Impacts on Teaching Practices from a Solar Photovoltaic Institute Faculty Professional Development Program

Dr. Kenneth Walz, Madison Area Technical College

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Dr. Walz is an alumnus of the Department of Energy Academies Creating Teacher Scientists (DOE ACTS) Program, and he is an instructor for the National Renewable Energy Laboratory (NREL) Summer Institute, providing professional development for middle and high school STEM teachers. Dr. Walz has been recognized as Professor of the Year by the Carnegie Foundation and the Council for Advancement and Support of Education, and as the Energy Educator of the Year by the Wisconsin Association for Environmental Education.

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Joel Shoemaker is a Wisconsin state-certified Master Electrician with over 18 years of experience with solar photovoltaic systems, and currently serves as a Co-Principal Investigator for the National Science Foundation-funded Center for Renewable Energy Advanced Technological Education (CREATE). He has been teaching at Madison Area Technical College for the past 12 years. In 2011, the Wisconsin Bureau of Apprenticeship Standards and the Wisconsin Apprenticeship Advisory Council recognized Shoemaker as a Centennial Educator. He has taught solar photovoltaic trainer programs offered by CREATE and Solar Energy International and led the inception of Madison College’s STEM Educator Solar Institute for high school and community college teachers. Shoemaker will spearhead the design and construction of a model energy storage lab facility at Madison College that will be integrated into the existing solar energy installation lab and used for teaching about the interaction of these complimentary technologies.

Mr. Scott Liddicoat, Green Bay Southwest High School

Scott Liddicoat teaches high school classes on Chemistry and Renewable Energy at Green Bay Southwest High School. He has authored numerous classroom lessons as a teacher trainer for the SolarWise for Schools program and the CREATE (Center for Renewable Energy Advanced Technological Education) training team.

Mr. Cris Folk, Madison College

Cris, retired from full time teaching at Madison Area Technical College in 2017 after having taught for 18 years in the classroom and at a variety of business and industry locations in southern Wisconsin. While primarily an electronics professor, Cris also developed and delivered coursework and training for industrial equipment maintenance, general electricity, heating ventilation and air conditioning, robotics, food processing, interpreting engineering drawings, solar and wind energy, energy management and building automation. He was the Renewable Energy Program Director from 2012 until his retirement in 2017. Before working at the college, Cris served for 20 years in the US Navy as an Electronics Technician (ET), having retired from active duty at the rank of Chief Petty Officer with Enlisted Surface Warfare (ESWS) and Master Training Specialist (MST) certifications.

A life member of the Midwest Renewable Energy Association (MREA) in Custer, WI. Cris began teaching with MREA in 2006 and continues to teach and develop courses in photovoltaics and wind energy as an IREC certified instructor. Cris lives with his wife and life partner Susan in a renovated farmhouse near
Watertown, WI, employing wind, solar and biomass energy technologies to reduce their carbon footprint. Early adopters of sustainable living methods and renewable energy usage, Cris has presented at local events and has been frequently interviewed by the media as a subject matter expert. Cris volunteers as a mentor and judge for the Kidwind, SkillsUSA, Project Lead the Way and Electrathon events in the Midwest. He continues to teach industrial electricity topics for local businesses and industries as a private contractor on an as needed basis, and remains active with Madison College faculty teaching with the CREATE Solar Academy classes every summer.
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Faculty Professional Development Program

Abstract
The Center for Renewable Energy Advanced Technological Education (CREATE) and Madison College has run a Solar Photovoltaic Institute for STEM Educators for the past three years. The institute provides three days of intensive professional development for high school and two-year college instructors who seek to incorporate solar photovoltaic technology into their curriculum. Participants work with the tools of the trade to install and commission residential sized solar arrays, including sloped roof, flat roof, and dual axis tracking systems. Instruction includes electrical fundamentals, code compliance, and safe workplace practices. The outdoor hands-on instruction is complemented with several smaller bench scale lessons and activities that can be replicated easily in the classroom. In 2017, CREATE and Madison College conducted a follow-up study to assess the impacts of the Solar Institute on the participants’ teaching practices. The results showed significant changes to participants’ curriculum and instruction. The findings yielded several useful lessons learned, and recommendations for future faculty professional development programs in the STEM fields are suggested.

