TEACHERS CLEARINGHOUSE
FOR SCIENCE AND SOCIETY EDUCATION
NEWSLETTER

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U.S. charts solar energy future

In 2020 only 3% of U.S. electricity was generated from solar energy. That's going to have to increase a lot if the U.S. is to reach a target of zero greenhouse gas emissions by 2050. The National Renewable Energy Laboratory has been modeling a way "to envision a decarbonized grid and solar's role in it," and it has resulted in a September 2021 publication of the U.S. Department of Energy (USDOE), *Solar Futures Study*. Building on the Department's earlier Sun Shot Initiative of 2011, whose *Sun Shot Vision Study* held forth the possibility of 27% of electricity from solar, the current *Study* determines that generation of 40% of U.S. electricity from solar energy by 2035 requires doubling the solar energy electricity generation every year in the early 2020s, then quadrupling it every year in the latter 2020s and thereafter.

Solar Futures Study investigates three scenarios relative to a base of 80 GW (gigawatts) of installed solar energy generation in 2020:

Reference Scenario, in which solar electricity generation has increased to 380 GW in 2035, resulting in a 45% reduction in greenhouse gas emissions from electricity generation relative to 2005, increasing to 670 GW of solar generation and a 61% reduction in greenhouse gas emissions from electricity generation in 2050.

Decarb Scenario, in which solar electricity generation has increased to 760 GW in 2035, resulting in a 95% reduction in greenhouse gas emissions due to electricity generation relative to 2005, increasing to 1050 GW of solar generation and a 100% reduction in greenhouse gas emissions due to electricity generation in 2050.

Decarb+E(for electrification) Scenario, in which solar electricity generation has increased to 1000 GW in 2035, resulting in a 105% reduction in greenhouse gas emissions due to electricity generation relative to 2005, increasing to 1570 GW of solar generation and a 155% re-

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Brits Build Back Greener

By legislating Net Zero emissions of greenhouse gases by 2050 in 2019, "pursuant to Section 14 of the Climate Change Act 2008," the United Kingdom became the first "major economy in the world" to do so. This legislation requires the UK to limit the increase in global temperature since the pre-industrial era to 1.5^{o}C in order to prevent increase of floods and torrential downpours that it is now experiencing. It means ending coal-generated electricity, petrol-fired cars, and deforestation.

The UK wants to "build back better . . . by building back greener." This also "means no longer burning fossil fuels for power or heating; . . new ways of making concrete, cement, steel; . . . the end of the petrol and diesel engine," according to *Net Zero Strategy: Build Back Greener*, published in October 2021. (p. 15) By moving first, this report continues, the UK can . . . make the birthplace of the industrial revolution the home of the new Green Industrial Revolution." (p. 15) The UK also looks forward to setting a good example for other nations to follow and the end of dependence on volatile fossil fuel markets. It has already reduced its greenhouse gas emissions by 44% while growing its economy by 78% since 1990 (largely from shifting from coal to natural gas in power generation).

Britain's *Net Zero Strategy* is built on a Ten Point Plan (pp. 30-33), whose principles are the following:

1. Advancing Offshore Wind – 40 GW plus 1 GW on a floating platform, with 10.5 GW already achieved in 2020)
2. Driving Growth of Low Carbon Hydrogen – 5 GW "low carbon hydrogen production capacity" by 2030
3. Delivering New and Advanced Nuclear Power – to include Small and Advanced Modular Reactors
4. Accelerating the Shift to ZEVs – no petrol or diesel cars to be sold after 2030
5. Green Public Transport – walking, cycling, ZE buses, rail electrification

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Raven advocates for global stability

Peter Raven, emeritus President of the Missouri Botanical Garden and Biology Professor at Washington University, spoke to the Washington University community via Zoom about his new memoir, *Driven by Nature*, on 11 October 2021, in a talk titled "Journey in Botany and Global Sustainability." As Raven revealed in his talk, his dual role as biology professor and President of the Missouri Botanical Garden dates back to 1884, when Henry Shaw, whose garden (historically known locally as "Shaw's Garden") was established in 1859, used it as the basis for a botany school at Washington U.

Raven recalled how his interest in science was stimulated by a book on insects his mother gave him while he was recovering from the measles at age seven. He also recalled benefiting from after-school science programs, a recollection that led him to be interested in providing such programs during his presidency of the Missouri Botanical Garden. But not until he reached graduate school did he realize that what he thought would be an avocation could become a career.

Among the things he did in his professional career was to see evidence for continental drift in the difference in plant species in New Zealand and Australia. But most important on his agenda today, at age 85, is advocacy about things that concern him because they concern the future of planet Earth. One of the reasons he gave for writing *Driven by Nature*, in fact was to document his change from academic science to advocacy for global stability.

Raven vociferously expressed his concern about climate change and its effect on evolution. Particularly endangered are plants which grow on mountains, whose habitats are shrinking upwards. Also endangered are plants living at the southern fringes of the Southern Hemisphere, whose habitats are shrinking toward the South Pole. When asked his feeling about E. O. Wilson's suggestion to preserve half the Earth in its natural state, Raven responded that the location of the preserved part was critical to determining which species would be preserved.

Raven also displayed a concern about future global population not heard since the passing of the late Al Bartlett. The world's population in excess of seven billion far exceeds its carrying capacity of 1.5 – 2 billion, he pointed out; and if everyone on Earth lived by U.S. standards, we'd need between four and five Earths. Furthermore, that not everyone lives by U.S. standards is a consequence of the social injustice resulting from economic inequity in the world's population. Achieving global stability requires a global outlook, he emphasized.

IN THIS ISSUE

The TEACHERS CLEARINGHOUSE FOR SCIENCE AND SOCIETY EDUCATION, INC., was founded at The New Lincoln School on 11 March 1982 by the late Irma S. Jarcho, John L. Roeder, and the late Nancy S. Van Vranken. Its purpose is to channel information on science and society education to interested readers. To this end it publishes this *Newsletter* three times a year. Thanks to funds from tax-deductible contributions, the Clearinghouse is happy to be able to offer its services for a one-time nominal charge. In order to continue offering its services for a nominal charge, it also solicits underwriting of its publications by interested corporate sponsors. All correspondence should be addressed to the editor-in-chief at 17 Honeyflower Lane, West Windsor, NJ 08550-2418 or via e-mail at <JLRoeder@aol.com>.

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Gangji advocates a culture of the love of learning

The first presenter at the 2021-2022 series of monthly programs of the PoLS-T (Physics Of Living Systems Teacher Network) organized by Professor Eric Mazur of Harvard University was Al-Karim Gangji of Queens College and Harris High School (New Hyde Park, NY). Following a "flipped classroom" protocol, participants were asked in advance to watch on Perusall the video which Gangji had prepared, "Changing the Culture for the Love of Learning."

Gangji began by speaking about the conceptual physics course he teaches to elementary education majors at Queens College. He said that teaching this course has enabled him to understand the mindset of students and probe deeper into their fear to understand what they consider to be difficult and abstract – which, combined with the language of mathematics, constitutes the subject matter of science. This fear, he said, is observed at all levels and stems from students' past experiences.

Rather than blame educators, Gangji blames the system for its reliance on teaching students how to take tests rather than evaluate them for their understanding, imagination, and creativity. This, he said, takes the joy out of learning. Because of this, he advises his students to chase knowledge instead of grades. Gangji conceded that he doesn't have a magic formula to evaluate students by these criteria, but he seeks to remove their fear of failing and enable them to enjoy learning and gain confidence.

Is the art of teaching, Gangji asked, out of synch with the joy of learning? Testing for memorized

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Garland promotes "physics identity"

The second presenter at the 2021-2022 series of monthly programs of the PoLS-T (Physics Of Living Systems Teacher Network) organized by Professor Eric Mazur of Harvard University was Catherine "Cat" Garland of the Community College of Vermont. Following a "flipped classroom" protocol, participants were asked in advance to watch on Perusall the video which Garland had prepared, "Cultivating a Passion for Physics: Everyday Actions for Developing Your Students' Physics Identity," using research conducted by the STEP UP program of the American Physical Society.

Identity relates to many things about us and what we do, Garland began. *Physics* identity arises from mental models about physics. Is it done only by geniuses or is it accessible to all? Is it done by white men or by diverse people? Does it consist only of equations or does it describe the world in many ways? And is it about not helping people or helping them? These are among the questions STEP UP has for people to ask to ascertain their physics identity, which, Garland said, is a significant predictor of students' persistence in physics. And students from underrepresented groups in the U.S. see themselves less identified with physics than white men.

How can we support students to develop their physics identities, Garland next asked. She went on to list five hypotheses to stimulate physical science career interest of female students:

1. All-girl physics classes.
2. Female physics teachers.
3. Female scientist guest speakers.
4. Discussing work of female scientists.
5. Discussing underrepresentation of women in physics.

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Thomas-Palmer describes Asynchronous Flipped Gameful Mastery Learning

The third presenter at the 2021-2022 series of monthly programs of the PoLS-T (Physics Of Living Systems Teacher Network) organized by Professor Eric Mazur of Harvard University was Jonathan Thomas-Palmer of Flipping Physics and Community High School, Ann Arbor, MI. Following a "flipped classroom" protocol, participants were asked in advance to watch on Perusall the video which Thomas-Palmer had prepared, "The Flipping Physics Journey into Asynchronous Flipped Gameful Mastery Learning."

In the journey Thomas-Palmer related in his prepared video, he found halfway into his 20-year teaching career in 2011 that flipped learning, in which watching prerecorded lectures is assigned as homework and class time is spent on laboratory work and problem solving, is a better alternative to classroom lectures. This prompted him to leave the classroom in 2013 to found Flipping Physics – with a mission to "make the world a better place through real, fun, and free physics education."

Two years later he returned part-time to the classroom using flipped learning, but then he realized that he "didn't like telling students what to do." This quandary was resolved when he learned about Gameful Learning (in which student progress is reflected in the number of points they accumulate), which he regards as Flipped Learning 2.0. He learned about it in a Massive Open Online Course (MOOC) on "Leading Change: Go Beyond Gamification with Gameful Learning," by Barry

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Gangji

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material regurgitated on a test is not consistent with understanding, he maintained. Turning to the AP Physics C course he teaches at Harris High School, he said that he has these students grade their own work, but he asks them to be hard on themselves, in order to establish a culture of learning with enjoyment. Independent and creative thinking are key to success and there is no single method to evaluate them, he averred. Therefore, he counseled that we need to find our own way to enable our students to experience the joy of learning for its own sake.

The following Q & A at the virtual discussion meeting on 25 September 2021 ensued: Gangji opened by observing that he gives quizzes with Column A for the "first try," and columns B and C for subsequent tries as needed. Mazur rejoined with a reference to students who feel that are having fun but not learning because they felt that learning couldn't be fun.

May Lerner asked how to structure assessment, and Gangji counseled maximizing opportunities for students to show what they've learned. He often has students write him self-evaluation letters. Mazur interjected that assessment leads to both feedback (how to improve) and a grade (where you stand).

Gangji observed that he has Physics Phridays for his AP Physics C students to help students in lower level courses. He added that it is important for students to have time to learn by playing and reiterated his concern that test prep courses don't teach anything but how to take tests. We should be preparing students to be thinkers – with compassion – he argued.

Joseph Bellina iterated the argument for high-stakes testing that it is to give science the attention it needs. Gangji rejoined that it takes time to persuade students used to a culture in which grades are important to learn for the sake of learning.

Garland

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Garland found that only the last of these five mattered, plus two other things:

6. Exploring careers of physicists
7. Everyday actions at school, such as the following:

   a) *Talking to individual students* – about why they are a good fit for physics; attributes they may not be aware of; encouragement to apply for physics-related activities; providing assurance; learning what they value.
   b) *Facilitating group work* – ensuring that all are taking active roles (no isolated group members); bolstering confidence with lab equipment; scaffolding collaboration skills (FORM → STORM → NORM → PERFORM).
   c) *Planning and assessing* – using real world examples of interest; clear and consistent grades; allow second chances.
   d) *Whole class instruction* – setting the tone in terms of expectations, a sense of community, a growth mindset, and valuing many types of skills.
   e) *Outside the classroom* – finding out who teaches students "feeding" into physics classes and what messages they are sending; talking about the "beyond physics" benefits of studying physics.

Those who had watched Garland's presentation on Perusall gathered on Zoom for a Q&A with Garland on 27 October 2021. Eric Mazur raised the question of the relationship between growth mindset and self-efficacy, and Garland responded that a growth mindset is absolutely essential to physics identity. She added that STEP UP is extending its efforts from women to other underrepresented groups in physics and that preliminary results are encouraging (The URL to access STEP UP materials is https://engage.aps.org/stepup/home).

Franklin creates Science 100

by John L. Roeder

A fellow Physics Teaching Resource Agent friend of mine named Don Franklin has written me about his work with the Openstax college collection of ebooks that can save students the high cost of college science textbooks. For a course he taught for Mercer University he needed a curriculum that stressed biology but included all the other sciences. Don wrote me that "The advantage of Openstax was that I could sort through their ebooks and find the components of Energy from each Science."

The result he called Science 100, from the course he taught at Mercer. "Students were adults returning to education after working a few years," he wrote. "This gave them an update from high school. It also fulfilled the requirement for rural schools." Science 100 has also been found useful for rural schools, from Northern Canada to Africa.

Science 100 consists of four sections: 1) "Energy and Metabolism" (biology); 2) "Energy Basics" (chemistry); 3) "The Behavior of Light" (earth and space); and 4) "Work: the Scientific Definition." If you feel that it would be useful for a course you teach, check it out at the following link: https://openstax.org/r/Science100. And if you are interested, Don Franklin would like to hear from you as well. His email address is <donfranklin8@gmail.com>.

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Physics Club of New York

Rayner-Canham: Women in Science

by John L. Roeder

Geoff Rayner-Canham, Chemistry and Environmental Science Professor at the Grenfell Campus of Memorial University of Newfoundland & Labrador, not only presented the last talk of the 2020-2021 season of the Physics Club of New York but also presented the first talk of the 2021-2022. His talk on 24 September was about "A Novel Course on Women in Science" which he has been teaching with Debbie Wheeler. Rayner-Canham characterizes the course as HERstory of Science, which seeks to identify important contributions made by women in the various fields of science in the context of their lives, identify factors which hindered or helped their progress, and recognize the contemporary issues faced by women scientists. Each week of the course covers six or seven sections of it, Rayner-Canham said, most of them case studies of individual women scientists and their contributions and life stories. The page on the website for the course has rich visual components with a youthful photo of the scientist, to which Rayner-Canham said young students relate to really well, and many of these pages also have videos to be viewed for enrichment. Some of these photos are included in the panel he sent us when we asked him to provide a brief taste of his talk to send our members in advertising it:

Cohen: "Buried Scientific Treasures"

by John L. Roeder

Science and technical writer Stephen Cohen spoke to the Physics Club of New York on 8 October 2021 about "Buried Scientific Treasures." The basis for this talk was the recently-released second edition (as both an e-book and in hard copy) of *America's Scientific Treasures* (Oxford University Press, 2020), which he has co-authored and describes sites with significant science and technology content from which adults can learn.

