Curie, Madame Curie: A Biography (1937).

Marie Curie, Pierre Curie With Autobiographical Notes (1930).

Françoise Giroud, Marie Curie: A Life (1981).

Susan Quinn, Marie Curie: A Life (1995).

The Carbon Crunch

By Dieter Helm (Yale University Press, updated edition 2015), 304 pages, $22, ISBN 9780300215328

The Carbon Crunch by Dieter Helm is a measured and dispassionate look at the economics and politics behind tackling climate change. The first section of the book establishes the basic realities of the problem from a scientific and economic standpoint. The second looks at why nothing has been accomplished over the past two and a half decades. The third and final section is more optimistic and outlines the author's plan for more effectively attacking the problem. This updated edition includes new insights and reflections on recent events, including the shale gas boom that continues in the US, recently plummeting fossil fuel prices, and the 2015 Paris Agreement which was imminent at the time the updated edition was published.

Helm begins by laying the foundation and the science of climate change research, much of which has been addressed many times before. Perhaps most interestingly, he examines the question of who is to blame for our carbon emissions and who should be asked to pay for it. The author makes the careful distinction between carbon production and carbon consumption. While production is relatively easy to assess, carbon consumption is a more accurate measure for blame. One rather brilliant example that Helm uses is the supposed decrease in carbon emissions that many European countries have achieved in recent decades, for which European leaders have congratulated themselves greatly. While it is true that European countries have decreased their own emissions, much of that reduction is due to de-industrialization. But that does not mean that these countries have stopped consuming carbon intensive products; they instead import products from countries like China and India. The author calls this problem "carbon leak," in the sense that one may have controlled emissions within a country, but emissions are still leaking across the borders. If you look at the consumption-based emissions from some European countries over the past decades, those emission numbers have actually increased. With many developing nations planning on building up their economies with large numbers of new coal-powered plants over the coming decades, Helm makes a compelling argument that the only way to contain this carbon leak is to have an effective tax on consumption that mirrors the true cost of carbon intensive products.

In the second section of the book, Helm analyzes the reasons for the lack of any real action on climate change. The author makes an unapologetically harsh assessment of the largely ineffectual measures enacted by the world's governments and politicians. Helm has a decidedly skeptical outlook on the effectiveness of global accords like the Paris Climate Agreement, for which time will have to be the final judge. But the author also spreads the blame for inaction around to other parties. He is skeptical that current renewable technologies have the ability to be truly viable alternatives for our global energy budget, and argues that lobbyists for the renewable sector today actually do more harm than good. He is particularly critical of current wind and nuclear technology but seems more optimistic about solar energy. A third criticism he makes in regards to inaction amounts to a figurative moving of the goalpost. Many tout energy efficiency as part of the solution to reducing our carbon footprint. However, Helm points to historical data that shows while efficiency is always a good thing, it leads simultaneously to increased consumption. One could argue with the author that those two are not necessarily causally linked. But it is hard to argue that, while many devices have indeed become more energy efficient, at the same time we have also greatly increased the number of power-hungry devices in our households.

While the first sections of the book largely paint a very bleak picture, the book ends on a more positive note as the author constructively explores his vision of what an effective approach to tackling climate change would look like. Having a background in economics, the author is very keen on free market solutions, yet also notes that the market we have today is not free and informed when it comes to the true cost of carbon. Helm advocates for appropriate carbon pricing through the implementation of a carbon tax. But by targeting carbon consumption, not production, and having a border adjustment tax on imported carbon-intensive products, one can attempt to deal with the aforementioned "carbon leak" problem. The revenues from these taxes can then be funneled into research that comprises the next part of the author's approach to climate change: future renewable technologies. As mentioned, Helm is skeptical of current renewable technologies, but more optimistic about potentially transformative future technologies and advocates for their continued research and development using the proceeds from carbon taxes. He offers no clear details on any particular future technology, which seems in line with his opinion against picking favorites. Finally, to bridge the divide while awaiting those future technologies, Helm encourages the idea of shale gas as a transition energy source. Being cheap, abundant, and lower in carbon emissions when compared with other fossil fuels, the author argues that natural gas will provide the necessary stability in our energy production while simultaneously allowing developing nations to achieve their own economic goals in a reasonable and environmentally conscious manner.

Overall, Helm offers unique insights into the discussion on climate change. While some readers from the scientific community might not like the harsh economic realities behind his criticisms, and while it's perfectly reasonable to question some of his criticisms, they are all most certainly worth reading. While climate change is an imminent threat, we cannot rely on continued alarmist calls for action if those calls are ultimately ineffective. One could argue over a market-driven approach being more effective, but if it shifts the needle in the right direction, it should definitely be worth consideration.