Introduction
Electrical energy generation trends of the 21st century have been characterized by a surge in the growth of clean renewable energy generation in the form of biomass, wind, and most recently solar power. Building on a decade long trend of double digit growth rates shown in Figure 1, global installed solar photovoltaic capacity has now exceeded 300 gigawatts (GW) [1], Including projects still under construction in the fourth quarter, it is estimated that the United States alone installed approximately twelve GW of new solar photovoltaics in 2017 [2]. Even after accounting for capacity factors when the sun does not shine, these new renewable power production facilities installed in a single year provide the equivalent amount of electricity of several nuclear power plants.

Recent analyses have shown that growth of the renewable energy industry over the past two decades repeatedly beat predictions by experts such as those at the International Energy Agency and the U.S. Energy Information Administration [3,4]. This trend is being further accelerated by tremendous reductions in the price of solar technology. Numerous records for solar pricing have been set in recent years, with auction bids and contracts signed for prices at or below 2.5 cents per kilowatt hour (5, 6, 7). These developments have positioned solar technology as a low-cost generation source that is cheaper than electricity from fossil fuels in many markets [8].
Preparing the Renewable Energy Workforce

The rapid growth in solar energy presents a challenge for educators to teach the next generation of scientists, engineers, and technicians who will implement solar technologies on a greater scale and integrate these resources into our energy systems. As of 2016, the renewable energy industry employs over 8 million people worldwide, and these numbers are certain to continue to grow in the years ahead [9]. The solar industry alone now employs more than oil and gas combined, and recent solar workforce surveys have shown that two thirds of employers have difficulty finding qualified workers [10]. Most of these jobs require some type of education and training beyond a high school diploma. Jobs include solar design and engineering, solar installation (both electrical and construction workers), operations and maintenance, technical sales, finance, and project management. A somewhat smaller number of jobs also exist in solar manufacturing, and research and development.

Solar energy education in the late 20th century was summarized by Goswami [11]. The paper concluded that at the turn of the century there was, “enough solar energy educational materials (such as textbooks) available for traditional undergraduate and graduate courses in science and engineering.” It is notable that this study did not make any mention of two-year engineering or technical schools, or high school STEM education programs; despite the fact that the majority of jobs in the solar industry require less than a four-year degree [12]. More recent studies have examined the renewable energy and green jobs landscape, and have documented the need for workers with “middle skills” training in engineering and technical fields [13, 14, 15].

As recently as 2009, it was observed that “most engineers are not trained to use these renewable energy technologies and most are not aware of the principles of sustainability. There is therefore an urgent need to develop and implement new courses that prepare engineers, scientists and energy planners to work with renewables to produce sustainable energy generation systems” [16]. Through the SunShot Initiative, the Department of Energy has funded major efforts to train engineers and other professionals in solar technology [17], but to our knowledge there have been no major studies specifically examining the preparation of teachers in solar technology.

The Center for Renewable Energy Advanced Technological Education (CREATE) is a collaborative effort between Madison College, Lane Community College and College of the Canyons that is funded by the National Science Foundation. CREATE’s goal is to advance the field of renewable energy by supporting renewable energy programs. Madison College serves as the lead institution for CREATE, and has developed and delivered various types of faculty professional development programs in solar energy for over a decade [18].

The need to build a renewable energy educational pipeline

A major challenge to educating future renewable energy professionals, is the need to build an educational pipeline. Since this is an emerging field, many potential young students have limited knowledge of renewable energy career opportunities, and they lack professional role models. Young adults with an interest in STEM have at least some awareness of what scientists, engineers, and health care professionals do, and many of them can identify relatives or family friends in these fields that serve as sources of information about their disciplines. The same cannot be said for renewable energy. As a result, for most students, their only source of information about renewable energy careers is from their teachers. However, until relatively
recently, there were few if any academic programs - or even courses - offered in renewable energy at institutions of higher education. Thus, the vast majority of high school and college STEM educators also have only limited exposure to renewable energy topics.

In attempt to quantify the needs of STEM teachers related to renewable energy, CREATE conducted an educator needs survey. The survey was distributed to over 400 high school and two-year college educators nationwide, and had a response rate of 25%. As shown in figures 2 and 3, the survey showed a strong desire for instructional resources in all types of renewable energy technology, and a need for all types of instructional materials. However, due to the design of the survey, it was difficult to determine if preferences for individual choices were statistically significant, thereby making difficult to establish teacher priorities.