Cohen noted that art museums are typically thought of as being intended for adults, while science museums have been thought of as being for children. But he countered that science is important for *all*, and to this end he seeks for inclusion in his book sites from which high school students and older people can learn about science and technology.

Cohen seeks sites that have unusual collections – they could be museums or zoos, which have a focus on education, but they could also be natural sites (as in national parks), living history sites (which recreate science and technology practices of the past), historic sites (*e.g.,* the Joseph Priestley house), and factories

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Rae: "Arsenical Odyssey"

When University of Melbourne (Australia) chemist Ian Rae told the Physics Club of New York the title of his 12 November 2021 talk, it was "Arsenic: the rogue element that shows up everywhere." By the time Rae presented his talk, it was titled "An Arsenical Odyssey." Either title was appropriate for a most engaging tour of the many roles that element #33 has played throughout history and the world.

In addition to beginning with well-known properties of arsenic, Rae included some lesser-known curiosities – that it is one of only 21 elements with a single stable isotope and the fifty-second most abundant element on Earth, following uranium (#48), bromine (#49), and tin (#50). The first stop on his tour of the roles of arsenic was to note that it is mined with cobalt in the form of cobalt arsenide, then removed by roasting in the form of arsenic trioxide, which is used as a rodenticide. The cobalt remaining behind, Rae added, is used to make the cobalt blue glass bottles used to contain toxic chemicals.

Rae next turned to the role that arsenic plays in minerals. Orpiment, whose yellow color led to its use in fake gold "made" by alchemists and cited by Geoffrey Chaucer in the

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Cohen

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(Harley Davidson in York, PA). He added that science and technology can also be found in unexpected places. Cited examples were Mystic Seaport (Mystic, CT), the Arctic Museum (Brunswick, ME), the Paper Discovery Center (Appleton, WI), the Printing Museum (Houston, TX), Fort Clatsop in Lewis and Clark National Historical Park (Astoria, OR), Bartram's Garden (home of the Franklin tree in Philadelphia, PA), the Musical Instrument Museum (Phoenix, AZ), and the Glore Psychiatric Museum (St. Joseph, MO). Alas, Cohen also noted, science and technology sites come and go, thus rendering the first edition of the book (which came out in 1998) obsolete.

After illustrating the wide spectrum of places to learn about science and technology throughout the nation, Cohen then turned to focus on what is offered in our own locale. In New York City alone he cited the American Museum of Natural History, the *Intrepid* Sea, Air, & Space Museum, the New York Botanical Garden, the New York Aquarium, the Bronx Zoo, the Metropolitan Museum of Art (for armor, musical instruments, and Egyptian technology), and the Staten Island Museum (for its collection of insects and minerals). On neighboring Long Island is the Planting Fields Arboretum in Oyster Bay. And in New Jersey is the Edison Historic Site in West Orange (which contained Edison's chemistry laboratory as he left it upon his death in 1931, until OSHA required that the reagent bottles be emptied in the 1990s); the Information Age Science and History Museum and Learning Center in Wall Township; the Sarnoff Collection, formerly housed in the RCA David Sarnoff Research Center in West Windsor, now relocated to The College of New Jersey in Ewing; Historic Speedwell in Morristown; and the Sterling Hill Mining Museum in Ogdensburg.

If Cohen's presentation of this smorgasbord of places to learn about science and technology was the main course, the dessert of discussion that followed was the capstone of a perfect meal. Many mentioned additional science and technology learning sites that they had visited, and Cohen suggested that they might well belong in the third edition of *America's Scientific Treasures* – in another twenty years. With his Ph.D. coming in physical chemistry, Cohen lamented that there weren't more sites to learn chemistry but recognized the problem of disposing of products from exhibits presenting live demonstrations of chemical reactions. The alternative of videos was brought up, which is what the late extraordinary chemistry demonstrator Hubert Alyea used in his later years.

In his talk Cohen also lauded The Exploratorium in San Francisco as what might be called the gold standard of contemporary science museums, even the source of exhibits for science museums in other cities. I cite this at the end of this report because of a related anecdote that I forgot to share at the meeting but would like to share here. While I was teaching at Transylvania University in Lexington, KY, prior to coming to The Calhoun School, my undergraduate advisor, Edward D. Lambe, who had spent time on the staff of the Commission on College Physics, invited me to participate in a conference organized by the Commission. One of the members of my group at the conference was Frank Oppenheimer, younger brother of J. Robert Oppenheimer, director of the Manhattan Project. Frank was also a physicist and a member of the physics faculty of the University of Minnesota, but his membership in the Communist Party led to his ouster from that position. Mindful that I could engage a celebrity in conversation but not wanting to discuss unpleasantries that had occurred some 25 years in the past, I thought to ask him what he had been doing. Not until then did I learn that The Exploratorium was his brainchild and that he had been spending his time revolutionizing science museums to engage their visitors more actively. As he put it, "I've been working on an idea that if you've got five minutes to spare, you can learn something." That's the kind of "buried science treasure" that Cohen was talking to us about.

Rae

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canon's yeoman's tale in *The Canterbury Tales*, is As_2S_3. Erythrite is cobalt arsenate, $Co_3(AsO_4)_2$.

In addition to resulting from roasting cobalt arsenide, arsenic trioxide also results from roasting arsenopyrite, FeSAs, which is found mixed in with pyrite, FeS_2. Arsenic trioxide can be oxidized with concentrated nitric acid to form arsenic pentoxide, whose much greater solubility in water allows it to be sprayed as a pesticide. The example cited by Rae was its application to kill the prickly pear cactus. Another cited use of arsenic to kill the prickly pear was spraying arsenic trichloride (which is a liquid) and having moisture in the air convert it to arsenic trioxide and hydrochloric acid. Other pesticidal uses of arsenic described by Rae were the use of a water solution of arsenic trioxide as a "dip" through which cattle move for protection against ticks and the use of lead hydro-arsenate ($PbAs(OH)O_2$) mixed in a slurry with detergent as a spray on apple and pear orchards.

Arsenic also has preservative qualities. Along with copper and chromium, it preserves lumber and in doing so gives it a greenish tinge. It is also used in taxidermy. Now used to preserve a New Zealand-born race horse, Phar Lap, in a museum, it was also found to have been responsible for its premature death.

Although arsenic is notorious for its toxicity, it also has medical uses. Fowler's solution is one percent potassium

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Webinar highlights NOAA educational programs

On 9 December 2021 the United States Department of Education hosted a webinar to emphasize the importance of environmental literacy, with particular emphasis on the role of the National Oceanographic and Atmospheric Administration (NOAA) to promote it. The motivation for the webinar, host Patti Curtis pointed out, was the foreseen need for workers to fill the following green job openings projected for the decade, 2019-2029:

Job title	Median salary ($)	Number of jobs	Required degree
Biochemist/ biophysicist	94270	34600	Doctoral
Geoscientist	93580	31800	Bachelor's
Environmental engineer	92120	55800	Bachelor's
Chemist	79300	86700	Bachelor's
Environmental scientist	73230	90000	Bachelor's
Conservation scientist	64200	24800	Bachelor's
Environmental protection technician	46850	34700	Associate's
PV cell installer	46470	12000	High school
Hazardous material remover	45270	45000	High school

Curtis noted that environmental education is required to introduce students to these types of jobs. While the Department of Education is not allowed to develop or endorse environmental education curricula, they do recognize schools who are exemplary in their environmental education. Andrea Falkan, director of the department's Green Ribbon Schools program, described how schools are awarded this designation according to three pillars of criteria: 1) environmental impact and costs, 2) health and wellness, and 3) effective environmental and sustainability education.

Next five representatives from NOAA spoke about their programs. Sarah Schoedinger described how NOAA monitors the ocean and atmosphere to protect it as well as forecasts weather. It also has an education mission to support the future workforce and partners with the North American Association for Environmental Education (naaee.org). Schoedinger stated that environmental literacy involves knowledge, skills, dispositions, and behavior and emphasized the importance of community resilience education.

Shannon Sprague emphasized that environmental literacy K-12 is essential for dealing with the future and how NOAA supports this through Systemic School District Implementation. One specific program is B-WET (Bay-Watershed Education and Training), which leads to a MWEE (Meaningful Watershed Education Experience) and also provides watershed STEM program resources. Bronwen Rice, national coordinator of the B-WET program, noted that it can be implemented through the Afterschool Environmental Literacy program.

Bart Merrick spoke about NOAA's programs in place-based learning focused on local sites, NOAA in Your Backyard, NOAA's programs related to National Estuarine Research Reserves and National Marine Sanctuaries, and NOAA's Resource Collections. Frank Niepold addressed NOAA's efforts in climate literacy – educational preparedness to deal with climate disaster – and noted that NOAA is Congressionally-mandated to partner with diverse organizations for environmental education. Niepold concluded with NOAA's educational mission: "to educate and inspire the nation to use science toward improving ocean and coastal stewardship, increasing safety and resilience to environmental hazards, and preparing a future workforce to support NOAA's mission."

NOAA's educational resources can be accessed at <noaa.gov/education>.

Rae

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arsenite ($KAsO_2$), developed by Thomas Fowler in 1786. Almost a century later (1865) it was found to be useful in treating leukemia, as is also arsenic trioxide. Arsenic cigarettes have been developed for asthmatics. And arsenic is found in a treatment for syphilis, Salvarsan, developed in 1910 by Paul Ehrlich.

Depite the toxicity of arsenic, some have succeeded in developing a tolerance for it, most noteworthily the "arsenic eaters" of Austria, who ingested it for their well-being. One such arsenic eater found his way into Dorothy Sayers's *Strong Poison* as a murderer who killed his victim by sharing an arsenic-laced meal. Rae also noted the use of arsenic as a poison by Agatha Christie and most famously by Gustave Flaubert in *Madame Bovary*.

Rae reported that Michael Faraday was called to analyze whether arsenic had been used in an actual murder, but he turned the case over to his assistant, James Marsh. Marsh's approach to test for arsenic in a sample was to expose it to zinc in acid, which generates hydrogen and reacts with any arsenic present to form arsine, AsH_3, which forms a film of arsenic when burned. Rae pointed

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How Nuclear Technology can contribute to UNSDGs

As reported in our Winter/Spring 2018 issue, the United Nations in 2015 evaluated progress toward the eight Millennial Development Goals it had promulgated in 2000 to be achieved over a 15-year period. One outcome of that evaluation was promulgation of 17 Sustainable Development Goals to be achieved by 2030. According to the *World Nuclear News* for 26 October 2021, a "new report - titled *Nuclear's contribution to achieving the UN Sustainable Development Goals* - was produced through collaboration by the Canadian Nuclear Association (CNA), European nuclear trade body Foratom, the Japan Atomic Industrial Forum (JAIF), the Nuclear Energy Institute (NEI), the Nuclear Industry Association (NIA) and World Nuclear Association." The 24-page report, which can be accessed at <https://world-nuclear.org/getmedia/87cb4c06-9bbd-4c95-a1e4-a2d653b7a3ba/Nuclears-contribution-to-achieving-the-UN-Sustainable-Development-Goals.pdf.aspx>, devotes a page to each of the 17 goals, listing the short title for each goal, a broad statement of how nuclear technology can contribute to achieving it, followed by some specific examples and elaboration on those examples.

The short title and specific examples for each goal are listed as follows:

1. *No poverty.*
   Nuclear generation provides affordable and reliable electricity supplies without greenhouse gas emissions or air pollution.
   Investment in nuclear energy boosts economies and provides employment.

2. *Zero hunger.*
   Nuclear technologies help fight against pests, avoiding the need to resort to harmful pesticides.
   Using nuclear techniques to develop new plant breeds means that farmers can grow crops that need less water and that are more resistant to the impacts of climate change.
   Fresh food can last longer if irradiated, and this process also kills E. coli, listeria and salmonella.

3. *Good health and well-being.*
   Every year, nuclear medicine helps doctors diagnose and treat tens of millions of people.
   Nuclear materials are essential for medical research, as they are used to analyze specific molecules inside the body.
   Radiotherapy helps treat and cure many kinds of cancer.
   Irradiation is used to sterilize medical equipment, such as syringes and catheters.

4. *Quality education.*
   The nuclear industry offers long-term, high-skill jobs.
   Companies invest in training and education to encourage the development of a workforce with the skills required to construct and operate their plant.

5. *Gender equality.*
   Lack of access to clean, reliable and affordable energy disproportionately disadvantages women and girls.
   Nuclear companies have signed up to initiatives encouraging young women to move into STEM careers, and to provide training to prevent discrimination and fight against bias.

6. *Clean water and sanitation.*
   Nuclear energy has a central role to play in achieving universal access to clean water and sanitation.
   Desalination of seawater using heat generated by nuclear reactors produces pure, clean water, without the greenhouse gases emitted by the fossil fuel plants that power desalination units.

7. *Affordable and clean energy.*
   Demand for electricity is increasing, driven by a growing global population, increasing electrification of energy supply, and the needs of the billions of people who still don't have access to affordable and reliable electricity supplies.
   Meeting this increasing demand for electricity by burning fossil fuels is not sustainable. Switching to clean technologies such as nuclear energy is vital.
   If the world is to help lift people out of poverty and meet energy demand, then significant investment in low-cost, low-carbon nuclear energy is needed.

8. *Decent work and economic growth.*
   Construction of a new nuclear power plant generates thousands of jobs onsite and thousands more in the supply chain.
   The operation of a nuclear power plant provides hundreds of high-skill jobs for people in local communities for many decades.
   A nuclear power plant brings broader investment that benefits local economies.

9. *Industry, innovation, and infrastructure.*
   Innovative designs allow nuclear reactors to operate in new locations and enable decarbonization in new applications beyond electricity supply.
   High-temperature reactors will offer an alternative to fossil fuels for process heat and provide new options for hydrogen production.
   Innovations in nuclear fuel can enhance the performance of reactors in operation today.