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My Nuclear Nightmare: Leading Japan through the Fukushima disaster to a nuclear-free future

by Naoto Kan, translated by Jeffrey S. Irish, Cornell University Press, 2017, hardcover $24.95, 200 pp., ISBN 978-1-5017-0581-6

This is a worthwhile story of politics based upon science and technology, written by Naoto Kan who served as Prime Minister of Japan during the Fukushima disaster, dealing with the initial earthquake, its initial effects and the recovery efforts.

In the prologue we learn how, as a university science student, he turned to politics. Kan learned to be against nuclear power via considering his government's reaction to the "Fukushima Disaster", and its interaction with the private corporation (TEPCO) owning the Fukushima reactors. Kan describes how the disorganized private corporation tried to walk away from the disaster. His government had to force all parties – the corporate executives, the technical and non-technical government officials, the politicians, the police and fire departments (local and national), and the military - to cooperate to minimize the damage and initiate the recovery process.

The long second chapter is a daily account of the bureaucratic processes and snafus from the viewpoint of Prime Minister Kan: "There was no bottom, so there was no choice but to work from the top down. Actually there was no 'Down' to go to, so the top (the prime minister's office) had no choice but to do the work… The reason there is no organization for the containment of a nuclear accident is because an accident was not supposed to occur."

The remaining two chapters describe Kan's resignation from office and give insights into the Japanese Parliamentary system. He ends up being strongly opposed to nuclear power and suggesting possible alternatives for the Japanese energy economy. Many other books have dealt with the scientific aspects of the Fukushima event, few have dealt with the political and social aspects as this book successfully does.

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Solar Energy: An Introduction

by Michael E. Mackay (Oxford University Press, 2015), 226 pages, ISBN 978-0-19-965211-2 (paperback) $40

Michal Mackay is a Distinguished Professor of Materials Science and Chemical & Biomolecular Engineering at the University of Delaware. The book is an introduction to a wide range of topics related to solar energy. It is divided into two parts: photovoltaics and thermal processes. The book came about from teaching a course on solar energy to upper level undergraduates and graduate students in the fields of chemical engineering, electrical engineering, materials science, mechanical engineering, physics and chemistry. On the back cover Mackay says the book "presents an introduction to all aspects of solar energy, from photovoltaic devices to active and passive solar thermal energy conversion, giving both a detailed and broad perspective of the field. It is aimed at the beginner involved in solar energy or a related field, or someone wanting to gain a broader perspective of solar energy technologies." This is not a book for a general audience. *Solar Energy* does the details with the requisite equations. It is a serious book with serious equations for the serious student. It is all here and there is a lot to chew on.

Mackay states his purpose to "present disparate, solar-based technologies so the reader can generalize the information and make a holistic decision when using this renewable energy source." Of the nine chapters, six of them focus on photovoltaics and three on thermal but there is a mixture which of course is unavoidable. The chapters with some of the specific chapter content in parenthesis:

1. Why solar energy is important (energy consumption)
2. Solar radiation (how much energy per area is available)
3. Basic principles (light absorption, photovoltaic devices, solar thermal)
4. Electrons in solids (semiconductor physics and some quantum physics)
5. Light absorption (macroscopic theory of absorption)
6. Photovoltaic devices (details of solar cell theory)

7. Solar chimneys and towers (movement of air in a chimney)
8. Flat plate solar energy collectors (including heat transfer)
9. Solar thermal energy generated electricity (Rankine cycle and optics to concentrate radiation)

One of Mackay's goals is to bring this vast subject together with a "consistent nomenclature." Due to the large scope of the book some laws are derived in detail from basic principles while others are given. I would like more links between equations and highlights indicating the importance of certain equations over others. The equations and subject matter all flow at one rate with few highlights of the most important material. On the other hand the author's examples were excellent and clarified the usefulness of specific equations.

Each chapter has textbook-type exercises. Some of the exercises are open-ended in the sense that not all the required information is available in the book, thereby "expanding the scope of the textbook with the ubiquitous WWW" as Mackay puts it. These exercises can, in many cases, be answered quickly; however, there are also details or layers to the problems when one begins to form an answer. Many problems could be large in scope, making it interesting to dig into the details. Things are not always as simple as they originally appear, and this is nice. Many exercises would make good group projects for presentation.

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