*Figures 2 & 3) Results of the initial faculty needs survey (rated on a scale of 0-4, low-high)*

A follow-up survey asked respondents to *rank and weight* their preferences for different types of instructional materials and different types of professional development, at which point clear preferences emerged. Strong priority was revealed for instructional resources that included hands-on student activities, lab experiments and project or problem based learning (see Table 1), while three to five-day summer workshops were the preferred format for professional development activities (see Table 2).

*Tables 1 and 2) results from the follow-up CREATE faculty needs survey*

<table>
<thead>
<tr>
<th>Priority for Renewable Energy Resources</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model Hands-on Student Activities</td>
<td>123</td>
</tr>
<tr>
<td>Lab Manuals/Lab Experiments</td>
<td>97</td>
</tr>
<tr>
<td>Problem/Project Based Learning Activities</td>
<td>96</td>
</tr>
<tr>
<td>Textbooks</td>
<td>84</td>
</tr>
<tr>
<td>Video Clips or Narrated Slide Presentations to Support Online or Hybrid Instruction</td>
<td>61</td>
</tr>
<tr>
<td>Model Course Syllabi</td>
<td>42</td>
</tr>
<tr>
<td>Test Banks, Sample Exams, &amp; Sample Quizzes</td>
<td>40</td>
</tr>
<tr>
<td>Homework Problems and Exercises</td>
<td>34</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Would you be interested in participating in the following professional development opportunities? (mark all that apply)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>participating in 3-5 day summer RE workshops</td>
<td>75</td>
</tr>
<tr>
<td>receiving a CREATE newsletter and RE communications</td>
<td>59</td>
</tr>
<tr>
<td>participating in online webinars on RE topics/technologies</td>
<td>53</td>
</tr>
<tr>
<td>accessing and/or contributing to a showcase of RE teaching materials</td>
<td>48</td>
</tr>
<tr>
<td>participating in an online community of RE faculty</td>
<td>46</td>
</tr>
<tr>
<td>participating in online webinars on renewable energy</td>
<td>38</td>
</tr>
<tr>
<td>participating in 1-2 day workshops before or after a conference</td>
<td>35</td>
</tr>
</tbody>
</table>
At the same time, when the survey respondents were asked to weight which renewable technologies they most sought professional development, solar photovoltaics clearly stood out as the strongest preference with a weighted score more than twice as high of many other renewable technologies (see Table 3).

### Solar Photovoltaic Institute
In attempt to build solar career pathways, Madison College created a three-day professional development Solar Photovoltaic Educator Institute designed specifically for STEM teachers. The STEM Solar Institute combines hands-on experience installing PV systems along with smaller bench scale activities that can be easily replicated in a high school setting. The institute is taught using Madison College’s Solar Training Lab which features six residential sized 2.0 kW solar PV systems. Participants are able to install, inspect, commission and de-commission multiple types of PV systems including dual axis tracking, flat roof, and sloped roofs of different pitch. The Institute emphasizes safe installation and commissioning procedures (see Figures 4 and 5), and highlights techniques for teaching PV both in the field and in the classroom. Classroom lessons include measuring the open circuit voltage and the short circuit current of a solar panel, solar site assessment using a Solar Pathfinder, determining the maximum power output of a solar module, and solar performance modeling using the online tool PV Watts created by the National Renewable Energy Laboratory.

#### Figures 4 and 5) Participants in the solar institute install solar panels and execute proper lock-out tag-out procedures at the point of electrical disconnecting means.

### Target Audience
Many STEM initiatives at the high school level tend to focus on Science and Math, since these are both subject areas that are required for all students to complete in order to graduate. By comparison, high school courses in technology and engineering are usually elective credits. As a result, fewer students enroll in these classes, fewer faculty teach them, and there has been comparatively less attention given to faculty professional development in these disciplines. Thus, our original intention with the Madison College Solar Institute was to target high school
technology and engineering instructors. In Wisconsin, several high schools operate technical education programs that involve students in the design and construction of residential homes, and this was a target audience of particular interest, since reaching these faculty could enable the students to become involved directly in solar home construction.