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Nuclear Tech and UNSDGs

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10. *Reduced inequalities.*
    The overall generation costs of nuclear plants are less susceptible to price volatility than fossil plants. Rising fuel costs can have an inequitably high impact on lower-income households.
    Using nuclear power enables those countries with limited domestic fossil fuel reserves to have greater control over their own energy systems.

11. *Sustainable cities and communities.*
    Over half the population in the world's cities endures worsening air pollution. One major contributor to air pollution in cities is the exhaust fumes from petrol or diesel road vehicles.
    Using nuclear generation to recharge electric vehicles helps reduce transport greenhouse gas emissions as well as reducing air pollution in cities.
    Nuclear power plants can also be used for district heating, avoiding pollution from fossil fuels.

12. *Responsible consumption and production.*
    Responsible consumption and production should still allow everyone to enjoy a high quality of life, with sufficient energy supplies to enable the achievement of all of the Sustainable Development Goals.
    Nuclear power plants supply large amounts of electricity from compact sites, using fuel that has the potential to be recycled.

13. *Climate action.*
    The effects of climate change caused by anthropogenic (human-caused) emissions are numerous and far-reaching.
    Nuclear plants avoid the emission of over 2 billion tonnes of carbon dioxide each year.
    New nuclear power plants can be deployed at scale, enabling rapid decarbonization of a country's electricity generation mix.

14. *Life below water.*
    By generating electricity without producing carbon dioxide, nuclear reactors help reduce ocean acidification caused by burning fossil fuels.
    Nuclear techniques can help monitor the health of aquatic ecosystems.

15. *Life on land.*
    Nuclear energy plays an important role in preserving biodiversity, thanks to its uniquely small physical footprint.
    Mining for coal to power fossil fuel generation plants can result in destruction of forests.

16. *Peace, justice, and strong institutions.*
    Signatories to the Non-Proliferation Treaty undertake to not pursue a nuclear weapons program and cooperate on peaceful uses of nuclear technology.
    Nuclear techniques can also be used to detect weapons and drugs.

17. *Partnerships for the goals.*
    To implement the other 16 Sustainable Development Goals, governments, civil society, scientists, academia, and the private sector need to work together, combining their skills and expertise to be better able to achieve a common objective.
    Organizations such as CNA, Foratom, JAIF, KAIF, NEI, NIA and World Nuclear Association bring representatives of different nuclear companies together to work on areas of common interest and engage with other stakeholders.

Rae

(continued from page 7)

out that this happens because arsenic, as a metalloid (along with silicon, germanium, antimony, tellurium, and polonium), forms volatile hydrides and chlorides.

Rae observed that the exact mechanism of arsenic's toxicity is not known, but it is suspected to relate to arsenic's tendency to bond strongly to sulfur and could thus affect cysteines in proteins and cofactors lipoic acid and glutathione. The compound $HS\text{-}CH_2\text{-}CH(SH)\text{-}CH_2OH$ has been developed as an antidote.

Rae closed his arsenic odyssey with some interesting observations of the role of arsenic in particular species. Among them were 1) the presence of low-toxicity arsenobetaines ($(CH_3)_3As^+CH_2COO^-$) in several species of fish; 2) the ability of the plant *Ptoris vitatta* to sequester up to 7500 ppm by isolating it in special structures to keep it out of metabolic processes; 3) the concentrations of arsenic in the Bogong Moth, *Agrotis infusa.*

The ensuing Q&A elicited that arsenic is an element important in the semiconductor industry and that arsenic's presence in groundwater causes it to be absorbed by rice grown with it. Rae noted that arsenic can be removed from water with iron filings, which result in the formation of iron arsenate, but added that this would be impractical at the scale of agriculture.

Garland

(continued from page 4)

Garland pointed out that middle school is a level to interest girls in science but that physics is not differentiated until the high school level. She offered the following talking points to promote physics identity: 1. Physics is a way of thinking; 2. Physics is team-based; 3. Physics is accessible to everyone; 4. Physics is not just math.

Rayner-Canham

(continued from page 5)

The first week begins the course within the context of five female scientists and one male cited for his role in mentoring women scientists: Polly Porter (1884-1972), whose father limited her education to reading and writing but nevertheless became a crystallographer who mentored Nobel laureate Dorothy Hodgkin; Agnes Pockels (1862-1935), who, despite the lack of a university education, played an important role in the discovery of molecular films; Marjory Stephenson (1885-1943), a biologist who was barred from the Royal Society because of her gender and thus deprived of a Nobel Prize; Eunice Newton Foote (1819-1888), whose discovery of the heating effect of atmospheric carbon dioxide three years before that credited to John Tyndall had been overlooked until 2018; Alice Ball (1892-1916), who developed a treatment for leprosy and only recently has been credited for her work in tropical diseases; and Frederick Gowland Hopkins, recipient of the 1929 Nobel Prize is Physiology or Medicine for his discovery of vitamins, but more importantly a mentor to women in biochemistry.

The second week of the course goes back to the earliest women scientists: Fang and Keng Hsien-Seng (BCE), two Chinese alchemists who used mercury to extract silver from ores; Hypatia (360-415), who made contributions to philosophy, astronomy, and mathematics in ancient Alexandria; Martine de Bertereau (1600-1692), the first mineralogist, who was imprisoned because she was believed to be a witch; Marie Meudrac (1610-1680), who wrote a treatise on chemistry for the average woman; and Maria Merian (1647-1717), who was a naturalist and science illustrator.

The women scientists considered in the third week of the course are characterized by Rayner-Canham as "scientific ladies": physicist Laura Bassi (1711-1778), who earned the first doctorate in science, and mathematician Maria Agnesi (1718-1799), both at the University of Bologna and supported by Pope Benedict XIV; natural philosopher and mathematician Émilie du Châtelet (1706 -1749); Marie Lavoisier (1758-1836), who assisted her husband Antoine Laurent until he was beheaded in the French Revolution for collecting taxes for the King, later married Benjamin Thompson, Count Rumford; chemist, mineralogist, meteorologist, and translator Claudine Picardet (1735-1820); Mary Sommerville (1780-1872), who Rayner-Canham calls "the first women science superstar" and one of the first two women elected to be *honorary* members of the Royal Society; paleontologist Mary Anning (1799-1847); and Ada Lovelace (1815-1852), who worked on Charles Babbage's proposed mechanical general purpose computer. Rayner-Canham added that he didn't invent the term "scientific lady." Rather, it was in use in that period and one very useful book had it in its title: *The Scientific Lady: A Social History of Women's Scientific Interests, 1520-1918* – "a study of the rise (between 1650 and 1850) and subsequent fall in the custom for clever women to seek intellectual solace through scientific study." Indeed, until the end of the 19th century, science was considered a much more appropriate field of study for a woman than the classical education reserved for men.

The women Rayner-Canham and Wheeler consider in the fourth week of their course come from the chemical industry: Alice Hamilton (1869-1970), a physician who pioneered in industrial toxicology and occupational health; Annie Besant (1847-1933), one of the "match girls," who died from phosphorus poisoning in making matches and was a socialist and women's rights activist who gave voice to the match girls; Martha Whiteley (1866-1956), who worked with explosives and tests for mustard gas during World War I; Grace Fryer (1899-1933), one of the "radium girls" who experienced radium poisoning from painting watch dials with radium paint and using their mouth to bring the brush to a point, as portrayed in the book by Kate Moore and the film, *Radium City*, by Carole Langer, who showed her film at The Calhoun School on 30 November 1987, as reported in our Winter 1988 issue; Joan Hinton (1921-2010), who worked on the first nuclear weapons but fled to China in shock upon learning it was dropped on cities; and Karen Silkwood (1946-1974), chemical technician and union activist concerned about safety in nuclear facilities.

The fifth week of the course brings consideration of women in astronomy: Sofie Brahe (1559-1643), who worked alongside her more well-known brother Tycho; Nicole-Reine Lepaute (1723-1788), who predicted the return of Halley's comet; Caroline Herschel (1750-1848), who also had a more well-known brother who discovered Uranus but nevertheless discovered eight comets on her own; Maria Mitchell (1818-1889), first astronomy professor at Vassar College; Annie Jump Cannon (1863-1941), who catalogued about two hundred thousand stars at the Harvard Observatory and also contributed to our present system of star classification; Cecilia Payne-Gaposchkin (1900-1979), who began work at the Harvard Observatory but went on to earn the first astronomy Ph.D. from Radcliffe (Harvard's college for women), identify hydrogen and helium as the most abundant elements in stars, and became the chair of Harvard's astronomy department; Margaret Burbidge (1919-2020), who worked with her husband Geoffrey in understanding the processes of nucleosynthesis in stars; and Jocelyn Bell Burnell (b. 1943), who discovered the first pulsar only to have her supervisor Anthony Hewish credited for it as co-recipient of the 1974 Nobel Prize in physics.

The sixth week of the course turns to women in nuclear science: Marie Skłodowska Curie (1867-1937), who won a Nobel Prize in physics with her husband Pierre in 1903 for their early researches in physics and the Nobel Prize in chemistry on her own in 1911; Irène Joliot-Curie

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Rayner-Canham

(continued from page 10)

(1897-1956), daughter of Marie and Pierre who, with her husband Frédéric, won the Nobel Prize in chemistry in 1935 for their work on artificial radioactivity; Harriet Brooks (1876-1933), Canadian pioneer nuclear scientist who was Ernest Rutherford's first Canadian graduate student; Lise Meitner (1878-1968), second female recipient of a doctorate in physics in the world and the first at the University of Vienna, had worked with Otto Hahn before he and Fritz Strassmann discovered nuclear fission but had to escape Germany for religious reasons and was excluded from a Nobel Prize, yet co-interpreted Hahn's data and has element 109 named after her; Maria Goeppert Mayer (1906-1972), second woman (after Marie Curie) to receive the Nobel Prize in physics (1963) for the shell model of the nucleus; and Chien-Shiung Wu (1912-1997), who led the team that discovered non-conservation of parity in nuclear beta-decay but was not included among the recipients of the Nobel Prize, which was awarded to theorists T. D. Lee and C. N. Yang.

Week seven addresses women in mathematics and physics: Sophie Germain (1776-1831), who did work with Chladni patterns, elasticity, and number theory; Sofya Kovalevskaia (1850-1891), noted for her work in partial differential equations, but, as a woman, could not attend a Russian university or, without permission of her husband or father, leave Russia to study abroad; Emmy Noether (1882-1935), famous for her work on the relationship between symmetries and conservation principles in nature; Mileva Marić (1875-1940), fellow student and first wife of Albert Einstein, believed by some to have contributed to the special theory of relativity; Katherine Johnson (1918-2020), one of the "computers," so named because they computed flight paths for NASA, described by Margo Lee Shetterly in *Hidden Figures*; and Vivienne Malone-Mayes (1932-1995), a Black mathematician refused admission to Baylor University because of the color of her skin who later became a professor there.

In the eighth week, women in chemistry and geology are considered: Chika Kuroda (1884-1968), who traveled all the way from Japan to Britain to study chemistry and became noted for her work on the chemistry of pigments in local food plants; Erika Cremer (1900-1996), who invented the gas chromatograph in 1944; Dorothy Crowfoot Hodgkin (1910-1994), awarded the 1964 Nobel Prize in chemistry for her work in X-ray crystallography to determine the structure of biomolecules; Rosalind Franklin (1920-1958), whose work on DNA was deemed to be of Nobel quality but who died four years before the Nobel Prize was presented to James Watson, Francis Crick, and Maurice Wilkins; Alice Wilson (1881-1964), who is noted for studying the geology of the province of Ontario; and Marie Tharp (1920-2006), who co-created the map of the Atlantic Ocean floor and thus explained continental drift.

The women scientists in the ninth week of the course come from biology and biochemistry: Maud Menten (1879-1960), a Canadian noted for her work in enzyme kinetics (all biochemists have used the Michaelis-Menten equation for enzyme kinetics); Beatrix Potter (1866-1943), although better known in wider circles for *The Tale of Peter Rabbit*, also known in science for her work on fungi; Gerty Radnitz Cori, the third female Nobelist in science who shared the 1947 Nobel Prize in medicine or physiology with her husband Carl for their work on the catalytic conversion of glycogen; Barbara McClintock (1902-1992), who received the 1983 Nobel Prize in medicine or physiology for her discovery that genes can be mobile on their chromosomes; Rachel Carson (1907-1964), whose *Silent Spring* ushered in the modern environmental movement; and Elizabeth Hazen (1885-1975) and Rachel Fuller Brown (1898-1980), who discovered treatments for fungal diseases.

The tenth week considers "leaks from the pipeline." While boys were learning Latin and Greek, girls had more time to learn science, Rayner-Canham pointed out, and they did so from such books as *Conversations on Chemistry*, written by Jane Marcet (1769-1858).

Science as a male culture and feminist analyses of science are the focus of the eleventh week, which considers such science feminists as computer scientist Margaret Lowe Benston (1937-1991), and biographer of Barbara McClintock Evelyn Fox Keller (b. 1937), also Audrey Ralph Lee (1921-2021), who was forced to give up a teaching position at a Canadian university for lack of a Ph.D.

Weekly quizzes and the final exam counted for half the grade in the course, with students allowed to use their course notes, Rayner-Canham stated. Another 40% came from a required reflective journal. The remaining 10% came from weekly discussions; but Rayner-Canham felt that they were so good that he wished they had counted for more. He concluded his talk with the answers to the pictures of the female scientists he had displayed at the beginning of his talk (see next page).

Rayner-Canham's talk was so well received that one participant hoped that he would write a book so that others could teach the course. Little did we know then, but learned the next day from six articles he shared with us, that his wife Marelene and he had already written extensively on the subject – their 38th publication is due out soon. A complete listing of their recent bibliographic information appears on the next page.

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Brits Build Back

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6. Jet Zero and Green Ships – production of sustainable aviation fuels and zero emission hydrogen propulsion
7. Greener Buildings – heat pump installations
8. Investment in Carbon Capture Usage and Storage – 2 clusters by 2020, 4 by 2030, each capturing almost 10 Mt (megatonnes) CO_2 per year
9. Protecting Our Natural Environment – flood and coastal defenses, forest restoration
10. Green Finance and Innovation – funding for low-carbon technology

Added to this are "four key principles" (p. 16):

1. "Work with the grain of consumer choice" – no one required to give up a present heating system or car.
2. "Ensure the biggest polluters pay the most" – "through fair carbon pricing"
3. "Ensure that the most vulnerable are protected" – through "energy bill discounts and energy efficiency upgrades"
4. "Work with businesses to continue delivering deep cost reductions in low carbon tech" – "through support of the latest state of the art . . . to bring down costs for consumers and benefits for businesses"

Net Zero Strategy considers Britain's greenhouse gas emissions to be broken down among seven sectors, as follows:

1. <u>*Power*</u>. The role of this sector is to "generate electricity to meet low carbon energy demand across all sectors." (p. 64) "A clean, reliable power system is the foundation of a productive net zero economy as we electrify other sectors – so **we will fully decarbonize our power system by 2035**, subject to security of supply. Our power system will consist of abundant, cheap British renewables, cutting edge new

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Rayner-Canham

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Articles in the *Bulletin of the History of Chemistry*:

"British Women Chemists and the First World War," **23**, 20-27 (1999)
"Chemistry in English Academic Girls' Schools, 1880-1930," **36**(2), 68-74 (2011)
"Early Practical Chemistry at British Private Girls' Schools," **39**(2), 131-137 (2014)
"The Rise and Fall of Domestic Chemistry in Higher Education in England During the Early 20th Century," **36**(1), 35-41 (2011)
"British Women and Chemistry From the 16th to the Mid-19th Century," **34**(2), 117-123 (2009)
"Mary 'Polly' Porter (1886-1980): Pioneer Woman Crystallographer," **46**(1), 68-82 (2021)
"Out of Obscurity: Contextualizing Forgotten Women Chemists," invited paper, in press.

Books:

Women in Chemistry: Their Changing Roles from Alchemical Times to the Mid-Twentieth Century (Chemical Heritage Foundation, 1998) – profiles the work of 47 women chemists
Chemistry Was Their Life: Pioneer British Women Chemists, 1880-1949 (2008)
(eds.) *Creating Complicated Lives: Women and Science at English Canadian Universities, 1880-1980* (2012)
A Chemical Passion: The Forgotten Story of Chemistry at British Independent Girls' Schools, 1820s-1930s (Institute of Education Press)
Pioneering British Women Chemists: Their Lives and Contributions (World Scientific Publishing Co.)

Brits Build Back

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nuclear power stations, and be underpinned by flexibility including storage, gas with CCS, [and] hydrogen." (p. 19)

2. *Fuel Supply and Hydrogen*. This sector "supports energy supply, especially in areas that are harder to electrify such as heavier transport. Oil and gas play a far reduced role where needed and abated by carbon capture technology where possible." (p. 65) Uses of oil and gas not easily replaced by electricity will be met by hydrogen and biofuels. Oil and gas usage is slated to be halved by 2030 and replaced by the aforementioned 5 GW "hydrogen production capacity."

3. *Industry*. This sector "develops cleaner ways to produce the wide range of products we all rely on, from food and drink to iron and steel." (p. 64) In addition to transforming industries to use electricity and hydrogen fuel, the "four carbon capture usage and storage (CCUS) clusters" cited above are planned.

4. *Heat and Buildings*. The domain of this sector is "our public, business, industrial and residential buildings, as well as products we use for cooking and everyday living." (p. 65) After 2035 new heating systems will be electric heat pumps or hydrogen boilers, with the role of hydrogen to be determined in 2026. Before 2035 a three-year Boiler Upgrade Scheme will provide grants so that purchasing a heat pump will cost no more than a gas boiler. Gas and electricity costs will be adjusted to favor the former.

5. *Transport*. This sector covers "all forms of travel that keep modern society moving – road, rail, aviation, and shipping." (p. 65) *Net Zero Strategy* has a vision for the future of transport that calls for more walking cycling, electrified public transport, and ZEVs (zero emission vehicles). To achieve this, no petrol and diesel cars will be sold after 2030; all cars after 2035 must be "fully zero emissions capable"; and there will be no more all-diesel trains after 2040. The two forms of transport not lending themselves well to electrification are aviation and shipping. Sustainable aviation fuels are envisioned for the former, but the future energy source for maritime transportation still appears to need to be worked out.

6. *Natural Resources, Waste, and Fluorinated Gases*. This is a "catch-all" sector that includes "land, . . . including agriculture and the treatment of waste," and singles out fluorinated gases, used for refrigeration, because they are also greenhouse gases. (p. 64) To offset greenhouse gas emissions from this sector, *Net Zero Strategy* envisions replanting forests and the separate collection of food waste from other municipal waste.

7. *Greenhouse Gas Removals*. This sector "compensates any residual emissions to ensure a net zero system." (p.64) Among other things, greenhouse gas removals are needed to offset emissions from aviation, agriculture, and heavy industry. Greenhouse gas removals can be nature-based (like afforestation and soil carbon-sequestration) or engineered (carbon capture and sequestration (CCS) operations directly from the air or in conjunction with bioenergy are cited).

The following chart shows the percentage that each sector contributed to the UK's greenhouse gas emissions in 2019, the percentage reduction required between 1990 and 2035, the percentage reduction achieved between 1990 and 2019, and the residue of greenhouse gases expected to remain in 2050, to be offset by the "Greenhouse Gas Removals" sector:

Sector	% of 2019 emissions	% reduction required, 1990-2035	% reduction achieved, 1990-2019	2050 residue (Mt CO_2e)
Power	11	80-85 (w/40-60% demand increase)	72	1-3
Fuel Supply & Hydrogen	5	53-60	61	0-8
Industry	15	63-76	<50	3-10
Heat & Buildings	17	47-62	17	0-2
Transport	32	47-59	About 0 (domestic); -100 (air)	23-40
Natural resources, *etc.*	20	39-51	45	26-34
Greenhouse Gas Removals	NA	NA	NA	(-87)-(-53)

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solar energy future

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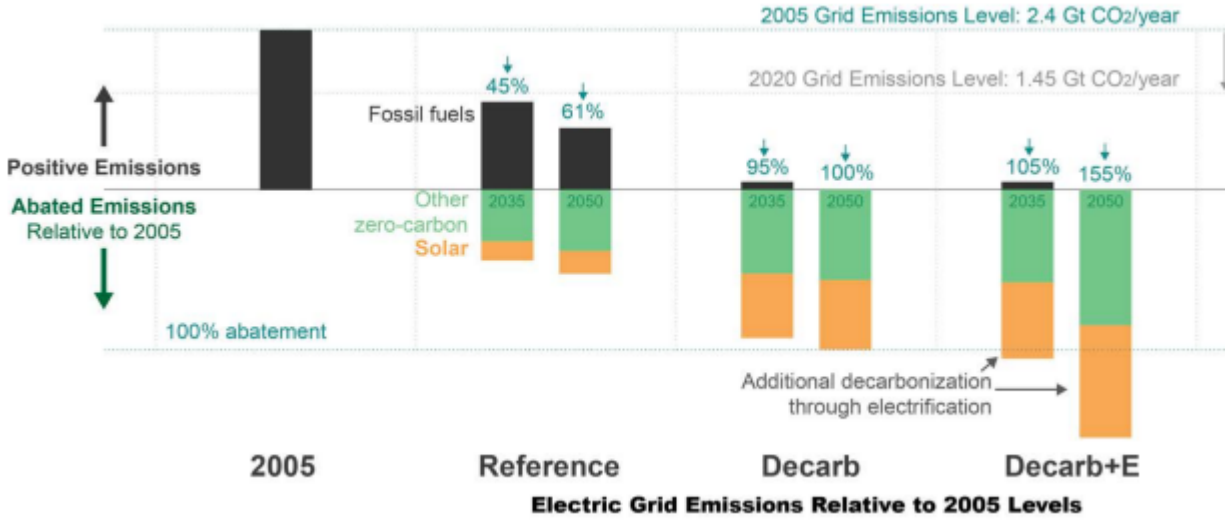
duction in greenhouse gas emissions due to electricity generation in 2050. (The reductions greater than 100% arise because the Decarb+E scenario envisions increasing non-carbon electricity generation to replace carbon dioxide-emitting fuels in other sectors, to provide 30% of the energy used in buildings and 14% of the energy used in transportation by 2050.)

The emission reductions and the increase in solar and other non-carbon energy sources to generate electricity for each scenario are displayed in the following bar graph:



Note that the aforementioned goal of 40% of electricity generation from solar energy requires other non-carbon energy sources to meet the targeted reductions in greenhouse gas emission, as shown in TWh (terawatt-hours) in the bar graph below, with solar the bottom layer in yellow, wind above that in cyan, nuclear in maroon, hydroelectricity in dark green, natural gas in the Reference scenario and biomass/geothermal in the others in purple in 2035, replaced by renewable combustion turbine in light green in 2050. Black is used for coal in the Reference scenario, and a gold layer for concentrated solar power is inserted over the yellow solar layer in the Decarb scenario in 2050. For the Decarb scenario in 2035, 37% of the electrical energy is to come from solar, 36% from wind, 11% from nuclear, 5% from hydroelectricity, and 1% biomass/geothermal. For the Decarb+E scenario in 2035, 42% of the electrical energy is to come from solar, 36% from wind, 13% from nuclear, 6% from hydroelectricity, and 1% biomass/geothermal. For the Decarb scenario in 2050, 44% of the electrical energy is to come from solar, 40% from wind, 4% from nuclear, 3% from hydroelectricity, and 1% biomass/geothermal. For the Decarb+E scenario in 2050, 45% of the electrical energy is to come from solar, 44% from wind, 5% from nuclear, 5% from hydroelectricity, 2% from hydrogen and other zero-carbon fuel, and 1% biomass/geothermal.

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Thomas-Palmer

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Fishman and Rachel Nismer, then spent 2017 planning the switch to Gameful Learning in his classroom after obtaining support from his administration and began implementing it in his classroom the second semester of 2018, with full recognition that such a paradigm shift in teaching would come with mistakes.

Thomas-Palmer's experience showed that students couldn't be as autonomous as he had hoped. They needed suggested due dates and need to have their progress monitored. They even asked for a smattering of lectures, he said. He also posts weekly progress reports of points accumulated *vs.* the number of points which should have been accumulated.

This is not "normal" teaching, Thomas-Palmer acknowledged, and he noted that the teacher must have all the course assignments laid out before the course begins. Furthermore, students are entitled to preliminary feedback before turning in their assignments. The time he spends on grading student work is continuous rather than in spurts, and all materials are provided digitally. This maximizes students' use of time, he said, because there is always something for them to do. It also allows for absences and "shakes up" lab groups, because students work with whatever students are doing the same labs. He also finds many students putting in extra time. Starting this year he is offering calculus-based physics concurrently with algebra-based physics, which is possible only because all students are learning at their own pace.

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solar energy future

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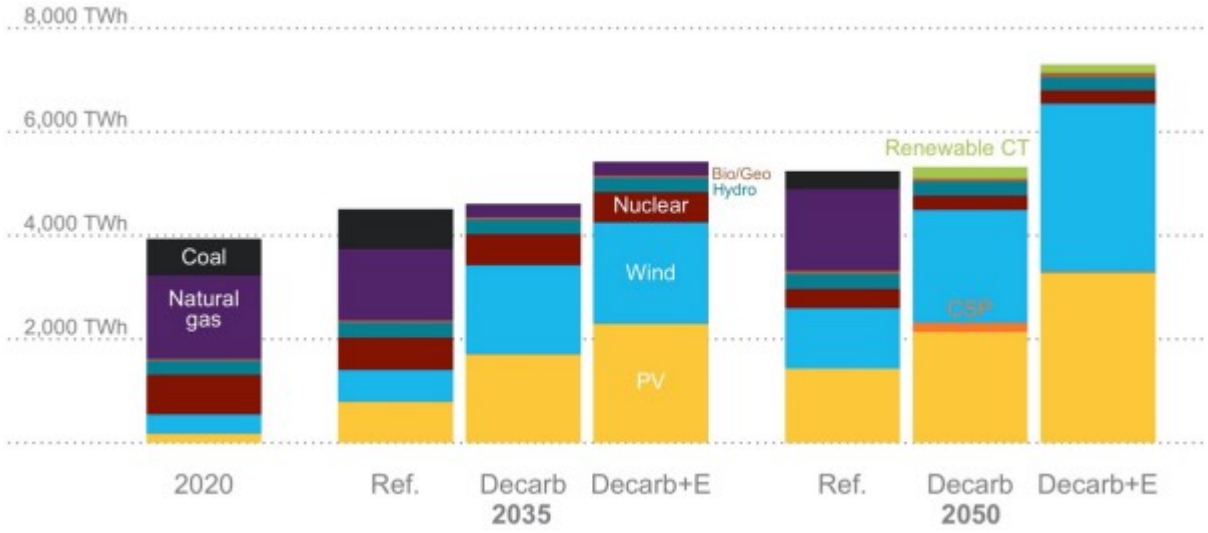
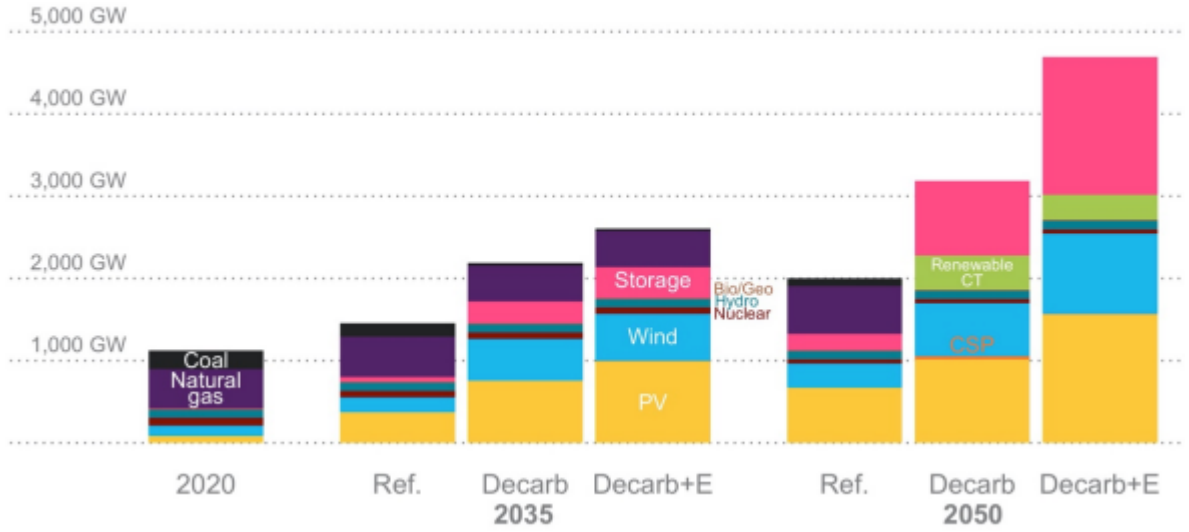


Yet another bar graph shows the installed capacity in GW, with an additional hot pink layer to indicate energy storage (needed to compensate for the lack of reliability of solar energy during the night and wind energy when nothing is blowing).