In practice, the recruitment and selection of teachers for the institutes was not so cut and dried. In Wisconsin, as in many other states, teachers can hold dual licenses or certifications in multiple areas. Thus, an individual may be certified as both a science and an engineering instructor for example. Likewise, an individual may be certified to teach both high school and middle school. Increasingly, many high school teachers are certified to teach dual-credit, advanced placement, or international baccalaureate classes that are equivalent to college level coursework. For teachers with multiple certifications, their teaching assignments might change from one year to the next, or if they change employers. Furthermore, some high school instructors might also be engaged as part time adjunct faculty teaching evening or summer school courses with a local college or university. In practice, we found that selection of STEM teacher participants based on subject matter or grade level was not as important as their interest in the subject matter and desire to learn. In retrospect, we also found that having a diverse mix of participants helped to foster a dialogue across disciplines, grades and age-levels, helping to further advance the creation of a renewable energy educational pipeline.

**Participant Demographics**
The map and accompanying table in Figure 6 show the participant demographics for the Solar Institute. As shown in the maps, participants were drawn from a wide geographical area, well beyond that of the Madison College school district. Participants came from urban, suburban, and rural areas, representing both public and private school systems. Although the participants were predominantly Wisconsin high school teachers, the institutes also included some out of state participants and some representatives from middle school and higher education. Eighteen of the forty-seven participants were female teachers. This number represents a significant accomplishment for a teacher education program, considering that women are historically under-represented in the STEM instructor ranks.

**Participant Learning Gains**
Participant learning gains were measured for each of the institutes using pre- and post-test assessments. The graph in Figure 7 and the accompanying table below show the pre- and post-test results from the 2017 Solar Institute participants. As shown, solar content knowledge improved markedly with mean scores improving by over 15% while the standard deviation of scores was cut roughly in half. The pre- and post-test assessment tool was modified each year to...
refine its effectiveness, so it was not possible to merge data across years. However, the 2017 results are illustrative of the overall findings across years.

**Figure 7) Solar Institute Participant Learning Gains**

![Figure 7) Solar Institute Participant Learning Gains](image)

The pre- and post- test scores are consistent with participant feedback gathered on the evaluation of the Solar Institutes. Participants were asked to self-evaluate their own knowledge of solar energy before and after the workshop. As shown in Figure 8, participants perceived that they had made significant gains in their knowledge. This result is consistent with the pre- and post- test findings, and also indicates that participants were consciously aware of their own learning. It is also notable that 100% of the participants indicated that as a result of the Solar Institute they were more likely to include discussion of renewable energy in the classes that they teach, and that they were more likely to pursue additional faculty professional development in renewable energy. When asked about the value and quality of the Solar Institute, the average grade assigned by participants was a 3.9 on a 4.0 scale, and all of the participants indicated that they would recommend the Solar Institute to a colleague. Included amongst the many participant evaluation comments were the following testimonial statements:

“I liked the solar training and it gave us a chance to see and learn more about post-high school career options to share with our students.”

“Wonderful experience that will benefit my students. I plan to purchase solar equipment to use in my class this year.”

“Really appreciate the opportunity. The safe commissioning process for solar systems was a great lesson that I will use with my students.”

**Figure 8) Self-assessed knowledge of solar photovoltaics before and after the solar institute.**

![Figure 8) Self-assessed knowledge of solar photovoltaics before and after the solar institute.](image)
Impacts on Instruction
In order to determine the impacts of the Solar Institutes on the teaching practices of participants, a follow up survey was implemented roughly six months after each of the Institutes. Participants were asked various questions related to how the institutes might have altered their curriculum and instruction, and how this might have impacted their students learning experiences. As shown in Table 4, a large number of teachers had shared the knowledge that they learned with others in their school community, and a strong majority had modified their curriculum by creating or modifying various types of instructional materials.

Table 4) Teacher participants reporting changes in educational practices.

<table>
<thead>
<tr>
<th>Answer Choices</th>
<th>Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Educate other staff at your school (colleagues, administrators, etc)</td>
<td>86.1%</td>
</tr>
<tr>
<td>Enhance classroom lessons</td>
<td>81.0%</td>
</tr>
<tr>
<td>Modify course curriculum</td>
<td>79.8%</td>
</tr>
<tr>
<td>Create new lab activities</td>
<td>78.5%</td>
</tr>
<tr>
<td>Improve or modify existing lab activities</td>
<td>77.2%</td>
</tr>
<tr>
<td>Add more hands-on learning to the curriculum</td>
<td>57.0%</td>
</tr>
<tr>
<td>Improve safety procedures and protocols</td>
<td>55.7%</td>
</tr>
<tr>
<td>Create new course curriculum</td>
<td>51.9%</td>
</tr>
<tr>
<td>Acquired new lab equipment, supplies, or materials</td>
<td>48.1%</td>
</tr>
<tr>
<td>Participate in other professional development activities</td>
<td>39.2%</td>
</tr>
</tbody>
</table>

Figure 9 illustrates that these changes were also judged by teachers to have had significant impact on their students learning experiences, improving their awareness, attitudes, interest, knowledge and skills related to renewable energy. These results offer encouragement that the Solar Institute is helping to promote pathways to renewable energy careers, and it is our hope that in the near future these students may fill some of the renewable energy workforce needs.

Lessons Learned and Faculty Professional Development Recommendations
In implementing the STEM Educator Solar Institute at Madison College, we have happened upon several practices that we believe are integral to the Institute’s success. Here we share the most significant of these as recommendations so that others developing faculty professional development programs can learn from our experience.

i) Ask teachers what they need. The CREATE faculty needs surveys show that it is important to ask teachers about the type of professional development that they most desire. Time and human resources are limited, so a faculty professional development program cannot be all things to all people. Likewise, financial resources are limited, so it makes sense to target professional development to the areas of greatest need to make the best use of funds. Furthermore, the importance of a well-crafted needs survey is critical; questions that force respondents to rank their choices help to establish priorities.

ii) Participant recruitment and selection. We were fortunate that the vast majority of teachers who applied to the Solar Institutes were well qualified, and suitably matched to the institutes goals. As a result, we did not have to reject very many teachers who applied to participate in the
Solar Institutes. We attribute the strong applicant pool to two factors. First, since the institute was held during the summer months, and teachers were voluntarily investing their own time, we had a self-selected audience of motivated individuals. Second, we made a conscious effort to provide a great deal of information in the recruiting materials to make sure that applicants understood what the Solar Institute would involve. Efforts were made to ensure that applicants understood that hands-on work was a significant component of the Institute, and all marketing materials featured past participants wearing hard hats and eye protection while working with tools. It was also important for applicants to know ahead of time that they would be working with outdoors in the hot sun for several hours a day. The need for sunscreen, and the risk of dehydration and exposure was clearly stated in the application form. Applicants were also made aware of safety risks such as hazards associated with working with live electrical equipment, and risks of falling from roofs, ladders, and/or construction scaffolding, and all participants had to sign and submit a safety liability document as part of their application materials.

Application forms also included a series of essay questions to ascertain the applicant’s current teaching assignment and past experience, interest in renewable energy, and intended reasons for participating to the solar institute. As a result of this messaging, the Solar Institute applicants were very well informed. Upon receipt of the applications, senior personnel reviewed each applicant’s documentation, to ensure that they would be a good match for the program. In the few instances where an applicant was not judged to be a suitable fit, we were instead able have a follow up conversation with the applicant and refer them to other programs that might better suit their needs/interests (such as those offered by the University of Wisconsin Stevens Point, the Midwest Renewable Energy Institute, or the National Renewable Energy Laboratory).