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Thomas-Palmer

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Each semester of Thomas-Palmer's course consists of about six "levels," each containing between five and 30 problems (at one point each), with a minimum of all of them or 10 required for credit; a six-point mandatory and optional worksheet; a six-point optional practice quiz; and a 25-point mandatory quiz. Most levels also contain 15-55 point labs and some have optional 15-30 point labs. Each semester has a 90-point group project. An 80% quiz score is required to pass, and students scoring lower must do corrections for half credit. Students scoring less than 60% on a quiz must also do a retake (there are five available versions of each one), with the final quiz grade being the average of both quiz grades. Students take quizzes when they are ready for them.

Thomas-Palmer pointed out that having most work done in the lab mitigates against cheating. Students are encouraged to learn from each other by working in groups on all assignments except for quizzes and final exams. He makes solutions to the assignments available, but students realize that just copying them or another student's work does not help them learn and prepare

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solar energy future

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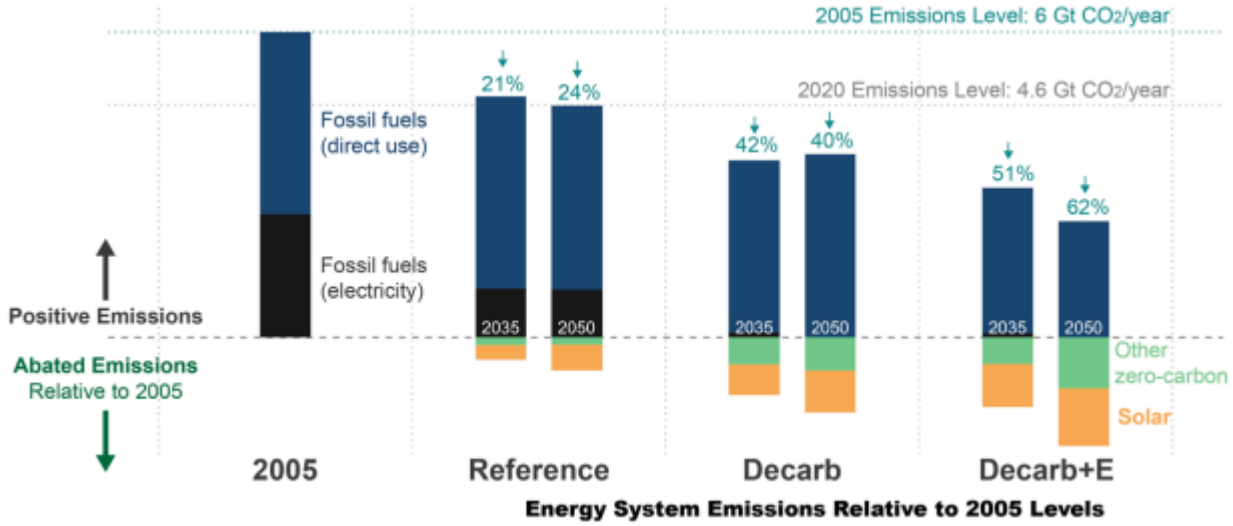
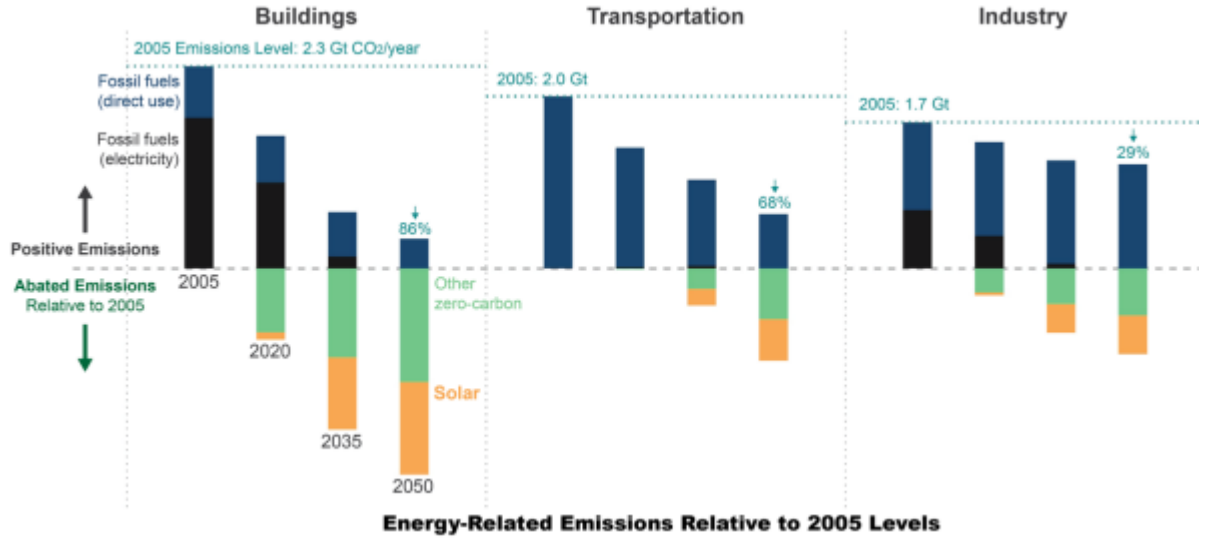
Note that while the Decarb scenario eliminates greenhouse gas emissions from electricity generation and the Decarb+E scenario also reduces emissions from other sectors, neither scenario eliminates all the greenhouse gas emissions from buildings, transportation, and industry. In 2035 the Reference scenario reduces total emissions by 21%, the Decarb scenario by 42%, and the Decarb+E scenario by 51%. In 2050 these percentage reductions become 24% for the Reference scenario, 40% for the Decarb scenario, and 62% for the Decarb+E scenario, as is seen from the following graph:



The Decarb+E scenario envisions that "solar electricity powers about 30% of all building end uses by 2050" and "around 14% of transportation end uses," (p. 17), as is seen in the following graph:



Solar Futures Study recognizes that only the Decarb+E scenario is slated to achieve a grid totally free of greenhouse gas emissions by 2035, as the Biden Administration has targeted, based on extending the *2035 Report*'s projection of a 90% "Clean grid," which was described in our Fall 2020 issue and also referenced by *Solar Futures Study*. It also recognizes that even the Decarb+E scenario doesn't achieve "net-zero emissions by 2050" (p. 1), another Biden Administration goal, as can be seen by the bar graph above.

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solar energy future

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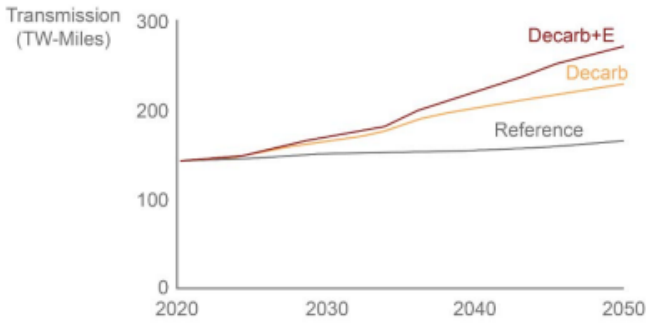
Because consumers expect the lights to go on when they flip the switch, the grid must have energy sources available to generate electricity 24/7. Because the Sun shines only during the day and the wind is not always blowing, neither of the two most abundant renewable sources of energy can meet this requirement for reliability. "Maintaining grid resource adequacy" and reliability, *Solar Future Study* states, requires zero-carbon energy sources that can be there when solar and wind can't, among them "hydrogen manufactured using zero-carbon electricity . . . CSP [concentrating solar power] with thermal energy storage, hydropower, geothermal, long-duration storage, nuclear, and natural gas with carbon capture and storage." The Study also notes that "distributed energy resources – electric vehicles, [other] batteries, and flexible loads" – can enhance both the reliability and resilience of the grid. (p. 13) These considerations become all the more important as the percentage of electricity generated from solar and wind increases.

In addition to the need for alternative energy sources to generate electricity when solar and wind aren't available, *Solar Futures Study* also considers situations in which these intermittent renewable sources can provide more energy than the grid demands. Four possibilities are considered: 1) "curtailment," which is a euphemism for, in effect, "wasting" the energy by letting it escape into the environment; 2) "shift it" (which means to store it for when it is needed later); 3) "shift it spatially" (transmit it to where it is needed); and 4) "shift demand" (by transmitting it to a flexible load, such as an electric vehicle).

The possibility of storing energy not immediately needed to generate electricity or transmitting to where it is needed points up that establishing a grid energized by sources that don't emit greenhouse gases requires more than just energy sources like solar cells and windmills. It also requires building associated infrastructure like storage facilities and (additional) transmission lines. The following graph shows the increase in transmission lines envisioned under each of the three scenarios considered in *Solar Futures Study*:



Land will also need to be acquired to emplace the solar collectors (and other sources of renewable energy) and the associated infrastructure, planning will need to be done for the recovery of materials for reuse at the end of their life cycle, and a diverse group of people will need to be hired to do the work. Although environmental justice considerations may argue in favor of producing solar collectors domestically, *Solar Energy Futures* states that the workforce in the solar industry is racially diverse. However, it is "disproportionately male."

Solar Energy Futures sees no obstacles to implementing any of the scenarios it considers in terms of land, materials, or personnel. In addition to reducing greenhouse gas emissions, the Decarb and Decarb+E scenarios offer the benefits of new jobs, relief for people of color from fossil-fuel energy systems, and reduced need for water.

Solar Energy Futures can be accessed online at <energy.gov/eere/solar/solar-futures-study>.

Thomas-Palmer

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them to do well on the quiz on which they must score 80%.

All of this combines to make Asynchronous (work done at students' own pace) Flipped (lectures at home and homework at school) Gameful (students score points from doing work) Mastery (proficiency needed to go to the next level) Learning in Thomas-Palmer's classroom.

At the ensuing virtual conversation on 20 November 2021, Thomas-Palmer acknowledged that the hardest part of teaching with a flipped classroom is making the videos. He makes them by himself in his basement, largely at his own expense, because he has found grant money for this type of work hard to come by. He has colleagues review his original versions, then does final editing, based on the feedback he receives. He estimates that two hours of effort go into every minute of a final video. Because of the time required to do his type of teaching, he is employed by his district at only 40% of full time.

Much of the conversation focused on the role of time management in Thomas-Palmer's Asynchronous Flipped Gameful Mastery Learning. He said that this approach gives him time to walk around to get to know his students and to monitor how they are spending their time in his class. He emphasized that student management of time is key to their success in his course. Working one-on-one helps some students struggling with time management, he noted, but every year there is a handful of

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RECOMMENDED SCIENCE AND SOCIETY EDUCATIONAL RESOURCES

1. Casey Crownhart, "What it will take to unleash the potential of geothermal power," *MIT Tech. Rev.* (8 Dec 21).

The Earth generates geothermal energy at twice the rate its inhabitants need it, but harnessing it is difficult and expensive. Not all locations have the requisite heat, fractured rock, and water within the typical seven kilometer drilling depth (150^{o}C is required to generate electricity). So only 0.3% of Earth's electricity is generated geothermally.

But, unlike solar and wind, which are intermittent, geothermal has the advantage of being a constant source of renewable energy – this article refers to it as "the only baseload renewable." Because of this, a geothermal electricity plant can generate two to four times as much as a wind or solar plant of comparable capacity, thus offsetting its higher cost of $3000-$6000/kW, compared with $1700-$2100 for wind and solar, although presently required paperwork can drag the construction time up to a decade.

The U.S. infrastructure bill allocates $84 million for the U.S. Department of Energy to build four geothermal demonstration plants, one of them in the eastern U.S., where conditions for accessible geothermal energy are least prevalent. A Department of Energy report is quoted as heralding the possibility of 60 gigawatts of electricity generated geothermally by 2050 (9% of total U.S. electricity generation).

2. Sammie Buzzard, "The surface hydrology of Antartica's floating ice," *Phys. Today*, **75**(1), 28-33 (Jan 22).

This is an excellent primer for one interested in the basics concerning the ice covering the South Pole and what has been happening to it. Buzzard distinguishes the Antarctic ice *sheet*, which covers the land mass of Antarctica, from the Antarctic ice *shelf* attached to it covering the Antarctic Ocean along three quarters of Antarctica's coast and accounting for 11% of Antarctic ice. Ice shelves, she points out, have already displaced their own weight of water, so their melting won't increase sea level. But they do restrict movement of land-based glaciers, and shelf melting allows glaciers to slide from land into water and raise sea level.

Buzzard also points out that 70% of Earth's fresh water is Antacrtic ice, which would increase sea level 58 feet if it all melted. Of greatest present concern is the breakup and disintegration of ice shelves because of their implications for climate change. In 1995, the Larson A Ice Shelf (the first of four parts) disintegrated, and the same fate befell Larson B in 2002. More recently, in 2017, the Larson C Ice Shelf lost an iceberg whose area exceeded that of A and B combined. Also during 2012-2016 the Antarctic Ice Sheet lost 199±26 gigatons per year. Snow falling on the sheet adds ice but also complicates the estimate of melting, leading to lake formation, which accelerates melting due to lower albedo. Water getting into crevasses in a shelf also furthers melting.

Because of the remoteness of Antarctic ice, measuring it relies on satellite photography, which can be obscured by clouds and thwarted by winter darkness. COVID-19 has also restricted gathering of data from monitoring equipment at field stations. In addition, computer models have been developed to understand ice shelf processes, which also apply to the Greenland ice sheet, which behaves like an ice shelf because water reaching its base can lubricate it and cause it to slide out into the ocean. Buzzard closes by noting that Antarctic melt has raised sea level by 7.6 mm between 1992 and 2017 and that polar response to climate change is slowed by water's high specific heat.

3. Tyler St. Clair and Kristen Conklin, "Paying the Price of Palm Oil," *Sci. Teach.,* **89**(2), 50-55 (Nov-Dec 21).

In reading this article you will learn that palm oil is found in an unbelievable number of household products, and these authors teach this to their students by having them read package labels, for not only the term "palm oil" but also for the many chemicals it contains. They then introduce the impact of the palm oil industry on biodiversity by giving their students an adaptation of a published study of the investigation of the impact of replacing natural forests by palm oil plantations in Malaysia by comparing the distribution of ant species in both types of territory. Their students also simulated the scientific ant counts by counting the number of sprinkles of different colors spread over a large piece of paper laid out in transects.

4. David Kramer, "A windfall for US carbon capture and storage," *Phys. Today*, **75**(1), 22-24 (Jan 22).

Funding for the "carbon capture, utilization, and storage (CCUS)" that figures into the British net zero plan described in this issue is also contained in the $1.2 trillion bipartisan Infrastructure Investment and Jobs Act which President Biden signed on 15 November 2021. The US Department of Energy now has over $10 billion to spend "over five years for demonstration projects and R&D": "$3.5 billion for direct air capture (DAC)," $3.4 billion

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REVIEWS OF SCIENCE AND SOCIETY EDUCATIONAL RESOURCES

Michio Kaku, *The God Equation: The Quest for a Theory of Everything* (Doubleday, New York, 2021). ISBN 978 -0-385-54274-6.

Richard Feynman said of string theory, "It may be true," and I concur. This excellent book of less than 200 pages retraces the history and ongoing search for a full and complete mathematical explanation that would embody all of modern physics: all there is and all that occurs in all time explained by a single comprehensive equation. Kaku thinks that can be string theory. And this is by far the best book on the Standard Model and string theory I have seen so far (but there may be many more books in the future on this topic).

However, I write this with some reserve; there are many undemonstrated assumptions included in the premise of this book, that a single, complete and universal descriptive equation can be written of all forces and objects found in the physical universe. But is that possible? In fact, it still remains to be seen, and it may be many decades before it is finally written; here it is only suggested as possible. Kaku thinks string theory will provide the so-called God equation. The God equation will account for all forces and all things.

I find his title misleading as well. From a book naming the Higgs particle as the God particle, this will now become the standard moniker for an all-encompassing Grand Unifying Theory to average readers. Kaku makes it clear the Standard Model is incomplete. Einstein's gravity theory still stands apart as it is a local theory and that makes it independent from the rest of physics. General Relativity still has no experimentally verified quantum field theory treatment, although each decade new observations endorse Einstein's General Relativity in all its bizarre predictions. An all-encompassing theory of everything must be universal; and it must account for all time, including the original conditions before creation and leading to the Big Bang. Exclude gravity and the Standard Model does mostly account today for most objects and behaviors concerning three of the four known basic forces. And the Standard Model makes a great start on that. But the Standard Model has over twenty unaccounted-for quantities – values including the relative strengths of the three forces it describes, basic quantities such as the quark masses, and many fundamental constants like G, Planck's constant, the speed of light, and the charge on an electron. Many universal values remain still theoretically unaccounted for. With numbers so basic to our physical understanding of the universe (and all of physics), these quantities, still unaccounted for and not well-understood, how they come into being still are the profound mystery as to why they are what we observe in nature. Are these numbers favorable to life? Unknown but essential for us to exist and for this actual universe to be as we observe? Values we know that clearly determine the universe as we know it. And why are there three dimensions of space and one of time that we observe? These concepts and features are fundamental and basic to the context of the laws we know as written. Yet we know so little as to why. Can there be additional dimensions? We can make conjectures but there seems no sure way yet to make verifications.

Many quantities have been measured and found to have particular values, and with gravity outside the accepted Standard Model, a theory of all seems still a profound mystery. Why are there three families of basic particles? Will probing higher energies reveal any more? A completely unified theory could show a way to determine these values; yet the Standard Model as currently known has no way to determine any of these terms. And neither does Kaku. He admits that string theory is missing in action about these fundamental numbers and as yet cannot account for any critical values in a unified physics in a godly equation. As one of the founders of string theory, Kaku recounts and reiterates these serious limitations; here he does a wonderful job. He is fully aware of the failures of string theory; that is his day job. But here he does an excellent job explaining what we do know. He shares his insights of modern field theory's accomplishments and cutting edge determined experimental efforts as he shows the actual extents and hard limits as a knowledgeable expert-observer discussing the quest and still unattained dream of the god equation.

This quest for a complete fundamental description of all has inspired many thinkers throughout time. Newton in his day created a unification of motion, force, and gravity. The mechanical universe resulted. Maxwell, acting on the many ideas and discoveries of many others was able to theoretically unify electricity and magnetism into a single electromagnetism as we now know. And quantum physics and field theory unified all atomic and nuclear phenomena into an understandable framework. Discussing a successful Standard Model, Kaku shines light on obscure issues that helped me understand and advance my understanding here. Yet how can we ever know we have accounted for all behavior and everything explained? Nature may not be rational; we are driven to discover patterns. And nature may be complicated, intricate and mysterious; and may be unknowable. And it may well be we already know enough to account for a complete theory of all as Kaku asserts. But this is not done, only in a beginning.

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This book is strong, clear, full of deep enlightening insights. Kaku explains the math with his command of the material by adding meaning to many mystifying numerical processes and terms. His bold assertion is that string theory now holds great promise. This book is a well explained further addition from a modern expert in so many ideas. We know Kaku as the author of many bestselling books like *Hyperspace* and *The Physics of the Future*. As an effective popularizer, Kaku includes many well-known examples in this book that he employs when presenting it on television and radio. With mention of those nascent musings of atoms and harmony, two original ideas taken from Democritus and Pythagoras, Kaku sets the stage with ideas first hypothesized to unify and explain. And as with the concepts of atoms and harmony, he holds that we should expect string theory to eventually become something really useful and important. But will it take thousands of years? So, after reading his account of string theory, I now agree. Kaku is best able to explain the details; he knows the many pieces that fit together so well into the picture-puzzle of the many particles and forces that make up the physical universe. Kaku as a teenager observed upon Einstein's death that all attempts to unify physics were unsuccessful; and he decided to dedicate his studies and efforts at the unification of all theories, the biggest ideas there could be. To pick up that strand of a Grand Unified Theory Einstein had left unfinished when he died, Kaku was driven to accomplish what Einstein had failed at. As a young man, Kaku set out to study how symmetry and unification could account for all of physics in one equation. Determined not to make hydrogen bombs but to understand the whole of creation – the universe – Kaku has made this his life's work. What conditions existed before the Big Bang were the context that makes this particular universe possible? Where Einstein had failed, Kaku may have succeeded. His efforts creating and developing string theory over the past years have begun what now seems to me a credible, final and complete unification of all physical law into one complete equation he calls "The God Equation." This book is a clear exposition as to why I believe he has begun the effort.

- Jack DePalma

(*Editor's Note*: Jack Depalma is President of the Physics Club of New York.)

Jonathon Porritt, *Hope in Hell: How We Can Confront the Climate Crisis and Save the Earth* (Earth Aware Editions, San Rafael (CA), 2020). 312 pp. $22.17 (Amazon). ISBN 978-1-64722-361-8.

Jonathon Porritt is the founder and director of Forum for the Future (https://www.forumforthefuture.org/), which includes "Reinventing the way the world works" in the "About us" link on its website. Porritt has extensive involvement in the climate emergency movement. In the introduction to the book, he wrote "I have never read a more compelling, intellectually robust election statement on climate change than the Biden/Harris Plan for a Clean Energy Revolution and Environmental Justice." He is ambitiously inspired by the plan.

Porritt opens chapter 2 with a quote from Nelson Mandela: "It always seems impossible until it is done." To many people deeply involved with addressing the climate emergency challenge, we have reached a point where resolving the problems seems impossible. Porritt indicates that both optimists and pessimists excuse themselves from acting.

Anyone who is even only vaguely involved in the climate emergency is aware of the IPCC reports. Porritt indicates that the 2018 Special Report "spelled out what's really going on." A number of small nations have indicated that anything close to a 3.6^{o}F rise would result in the submersion of their nations. Included on pages 29 through 30 is the Summary for Policy Makers from the 2018 Special Report.

Good and surprising news is reported in the following chapter, "The Power of Technology," where Porritt reports that by 2024 the last coal-fired power stations in the UK will close, just as large increases in offshore wind power production come online. Among the number of data tables in the book, one provides information about contributions of renewable energy to five large industrial economies. One of the examples of a transition to renewable energy is Porritt's report that "In January 2020, [KIA] announced a five-year, $25 billion strategy to shift [one fourth of its sales to EVs]." I expect that a year from now my wife and I will be driving a KIA EV instead of the model we have enjoyed driving since 2011. Porritt goes on to advocate that we should be thinking of EVs as a temporary stopgap, which should be replaced by urban mobility systems, "where nobody will ever again need to own their own car."

Part 2 of the book is titled "The Climate Emergency." Going forward I will use that phrase to identify the climate challenges we face. An emergency is an event that must be addressed promptly, as opposed to a crisis which most likely could have a devastating outcome but is currently not a frightening threat. In the first chapter in Part 2, "Tell the Truth," Porritt writes of the UN Secretary General's Special Representative on Disaster Risk Reduction reporting that climate-related disasters are now occurring at a rate of about one per week.

Chapter 3 is titled "Melting Ice and Rising Seas," and Porritt includes data about rising sea levels. Greenland is

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a place that includes an ice sheet that measures 3,142 million million (3.142×10^{15}) tons, and in 2019 about 485 billion tons of that ice melted, half of that in July! Data about the extent of glacier retreat is also reported. Sea-level rise is identified as a threat multiplier. The chapter titled "Feedback Loops and Tipping Points" includes information from a book written by Professor Peter Wadhams, *A Farewell to Ice*. The chapter concludes with information about geoengineering, including details of a \$265 million ($\$2.65 \times 10^8$) experiment, comparing that expense with the contract a renowned Brazilian soccer player signed in 2017 for $\$2.65 \times 10^8$! At the end, Porritt wonders which parts of the "Climate Emergency" some climate campaigners are not hearing.

A quotation by British historian and author C. Northcote Parkinson opens the chapter titled "Out of Time? Just in Time?": "Delay is the deadliest form of denial." The author includes information about a paper published in 2018 written by climate emergency campaigner Professor Jim Bendell, who wrote of Inevitable Near-Term Human Extinction (INTHE).

Part 3 of the book, "Confronting the Emergency," opens with a quote from Greta Thunberg; "So everyone out there: It is now time for civil disobedience. It is time to rebel." Porritt writes of 1800 jurisdictions and municipalities that have declared a Climate Emergency. In a later chapter information is included about 28 countries/ regions that have enacted a tax on carbon. The contribution to increasing greenhouse gases by the agricultural industry is described in the Chapter titled "Peak Meat." Included is the statement that "Agriculture is responsible for 70 percent of all freshwater use in the world today."

Porritt analyzes the history of tackling the climate emergency and the things that stood in the way. His analysis includes the statement, "What really stood in our way then, and still does today, is a powerful, ruthless, self -serving political elite that will brook no barriers to further enriching itself at the expense of the whole of the rest of humankind." He also examines the evolving situation of democracy being at risk. In a section titled "Democracy First," Porritt quotes Astra Taylor, author of *Democracy May Not Exist, But We'll Miss it When it's Gone*: "Our democratic movements must be guided by a deceptively simple question: what kind of ancestors do we want to be?" He later writes that "…a tiny number of politicians dependent on the continuing success of [fossil-fuel based] industries are undermining the livelihoods and the life chances of the whole of the rest of humankind."

Things that give the author hope include the continuous improvement in solar cell efficiency. He notes that solar cells currently produced operate at an efficiency of 20 to 30 percent, and that there are protypes that are about 35 percent efficient, writing, "Commercializing that kind of efficiency gain would represent a further massive breakthrough." He also notes that in 2018 India was ahead of projections for solar installation, and has plans to have 100 gigawatts installed by 2022. Writing of wind power, Porritt indicates that the UK leads the world in offshore wind capacity and that "Offshore wind is now significantly cheaper than nuclear power."

Identifying the challenge presented by Russia and China (they did not have leadership representation at the Conference of Parties 26 in Scotland), Porritt writes of the Thunberg effect. He describes the actions of young people from those countries despite the inaction of their national leadership. He concludes the book by writing, "Who knows what lies beyond this decade? But if we haven't dramatically changed our ways by then, genuine hope will have become the scarcest resource on earth."

I spend time on Climate Emergency issues nearly every day. I expect my four grandchildren will be alive in 2121, and I want the climate they experience then to be a minimal threat. Porritt's book both inspires and encourages me.

\- Frank Lock

(*Editor's Note*: Frank Lock is a retired high school physics teacher and Climate Reality Project Leader and Mentor.)

Henry Kissinger, Eric Schmidt, and Daniel Huttenlocher, *The Age of AI And Our Human Future* (Little, Brown, New York, 2021). 254 pp. $30. ISBN 978-0316273800.

In the preface of this book the authors identify exactly what artificial intelligence is and what it is not. They write that it is not an industry, a single product, or a "domain." They indicate that it is an enabler of scientific research, education, manufacturing, defense, transportation, advertising, and more. The authors go on to indicate six questions they say they only begin to answer, including "What do AI-enabled 'best friends' look like, especially to children?" and "When AI participates in assessing and shaping human action, how will humans change?" Also listed are attributes AI does not possess, including empathy, curiosity, and worry.

In the chapter titled "Where We Are," an MIT research project investigating a strongly antibiotic-resistant strain of bacteria is described. This project was chosen because the MIT researchers "invited AI to participate." In the end the AI was quickly able to identify an antibiotic that it predicted would be effective, did not look like any existing antibiotic, and would be nontoxic. The AI chose this antibiotic from 61,000 possibilities. The researchers identified the drug as halicin (the reason for that name is

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interesting), and the authors describe it as "triumphant" and write, "Humans could not articulate precisely why it worked. The AI did not just process data more quickly than humanly possible; it also detected aspects of reality humans have not detected, or perhaps cannot detect." (To read more about halicin, see https://news.mit.edu/2020/artificial-intelligence-identifies-new-antibiotic-0220).

Considering whether humans will think of AI as a tool, a partner, or a rival, the authors write, "The advent of AI will alter humanity's concept of reality and therefore of itself." Chapter three puts AI in historical context and includes information about the "imitation game" developed by Alan Turing, which he developed to analyze machine intelligence. Machine learning algorithms are explained. They consist of steps for improving imprecise results. Details of a Defense Advanced Research Project Agency (DARPA) program called Alpha-Dogfight are provided. The program is an AI aviator program which the authors indicate has outperformed humans in simulated aerial combat. They indicate that AI is poised to significantly impact military and civilian aviation.