**iii) Content is available from many sources, but that is not enough.** There are now many avenues available for teachers to learn STEM content, including those interested in renewable energy topics. For example, Madison College offers an online course in renewable energy technology, and a hybrid class in solar photovoltaics. We know of several other similar courses offered by other colleges across the U.S. In addition, non-profit organizations such as Solar Energy International and the Midwest Renewable Energy Association also offer online courses in solar energy that are delivered asynchronously on-demand, and allow learners to work at their own pace. The University of Wisconsin Stevens Point K-12 Energy Education Program also offers online courses in energy education specifically developed for teachers. With the advent of modern information technology, teachers now have a wide number of options for learning STEM content in multiple accessible formats. However, what remains in short supply for teachers are professional development experiences that provide hands-on experience working with tools and real-world equipment. This is especially important for teachers in the technology and engineering fields, as there is only so much that can be learned through point and click simulation activities with a computer mouse. To prepare future technicians and engineers, it is important that teachers get to work with the tools of the trade, performing real activities such as measuring the open circuit voltage of a solar module, or using a clamp-on ammeter to observe the current produced by a live solar system. Furthermore, to provide students with insight on future careers, it is important for teachers to experience a real-world work environment. For example, utilizing personal protective equipment such as hard hats, safety glasses, and electrical gloves; and employing safe workplace practices to minimize risks from dangers such as fall hazards and live electrical circuits.
**iv) Sharing pedagogy is important.** While all of the participants in the faculty professional development workshops were interested in learning about solar technology, they were just as eager to learn about how to teach these concepts to students. The lead instructors took time to discuss instructional strategies with the faculty participants, pointing out common misconceptions and common mistakes made by students. These discussions were interspersed throughout the institute program, so that participants were engaged in a learning format that alternated between digesting new information and skills, and integrating this information into their instructional repertoire. Equally important was providing participants with instructional materials in an accessible format that they could easily utilize in their classrooms. Participants in the workshop were provided with both teacher lesson plans and student handouts for each of the classroom activities included in the Solar Institute. These files were made available in an open source format via Google Documents, so that teachers could edit or revise them as needed to fit the curriculum for their individual school, subject area, and grade level. For those teachers considering acquiring tools, equipment and materials, we also provided them with a list of all the various items that were used in the solar institute, along with vendors and prices. Although these resources greatly lowered the workload barrier needed for teachers to implement changes to their curriculum and instruction, we also found it beneficial to give teachers time during the institute to work with their peers. Teachers shared their current teaching practices, and discussed ideas for how they might develop these lessons to incorporate solar concepts into their own classroom.

**v) Award graduate credit, CEUs, and/or Clock Hours if possible.** Although requirements vary from state to state, most public-school teachers and college instructors need to engage in some kind of professional development as a condition of renewing their teaching credentials. In many cases, these professional development activities must be documented by some sort of institutional authority. The CREATE Solar Institutes were offered in partnership with the Colorado School of Mines Teacher Enhancement Program. For participants that chose to do so, they could apply, pay tuition, complete class requirements, and earn graduate teacher re-licensure credits through their participation in the Institute. While most states recognize university credits for the purposes of teacher re-licensing, there are also various alternative means of documenting professional development such as credit equivalency units (CEUs) and clock hours that are issued by state agencies such as the Department of Public Instruction. The best mechanism for documenting teacher professional development will likely differ from state to state, but the important lesson is that securing documentation in a format that will be recognized by school districts and regulatory authorities is important to deliver value to the participants.

**vi) Assessment and Evaluation are necessary components.** Perhaps the greatest finding from our work is that assessment of learning is a critical element of any faculty professional development program. Measuring faculty learning gains was important to make sure that the workshop activities were successful in teaching the concepts that we intended. Furthermore, evidence of successful learning has been crucial for reporting to our various sources of funding, and to make the case for continued support of the Solar Institute.

**Future Plans**
Madison College is offering the STEM Educator Solar Photovoltaic Institute for the fourth time in July 2018, and intends to continue this program each summer for the foreseeable future. We hope that the Solar Institute developed by Madison College can serve as a model for other colleges and institutions to replicate. With support from the National Science Foundation, Madison College and CREATE have sought to disseminate this model to other regions, identifying partner institutions, and working with them to deploy pilot programs at their campuses. Shoreline Community College in the Seattle metropolitan region hosted their own Solar Institute in 2017, and has plans to repeat the activity in 2018. CREATE is currently working with partners in Delaware, Illinois, and Maine, to conduct additional pilots in the year ahead, and is seeking additional schools interested in hosting future solar institutes. CREATE also offers similar programs in energy efficiency through the leadership of Lane Community College. We encourage teachers to check out CREATE’s website at www.CreateEnergy.org and subscribe to the newsletter to get notification of upcoming institutes in both solar photovoltaics and energy efficiency. On the website, teachers can subscribe to the CREATE email list, and can find additional details and application information for the CREATE professional development opportunities.

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References