The operation of neural networks is described in chapter three. These networks proceed through a training and inference phase, then develop a model. A challenge of deploying machine learning, the fact that differing goals require different training strategies, is also described. The authors identify three forms of machine learning as worth noting: supervised and unsupervised learning, and reinforcement learning. They then inventory current uses of AI including in agriculture, disease detection, finance, translation, energy production and use, to name a few. In writing about AI search engines, the authors write, "AI can remember the things a search engine has been asked before." Remembering is a human function, so I would prefer the word "process" to "remember." (One synonym for "remember" is "call to mind.")

The risks of AI are analyzed. The authors write, "We must all pay attention to AI's potential risks. We cannot leave its development or application to any one constituency, be it researchers, governments, or civil society." They also indicate that AI does not possess common sense, and that professional certification, compliance-monitoring, and oversight programs for AI are crucial.

In a section titled "The Dream of Artificial General Intelligence" (AGI) the authors differentiate between AGI and "narrow" AI, indicating that AGI must be able to complete any task of which humans are capable. They conclude the chapter by stating, "AI will transform our lives and futures. We must all ensure that AI is not created in isolation and accordingly, pay attention to both its potential benefits and its potential risks."

The fourth chapter deals with global network platforms. In analyzing how AI has changed navigation, the authors write of the process that was used before AI-enabled GPS, and that few have considered what a revolutionary change this is, or its consequences. They describe the process as a system in which human and machine intelligence are collaborating. They write, "The prevalence of this type of constant AI companion is likely to increase."

The authors make a good effort to predict where AI-enabled platforms may take humanity. They write that human perception and experience has rarely been global or universal, and that now, "Day-to-day reality is accessible on a global scale, across network platforms that unite vast numbers of users. The human mind has never functioned in the manner in which the internet era demands."

Chapter five presents an analysis of the role of AI in security and world order, indicating a race for an AI advantage is currently taking place between the U.S. and China, and "to some extent Russia." The authors indicate that they believe that once they are released, AI-facilitated cyber weapons may have the ability to adapt and learn well beyond their intended targets, and they write, "(Humans must) retain the ability to monitor and turn off or redirect a system that has begun to stray."

In discussing the impact of AI on civilian and military technology, the authors stress the importance of developing a common concept of limits. They write that if this is not done, "The compulsion to act first may overwhelm the need to act wisely." A dilemma of the age of AI is that the technology will be used widely, mastered, and employed.

Writing of AI use in international relations, the authors believe that strategists must integrate it into a responsible pattern. They write, "Before weapons are deployed, strategists must understand the iterative effect of their use, the potential for escalation, and the avenues for de-escalation." A great deal must be considered as AI weapons are developed, let alone deployed.

Describing AI as an interlocutor with a different perception, the authors address adjustments humans will make when working with AI as a partner, which they describe as "a shift in human experience more significant than any that has occurred for nearly six centuries." This is anticipated as being empowering, gratifying, and at times startling. Most startling for many people may be when they interact with AI unexpectedly or are presented with answers from AI when assistance was not requested.

In a section titled "Education and Lifelong Learning," the authors anticipate a future in which children grow up

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with AI assistants that are babysitter, advisor, tutor, and friend. They see the potential for individuals to prefer interaction with their AI partner to interaction with fellow humans. There are changes that may occur in such things as play, socialization, and development of imagination. In describing a new human future the authors indicate that "Society and their leaders will have to choose when individuals should be notified that they are dealing with AI as well as what powers they have in those interactions." Advisory bodies, such as the National Security Commission on Artificial Intelligence, are being formed. (To read the final report of that commission, go to https://www.nscai.gov/)

In a section titled "Perceptions of Reality and Humanity," the authors indicate that the AI revolution will occur quickly, and that "The age of AI has yet to define its organizing principles, its moral concepts, or its sense of aspirations and limitations." They describe AI as another sophisticated entity and indicate that it hastens dynamics that erode human reason.

An important problem identified by the authors is that the creators of AI are concerned with the applications they seek to enable as well as the problems they seek to solve. The jeopardy in that approach lies in the potential to produce "a revolution of historic proportions." The dilemmas raised by AI include questions about who should regulate it, who should deploy it, and how it should be scrutinized. The importance of developing a concept of arms control for AI is crucial, in part due to the fact that the divisions between offense and defense are currently unclear.

The authors write, "New technology has been developed, but remains in need of a guiding philosophy." They indicate that the U.S. must make high priorities of exploring the scope of AI, studying its implications, and beginning the process of reconciling with it. The last sentence of the book, "Now is the time to define both our partnership with artificial intelligence and the reality that will result," is a proposal that must be implemented.

This book provides valuable information about the current state of AI and its potential to mold our future. More than fifty-nine percent of people on our planet are connected to the internet and so are influenced by AI. Those people, and especially those in leadership positions, need the information the book provides. Forewarned is forearmed!

\- Frank Lock

James Gustave Speth, *They Knew: The Federal Government's Fifty-Year Role in Causing the Climate Crisis* (MIT, Cambridge, 2021). xxviii + 274 pp. $27.95. 978-0-262-54298-2.

Speth is a retired law professor who served as Chair of the US Council on Environmental Quality under Jimmy Carter, cofounded the World Resources Institute and Natural Resources Defense Council, and administered the UN Development Programme (1993-1999). The origin of his new book dates to 2010, when Julia Olson, inspired by James Hansen's *Storms of my Grandchildren*, founded Our Children's Trust (OCT) as a public law firm to represent youth in lawsuits against governments to "save our children's only planet from government-sanctioned climate destruction," (p. xi) by making the case that these governments have sanctioned an energy system dominated by fossil fuels. Of the lawsuits OCT has filed in seven U.S. states and more than 20 foreign countries, one of them was *Juliana v. United States*, filed in Eugene, OR, on 12 August 2015. An appendix written by Olson and Philip Gregory describes how governmental legal maneuvers have prevented this case from coming to trial thus far.

The basis for *Juliana* is "a state-created danger claim under the Due Process Clause" (p. xix) of the U. S. Constitution, which "arises where (1) 'the state affirmatively places the plaintiff in danger' and (2) the state 'act[s] with "deliberate indifference" to a "known or obvious danger."'" (p. xix) The plaintiffs' intent is that, by establishing that the U.S. government has by its energy policies placed children in danger to which it has been deliberately indifferent, the courts will mandate that future energy policies reduce atmospheric carbon dioxide concentration to "below 350 parts per million before the year 2100." (pp. xi-xii) Speth wrote an expert report in 2018 for the *Juliana* lawsuit and will present it as an expert witness at the trial, if and when it occurs. Meanwhile, OCT has published his report, updated to include subsequent events during the Trump presidency, as the text of *They Knew*, so that it can be made available to the general public. Olson and Gregory introduce it with an explanation of the origin and basis of the *Juliana* lawsuit.

Speth's text of *They Knew* is a chronological history of what has been learned about the effect of carbon dioxide emitted from the combustion of fossil fuels on climate at the level of presidential administrations. The first chapter is devoted to what happened before Jimmy Carter, and the seven following chapters describe what happened in the administrations of each of the seven presidents that came after.

In spite of what was known at the outset of the Carter Administration about the eventual climatic impact of carbon dioxide from fossil fuels combustion, the more immediate energy problem was a shortage of oil for transportation, framed by the OPEC oil embargo of 1973-1974. America was oil-poor but coal-rich. Therefore, in

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addition to expanded drilling for oil on the Outer Continental Shelf, Carter established the Synthetic Fuels Corporation to facilitate production of oil-substitutes from coal and oil shale. Neither of these measures made much impact on the Carter years, and Speth writes that "the United States was about 90 percent dependent on fossil energy at the beginning . . . and close to 90 percent at the end; there was only a slight decline in fossil dependency of 2-3 percent. Meanwhile, the fossil fuel mix was shifting toward coal and away from oil imports." (p. 36)

The energy policy of the Reagan administration was to support the development of fossil fuel resources, especially oil and gas, by deregulating their markets and increasing the amount of federal land available for gas and oil leases, while easing environmental restrictions on wastes from oil and gas extraction – and to relegate development of renewable energy resources to the private sector. More research on the effect of greenhouse gases on climate would be needed before taking any action.

Speth sums up the G. H. W. Bush administration's actions on climate change as follows: "Admit that it's happening on the one hand, but at the same time, cast doubt on the science, while supporting the fossil fuel industry and expanding fossil fuel development on the other hand." (p. 83) During what Speth calls the "first Bush" administration, the U.S. signed (on 9 May 92, and U.S. Senate ratified, Oct 92) the UN Framework Convention on Climate Change (UNFCCC), after weakening it. The Convention commits its signatories to "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system." (p. 80)

Although the Clinton administration recognized the need to take action to reduce greenhouse gas emissions for the sake of future generations (important in an expert paper for a suit brought by youth plaintiffs), its efforts to facilitate supplying the U.S. with continued supplies of oil and natural gas led to continued greenhouse gas emissions. Moreover, it did not increase the CAFE standards or regulate carbon dioxide as a pollutant. The 1997 Million Solar Roofs Initiative (finally achieved in 2016) and the 1999 Wind Powering Initiative led to benefits in later years, but not during the Clinton administration.

"The Kyoto Protocol was the first major agreement aimed at implementing the UNFCCC," (p. 92) "signed by roughly 190 countries . . . and was adopted in Kyoto, Japan, in December 1997," (p. 92) whereby developed countries "agreed to reduce their overall greenhouse gases by at least 5 percent below their 1990 levels by the 2008-2012 period," with the U.S. obligated to a reduction of 7 percent. (p. 93) While it was being negotiated, Senators Robert Byrd (D-WV) and Chuck Hegel (R-NE) moved a sense of the Senate resolution that "no protocol was acceptable unless it included the developing countries and would not harm the US economy," which passed 95-0. Although VP Gore flew to Kyoto to try to salvage the negotiations, the developing countries balked at having targets to meet, since the developed countries had caused most greenhouse gas emissions. The U.S. Senate was never sent the Kyoto Protocol to ratify, and G. W. Bush withdrew from it in 2007.

Speth's summation of the G. W. Bush administration is that "President George W. Bush at least superficially accepted climate science and announced measures in response. 'My administration is committed to a leadership role on the issue of climate change. We recognize our responsibility, and will meet it – at home, in our hemisphere, and in the world,' the president said in 2001." (p. 109) "As for actual climate policies, President George W. Bush offered only modest initiatives as he relinquished US climate leadership in the international area, and his EPA refused to regulate carbon pollution." (p. 107) "Notwithstanding the emerging impacts of climate change, the ever-growing literature on climate science, and the availability of renewable energy sources to provide energy for the nation, the Bush administration strategy was to cast doubt on the science and focus on the need for more research while prioritizing short-term economic interest, especially those of the fossil fuel companies." (p. 114)

Speth also sums up the activity of the Obama administration as follows: "President Barack Obama appeared to take the threat of climate change seriously and did more than any other president to address it." (p. 115) "He announced a Climate Action Plan, and his EPA issued regulations addressing emissions from motor vehicles and power plants. President Obama also participated in international climate summits, culminating in the Paris Agreement in late 2015. But by simultaneously pursuing an 'all-of-the-above' national energy policy [Obama's own name for it] and approving more fracked gas and unconventional fossil fuel pipelines than any president before him, his administration ensured that fossil fuels remained an entrenched engine of our economy and the dominant fuel of America's energy system." (p. 116)

In the midst of his coverage of the George W. Bush administration, Speth writes, "By the turn of the new century, it was difficult (but as we shall see, not impossible!) for any administration to simply walk away from the climate issue." (p. 109) When I read this, I recognized immediately what he was getting at – the presidency of Donald Trump. Until then, Speth chronicles the happenings in each administration in terms of reports and plans – things that are expected to happen in Washington. And in these chronologies we can see how our understanding

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REVIEWS

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of climate science has evolved and expanded. The Fourth Report of the Intergovernmental Panel on Climate Change (IPCC) in 2007 said that "Most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic GHG concentrations." (p. 102) But the Fifth Report seven years later said that "Human influence on the climate system is clear [no longer "very likely"], and recent anthropogenic emissions of greenhouse gases are the highest in history." (p. 120) At the outset, the focus of the research and reports was concern about global temperature and sea level, but the observant reader can see that, around the time of the Clinton administration, the reports extend their coverage to extreme weather events and the living conditions for wildlife. And, while generating electricity from renewables was a pipe dream during the Carter administration because of its comparative cost, Speth cites a 2012 report from the National Renewable Energy Laboratory, which states that "by 2050, 'Electricity supply and demand can be balanced in every hour of the year in each region with nearly 80% electricity from renewable resources, including nearly 50% from variable renewable generation.'" (p. 121)

But Speth's coverage of the Trump administration is more a list of things ridiculed and reversed, beginning with Trump's ridicule of the Fourth National Climate Assessment in 2017 and extending through repeal of Obama's Clean Power Plan, imposition of tariffs on solar panel imports, and withdrawal from the Paris Climate Agreement. Speth laments these setbacks, because "precious time and momentum will have been squandered -- and indeed squandered at a critical moment in the history of the issue when developments seem to be coming together to offer honest hope. "However," he writes, "not everything requested by the Trump administration moved through Congress. Congress resisted Trump's efforts to slash the budget of the EPA . . . and reaffirmed the danger of climate change in section 335 of the Defense Authorization Act of 2018." (p. 148)

Because Speth wrote the text of this book as an expert paper for the *Juliana* case, his coverage of the actions of the Trump Administration include a section about the effect of those actions on the twenty-one youth plaintiffs. He closes with his gratitude to Congress for passing a Concurrent Resolution "to protect the fundamental rights of children to a climate system capable of sustaining human life" to "support the young *Juliana* plaintiffs in recognizing that the current climate crisis disproportionately affects the health, economic opportunity, and fundamental rights of children, and demand that the United States develop a national, comprehensive, and science-based recovery plan to meet necessary emissions reduction targets." (pp. 149-150)

Because Speth wrote the text of *They Knew* as an expert paper for a court case, it is meticulously documented. There are 43 pages of footnotes, 28 pages of references, and 25 pages of index. The reader should also be conversant with such legal terms as "writ of mandamus," "interlocutory appeal," "summary judgment," and "*en banc*."

- John L. Roeder

(*Editor's Note*: A link to Bill Moyers' interview with Kelsey Juliana, one of the plaintiffs in *Juliana*, is https://billmoyers.com/episode/climate-change-next-generation/)

Thomas-Palmer

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students who fail. He added that asynchronous learning is necessary if a mastery approach is used. (This was also true for Jon Bergmann's pairing of the flipped classroom paired with mastery learning described at last summer's PoLS-T conference, reported in our Fall 2021 issue, but not emphasized then.)

Thomas-Palmer thus appears to be a man with a mission – his mission in founding Flipping Physics is now coming to fruition in the expansion into Asynchronous Flipped Gameful Mastery Learning. Several teacher participants in the conversation spoke of benefiting from it by using his videos, and he acted happy that they were doing so. In fact, his closing comments were expressions of amazement that so many teachers are asking how they can improve what they're doing.

The URL for Thomas-Palmer's website is <www.flippingphysics.com>.

Brits Build Back

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One can see that great strides have been made in power, fuel supply, and industry, but that much still remains to be done in heating buildings and transportation, where natural gas and petroleum, respectively, dominate.

RESOURCES

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for "commercial-scale demonstration plants and large-scale pilots of technologies for capturing CO_2 from fossil-fuel power plants and industrial facilities," "$2.5 billion for CO_2 storage demonstrations," and "$2.5 billion on six commercial-scale carbon capture demonstrations."

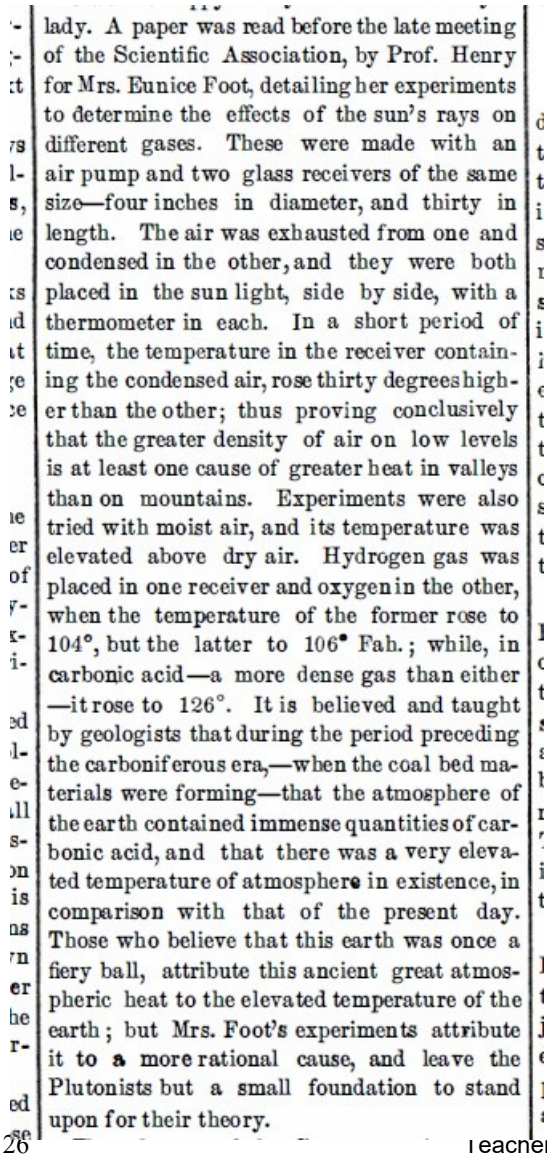
Clearinghouse Update

From time to time we update our readers on situations which have been described in our *Newsletter*.

More on Eunice Foote

One of the women scientists included by Geoff Rayner-Canham in his 24 September 2021 talk on women in science was Eunice Foote, who was reported in our Fall 2021 issue to have discovered in 1856 that the temperature of tubes of carbon dioxide and water vapor exposed to the Sun increased significantly while those containing hydrogen or oxygen did not – three years before John Tyndall was credited with this discovery. The story in our Fall 2021 issue was based on a *Physics Today* story that Joseph Henry read the results of Foote's observations but "failed to recognize the implications . . . on the heat-absorbing properties of carbon dioxide and water vapor."

Thanks to Rayner-Canham, we can now present how Henry's report of Foote's work was recorded in an 1856 issue of *Scientific American*:



lady. A paper was read before the late meeting of the Scientific Association, by Prof. Henry for Mrs. Eunice Foot, detailing her experiments to determine the effects of the sun's rays on different gases. These were made with an air pump and two glass receivers of the same size—four inches in diameter, and thirty in length. The air was exhausted from one and condensed in the other, and they were both placed in the sun light, side by side, with a thermometer in each. In a short period of time, the temperature in the receiver containing the condensed air, rose thirty degrees higher than the other; thus proving conclusively that the greater density of air on low levels is at least one cause of greater heat in valleys than on mountains. Experiments were also tried with moist air, and its temperature was elevated above dry air. Hydrogen gas was placed in one receiver and oxygen in the other, when the temperature of the former rose to 104°, but the latter to 106° Fah.; while, in carbonic acid—a more dense gas than either—it rose to 126°. It is believed and taught by geologists that during the period preceding the carboniferous era,—when the coal bed materials were forming—that the atmosphere of the earth contained immense quantities of carbonic acid, and that there was a very elevated temperature of atmosphere in existence, in comparison with that of the present day. Those who believe that this earth was once a fiery ball, attribute this ancient great atmospheric heat to the elevated temperature of the earth; but Mrs. Foot's experiments attribute it to a more rational cause, and leave the Plutonists but a small foundation to stand upon for their theory.

More on the Effect on Temperature from Doubled Carbon Dioxide

Our Winter/Spring 2015 issue listed all the stated values of the expected atmospheric temperature increase resulting from a doubling of the concentration of atmospheric carbon dioxide, known as climate sensitivity, that could be located. They ranged from 1°C to 4°C. A follow-up question to James Hansen reported in our Fall 2015 issue elicited that his first result in the 1970s was 4°C. Hansen acknowledged that 2021 physics Nobel Prize winner Syukuro Manabe got 2°C, but he added that he had assumed temperature-dependent cloud cover while Manabe used fixed cloud cover. An editorial in the 8 October 2021 issue of the *Trenton Times* states that Manabe's model prediction of climate sensitivity was 2.3°C.

The *Physics Today* electronic newsletter for 5 October 2021 expands on this, reporting that Manabe obtained "about 2°C" with a two-dimensional model in 1961 but "nearly 3°C" with a three-dimensional model, adding that in its latest report "the IPCC pegged the equilibrium climate sensitivity at 2.5–4 °C."

More on the War against Mosquitoes

As a follow up to our review of Timothy Winegard's *The Mosquito* in our Fall 2021 issue, the website for *Texas A&M Today* posted an article, "Seeking An Anti-Mosquito Molecule," by Adam Russell on 21 December 2021. It states that Texas A&M AgriLife Research Fellow and Professor in the Department of Entomology Patricia Pietrantonio is leading a three-year project funded by a $672,000 grant from the U.S. Department of Defense to find a new way to control *Aedes aegypti* and *Culex quinquefasciatus* mosquitoes to protect armed forces members from their bites and the diseases that can result therefrom. This is all the more important because of developing resistance to the traditional pyrethroid-based products or the organophosphate malathion used as insecticides.

They are presently focusing "on a novel approach relating to receptors in mosquito mouth parts, legs and internal organs," aiming "to test small synthetic molecules that may be used to create a compound toxic to mosquitoes. Pietrantonio and her team have screened more than 20,000 molecules and discovered several that could potentially inhibit bites, modify mosquito behavior or kill the insects" and "will test those molecules' impact on female mosquitoes."

The 14 January 2022 issue of *World Nuclear News* describes a study to investigate the effectiveness of sterilizing male *Aedes aegypti* mosquitoes to control the *Ae-*

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Clearinghouse Update

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des aegypti population which infests Cuba with dengue. It was conducted in 2020 by Cuba's Pedro Kourí Tropical Medicine Institute, with the assistance of the International Atomic Energy Agency and the UN Food and Agriculture Organization. Almost 1.3 million male mosquitoes, separated and irradiated with gamma rays and X-rays, were released in a 50 hectare neighborhood of southwest Havana, with another neighborhood of similar size designated as an untreated control site for comparison.

More on Israeli Nuclear Weapons

Our Fall 2013 issue reported on Israeli journalist Michael Karpin's book, *The Bomb in the Basement: How Israel Went Nuclear and What That Means for the World*. In the 2022 edition of the Federation of American Scientists *Nuclear Notebook*, Hans M. Kristensen and Matt Korda update what is known about Israeli nuclear weapons and delivery systems. Though they don't cite Karpin's book, they do cite the information Karpin describes from Israeli nuclear technician Mordechai Vanunu, who was interviewed by British nuclear physicist Frank Barnaby for the *New York Times Sunday Magazine* in 1986 (and, according to Kristensen and Korda, "was kidnapped by Israeli intelligence services and spent 18 years in prison" afterward). They also rely extensively on research by historians Avner Cohen and William Burr and note that "since the late 1960s, every Israeli government has practiced a policy of nuclear ambiguity," called "amimut," which "deliberately obscures whether Israel actually possesses nuclear weapons" and maintained that Israel would not "be the first to introduce nuclear weapons into the Middle East." Key to implementation of this policy was the Israeli interpretation of "introduce nuclear weapons," which was to admit to their existence.

Kristensen and Korda write that "after the end of the Cold War, Israel began to fear that the United States' tacit support for Israel's undeclared nuclear arsenal would soon fade"; citing articles in 2018 by Adam Entou in *The New Yorker*, they note that "Israel has reportedly requested that each American president since Bill Clinton sign a letter indicating that any future US arms control efforts would not affect Israel's nuclear arsenal." The other recent evidence cited by Kristensen and Korda come from improved satellite photography, because "in June 2020, the US Commercial Remote Sensing Regulatory Affairs Office announced that it would now allow commercial imagery providers to offer enhanced imagery of Israel at a resolution of 0.4 meters" (as opposed to the previous resolution limit of about two meters).

Bou-Zeid iterates urban technological frontiers

Princeton University Professor Elie Bou-Zeid began his Science on Saturday lecture at the Princeton Plasma Physics Laboratory on 29 January 2022 on "Technological Frontiers in Cities" as he had begun his previous 18 February 2017 lecture on "Cities in the 21st Century: the nexus of the climate, water, and energy challenges" – by showing an animated chronology of the founding of cities in 25-year intervals since 3700 BCE.

Cities were able to arise because of technology, Bou-Zeid said, and their future rests with technology as well. Expanded vertical and horizontal transportation have enabled cities to expand in both directions. This expansion also relies on social and economic interactions and support from planet Earth. Noting that cities have been studied as biological systems and natural ecosystems, Bou-Zeid also raised the question, "Are cities becoming too complicated?"

In addressing the technological frontiers faced by cities, Bou-Zeid noted that technology is a means to an end – to reach a goal, but not the goal itself. He recalled the "wedges" that Socolow and Pacala used to catalog ways in which the challenge of climate change could be met and adopted the same idiom to catalog technologies to solve 21st century urban problems, among which he listed sensors, alternatives to concrete, and water treatment technologies. (Socolow and Pacala's original paper in *Science* (**305**, 968-972 (13Aug04)) was first reported in our Fall 2004 issue.)

Turning to address the future of mobility in terms of these technologies, Bou-Zeid singled out four future approaches: micro vehicles (scooters and bicycles), shared vehicles, electric vehicles, and autonomous vehicles. Micro vehicles are cleaner, more efficient, and take up less space. Shared vehicles can reduce cost; and, because fewer of them would be needed, they would require less space. Electric vehicles, once electricity is obtained from clean energy sources, would be cleaner and more efficient. And autonomous vehicles would add convenience – but Bou-Zeid also expressed concern that this could also increase urban sprawl (they could also be equipped with sensors to gather environmental data).

Bou-Zeid also raised the question of equitability of technologies developed to solve urban problems. Is access to them equitable? Does a technology discriminate? Does its deployment discriminate? These questions became all the more significant as Bou-Zeid closed his talk

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(*Editor's Note*: If you would like a digital copy of Kristensen and Korda's work on Israeli nuclear weapons, which contains links to the research by Cohen and Burr, Entou, and others, please email the editor-in-chief at JLRoeder@aol.com.)

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Commuting by eVTOL by 2024?

Because transportation is clearly an application of science in society, this *Newsletter* has often carried stories about new forms of transportation. We've covered developments in self-driving vehicles and electric vehicles. Here we cover a new transportation form – electric Vertical TakeOff and Landing (eVTOL).

The manufacturer of the eVTOL in question is Joby Aviation, and reporting on it were two recent Princeton University graduates who are now Joby employees – equipment design engineer Madelyn "Mattie" Baron and software verification engineer Daniel Santillan – to a Zoom meeting of the "Princeton Propellers" on 12 October 2021.

Joby's eVTOL is a solution to a fundamental problem in transportation, Baron stated. It can offer aerial ridesharing which can reduce commuting time. And because it is electric, it can do so quietly. Jody's eVTOL vehicle in which one pilot can transport four passengers at up to 200 mph makes only 65 dBA of noise (the same as normal conversation) at takeoff, compared with 93 dBA for a helicopter; and the Jody eVTOL makes only 40 dBA of noise while cruising.

Contrasting electric propulsion transportation alternatives, Santillan noted that the Jody eVTOL is comparable in weight to a Tesla 3 but has greater battery capacity. An eVTOL could be called for like a taxicab and could take off from and land on parking garage roofs. But Baron also cautioned that eVTOLs would also need to coexist with existing air traffic and be subject to FAA regulation.

Santillan also spoke to the safety of the design of the Joby eVTOL and the history and future plans of Joby Aviation. The Joby eVTOL, he said, is designed for safety with high redundancy. Its control system is designed to provide stability in the event of human error, and he indicated that there are hopes eventually to develop an autonomous version. Already in 2017 Joby conducted its first full-scale prototype flight (you can see a video of the eVTOL in flight accessed from the Joby website), and Joby Aviation is now a fully-traded company on the New York Stock Exchange. Santillan said that the first commercial service is expected in 2024.

Bou-Zeid

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showing a video picking up where his opening video left off, indicating what were projected to be the world's 20 largest cities at 25-year intervals in the future. It showed the 20 largest cities to become increasingly concentrated in south Asia and Africa.

The following question-and-answer period yielded some significant further insights, among them the knowledge that technological bias will be revealed by the data it collects and Bou-Zeid's greater concern about running out of materials than running out of space, although he felt that battery recycling should alleviate battery materials shortage. One participant asked whether there is a maximum viable size for cities, and another asked whether aggressive human drivers would take advantage of autonomous vehicles.